



# 物理學史研習會（六）

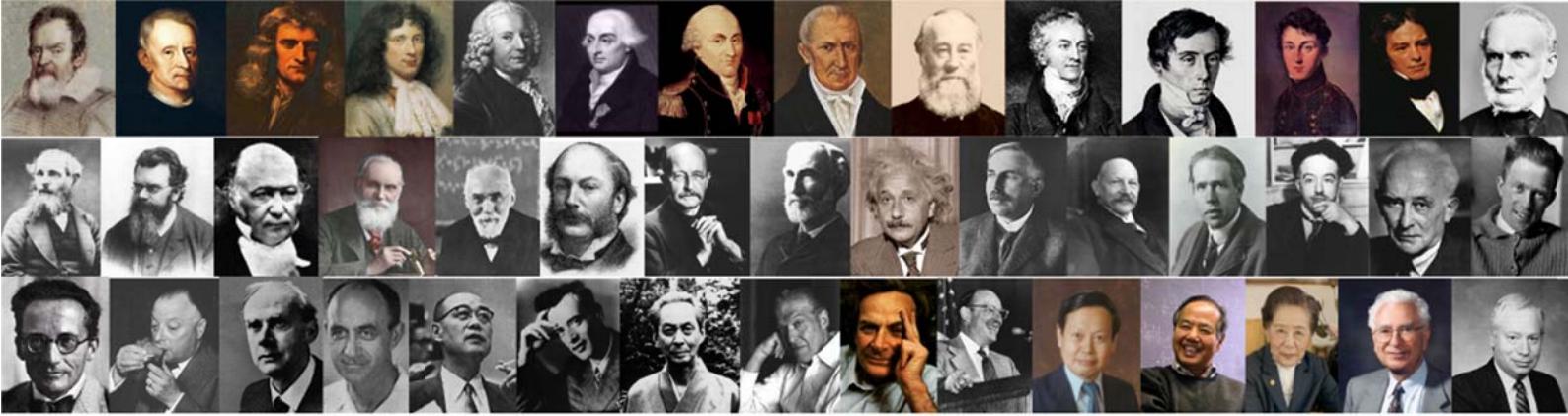
## 手冊

主辦：東吳大學物理學系

協辦：教育部普通高級中學課程物理學科中心

高雄市立高雄中學 科學館 視聽教室

2015 年 10 月 31 日



# 前言

東吳大學物理學系一向認為物理學史在人類文化發展中具有重大意義，因而重視物理學史的教育。

2013 年 9 月 28 日及 10 月 5 日，本學系於東吳大學外雙溪校區接連舉辦「物理學史研習會」(一) 及 (二)；2014 年 10 月 18 日及 25 日復各於東吳大學及臺中第一中學舉辦「2014 物理學史研習會」(三) 及 (四)。這四次研習會都因教育部「普通高級中學課程物理學科中心」參與協辦，得廣邀高中物理教師參加，裨益高中物理教育，同時增進相關學者交流，嘉惠在校學子。

今年本學系再接再厲，於 10 月 24 日及 31 日繼續舉辦兩場「研習會」；「研習會 (五)」仍在東吳大學舉行，「研習會 (六)」則選在高雄市立高雄中學。因為今年適逢紀念「國際光之年」，特選定「光學」為研習會的主題。兩次研習會因而也被列為「2015 國際光之年」在臺灣的慶祝活動之一。

這一梯次的「研習會」特別邀請現任「中華民國光電學會」理事長，也是東吳大學傑出校友的中央研究院應用科學研究中心的蔡定平主任做開場講演，不祇介紹「國際光之年」活動，也述說他自己學習光學的故事——這故事本身就足以呈現了現代光學的諸端發展。

同時，我們也邀請劉源俊、劉容生及邱爾德三位資深教授，各提供畢生的教學與研究經驗，各講述「光學的歷史」、「光電科技發展史」及「顯微術發展史」；也請後起之秀的李晁達教授講「雷射發展史」。

五項主題大致幾乎涵蓋了光學與光電科技的全面，是一次難得的盛事。講演的書面資料與錄影，將會是後人研習的重要參考文獻。三年的連續舉辦，已使「物理學史研習會」成為東吳大學物理學系的一項特色活動。未來本學系將會持續舉辦，每次訂定一個主題，俾利集中研習的焦點；希望大家繼續支持。

東吳大學物理學系主任

巫俊賢 謹誌

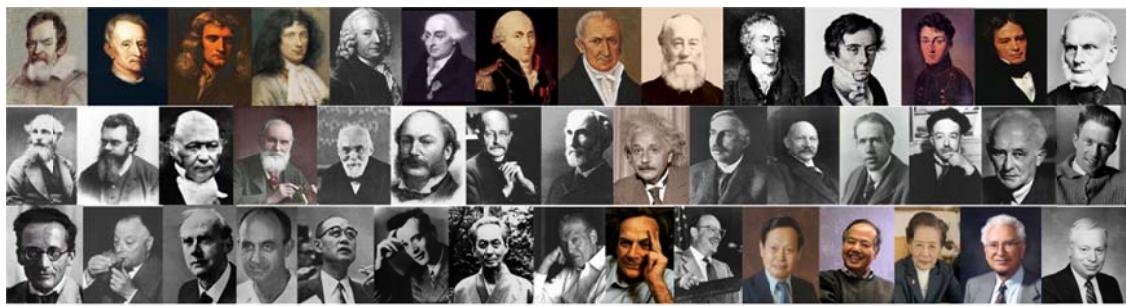
中華民國 104 年 10 月 24 日

# 物理學史研習會（六）

## 手冊

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學習光學的故事（PPT）
- 劉源俊 光學的歷史（PPT）
- 邱爾德 Story of Microscopy（PPT）
- 李晁達 Lasers: History, Basics and Applications（PPT）
- 劉容生 光電科技發展史（PPT）
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## 物理學史研習會（六）

時間：2015 年 10 月 31 日（星期六）

地點：高雄市立高雄中學 科學館 3F 視聽教室

主辦：東吳大學物理學系教學研發中心



協辦：教育部普通高級中學課程物理學科中心

| 時 間                     | 講 者                                 | 講 題                       |
|-------------------------|-------------------------------------|---------------------------|
| 09:00~09:10             | 謝文斌（高雄市立高雄中學校長）                     | 開幕致詞                      |
| 09:10~10:25             | 蔡定平（中央研究院應用科學研究中心主任<br>中華民國光電學會理事長） | 光學與我——兼介<br>紹「2015 國際光之年」 |
| <b>10:25 ~ 10:45 茶敘</b> |                                     |                           |
| 10:45~12:00             | 劉源俊（東吳大學物理學系名譽教授）<br>討論             | 光學的歷史                     |
| <b>12:00 ~ 13:00 午餐</b> |                                     |                           |
| 13:00~14:10             | 邱爾德（陽明大學醫光電暨分子影像研究中心主任）<br>討論       | 顯微術發展史                    |
| 14:10~15:20             | 李晁達（中山大學光電工程學系副教授）<br>討論            | 雷射發展史                     |
| <b>15:20 ~ 15:40 茶敘</b> |                                     |                           |
| 15:40~16:50             | 劉容生（清華大學退休榮譽教授）<br>討論               | 光電科技發展史                   |
| 16:50~17:30             | 綜合座談：光學與光電科技在臺灣                     |                           |

## 講師簡介

**蔡定平** 現任中研院應用科學研究中心特聘研究員及主任，合聘台灣大學物理系及應用物理研究所教授；中華民國光電學會理事長。曾任財團法人國家實驗研究院儀器科技研究中心主任（2008~2012）。

東吳大學理學士（1983），美國 U. of Cincinnati 物理學博士（1990）。

研究專長及領域是奈米光學（nano-photonics）及光電物理。

是美國物理學會（APS）會士（Fellow）、美國光學學會（OSA）會士、國際光電工程學會（SPIE）會士、國際電子電機工程學會（IEEE）會士、俄羅斯國際工程學院通訊院士、電磁科學院（EMA）會士、3M-NANO 會士、亞太材料科學院（APAM）院士及中華民國物理學會會士。

曾獲行政院傑出科技榮譽獎（2006）、國家科學委員會傑出研究獎（2009, 2012）、教育部學術獎（2011）。

曾任國際光電工程學會董事（2012~2014），國際電子電機工程學會 Joseph F. Keithley Award 評審委員會委員（2013~2015），美國光學學會及國際影像科學與技術學會（Society for Imaging Science and Technology, IS&T）Edwin H. Land Medal 嘉獎評審委員會主席（2014），美國光學學會獎評及會士評審委員會委員（2009, 2010），國際光電工程學會會士評審委員會委員（2010~2012）。



**劉源俊** 現為東吳大學物理學系名譽教授。

臺灣大學理學士（1966），美國 Columbia University 大學物理學博士（1972）。

在東吳大學物理學系任教已 42 年。曾任東吳大學物理學系主任、理學院院長、教務長（1972~1976）、校長（1996~2004）。又曾任臺北市立教育大學校長（2006~2008）。

在美國留學期間參與發起《科學月刊》，回臺後曾擔任總編輯、社長、理事長等重要工作二十餘年。現任臺北市科學出版事業基金會董事長。

曾獲教育部「社會教育獎章」（1982）、教育部「教學特優教師獎」（1989）、中華民國物理教育學會「物理教育傑出貢獻獎」（1990, 2008, 2012）。



興趣與專長主要在物理教育、教育理念與制度、文化發展、高等教育。

**邱爾德** 現任國立陽明大學生醫光電所教授(2003~)並兼任醫光電與分子影像中心主任；曾任該校生醫工程學院院長（2003~2009）及國際事務長。

緬甸國立仰光大學物理系學士，國立臺灣大學物理研究所碩士，美國加州理工學院（Caltech）應用物理博士（1983）。

先後任職於美國航空太空總署（NASA），加州理工學院噴射推進實驗室（Jet Propulsion Lab, JPL），IBM公司及 Rockwell International Science Center。回臺後擔任交通大學國科會特聘講座教授（1997）、東華大學電機系/所教授（1997~2003），並先後兼任電機研究所所長、電機系主任、理工學院院長。

研究專長為光學微操控、影像、與偵測於生物醫學的應用。

是美國光學學會（OSA）會士(Fellow)、國際光電工程學會（SPIE）會士及 Photonics Society of Chinese Americans 會士。於 2008 年度獲中華民國光學工程學會「光學工程獎章」。



**李晁達** 現任國立中山大學光電工程學系副教授。

國立清華大學物理學系學士（1994），國立交通大學光電系博士（2003），2005 年到日本東京大學物理系訪問。

博士論文為關於雷射光源研製、機制探討與應用，加入中山大學後研究領域為量子光電子學。

研究興趣在探討光與物質作用中的基本特性與相位的角色——色散動力學（chirp dynamics），同時探討二維材料的本質進而了解它對雷射應用的潛力。也投入開發新穎光電材料（雷射晶體、非線性材料）以期提高發光效率。

在光源開發上，在阿秒（attosecond,  $10^{-18}$  sec）雷射與藉由拓樸絕緣體達成超低脈衝預值固態雷射等，有重要貢獻。



**劉容生** 現為國立清華大學榮譽退休教授。

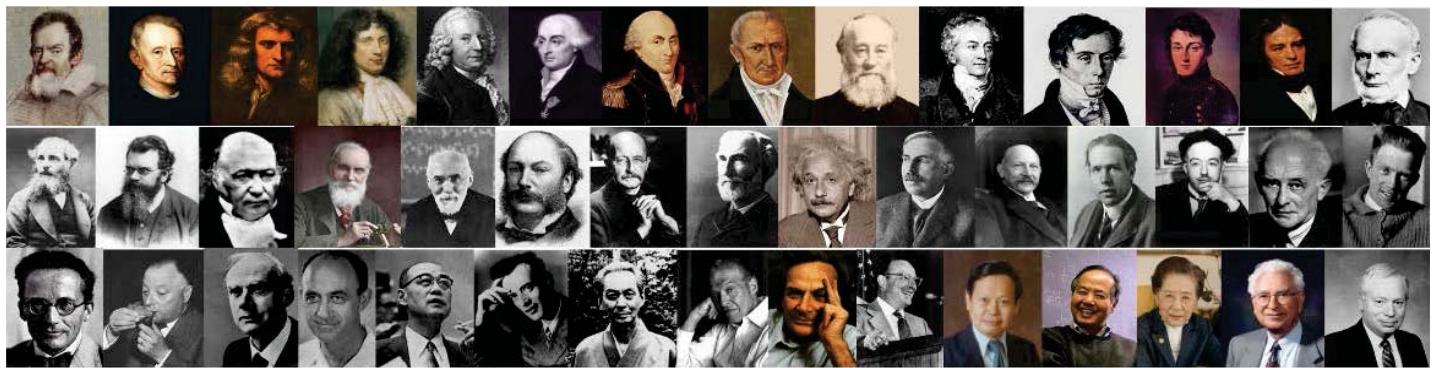
國立臺灣大學理學士（1966），美國 Cornell University 應用物理博士（1973）。

曾任美國奇異公司研發中心資深研究員（1972~1998），工業技術研究院光電所副所長、副院長暨光電所所長（1998~2006），清華大學電資學院旺宏電子講座教授兼光電工程研究所所長（2006~2009），兼臺灣聯合大學系統副校長（2010~2015）。

是工業技術研究院（ITRI）會士（Fellow）、美國光學學會（OSA）會士、國際光電工程學會（SPIE）會士，俄羅斯國際工程學院物理領域通訊院士。曾任中華民國光學工程學會理事長（2002-2007）。

曾獲經濟部「國家創新獎」金牌獎（2002）、第十屆「東元科技獎」（2003）、並在工研院光電所所長任職時帶領研發 On-Chip AC LED Lighting Technology 獲 2008 年「研發百大」科技獎（R&D 100 Awards）。





## 物理學史研習會（六）

時間：2015年10月31日（星期六）

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協辦：教育部普通高級中學課程物理學科中心



### 光學與我 — 兼介紹「2015國際光之年」

蔡定平

台灣大學物理系

中央研究院應用科學研究中心



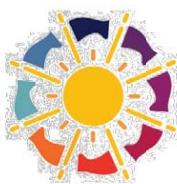
INTERNATIONAL  
YEAR OF LIGHT  
2015



# 報告大綱



2015 國際光之年在台灣  
IYL in Taiwan



學習光學的故事  
Learning Optics, my story



UNIVERSITY OF  
Cincinnati

MLI  
**OLLRC**



# 報告大綱



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**OLLRC**





# The International Year of Light and Light-based Technologies 2015



IYL2015官方宣傳影片

(感謝交通大學陳柏儒同學配音)



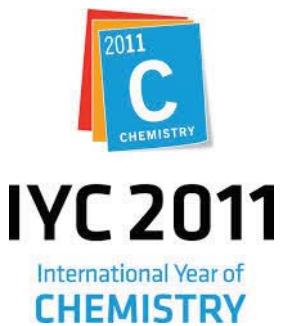
## 起源

2013年12月20日，聯合國教科文組織（UNESCO）宣佈將2015年訂為國際光之年（International Year of Light and Light-based Technologies），簡稱為（IYL 2015），將結合光科技相關學者專家、產業、社團協會與相關教科文人士來進行一個全球性的IYL活動。主要在感謝過去光科技對人類生活與文明進展的正面影響，同時在促進人們對於光科技的瞭解，以及持續光科技在環境保護、永續能源、教育、農業與生醫上的推進。



# Background

- 2015 International Year of Light (IYL 2015)
- 2011 International Year of Chemistry (IYC 2011)
- 2009 International Year of Astronomy (IYA 2009)
- 2005 The World Year of Physics



## Overview and Aims

The International Year of Light is a **cross-disciplinary** educational and outreach project with more than 100 partners from over 85 countries.

### Why Light?

The science and applications of light creates revolutionary - but often unseen - technologies that directly **improve quality of life worldwide**.

Light-based technology is a major **economic driver** with potential to revolutionize the **21st century** [as electronics did in the **20th century**].

#### Health



#### Communications



#### Economy



#### Environment



#### Social





# 100+ partners from 85 countries

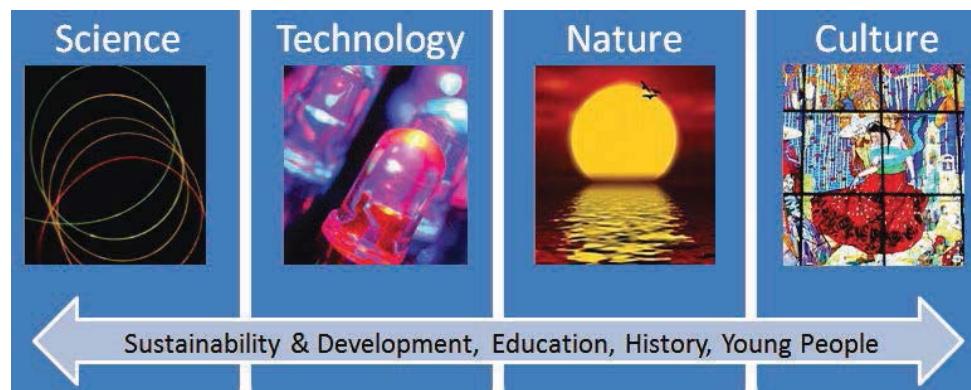


## Opportunity for the future

- The Proclamation of an International Year of Light is a tremendous opportunity to coordinate international activities and promote new initiatives to support the revolutionary potential of light technologies

### How?

- Clear themes, cross-cutting activities, communication with the public



# Light has an inclusive identity for all



- Origin of Life 起源
- Sustainability 永續
- Culture 文化
- Universal 恒常

- International 國際
- Inclusive 包容

- Spectrum 光譜
- Science 科學
- Art 藝術
- Culture 文化
- Education 教育



## 光學史

陽燧

聚光取火凹面銅鏡

西周，距今約3000多年。

晉人崔豹《古今注·雜注》曰：

“陽燧以銅為之，形如鏡，照物則影倒現，向日則生火，以艾炷之則得火。”

《本草綱目》卷主：「陽燧，火鏡也。以銅鑄成，其面凹，摩熱向日，以艾承之，則得火。」

《夢溪筆談》中便有對陽燧的介紹《陽燧照物》：陽燧照物皆倒。



三門峽虢國太子墓中發現西周陽燧，直徑7.5釐米





# 光學史

原文：二臨鑒而立，景到，多而若少，說在寡區。  
譯文：二人，臨鏡而站，影子相反，若大若小。原因在於鏡面彎曲。

原文：鑒位，景一小而易，一大而正，說在中之外內。

譯文：鏡子立起，影子小則是鏡位斜，影子大則是鏡位正中，是所謂以鏡位正中為準，分內外的原理。

原文：鑒團景一。

譯文：無論鏡子大小，影只有一個。

原文：景不徙，說在改為。

譯文：影子不移，是所謂沒改變的結果。

原文：住景二，說在重。

譯文：一止而二影，是所謂重複用鏡的結果。

原文：景到，在午有端與景長，說在端。

譯文：影子顛倒，在光線相交下，焦點與影子造成，是所謂焦點的原理。

原文：景迎日，說在搏。

譯文：影子在人與太陽之間，是所謂反照的結果。

原文：景之小、大，說在地（一說施，傾斜之意）

正、遠近。

譯文：影子的大小，是所謂光線所照地方的遠近而造成的原理。

包含針孔成像、凹凸面鏡成像、組合平面鏡成像、本影半影

墨子關於光學的研究，  
“比我們所知的希臘的為早”  
“印度亦不能比擬”。

---李約瑟《中國科學技術史》  
物理卷



《墨經》針孔成像



## 2015 Celebrates Major Anniversaries

1015 Ibn Al Haythem (伊本·海賽姆) *Book of Optics*



1815 Fresnel and the wave nature of light



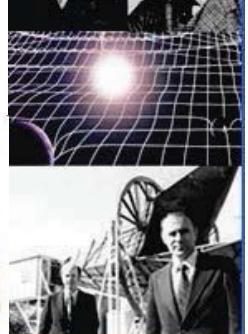
1865 Maxwell and electromagnetic waves



1915 General relativity – light in space and time



1965 Cosmic microwave background, Charles Kao  
and optical fiber technology





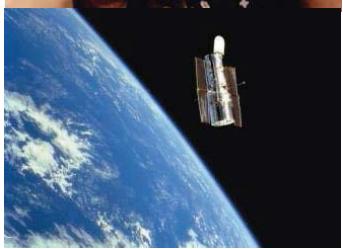
# Activities are very broad - science



Origin of Life



Healthcare



Communications & GPS

Optical Instruments



The Universe



## ... and more than science



Cultural Heritage



Education for All



Nature



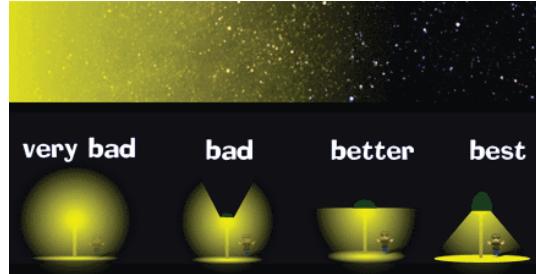
Light and Art



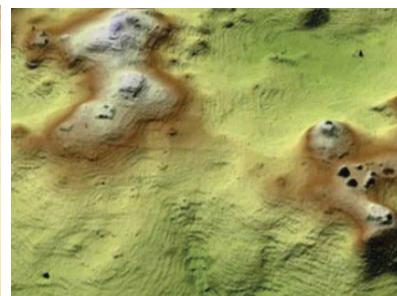


# Cultural Heritage

Smart lighting can both highlight culture and reduce light pollution



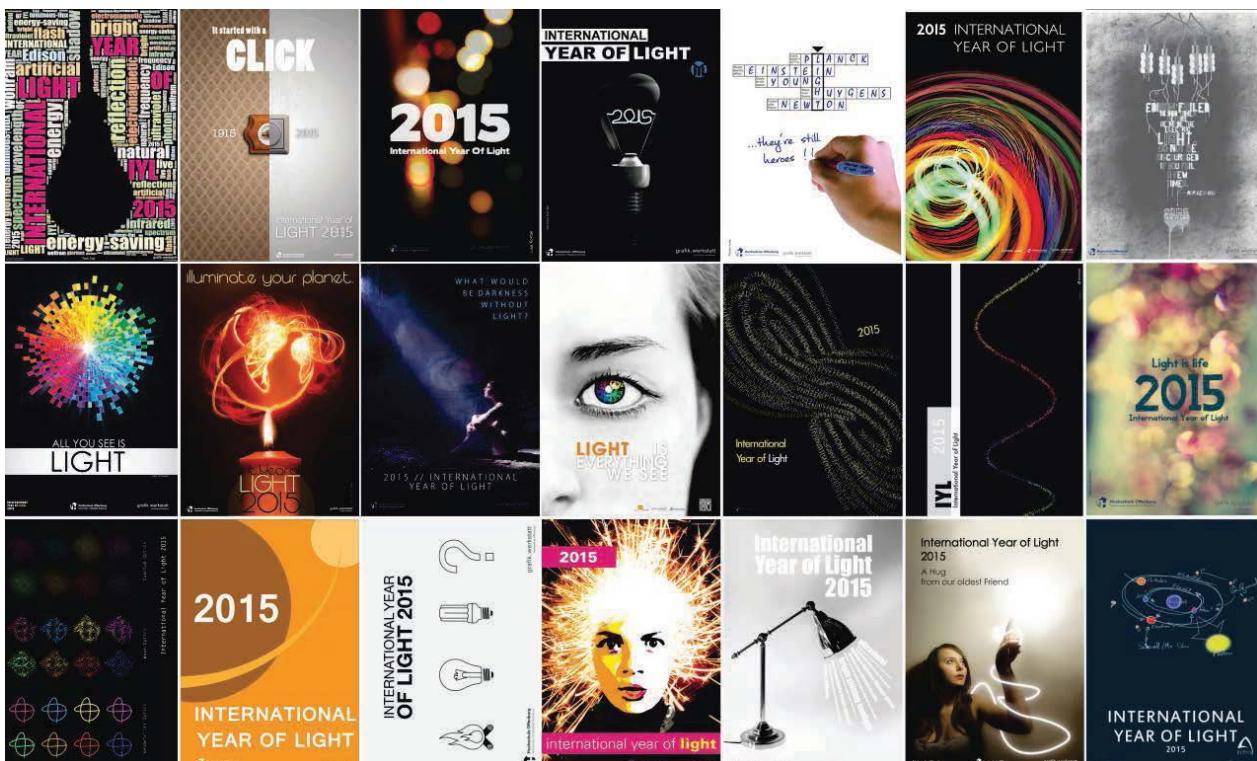
Optical technologies give new impetus - from art to archaeology



Laser imaging at Caracol, Mexico



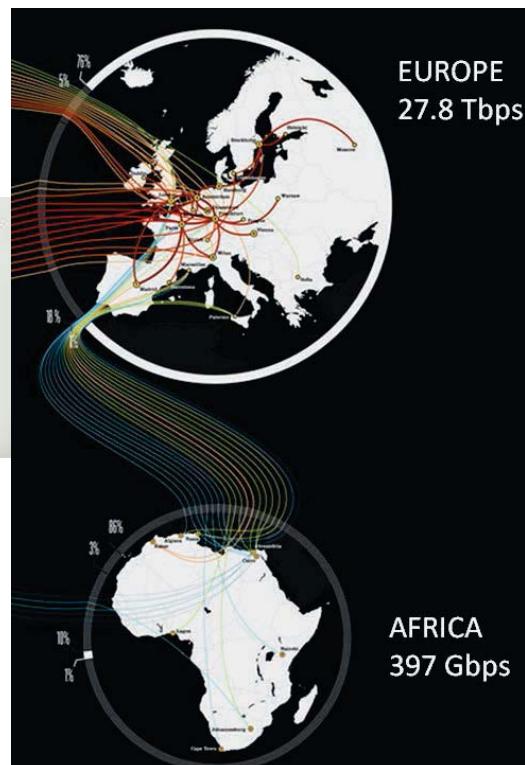
# Natural Connections with Art





# Highlighting Impact on Development

Light technology is at the heart of the Internet and communications



Raising awareness of disparities in information access is essential for future development of society



## Photonics Product Categories

### LED & Lighting Application

- LED Epi & Packaging
- LED Lamp

### Photovoltaic

- Crystalline Silicon Materials
- Silicon & Thin Film Solar Cells
- PV Cell Modules
- PV Power System

### FPD (Flat Panel Display)

- FPD Equipment
- LCD Material & Component
- TFT-LCD Panel & LCM
- TN/STN-LCD
- PDP, OLED, E-paper, 3D

### Image Sensor & Optical I/O Devices

- CCD, CMOS, PD
- Scanner, Bar Code Reader, Fax
- Laser Printer, Copier
- DSC, Camcorder

### Photonics Industry

### Optical Fiber Communication

- Optical Fiber & Cable
- OFC Components
- OFC Equipments

### Precision Optical Components & Lens

- Optical Glass / Plastic Material
- Lens Module

### Optical Storage

- Optical Disc Drive & Player
- CD, DVD, BD Optical Disc

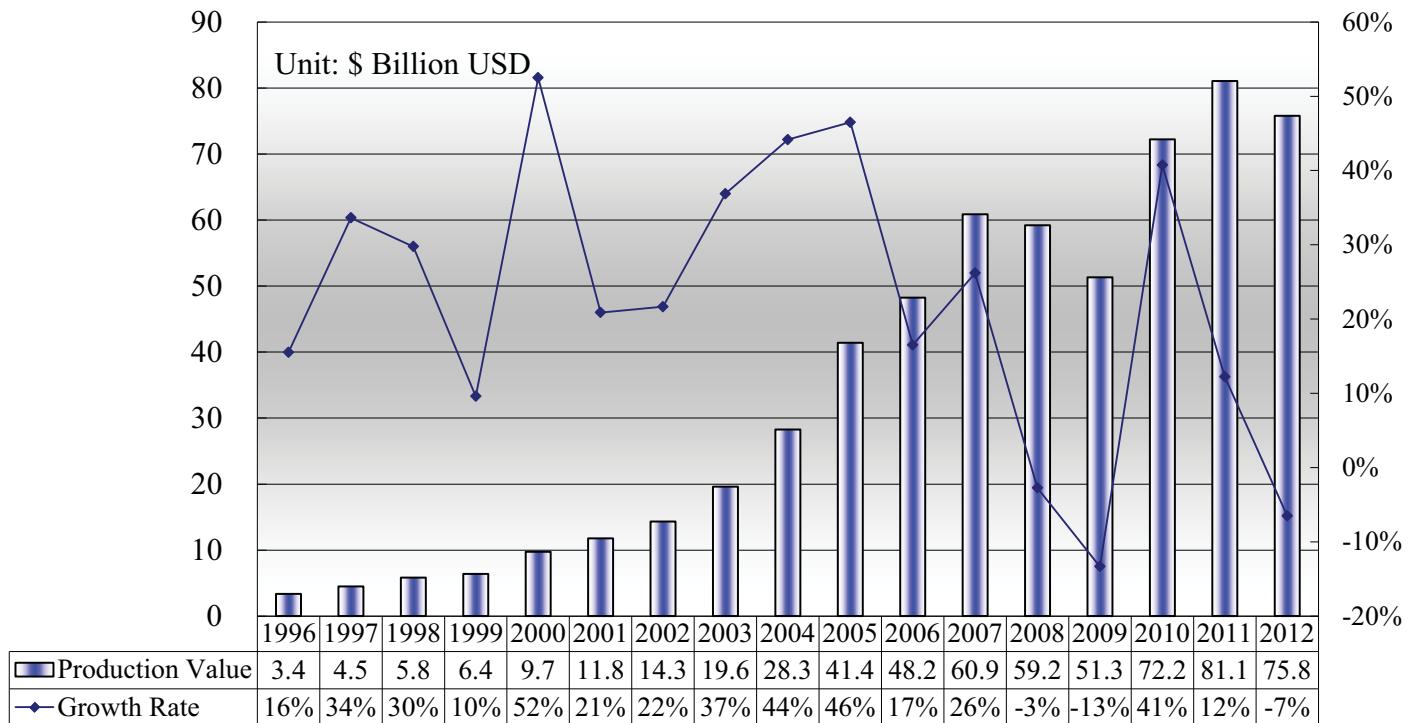
### LASER Light Sources & Industry, Biophotonics

- LD, CO<sub>2</sub> / HeNe Lasers
- Material Processing Machine, Medical Device, etc.



# Taiwan industry grew with worldwide market

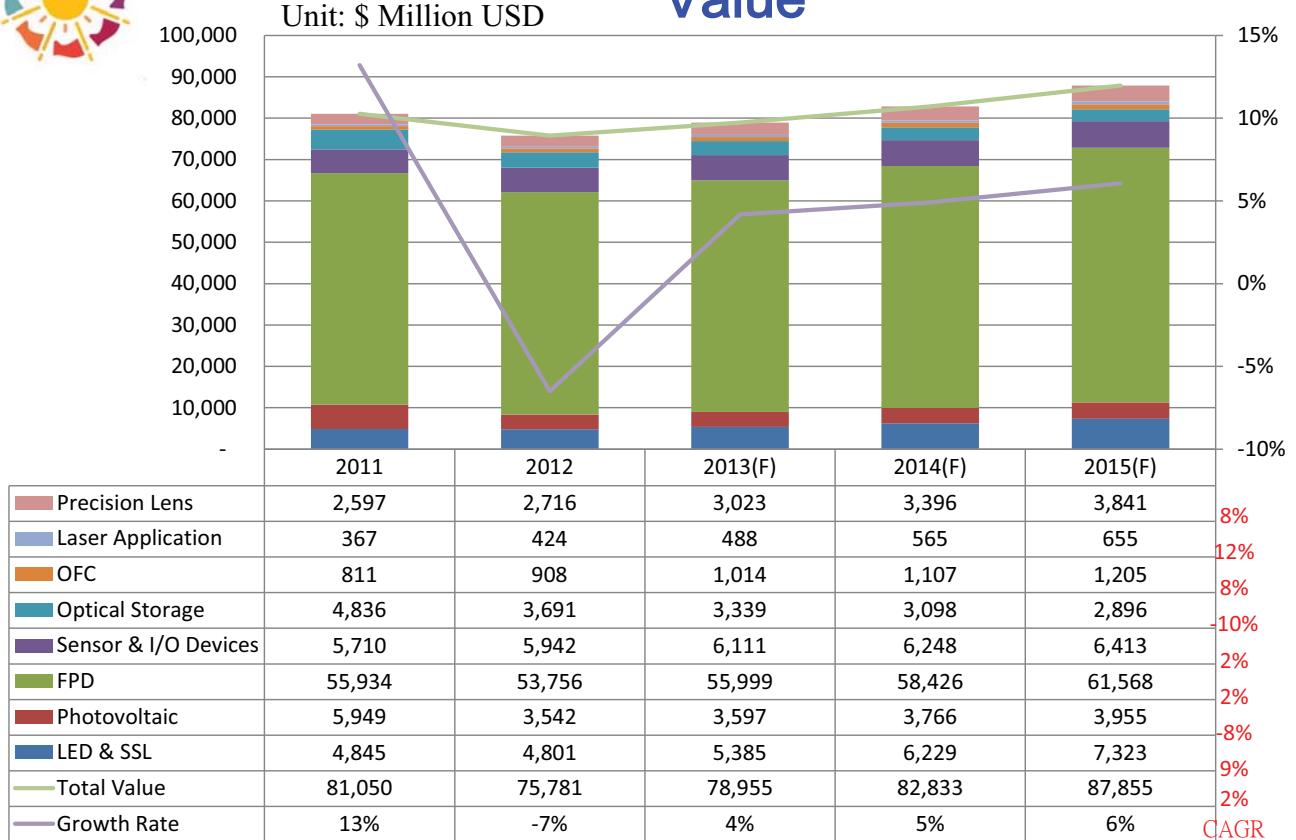
Taiwan Photonics Production Value Trend 1996~2012



June, 2013



## The Trend of Taiwan Photonics Production Value

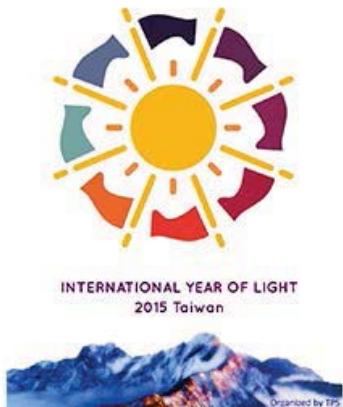


June, 2013



# 台灣光之年籌備委員會 Taiwan IYL Committee

中華民國光電學會代表台灣光電界與聯合國文教組織及國際光電工程學會合作，負責台灣2015年光學的推廣與宣傳。集結台灣包括PIDA（光電科技工業協進會）、TOOMA（台灣區光學工業同業公會）、TISA（台灣光存儲協會）、TVS(台灣真空學會)、TVA（台灣太陽光電產業協會）、台灣光伏產業協會（TPVIA）、TOSA（台灣矽基液晶產學研聯盟）、PSROC（中華民國物理學會）、TPS（中華民國光電學會）等國內主要光科技相關組織，與國內學術界光科技相關系所精英在2014年四月發起籌組Taiwan IYL Committee（簡稱 TIYLC）來統籌各項慶祝 2015 IYL的活動。



TIYLC LOGO



## 台灣光之年活動之國際推廣

光電學會副理事長中央大學孫慶成教授已於2014年8月應國際光電工程學會(SPIE)的邀請，代表台灣將2015年台灣燈會IYL愛因斯坦主燈的設計理念與內容，在美國聖地牙哥國際會議中心的邀請演講中發表，獲得在場許多國際友人的讚賞，也成為吸引國際光電界目光的一個焦點，成功地將台灣燈會這個結合文化與光電產業的年度盛會提升成國際盛事。





## 台灣IYL 活動 (since December, 2014)

- 中華民國光電學會與中興大學共同舉辦“2014 中華民國光電學會會員年度大會暨 IYL 2015 國際光之年開幕點燈儀式”

December 4-5, 2014

### Opening Ceremony for 2015 IYL in Taiwan



IYL 點燈儀式

### Visionary Award 頒獎典禮

台灣積體電路公司 張忠謀董事長獲頒 Visionary Award  
遠見獎之殊榮





## 台灣IYL 活動

- ▶ 陽明大學生醫光電所舉辦 “2nd Annual NYMU Biophotonics Workshop”

December 2, 2014



諾貝爾獎評審委員 Sune Svanberg  
與 Katarina Svanberg 教授夫婦受邀演講，  
並與陽明大學生醫光電所同學合影留念



## 台灣IYL 活動

- ▶ 陽明大學生醫光電所舉辦 “發現光之美”之體驗活動

December 22, 2014



陽明大學生醫光電所同學前進國小  
傳遞光的知識與奧妙



## 台灣IYL 活動

- 台灣大學光電所舉辦“2015國際光年台灣區揭幕式暨光之年系列演講”

January 9, 2015



IYL 揭幕式



光電科技工業協進會董事長  
石大成博士蒞臨給予演講



## 台灣IYL活動之國際推廣

此外，孫教授亦代表出席於今年1月19日在聯合國教科文組織巴黎總部所舉辦的 2015 國際光之年活動開幕典禮，代表台灣在國際上傳達台灣慶祝 2015 IYL的各項活動設計理念與精神，以及台灣光科技之發展現況。



孫教授與國際光電工程學會SPIE  
執行長 Dr. Eugene Arthur合影



## 台灣IYL 活動

- ▶ 國家同步輻射中心舉行“台灣光子源加速器落成典禮”

January 25, 2015



落成典禮點燈儀式



果尚志主任向總統介紹同步  
輻射加速器主體重要結構



## 台灣IYL 活動

- ▶ 台北市立天文館舉行“探索光的奧秘特展揭幕典禮”

January 30, 2015



揭幕典禮

臺北市教育局局長  
湯志民上台致詞





## 台灣IYL 活動

- 中華民國光電學會與台中市政府共同舉辦“台中光谷促進會專題演講暨2015國際光之年台灣光谷點燈儀式”

March 6, 2015



國際光之年愛因斯坦主燈  
於2015年3月5日至15日  
台中烏日「產業科技燈區」隆重展出



## 台灣IYL 活動

- 交通大學邀請諾貝爾獎得主－中村修二訪台

April 10, 2015



中村修二教授與  
馬英九總統會面





## 台灣IYL 活動

► 中央大學光電系暨光電中心國際光之年(IYL)點燈典禮

May 22, 2015

### 愛因斯坦紀念花燈點燈儀式



## 台灣IYL 活動

► 南港國際光電周

June 16-18, 2015



吳敦義副總統在光電週頒發  
第18屆傑出光電產品獎





## 台灣IYL 活動

► 南港國際光電周

June 16-18, 2015



國際光之年論壇講師合影



## 台灣IYL 活動

► 光電巡禮-大安國中參訪

June 18, 2015



於愛因斯坦燈前合影留念



李正中老師介紹光之奧妙



## 台灣IYL 活動

### ► Light Conference: ICOME-T2015

August 10-14, 2015



與會者合影留念



## 台灣IYL 活動

### ► 2015國際光之年科普講座暨創意光電DIY工作坊

October 4, 2015





# 台灣IYL 演講活動

## ► 國際光之年一、二、三月系列演講 (IYL Talks Series)

**2015 國際光之年系列演講  
IYL Talks Series  
一、二月演講活動**

|  |   |
|--|---|
|  | • 台灣科技大學電子系專題演講:<br>January 5, 14:00<br>台灣科技大學國際大樓IB-401<br>Title: Current Development of Volume Holographic Storage    |
|  | • 中興大學光電種子師資營:<br>January 30, 09:30-12:30<br>中興大學雲平樓 F12教室<br>Title: 楊敏太陽能電池實做<br>報名請洽: 林曉吟小姐 04-22840455 轉 2155        |
|  | • 臺灣大學光電系專題演講:<br>January 9, 16:30-18:00<br>台灣大學博理館101大講堂<br>Title: 臺灣光電產業發展<br>30周年之回顧與展望                              |
|  | • 中興大學光電種子師資營:<br>January 30, 13:30-16:30<br>中興大學雲平樓 F12教室<br>Title: 初步照明之製程介紹<br>與應用<br>報名請洽: 林曉吟小姐 04-22840455 轉 2155 |
|  | • 成功大學光電營:<br>February 3, 09:30-11:00<br>成功大學光復校區<br>國際會議廳第一演講室<br>Title: 奈米尺度下的光電<br>世界<br>林建中教授<br>交通大學光電學院           |
| <b>主辦單位:</b><br><b>2015 國際光之年籌備委員會</b> |   |
| 活動洽詢:<br>江采芳小姐 02-33665100             |   |

**2015 國際光之年系列演講  
IYL Talks Series  
三月演講活動**

|  |   |
|--|---|
|  | • "LIGHT FOR LIFE" SHORT COURSE:<br>March 2-12, 10:00-12:00<br>中研院跨領域科技研究大樓 1 樓<br>B106 演講廳<br>Prof. Yin Yeh<br>Dept. Applied Science, UC Davis<br>Title: Light for Life<br>評論評議會洽: 蘭玲蕙小姐 02-27873103 |
|  | • 台大物理系專題演講:<br>March 9, 14:20-16:20<br>台灣大學物理新館 R833<br>Title: 光速量測方法之探討<br>吳靜雄教授<br>台灣大學電機工程系   |
|  | • 台大光電系專題演講:<br>March 13, 16:30-18:00<br>台灣大學博理館101大講堂<br>Title: 信息醫學-X信息的發現<br>李嗣鴻教授<br>台灣大學電機工程系  |
|  | • 成大光電系專題演講:<br>March 15, 13:20-15:10<br>交通大学光電大樓103教室<br>Title: 全像術-近代光學的美與應用<br>許根玉教授<br>交通大学顯示科技所  |
|  | • 中央光電系書報討論:<br>March 13, 14:00-16:00<br>中央大學國鼎光電大樓1F<br>國際會議廳104室<br>林清富教授<br>台灣大學電機工程系  |
|  | • 台大物理系專題演講:<br>March 16, 14:20-16:20<br>台灣大學物理新館 R833<br>Title: 氧化鎗量子井發光二極體效率<br>瓶頸的探討及與組成份擾動之間的關係<br>吳育任教授<br>台灣大學光電工程系   |
|  | • 交大光電系專題演講:<br>March 27, 13:20-15:30<br>交通大学光電大樓103教室<br>Title: 光學與機械組曲-元件與系統<br>黃得瑞教授<br>東華大學光電工程系  |
|  | • 台大光電系專題演講:<br>March 27, 16:30-18:00<br>台灣大學博理館101大講堂<br>Title: 太陽能電池的發展思考與契機<br>黃吉宏博士<br>國家實驗研究院儀器科技研究中心<br>先進光學組   |
| <b>主辦單位:</b><br><b>2015 國際光之年籌備委員會</b> |   |
| 活動洽詢:<br>江采芳小姐 02-33665100             |   |



# 台灣IYL 演講活動

## ► 國際光之年四、五月系列演講 (IYL Talks Series)

**2015 國際光之年系列演講  
IYL Talks Series  
四月演講活動**

|  |   |
|--|---|
|  | • 中正大學光機電整合所演講:<br>April 8, 14:00-16:00<br>中正大學物理館530室<br>Title: Process Development of High Bright InGaN LEDs                      |
|  | • 中正大學光機電整合所演講:<br>April 15, 14:10-16:00<br>中正大學物理館530室<br>Title: 近紅外光影像技術於臨床醫學應用<br>孫家偉教授<br>交通大學光電系                               |
|  | • 中興大學精密所專題演講:<br>April 10, 10:10-12:00<br>中興大學電機大樓3樓302室<br>Title: 光速量測方法之探討<br>吳靜雄教授<br>台灣大學電機工程系                                 |
|  | • 清華大學光電所書報討論:<br>April 10, 14:20-16:00<br>清華大學台達館217會議室<br>Title: Color from nanostructure thin film in nature<br>李正中教授<br>中央大學光電系 |
|  | • 中央大學光電系書報討論:<br>April 10, 14:00-16:00<br>中央大學國鼎光電大樓1F<br>國際會議廳104室<br>Title: 金屬氧化物薄膜電晶體及其生醫感測應用<br>黃建璋教授<br>台大光電所教授               |
| <b>主辦單位:</b><br><b>2015 國際光之年籌備委員會</b> |   |
| 活動洽詢:<br>江采芳小姐 02-33665100             |   |

**2015 年五月國際光之年系列演講  
2015 May IYL Talks Series**

|                         |   |
|-------------------------|---|
|                         | • 新型光學與如顯微鏡技術<br>Digital optics and Iris Recognition<br>May 1, 16:30-18:00<br>台灣大學 博理館1F 101大講堂<br>田仲豪 教授<br>交通大學光電系  |
|                         | • 最新的半導體雷射-微共振腔<br>激子雷射與表面電層共共振<br>Lasers or not? Tailor the novel semiconductor coherent light emitters: microcavity-exciton-polariton lasers and surface plasmon polariton nanolasers<br>May 8, 14:00-16:00<br>中央大學 國鼎光電大樓<br>國際會議廳 104室<br>盧延昌 教授<br>交通大學光電系 |
|                         | • 使用石墨烯電極之全溶液型程溴<br>明光電光<br>Full solution-processed transparent optoelectronics with graphene electrodes<br>May 8, 14:10-16:00<br>東華大學 理工二館 C403<br>吳志毅 副所長<br>工研院光電所   |
|                         | • 極端環境的光學儀器設計<br>—以低溫高磁環境為例<br>Optical instrumentation in Extreme Environments - From Low Temperature to High Magnetic Field<br>May 12, 13:10-14:55<br>彰化師範大學 進德校區<br>致誠館 1F 22101室<br>孫允武 教授<br>中興大學物理系  |
|                         | • 功能性晶體光纖光子元件<br>Functional Crystal Fiber Photonic Devices<br>May 14, 14:00-16:00<br>東華大學 理工二館 C403<br>賴建智 教授<br>東華大學物理系  |
|                         | • 當原子級材料-金屬-介電質<br>多層膜結構之光學特性<br>Plasmonic Metamaterials - Optical Properties of metal-dielectric multilayered structures<br>May 29, 14:00-15:20<br>藍水強 教授<br>成功大學光電系<br>研華國際會議廳<br>傅水貴 教授<br>成功大學光電系   |
| 主辦單位: 2015 國際光之年籌備委員會   |   |
| 活動洽詢: 江采芳小姐 02-33665100 |   |



# 台灣IYL 演講活動

## ► 國際光之年六至十月系列演講 (IYL Talks Series)

**2015年國際光之年  
六月份系列演講  
2015 IYL Talks Series in June**

**砂基光學連接**  
silicon-based Optical interconnects  
June 2, 13:30-15:00  
逢甲大學 理學大樓 理101教室  
**伍慶仁 教授**  
中央大學光電系

**光速量測方法之探討**  
Discussing the methods of measuring the speed of light  
June 5, 13:10-15:00  
成功大學 成功校區 實驗大樓 格致廳大講堂  
**吳靜雄 教授**  
台灣大學電機系

**高功率LED熱管理的封裝研究**  
Thermal Management and Packaging of High-Power LEDs  
June 8, 14:10-16:00  
中山大學 光電系階梯教室  
工EC 4012室  
**成東昇 校長**  
大葉大學

**Plasmonic superlocalization in percolated random films**  
June 9, 13:30-15:00  
逢甲大學 理學大樓 理101教室  
**戴朝麗 教授**  
中央大學光電系

**光科技對過去、現在和未來人類文明的影響**  
The past, present and future impacts of optical and photonic technologies to human civilization  
June 12, 14:00-16:00  
中央大學 頤鼎光電大樓1F 國際會議廳104室  
**張萬志 主任**  
同步輻射中心

**主辦單位:** 2015 國際光之年籌備委員會  
**活動洽詢:** 江采芳小姐 02-33665100

**聯合主辦:** 中華民國光電學會 TPS  
DOP Department of Optics and Photonics, NSC  
IP-S International Photonic Society  
PHOTONICS

**2015年九、十月 國際光之年系列演講  
2015 September & October IYL Talks Series**

**電離子奈米光學:**  
從生物感測到金屬增強螢光  
Plasmonic Nanophotonics: from Bio-sensing to Metal Enhanced Fluorescence  
Sep. 25, 10:10-12:00  
中興大學 精密館M106教室  
**江海輝 教授**  
海洋大學光電系

**Tunable focusing liquid crystal lenses**  
Sep. 25, 13:30-15:00  
東海大學 科技大樓ST122  
**林怡欣 教授**  
交通大學光電系

**多頻譜攝影在生醫之應用**  
Multi-Spectral Images for Biomedical Application  
Sep. 29, 13:30-15:00  
中興大學 理學大樓101教室  
**歐陽盈 教授**  
交通大學光電系

**3D漂浮顯示與空氣觸控技術**  
3D Floating Display and Air-touch Interaction Technology  
Oct. 2, 10:10-12:00  
中興大學 精密館M106教室  
**黃乙尚 教授**  
交通大學光電系

**資料中心與雲端運算的興起-對光通訊發展的影響與衝擊**  
Big Data, Clouding computing and its Implications to optical communications  
Oct. 6, 13:30-15:00  
逢甲大學 理學大樓101教室  
**陳智弘 教授**  
交通大學光電系

**環保和維護健康的光電科技**  
Photonics for Environment and Health Protection  
Oct. 16, 13:30-15:00  
東海大學 科技大樓ST122  
**林育賢 教授**  
台灣大學電機系

**Solution Processable Small Molecule Solar Cells**  
Oct. 30, 14:00-15:20  
交通大學 台南校區奇美樓 研華國際會議廳  
**李治偉 研究員**  
中研院應科中心

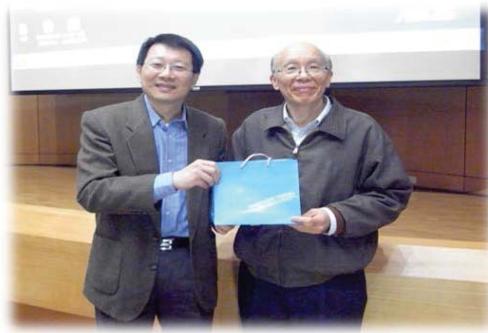
**光學與光學薄膜-慶祝2015國際光之年系列演講**  
Optics and Optical Thin Films-Series of Seminars in Celebration of International Year of Light 2015  
Oct. 30, 13:30-15:00  
**李正中 教授**  
中央大學光電系  
**主辦單位:** 2015 國際光之年籌備委員會  
**活動洽詢:** 江采芳小姐 02-33665100

**聯合主辦:** DOP  
IP-S  
PHOTONICS

至今已在全台各地舉辦超過40場光之年演講



中央大學李正中教授至  
高雄市鳳山高中給予演講



台灣大學李嗣涔教授至  
台大光電所給予演講



中央大學陳昇暉主任至  
台大物理系給予演講



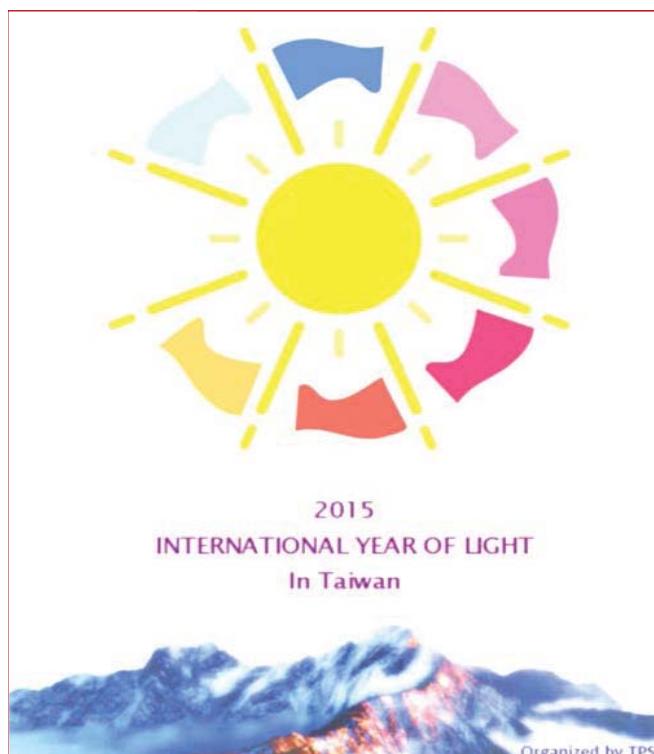
# The International Year of Light and Light-based Technologies 2015



## IYL2015國際光之年部分回顧



## 2015 International Year of Light in Taiwan



- (1) 國際光年 (International Year of Light, IYL)  
網站 : <http://www.light2015.org/Home.html>
- (2) 台灣 IYL (International Year of Light)  
網站 : <http://iyl2015.tps.com.tw/>
- (3) IYL 花燈動畫的連結網址  
: <https://www.youtube.com/watch?v=6A9Rz03VAT0>
- (4) IYL 2015 國際光年在台灣回顧影片的連結網址  
<https://www.youtube.com/watch?v=TUWEXKmVsn4>



# 未來活動規劃

| 活動時間                     | 活動名稱   | 活動負責人                    | 承辦單位    |
|--------------------------|--|--------------------------|---------|
| 2015/10/24<br>2015/10/31 | 物理學史研習會  | 劉源俊                      | 東吳大學物理系 |
| 2015/11/15~11/18         | 亞太地區光生物學國際研討會<br>(7th Asia and Oceania Conference<br>on Photobiology, AOCP 2015)                       | 涂世隆                      | 中研院植物所  |
| 2015/12/04~12/06         | 光電年會 OPTIC 2015<br>(Optics & Photonics Taiwan,<br>International Conference)<br><br>The End of IYL 2015 | 劉容生<br>王立康<br>黃衍介<br>李瑞光 | 清華大學光電系 |



## Summary

### Why light and optics?

Light is central to science, technology, art and culture.

Light can promote education at all levels.

Light technology drives development.

### Why an International Year of Light?

The importance of light technology needs to be appreciated.

International coordination will create durable programmes.

We aim to inspire a new generation to study science through light.

**The 21st century is the Century of Light.**

# 報告大綱



2015 國際光之年在台灣  
IYL in Taiwan



學習光學的故事  
Learning Optics, my story



UNIVERSITY OF  
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**OLLRC**



## 學習光學的故事my story



基礎光學, 全像片, 光波導  
Optics, Hologram, Optical Waveguide



UNIVERSITY OF  
**Cincinnati**



拉曼光譜, 光學子STM, 波導速逝波, 近場光學  
Raman Spectroscopy, Photon Scanning Tunneling Microscopy,  
Evanescence Wave, Near-field Optics



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奈米光學, 奈米光電, 電漿子光學  
Nano Optics, Nanophotonics, Plasmonics



超穎物質, 變換光學, 超穎表面, 超穎全像片, 超穎元件  
Metamaterial, Transformation Optics, Meta Surface, Meta Hologram,  
Meta Device and System



# 學習光學的故事my story



基礎光學, 全像片, 光波導  
Optics, Hologram, Optical Waveguide



拉曼光譜, 光學子STM, 波導速逝波, 近場光學  
Raman Spectroscopy, Photon Scanning Tunneling Microscopy,  
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奈米光學, 奈米光電, 電漿子光學  
Nano Optics, Nanophotonics, Plasmonics

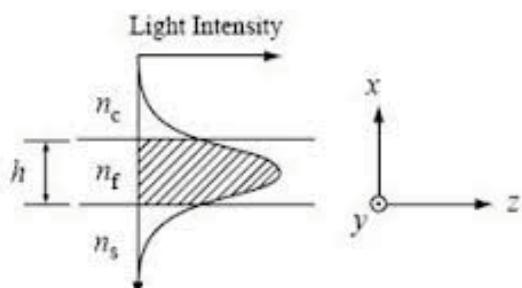


超穎物質, 變換光學, 超穎表面, 超穎全像片, 超穎元件  
Metamaterial, Transformation Optics, Meta Surface, Meta Hologram,  
Meta Device and System

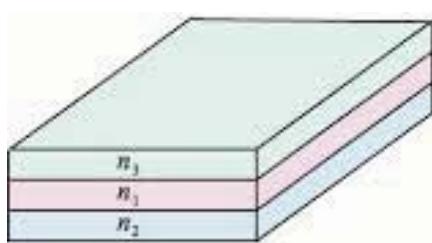
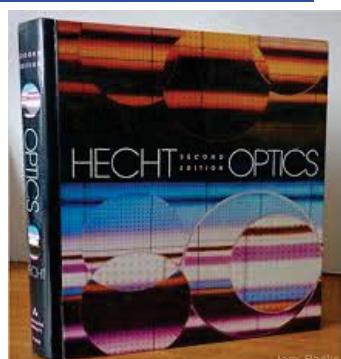


## 在東吳學習光學的故事my story

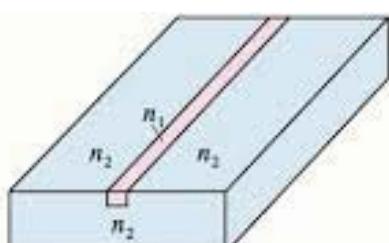
基礎光學 +  
光波導, 光學干涉儀, 全像片



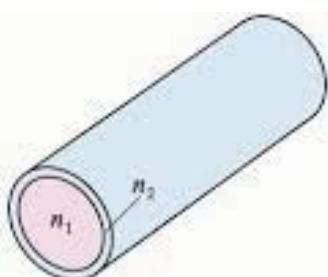
**Optics**  
作者：Eugene Hecht  
出版社：Addison-Wesley



a 平面介質光波導



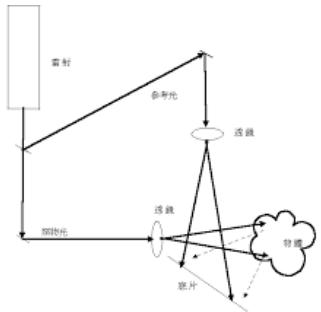
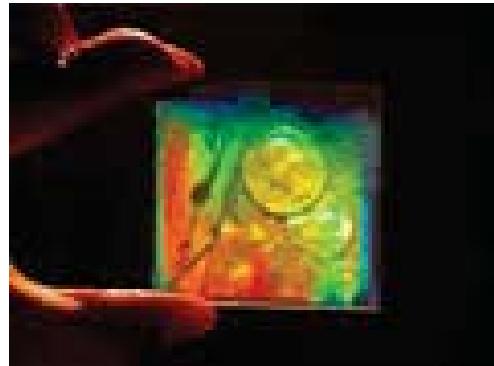
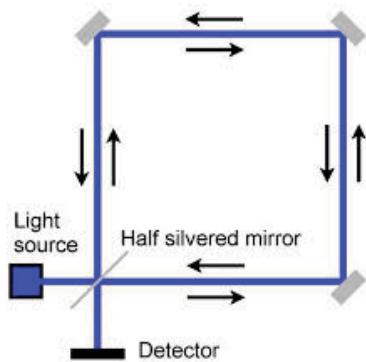
b 条形介質光波導



c 圓柱形介質光波導

# 在東吳學習光學的故事my story

基礎光學,光波導,光學干涉儀,全像片



## 學習光學的故事my story



基礎光學, 全像片, 光波導  
Optics, Hologram, Optical Waveguide



拉曼光譜,光學子STM,波導速逝波,近場光學  
Raman Spectroscopy, Photon Scanning Tunneling Microscopy,  
Evanescence Wave, Near-field Optics



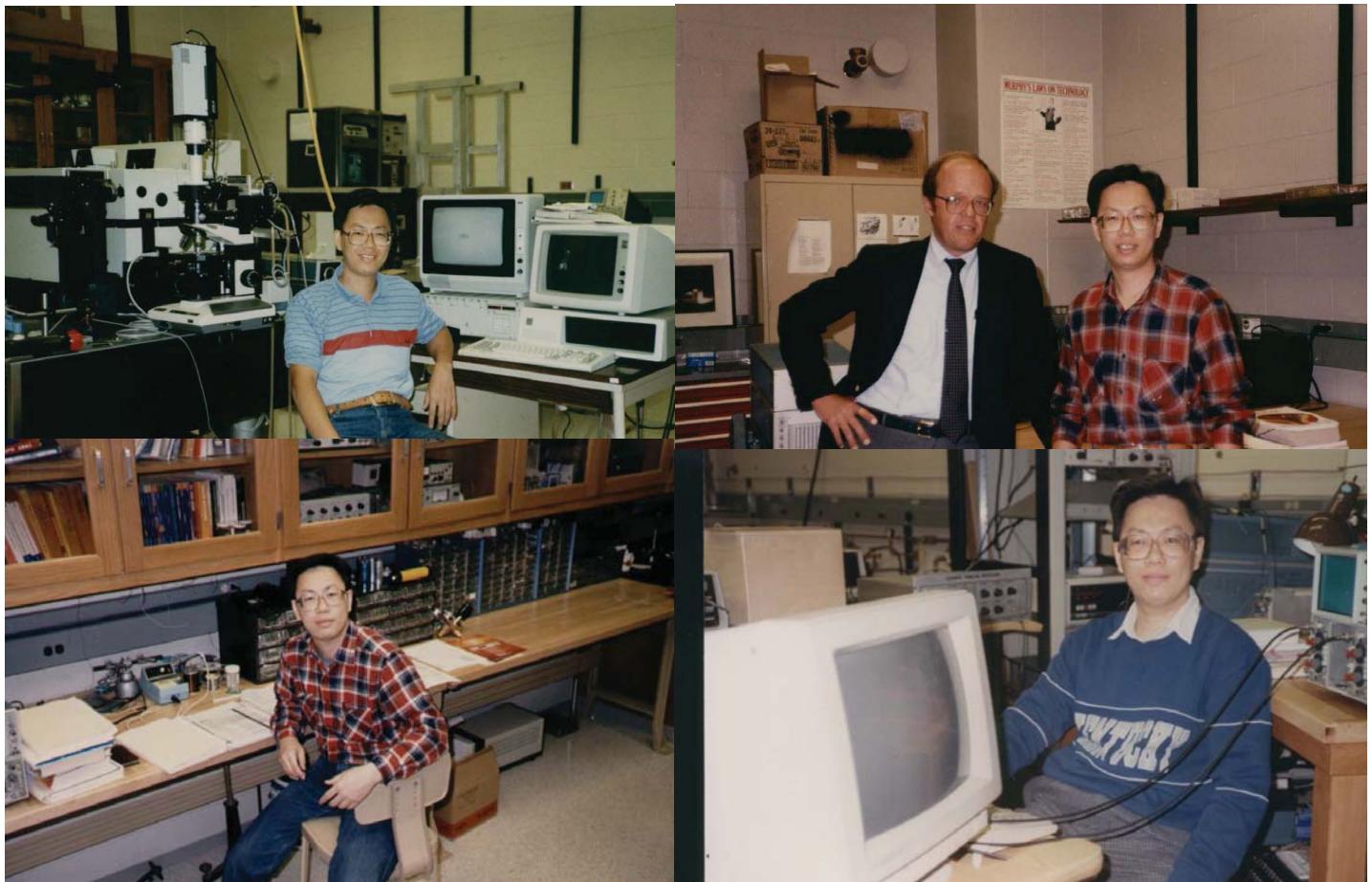
奈米光學, 奈米光電, 電漿子光學  
Nano Optics, Nanophotonics, Plasmonics



超穎物質, 變換光學, 超穎表面, 超穎全像片, 超穎元件  
Metamaterial, Transformation Optics, Meta Surface, Meta Hologram,  
Meta Device and System

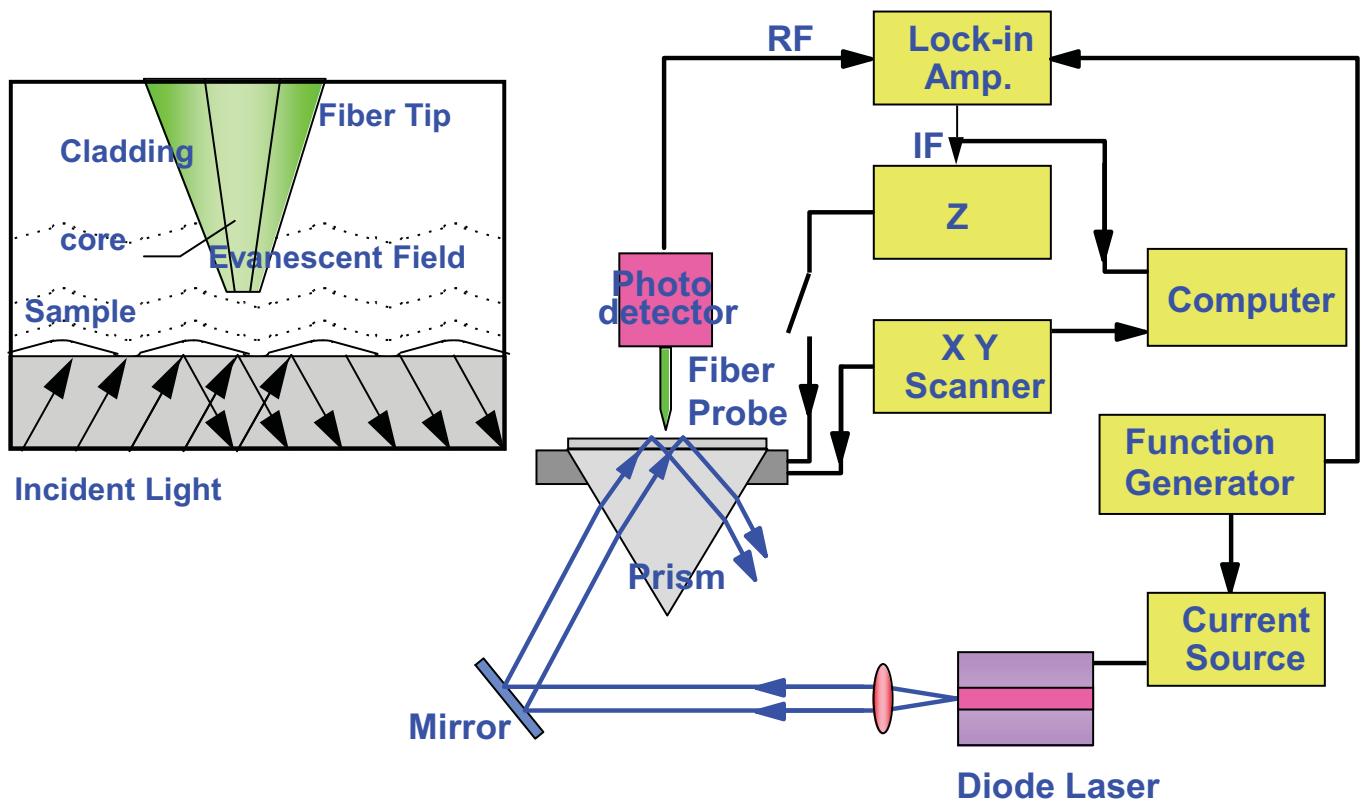


# 在辛大學習光學的故事my story



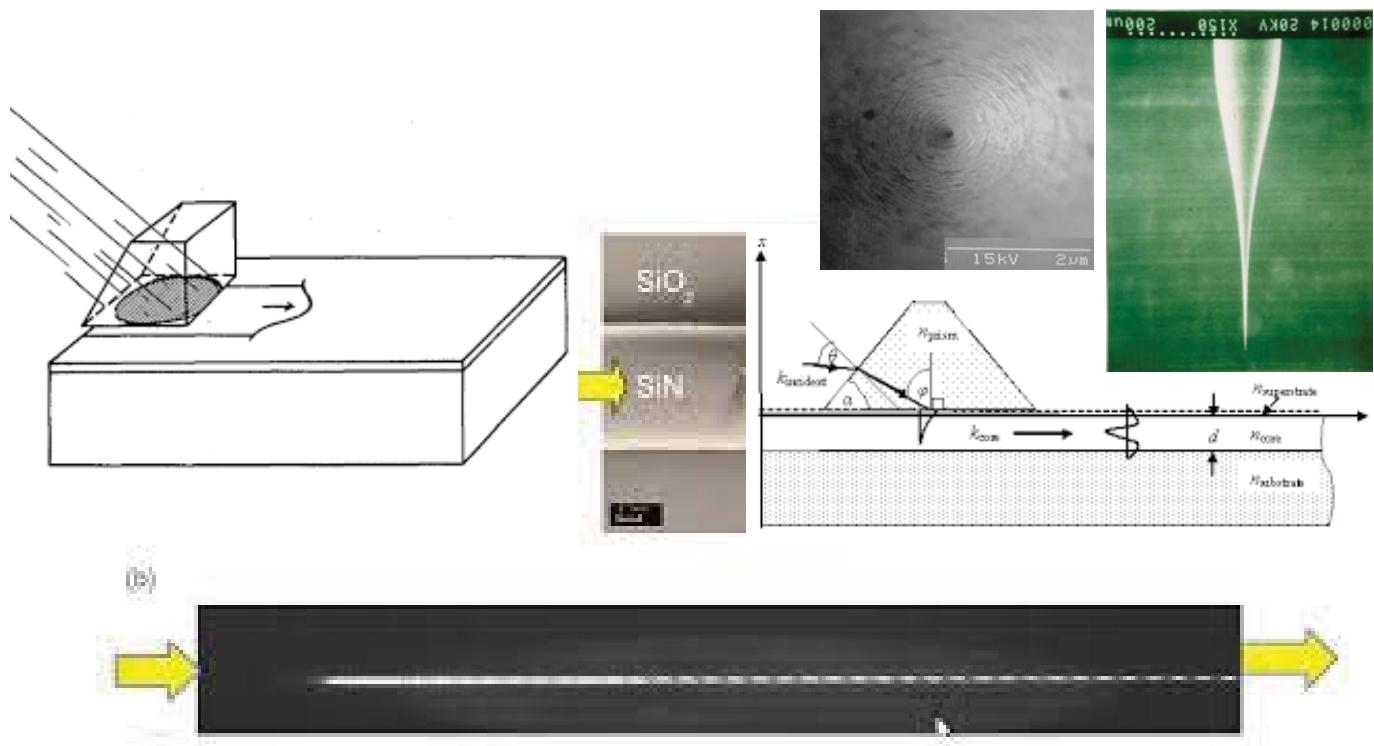
# 在辛大學習光學的故事my story

Photon scanning tunneling microscope (PSTM)

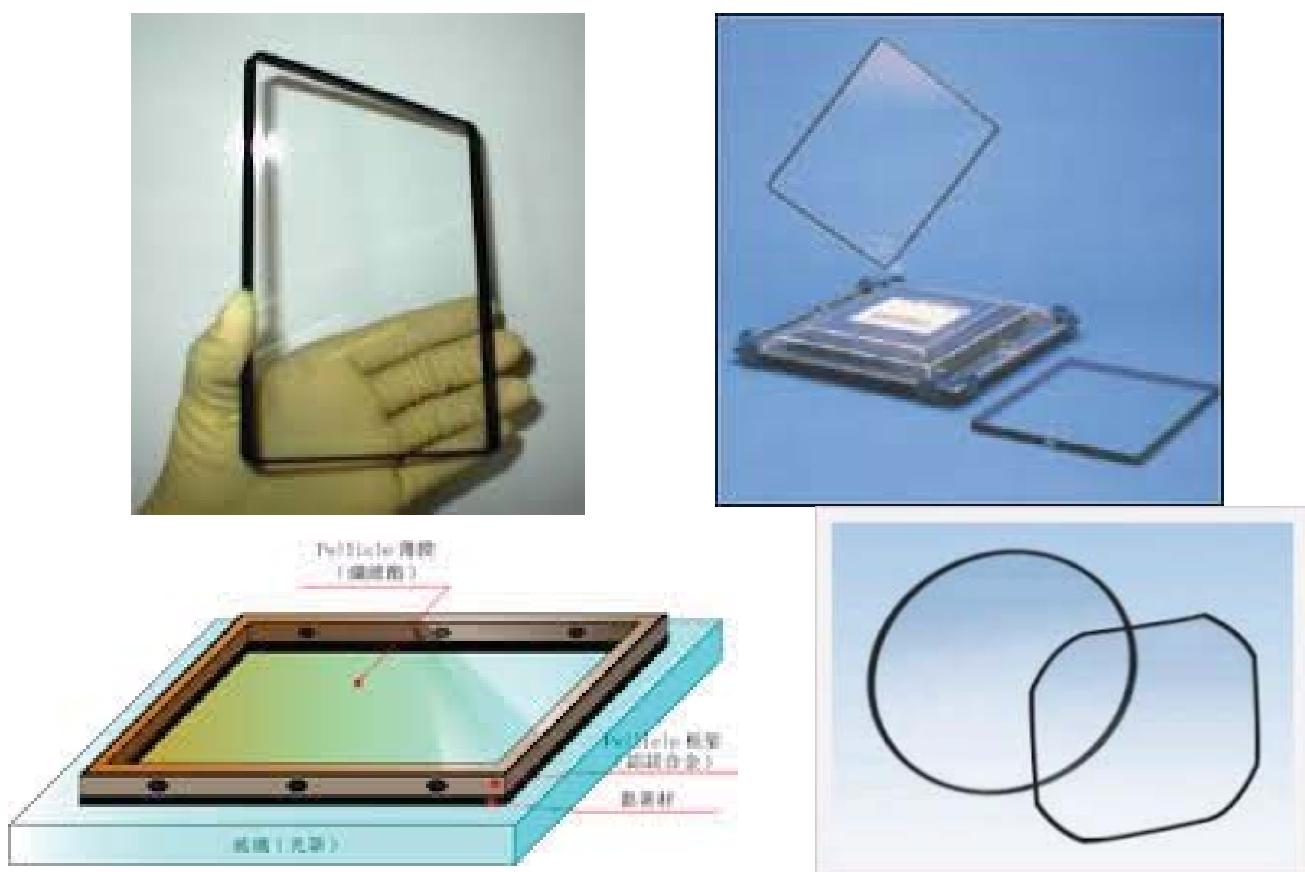


# 在辛大學習光學的故事my story

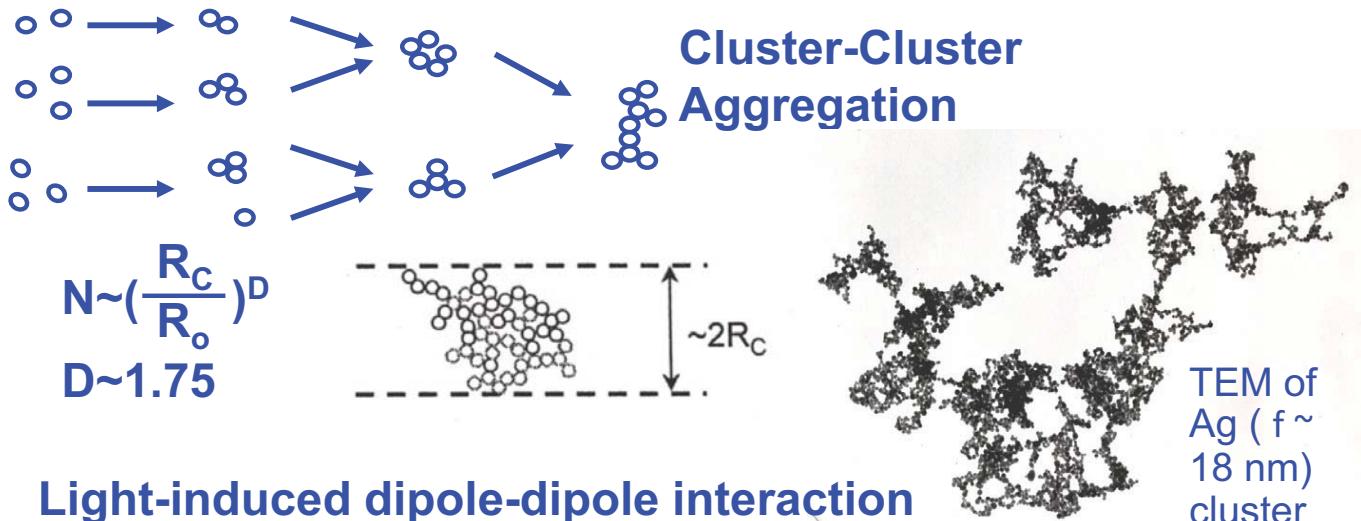
"Photon scanning tunneling microscope study of optical wave-guides," Applied Physics Letters 56(16), 1515 (1990).



# 在矽谷學習光學的故事my story



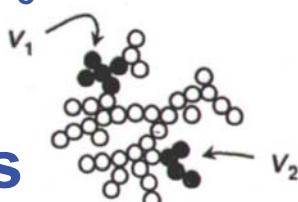
# 在OLLRC學習光學的故事my story



Light-induced dipole-dipole interaction

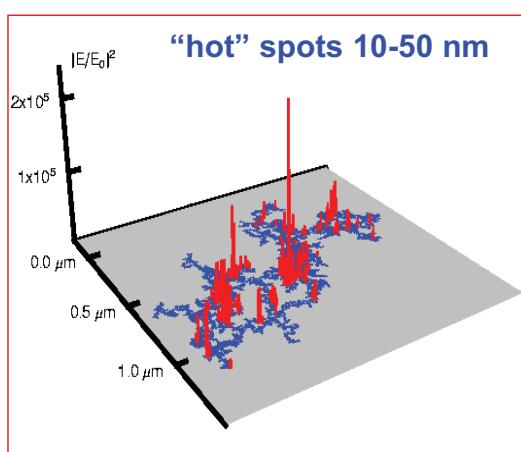
=>Each normal mode is localized at a portion of the fractal cluster  $\ll R_c$  but  $\gg R_o$

LSP model of fractal metal colloid clusters



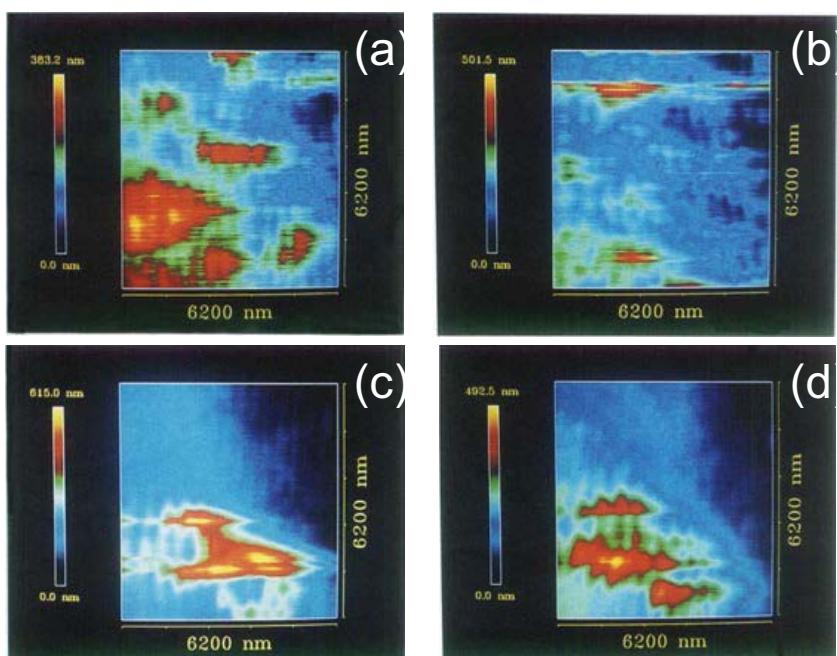
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# 在OLLRC學習光學的故事my story



Calculation results of the random particles

Localization, enhancement, and influence of polarization and wavelength!



Photon STM images of local fields in fractal silver colloid aggregates irradiated by light of varying wavelength and polarization (a), (b)  $\lambda=488 \text{ nm}$ , s and p polarization, respectively. (c), (d) p polarization,  $\lambda=488$  and  $514.5 \text{ nm}$ , respectively. Two different samples were used to obtain images (a), (b) and images (c), (d).

Localized surface plasmon

"Photon scanning-tunneling-microscopy images of optical-excitations of fractal metal colloid clusters," Phys. Rev. Lett. 72, 4149 (1994)

# 學習光學的故事my story



基礎光學, 全像片, 光波導  
Optics, Hologram, Optical Waveguide



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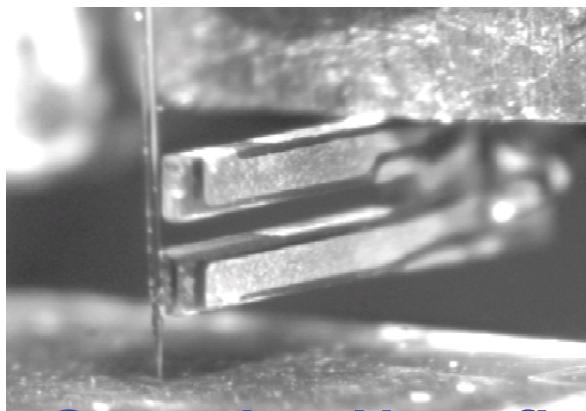
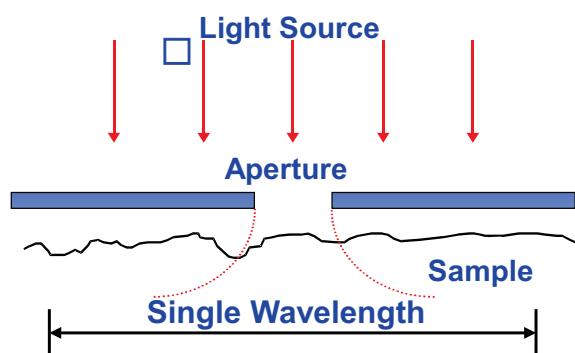


超穎物質, 變換光學, 超穎表面, 超穎全像片, 超穎元件  
Metamaterial, Transformation Optics, Meta Surface, Meta Hologram,  
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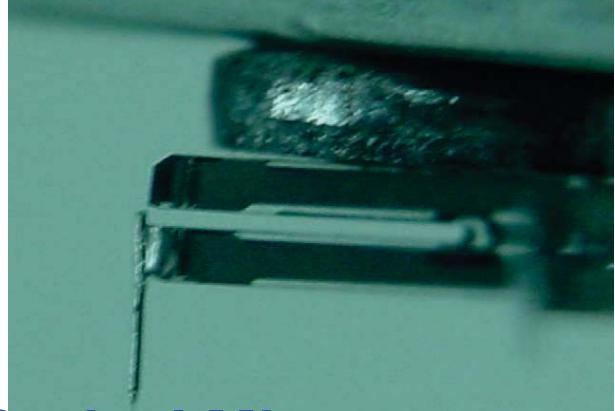
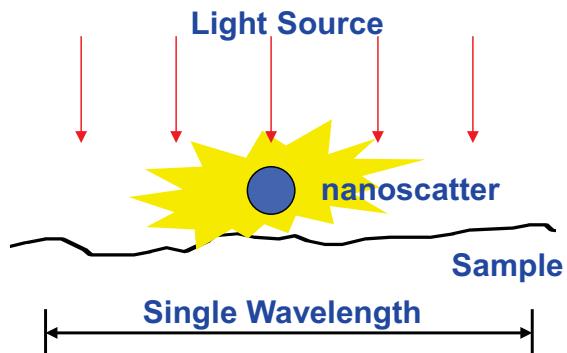


## 在中正學習光學的故事my story

(a) Aperture type



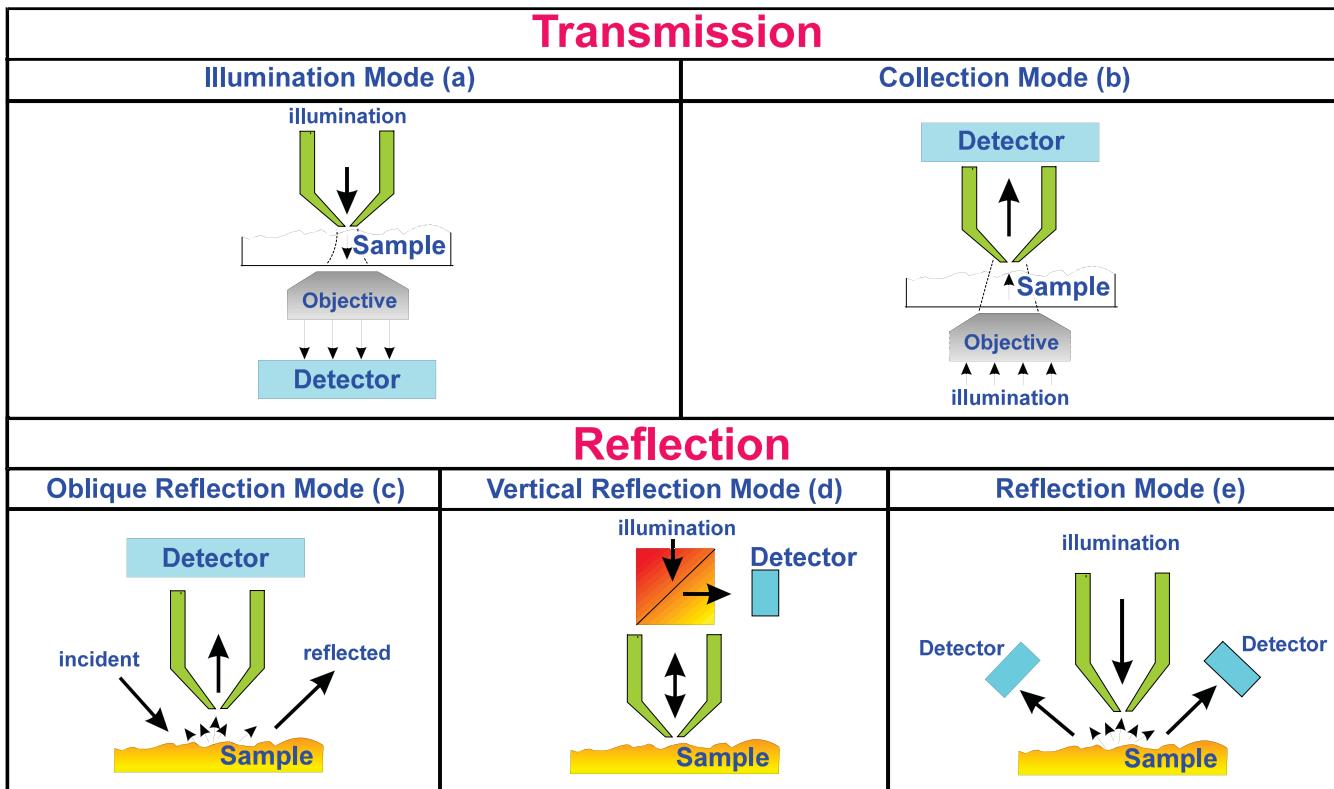
(b) Scattering type



**Scanning Near-field Optical Microscopy**

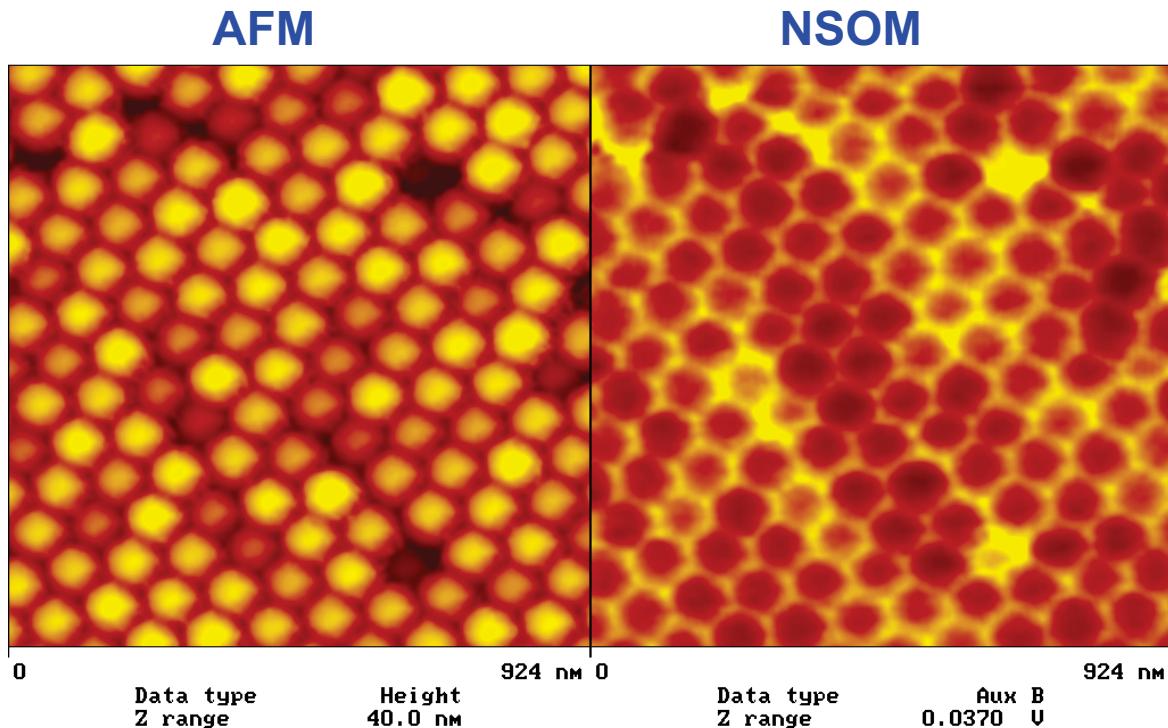
# 在中正學習光學的故事my story

## Modes of Operation for SNOM



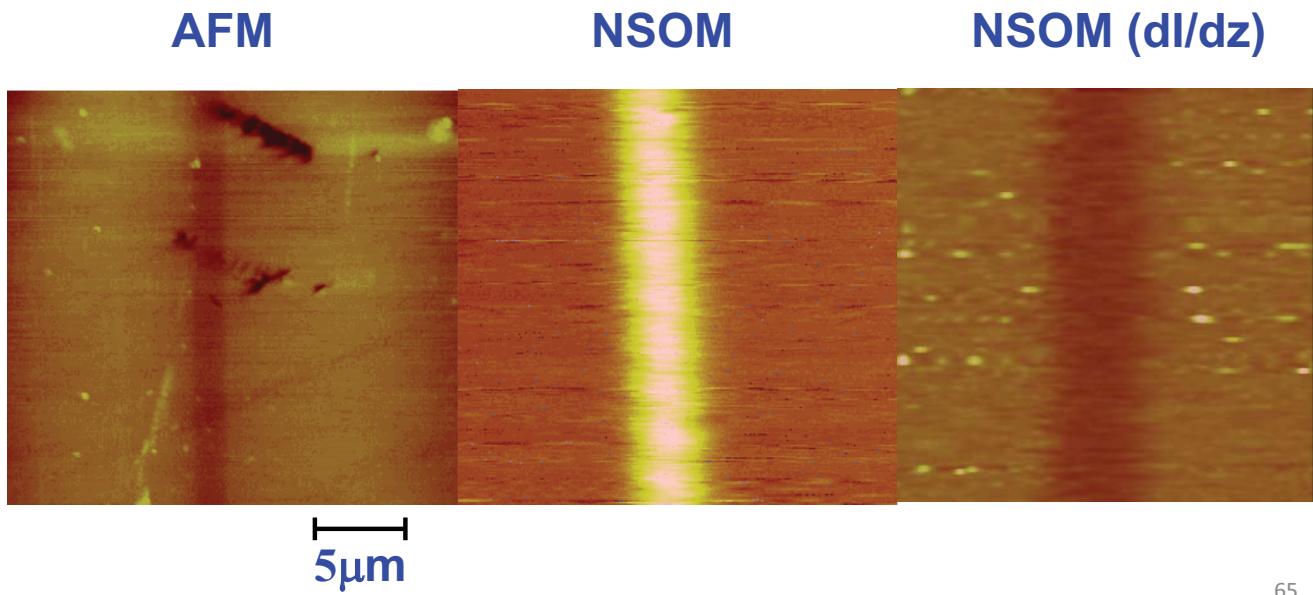
# 在中正學習光學的故事my story

□ 100nm polystyrene nanoparticles



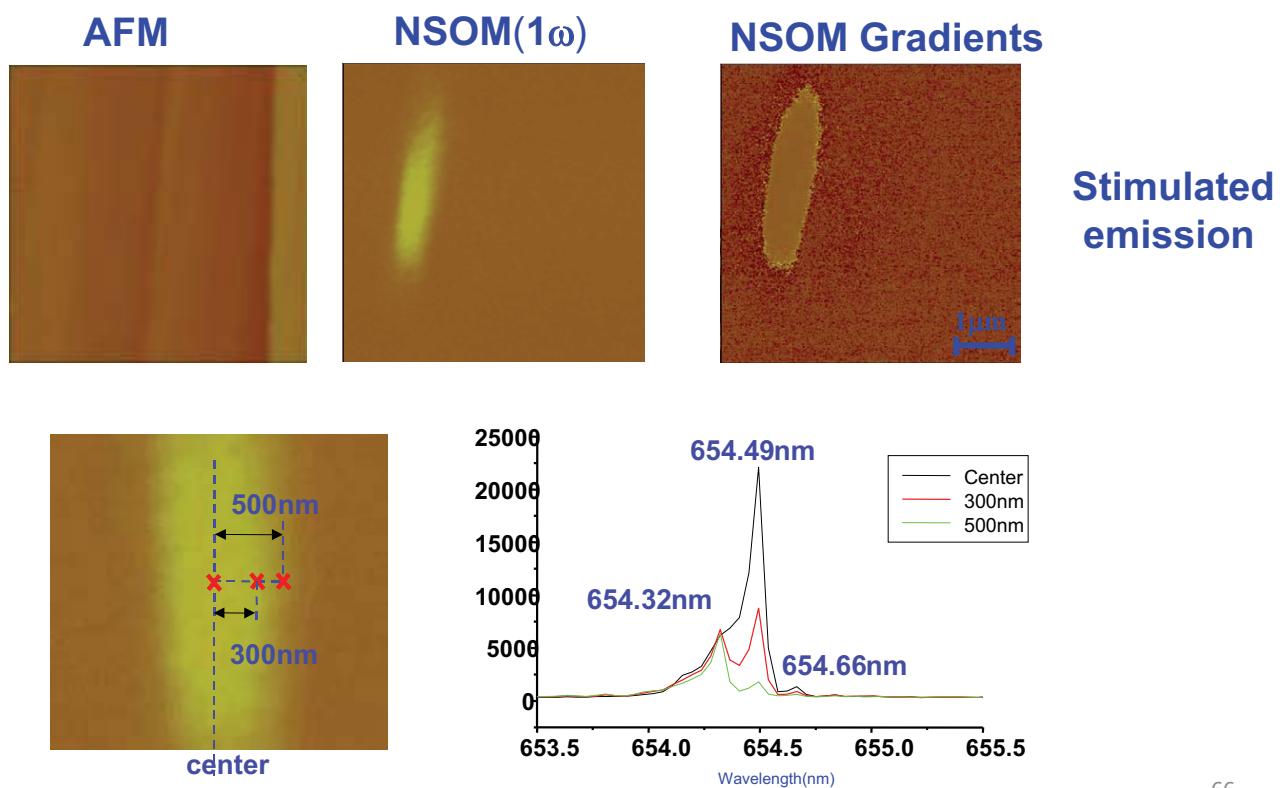
# 在中正學習光學的故事my story

## Near-field images of optical waveguides



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# 在中正學習光學的故事my story

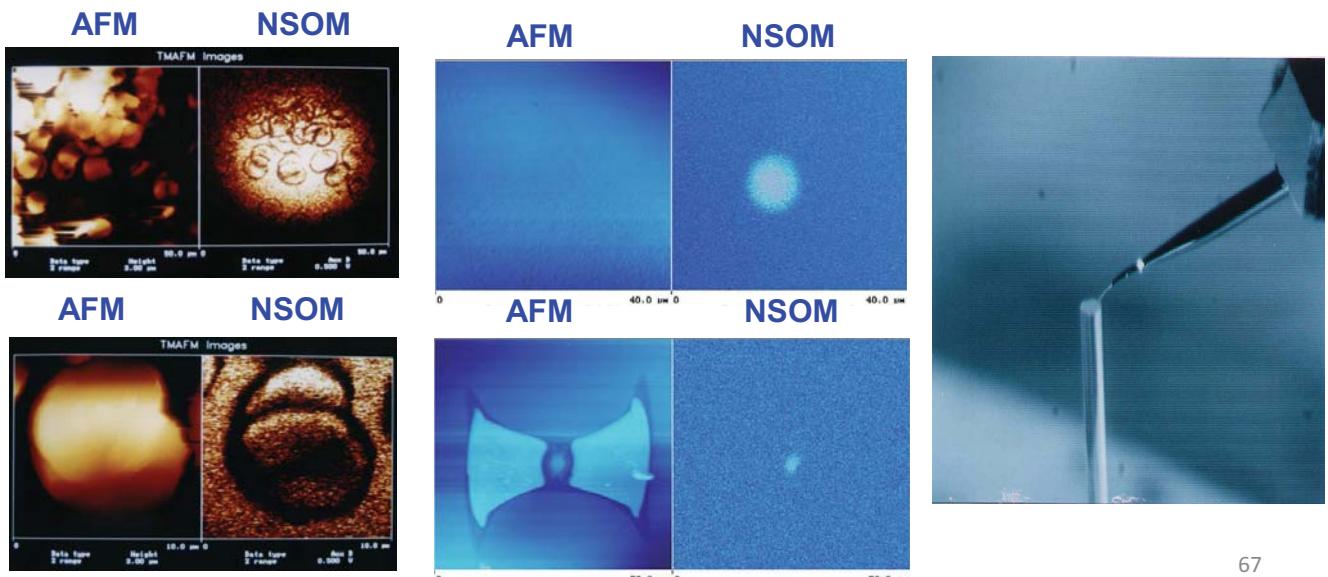
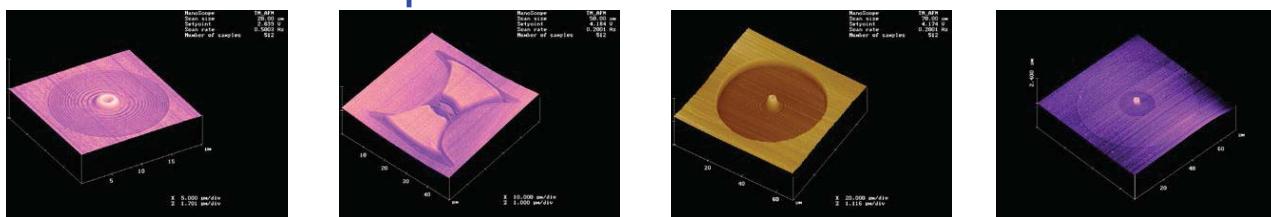


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NSOM images & spectrum of AlGaInP/GaInP multiquantum-well laser diode

# 在中正學習光學的故事my story

## Near-field optics at the facets of fiber end

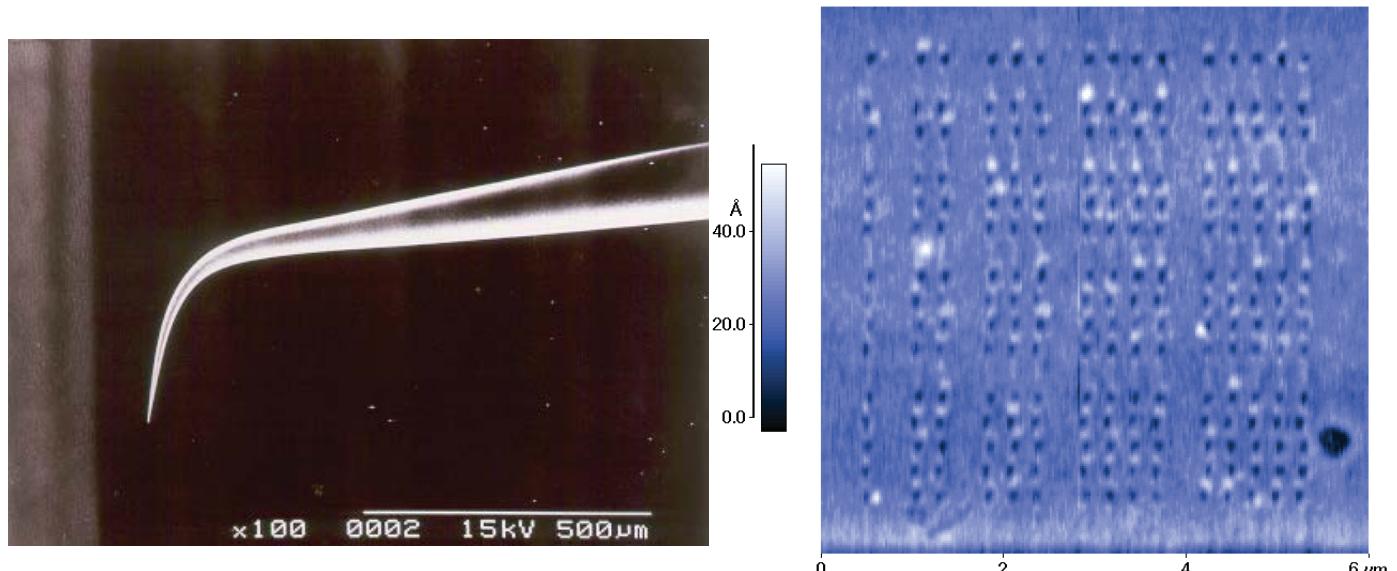


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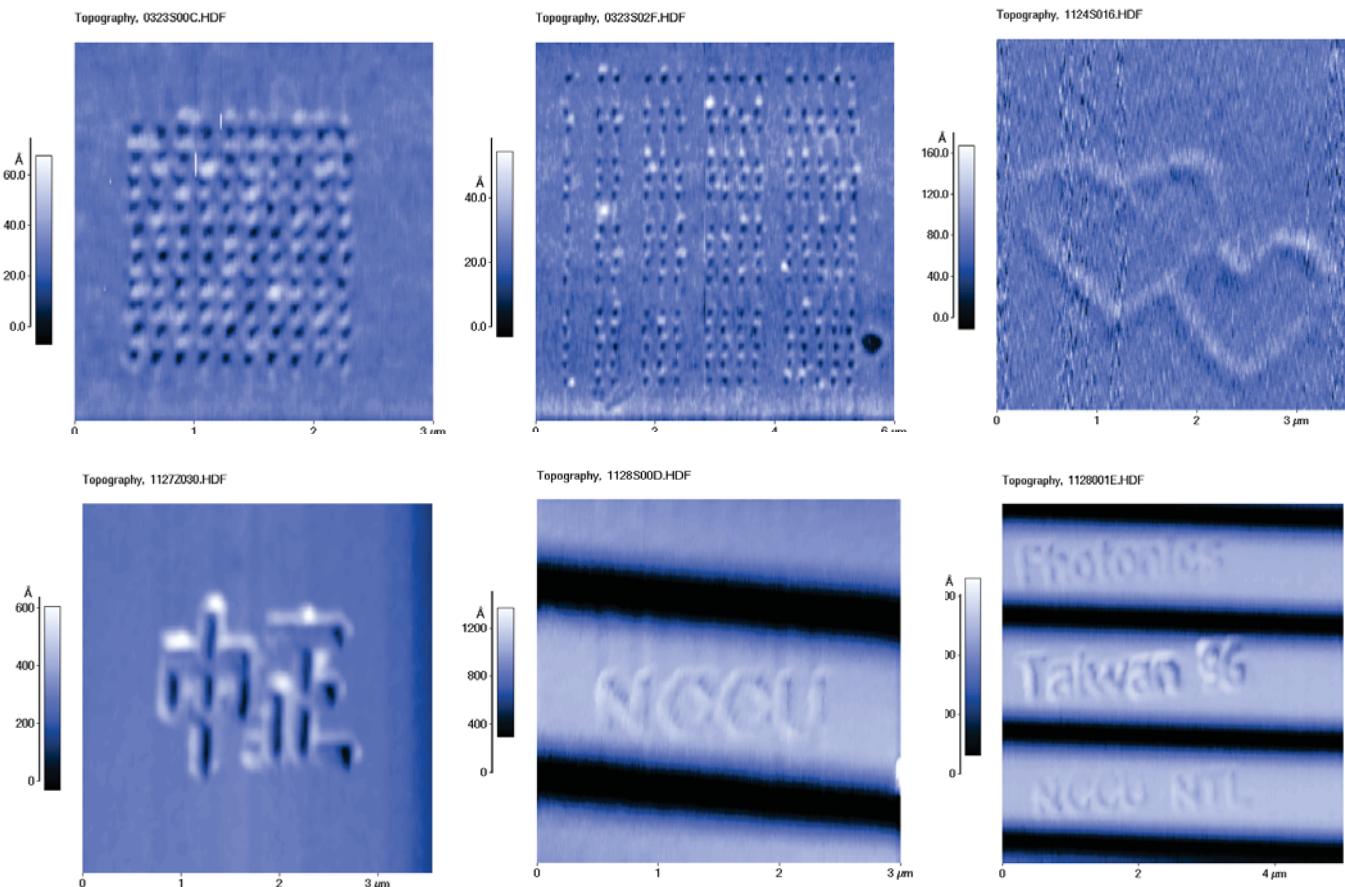
# 在中正學習光學的故事my story

## Near-field optical writing using a bent fiber probe NSOM

Topography, 0323S02F.HDF



@ D. P. Tsai et al., JVST 15, 1442 (1997).



# 學習光學的故事my story



基礎光學, 全像片, 光波導  
Optics, Hologram, Optical Waveguide



UNIVERSITY OF  
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拉曼光譜,光學子STM,波導速逝波,近場光學  
Raman Spectroscopy, Photon Scanning Tunneling Microscopy,  
Evanescence Wave, Near-field Optics



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奈米光學, 奈米光電, 電漿子光學  
Nano Optics, Nanophotonics, Plasmonics

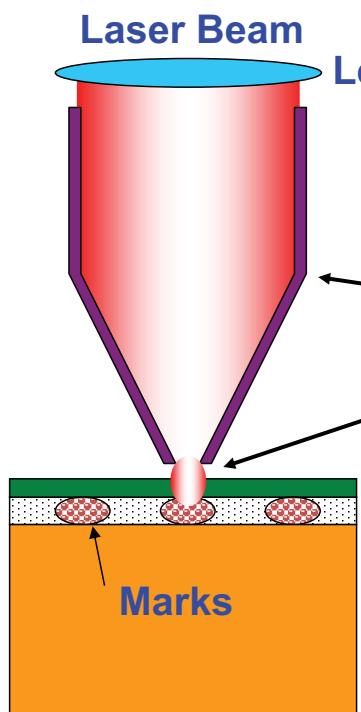


超穎物質, 變換光學, 超穎表面, 超穎全像片, 超穎元件  
Metamaterial, Transformation Optics, Meta Surface, Meta Hologram,  
Meta Device and System

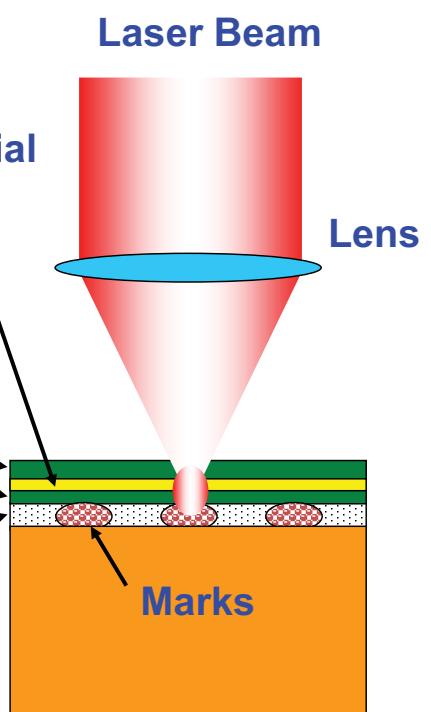


# 在台大學習光學的故事my story

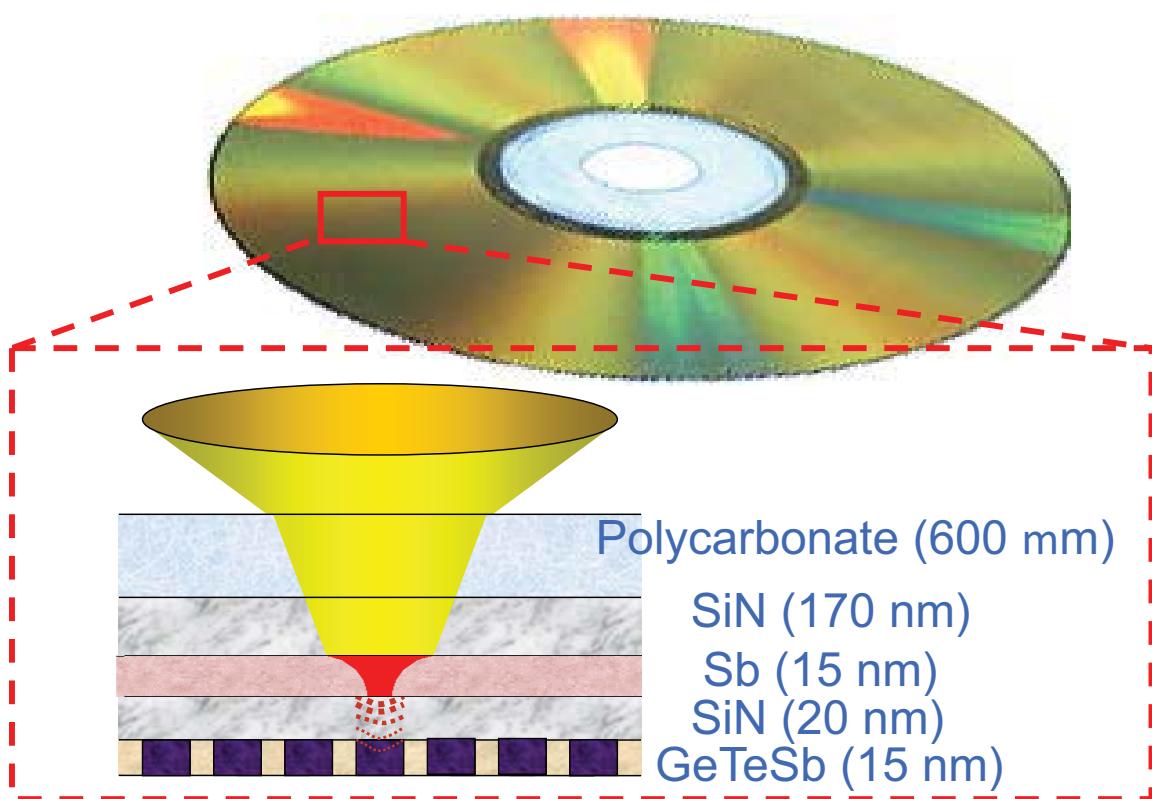
Near-field probe method



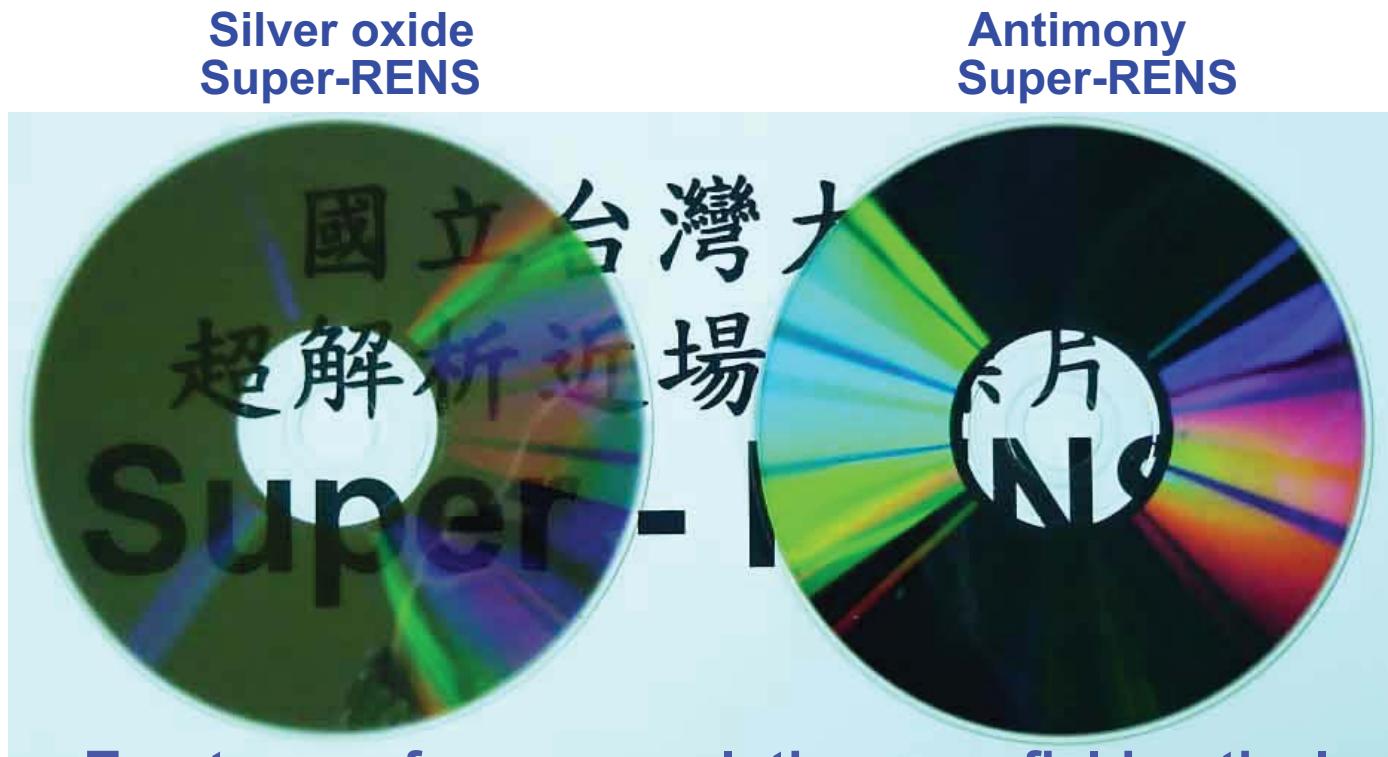
Super-RENS method



# 在台大學習光學的故事my story



# 在台大學習光學的故事my story

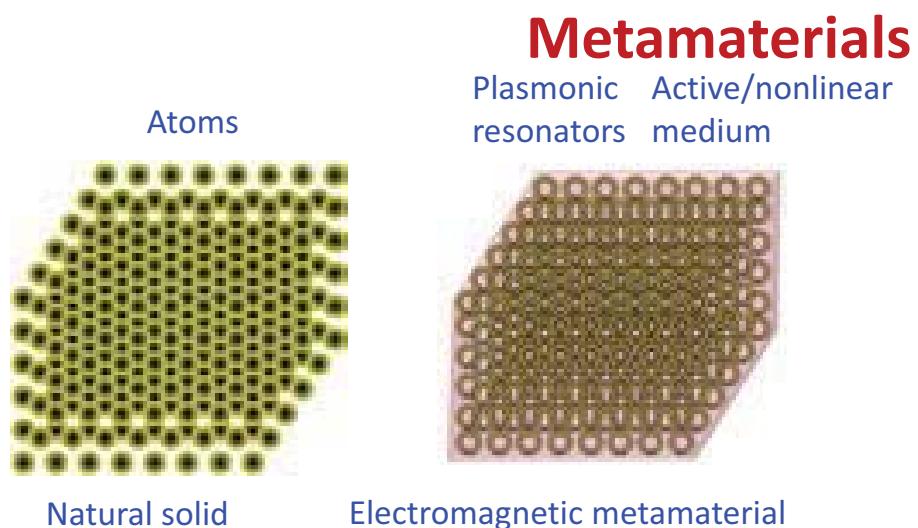


Two types of super resolution near-field optical structures on digital versatile disk (DVD)

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# 在台大學習光學的故事my story

Metamaterials are artificial media structured on a size scale smaller than the wavelength of external stimuli.



Metamaterials enable us to design our own “atoms” and thus access new functionalities.

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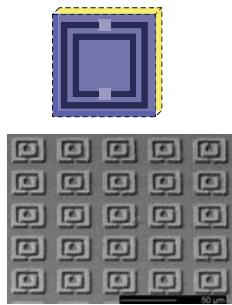
# 超穎物質(Metamaterials)

## □ What is metamaterial?

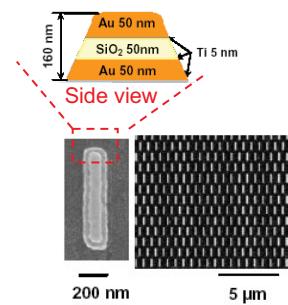
- Metamaterials are **artificial nanostructures** made of metals or composites that exhibit behavior which (i) either their component materials do not exhibit (ii) or is enhanced relative to exhibition in the component materials.
- The permittivity ( $\epsilon$ ) and permeability ( $\mu$ ) of a metamaterial are decided primarily by the **constitutive nano structure** of the component materials rather than what it is made of.

## □ Some examples of metamaterials

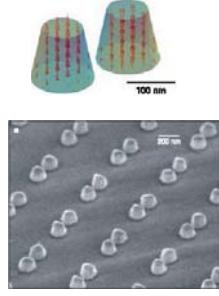
- metallic split-ring-resonator (SRR) and wire arrays
  - Array of metallic nanowire or nano pillar pairs
  - Array of chiral structures



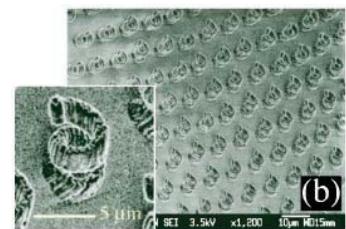
Cu SRR structure  
T. J. Yen, et al., *Science* **308**, 1494 (2004).  
75



Au nanowire pairs  
V. M. Shalaev, et al., *physics/0504091* (2005).



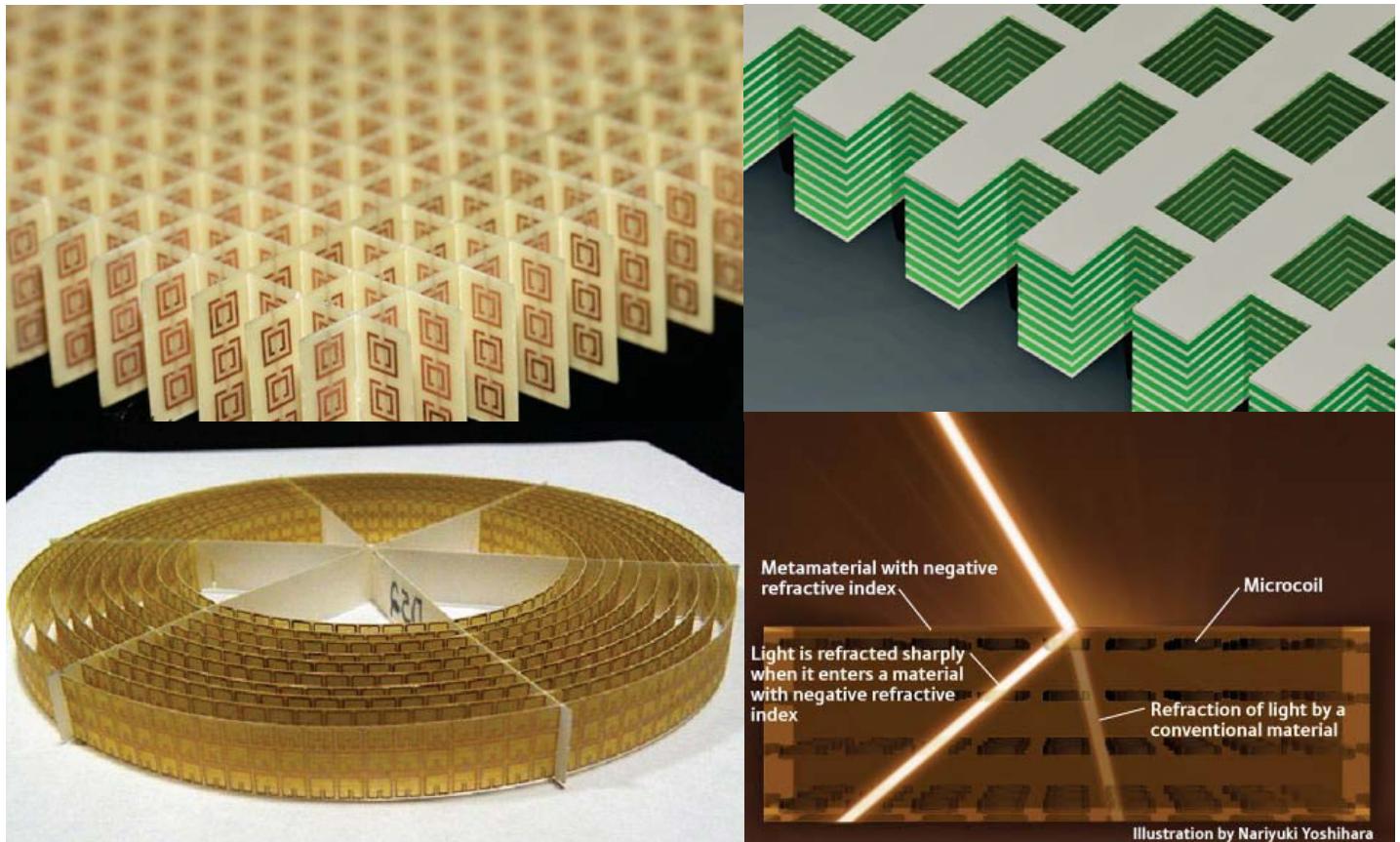
Au nanopillar pairs  
A. N. Grigorenko, et al., *Nature* **438**, 335 (2005).



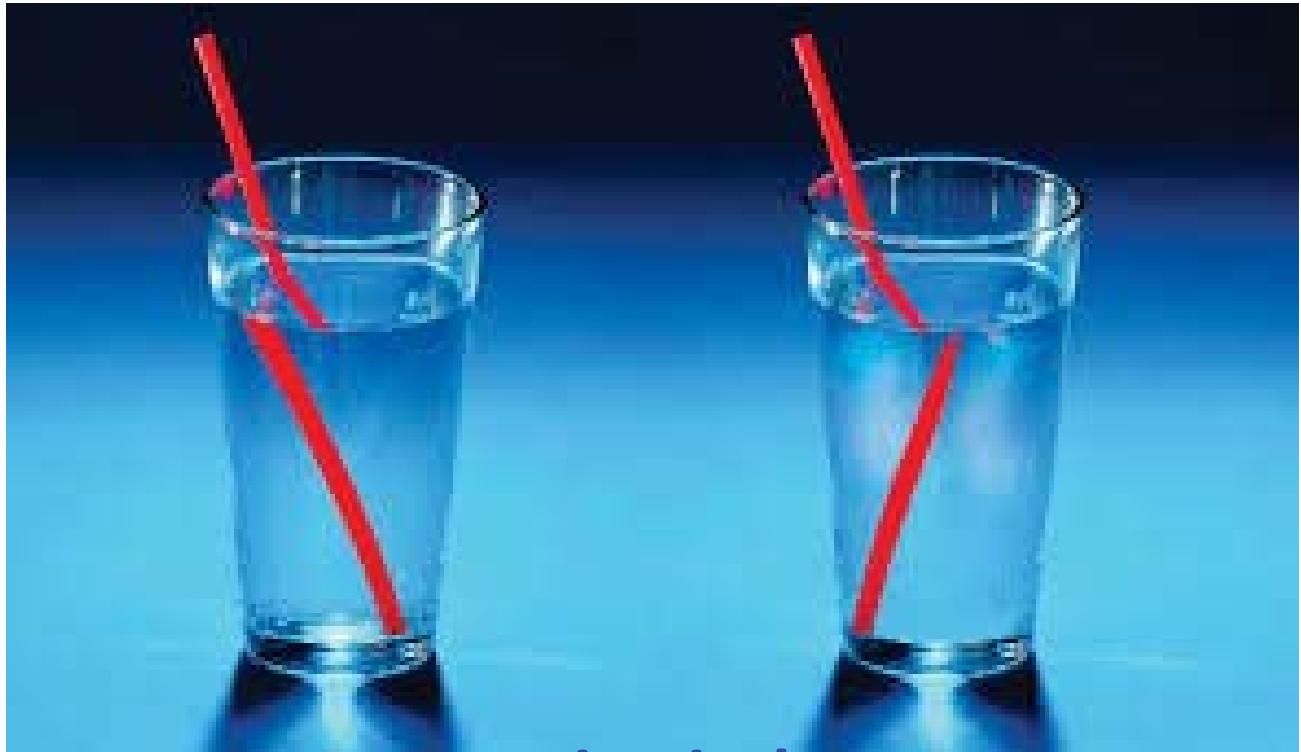
Resin with chiral structure

Jun-ichi Kato, et al., *Appl. Phys. Lett.* **86**, 044102 (2005).

## Metamaterials



# 在台大學習光學的故事my story



## **negative index**

<https://youtu.be/hUrrO8zt3a4>



### **讓光轉彎 隱形術大躍進**

【聯合報／編譯陳世欽／報導】

2008.08.11 03:45 am

星期泰晤士報十日報導，隱形裝置是科幻小說的主題之一；在科學家設計出一種能夠在物體周圍彎曲可見光的材料後，隱形科技又向前邁出一大步。

這項突破意味，科學家有朝一日或許能夠設計出可使人體以至戰車、船隻等大型物體「隱形」的系統。在美國軍方資助下，柏克萊加大的研究人員已經設計出多種能夠控制光行進方向的材料。

這項研究以倫敦皇家學院另一項以微波為對象的研究為基礎。和光一樣的是，微波也是一種電磁輻射，波長則比較長，比較容易操控。以可見的光達到同樣效果是一大突破。「科學」與「自然」期刊本周將刊登研究報告。

研究人員的假設是，如能在物體周圍彎曲可見的光，物體就會隱形。首席研究員張翔表示「隱形罩發揮功能的先決條件是，材質必須能使光波在物體周圍完全彎曲，就像溪水繞石而流。」旁觀者只能見到從物體後方發出的光，使物體達到隱形的效果。

這種材料名為「超穎材料」（metamaterial），能夠「抓住」電磁輻射，具有負折射率，能使光朝與正常相反的方向偏折，而且產生的影像解晰度不受波長的限制，不存在於自然界中。過去幾年來，奈米技術的飛速進展使科學家得以設計出這種單位極微小的材料。

【2008/08/11 聯合報】 @ <http://udn.com/>

但，我們沒有魔法！



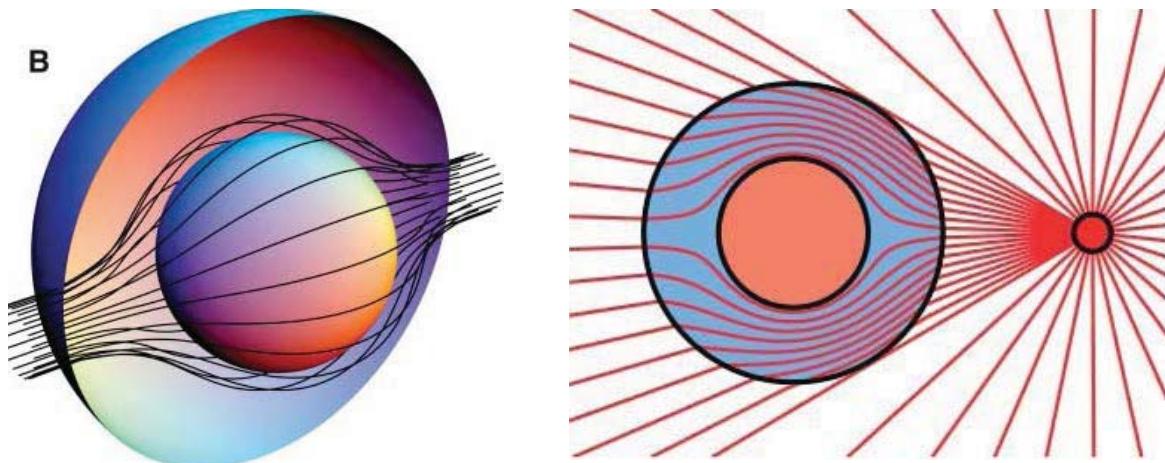
## 哈利波特的 「隱形斗篷」



Example



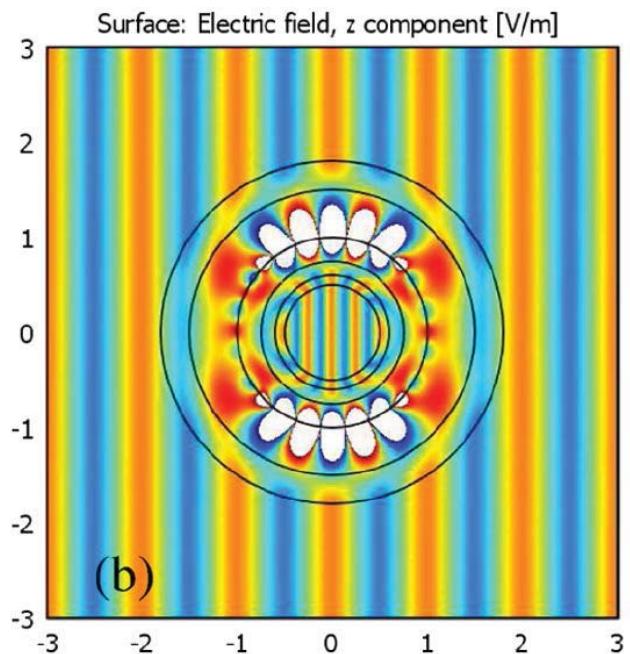
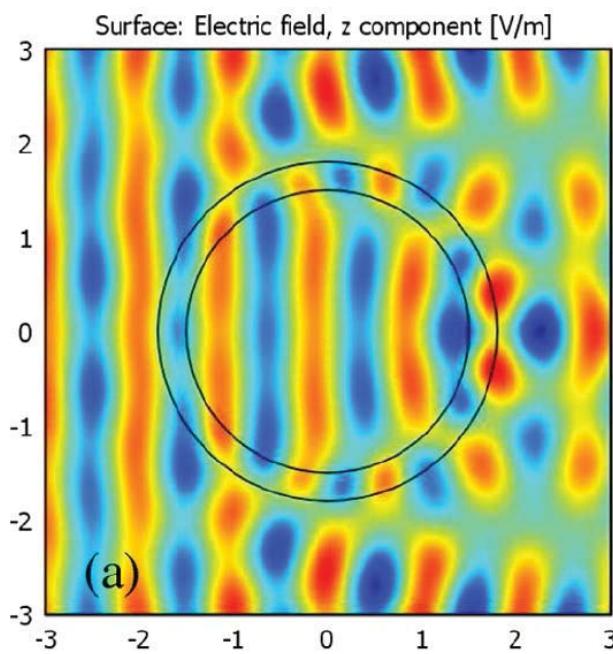
# 讓光轉彎-隱形術大躍進



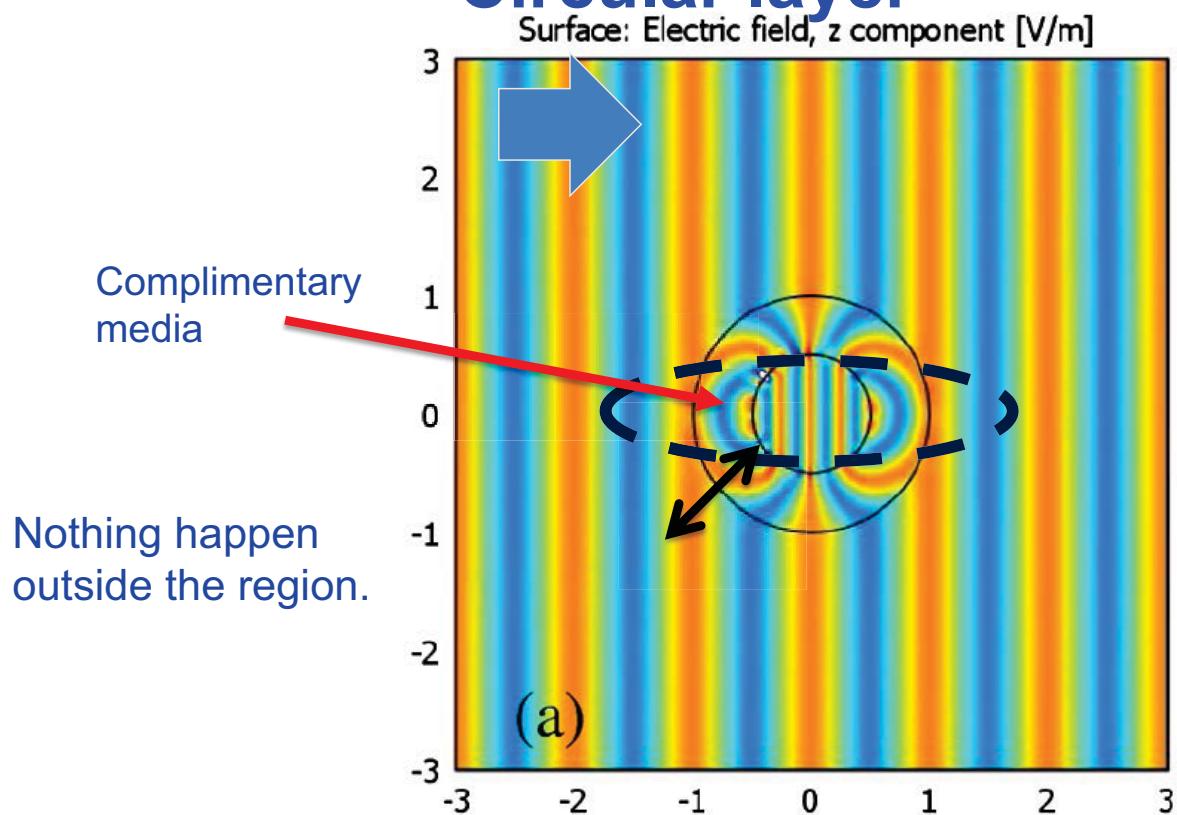
把球藏起來！

操控光，就可以操控看到的結果

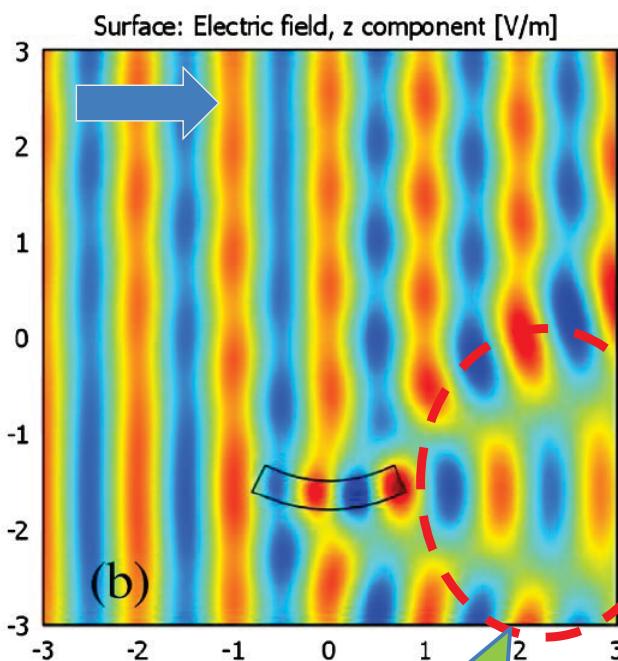
## A Dielectric Circular Shell



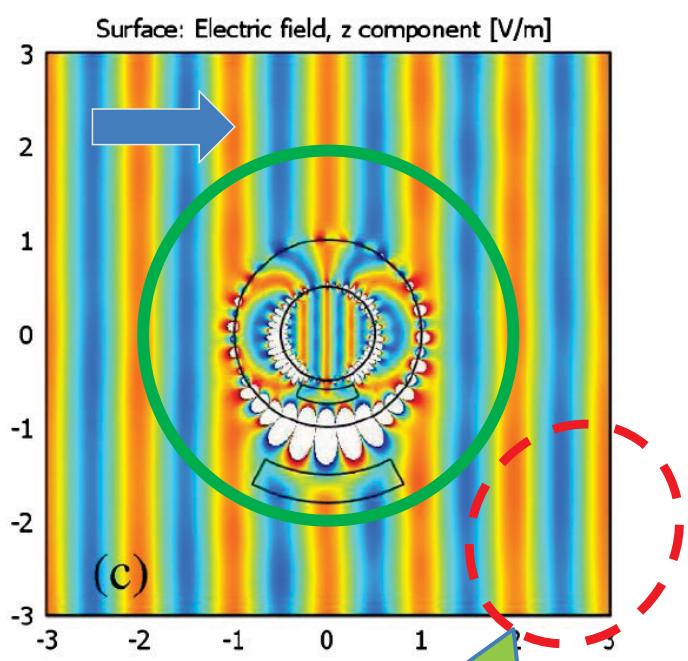
## Circular layer



## Cloak a Curved Sheet



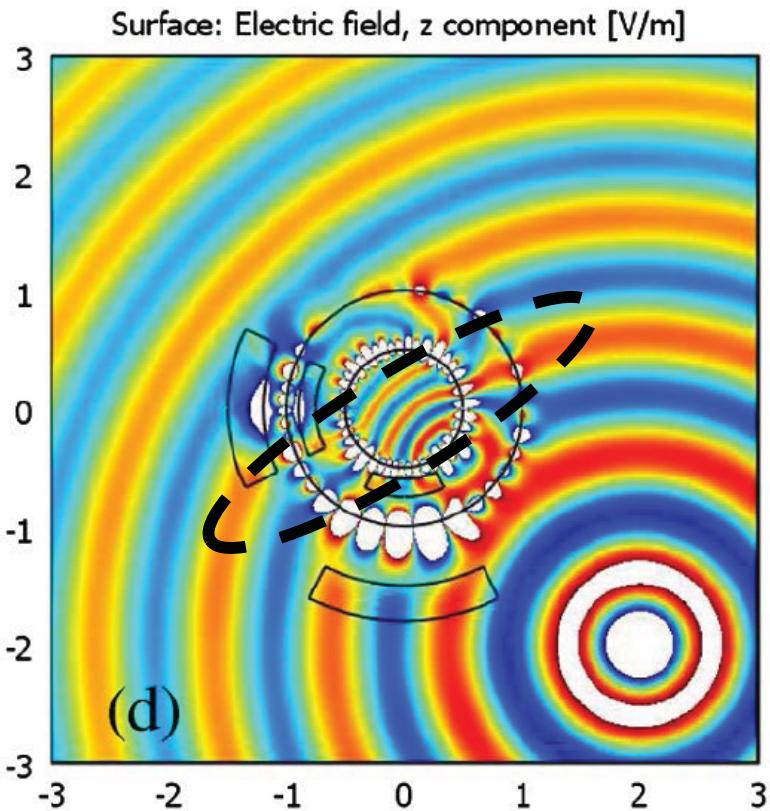
Some information about the curved sheet.



Cloak the information of the curved sheet.

# With a point source

Two curved sheets are cloaked.

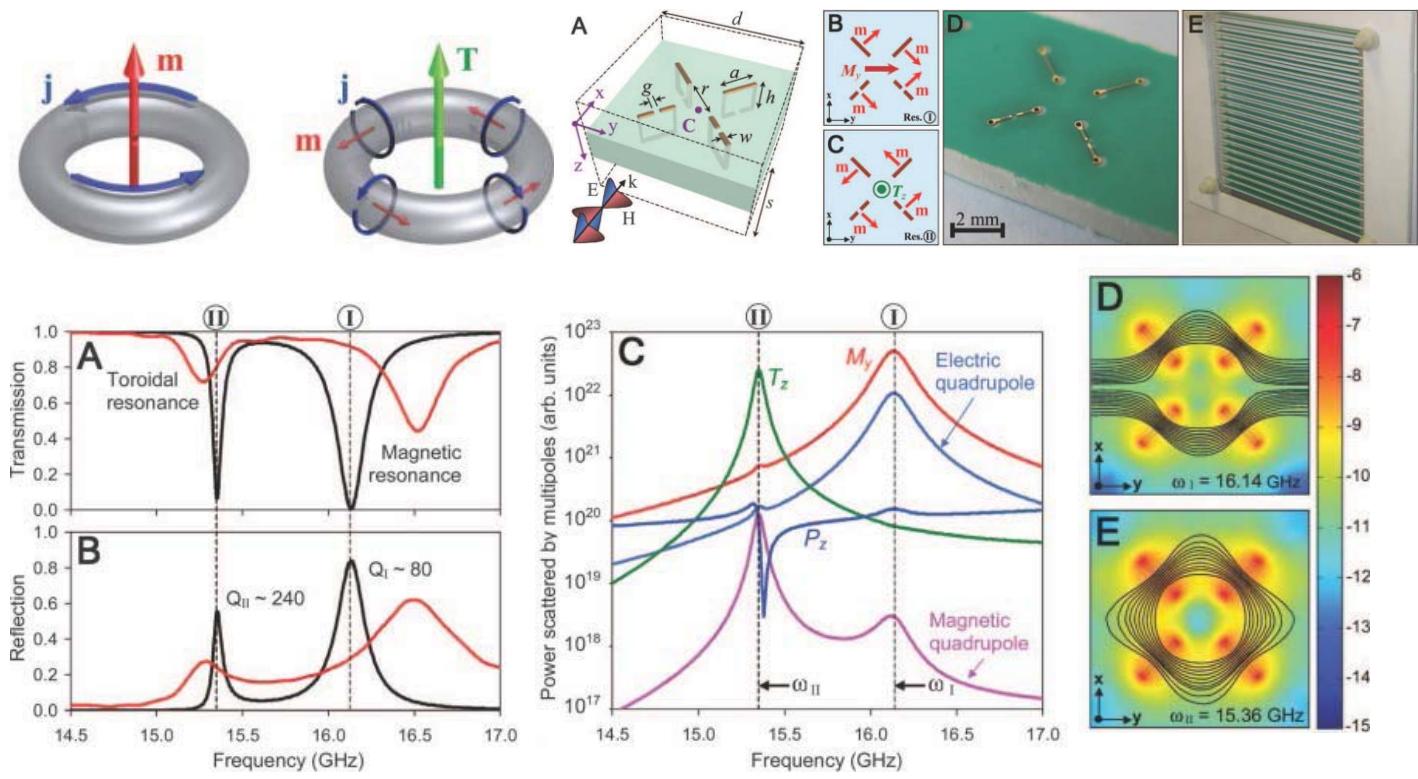


Phys. Rev. Lett. **102**, 093901 (2009)

“Toroidal Dipolar Response in a metamaterials”

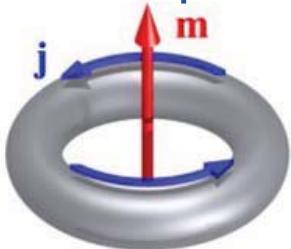
Science 330, 1510 (2010).

Science  
AAAS



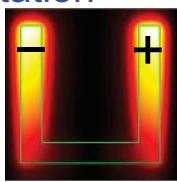
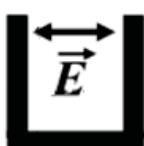
# Magnetic and toroidal dipole

## ◆ Magnetic dipole



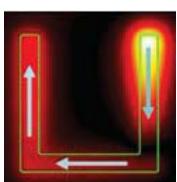
- Example in metamaterials:  
Split ring resonators, SRRs

- Electrical excitation



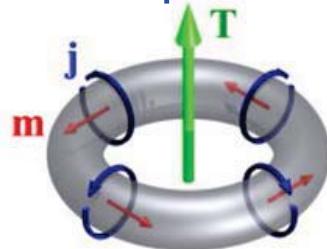
Opt. Express 14, 8827 (2006)

- Magnetic excitation



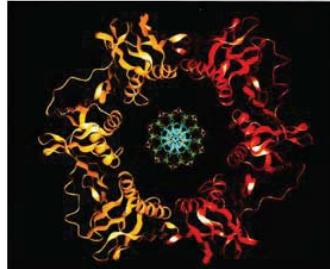
Opt. Express 15, 8871 (2007)

## ◆ Toroidal dipole



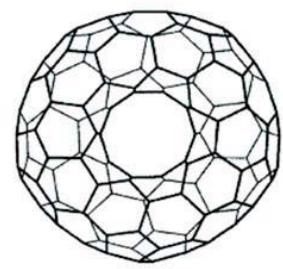
- Examples in nature:

- DNA polymerase



Cell 69, 425 (1992)

- Fullerene

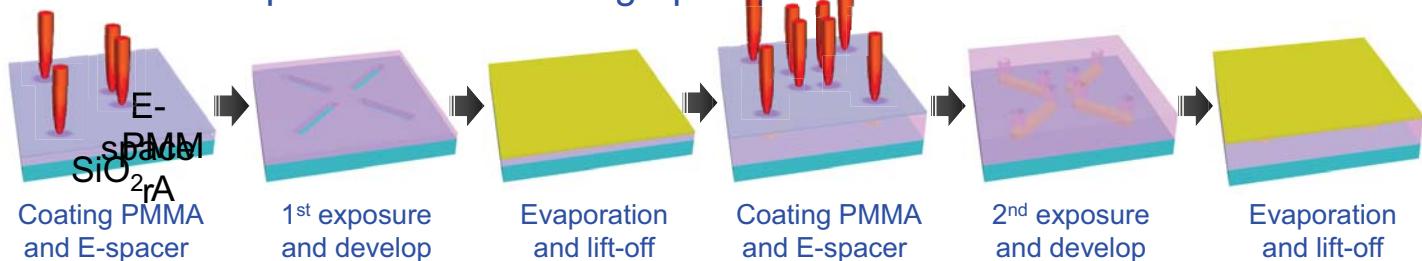


PRL 80, 1861 (1998)

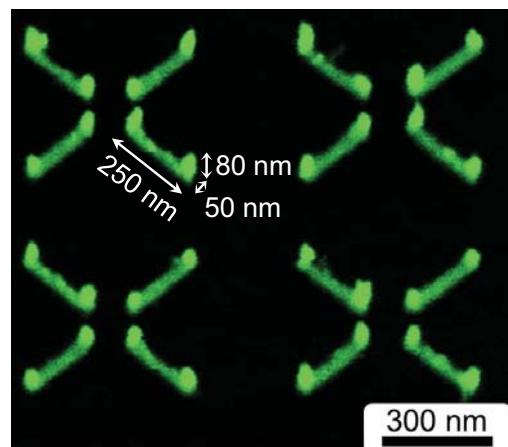
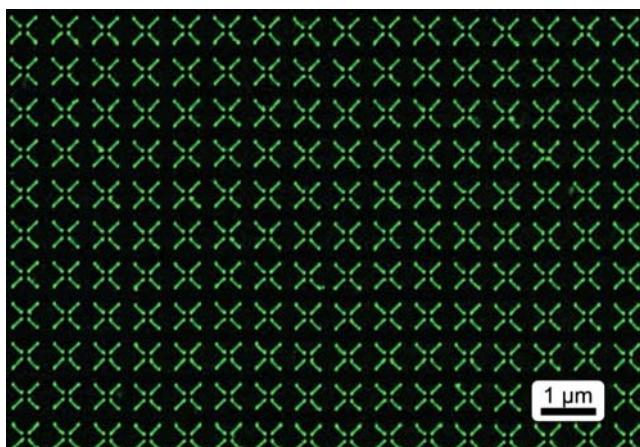
87

## 在台大學習光學的故事my story

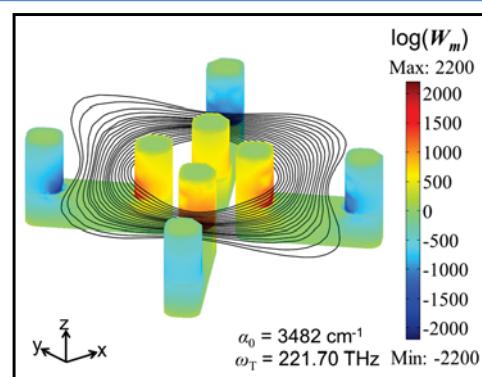
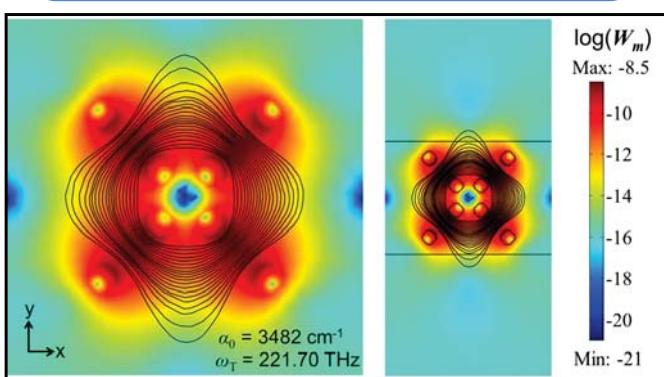
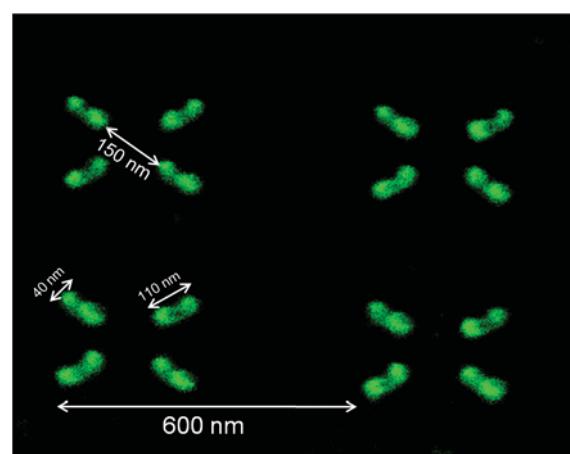
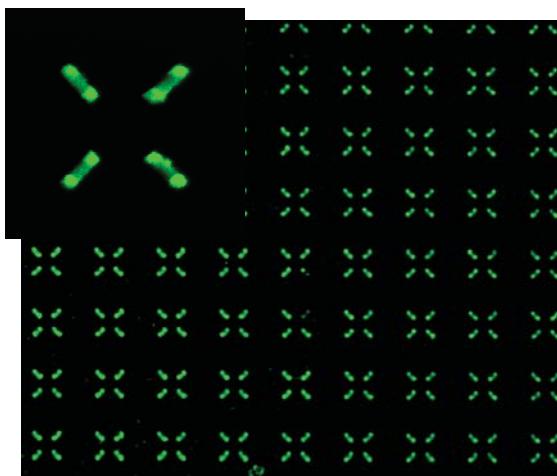
- Double exposure e-beam lithographic process



- SEM image of the fabricated plasmonic toroidal metamaterial



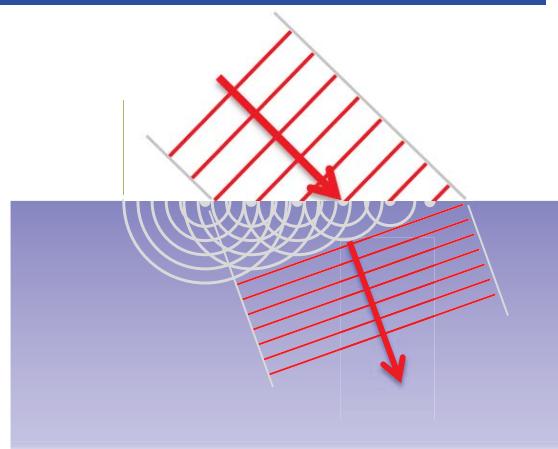
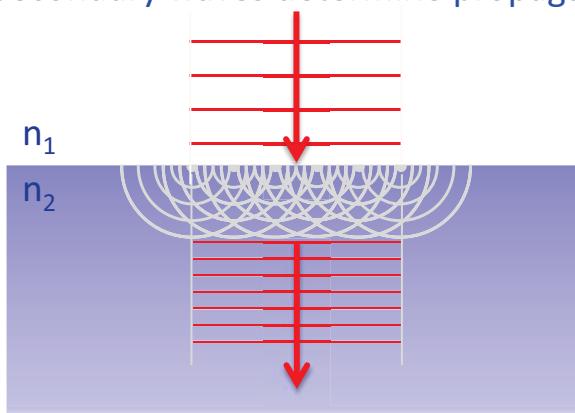
# Toroidal metamolecule



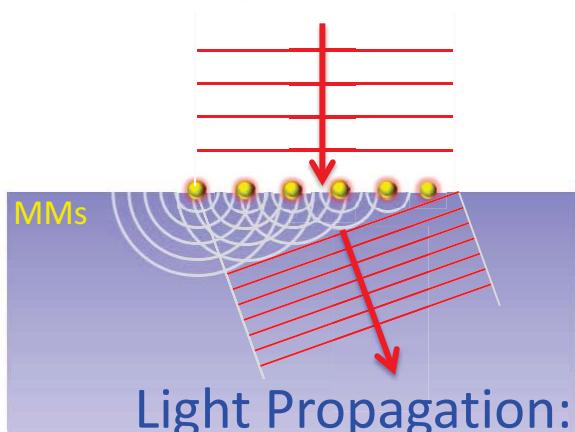
89

## 在台大學習光學的故事my story

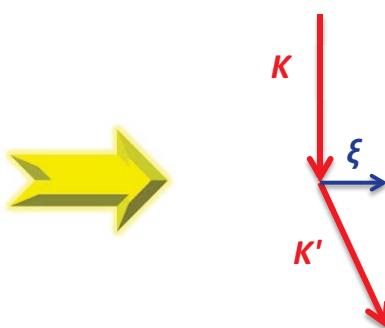
### □ Secondary waves determine propagation



### □ Meta-secondary waves



### □ Momentum picture

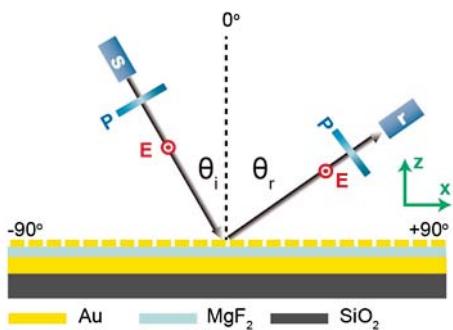


Light Propagation: Huygens-Fresnel Principle

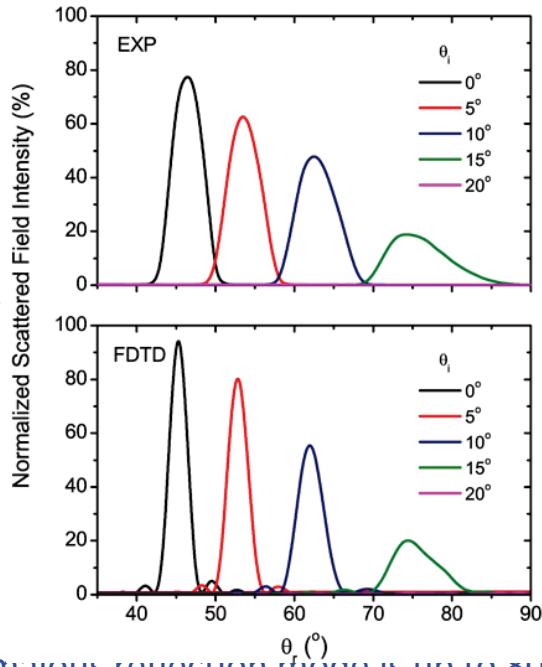
90

# 在台大學習光學的故事my story

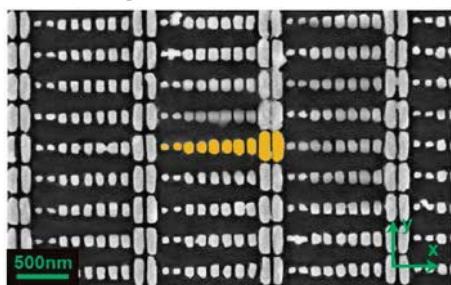
## □ Experimental setup



## □ Measured and simulated normalized scattered electric field intensity



## □ SEM image of meta-surface 超穎表面

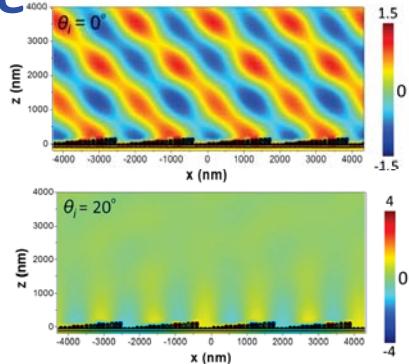
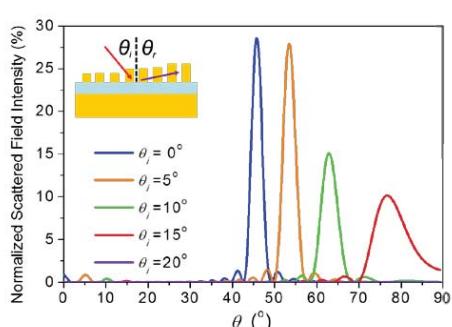
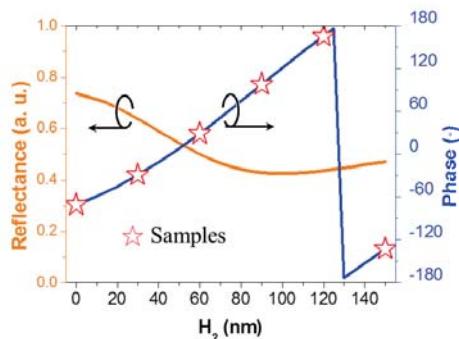


- Normalized scattered field peak of anomalous reflection regime is up to 80%.
- Experimental results match well with FDTD simulations

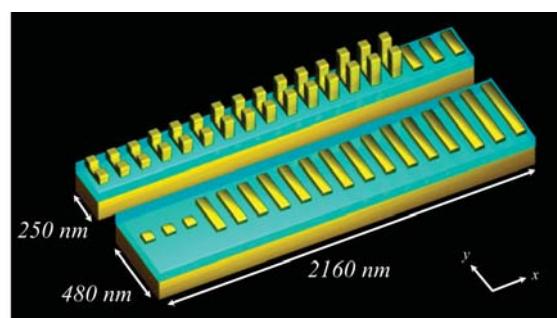
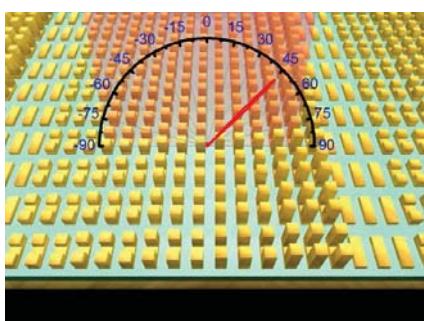
*Nano Lett.* **12**(12), 6223-6229 (2012).

# 在台大學習光學的故事my story

## Beam steering in vertical metasurface



## □ Footprint comparison between 2D and 3D metasurface



## 超穎表面

- ✓ High extinction ratio beam
- ✓ Lower footprint.
- ✓ high density integration

# 新隱形斗篷 奈米天線把不規則物變不見

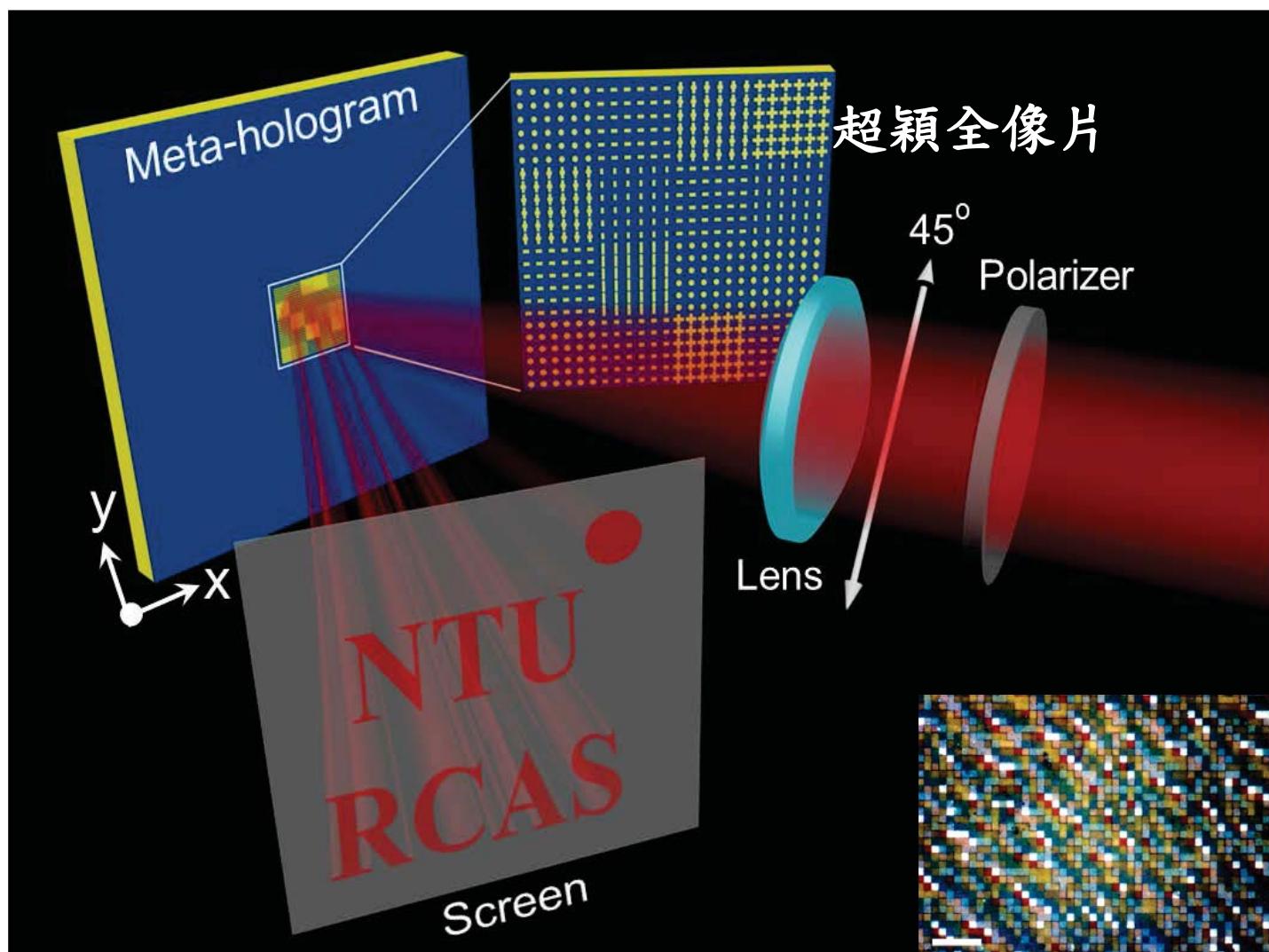
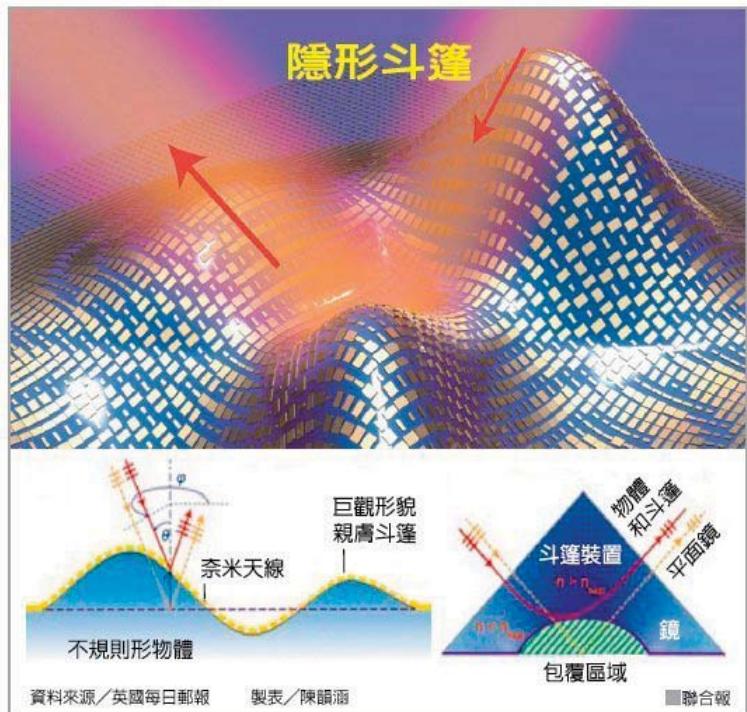
2015-09-29 15:44:36

新聞故事：美國柏克萊加州大學的科學家17日宣布，成功測試新型隱形斗篷（**invisibility cloak**），「哈利波特」般的隱身情節距離現實生活又近了一步。

美國能源部「勞倫斯柏克萊國家實驗室」材料科學所所長張翔（Zhang Xiang）領導的團隊，利用布滿金磚狀「奈米天線」（nanoantenna）的鎂氟化物，創造出80奈米的超薄隱形布料，能夠反射光波，就算布料覆蓋立體且凹凸不平的物體，也能達到肉眼無法辨識的「隱形」效果。

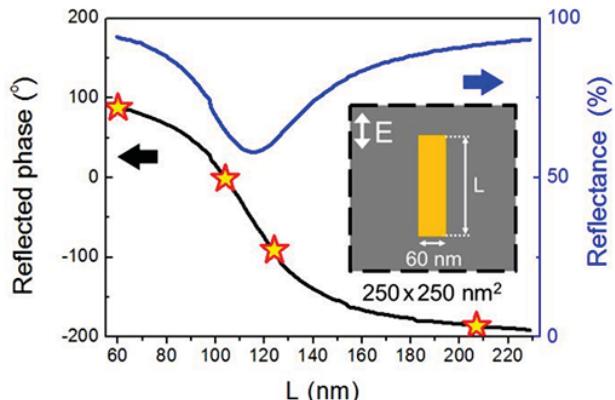
隱形斗篷的原理是操控光線，改變光波從物體上的折射方式。當光線照射到超薄布料的外層，奈米點會散射可見光、紅外線和X射線，就像鏡面反射光線一樣，讓覆蓋的物體不被肉眼看見。

2002年的007電影《誰與爭峰》就曾出現類似原理的隱形概念車。賓士汽車前年為宣傳它的新電動車，也打造了一台隱形汽車，採用大量LED及光學迷彩技術，利用光線反射使車體融入周邊環境，開上街頭時引起人們連聲驚呼。隱形斗篷的研究結果發表於《科學》（Science）期刊，不僅大幅減輕布料重量，且不再受限於觀看角度和覆蓋物體的光滑程度，新型隱形斗篷能夠包覆不規則形狀物體。不過，新型隱形斗篷仍有所限制，奈米天線布料必須精確地符合覆蓋物體，假如物體移動，就會失去隱形效果。張翔說，隱形斗篷技術可能要5~10年後才具備實用價值。除了軍事等用途之外，主導研究的賓州立大學電機工程學教授倪行潔（Ni Xingjie）還提出一些另類的應用想法，包括利用隱形布遮蓋臉上的皺紋和痘疤，還可以將啤酒肚變成6塊肌。

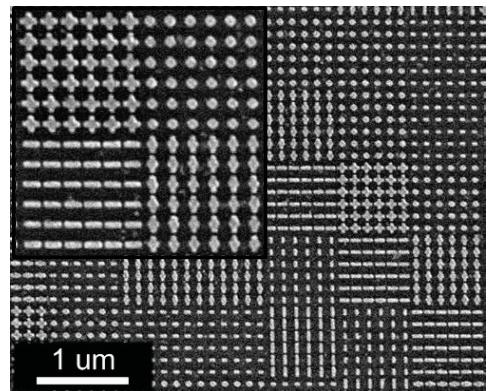


# 在台大學習光學的故事my story

□ Reflection phase / amplitude v.s. rod length



□ SEM image (1.5 μm per pixel)



超穎全像片

□ Reconstruction images ( $0^\circ$ ,  $45^\circ$ ,  $90^\circ$  incident polarization)



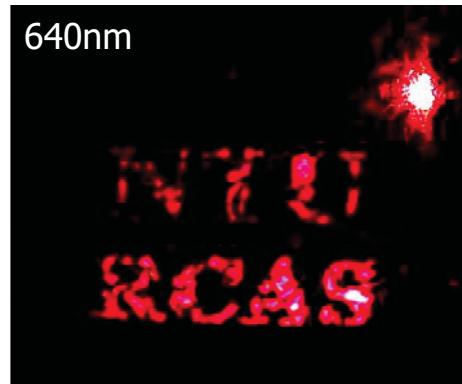
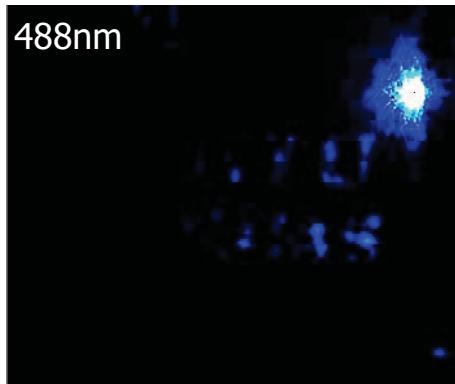
*Nano Letters* **14**(1), 225-230 (2014).

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超穎全像片



# 在台大學習光學的故事my story



□ Hologram images by 488 nm and 640 nm laser

Broadband working (even in blue light region)

*Nano Letters* 14(1), 225-230 (2014).



超穎全像片

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# 學習光學的故事my story



基礎光學, 全像片, 光波導  
Optics, Hologram, Optical Waveguide



拉曼光譜, 光學子STM, 波導速逝波, 近場光學  
Raman Spectroscopy, Photon Scanning Tunneling Microscopy,  
Evanescence Wave, Near-field Optics

UNIVERSITY OF  
**Cincinnati**



**OLLRC**



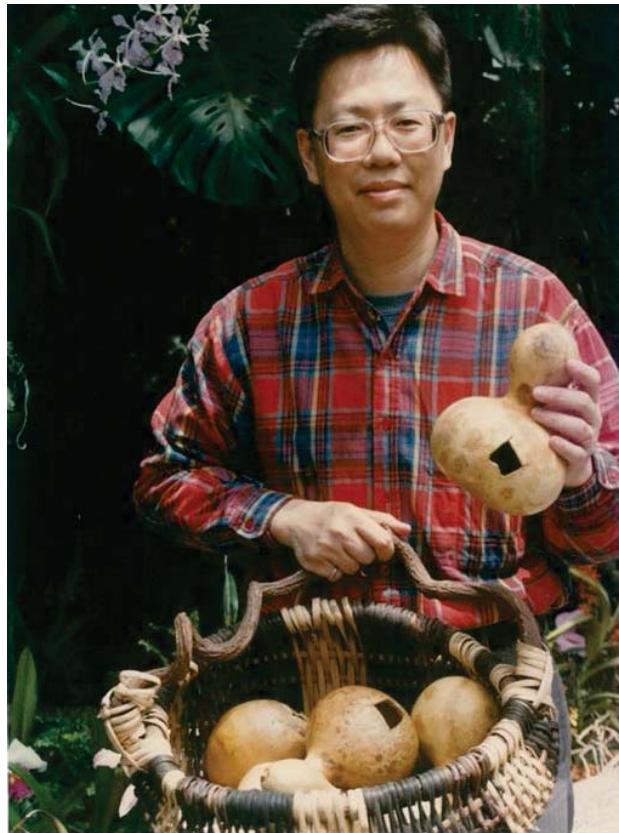
奈米光學, 奈米光電, 電漿子光學  
Nano Optics, Nanophotonics, Plasmonics



超穎物質, 變換光學, 超穎表面, 超穎全像片, 超穎元件  
Metamaterial, Transformation Optics, Meta Surface, Meta Hologram,  
Meta Device and System



# 學習光學的故事my story



## 光學新世(視)界-奈米光學

➤人類文明築基於"眼光"

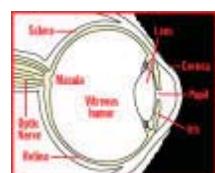
➤光速  $C = 3 \times 10^8 \text{ m/sec}$

光速最快、每秒三十萬公里

➤控制與操縱光的技術與方法

奈米超穎材料的設計、製作與應用

➤機會與挑戰=>奈米光學超穎材料的設計、製作與應用  
可控制與操縱光，是由奈米存儲光碟片的技術與方法走入奈米光學新世(視)界的新機會與挑戰。



# 五十年前



1956年IBM在台灣設立分公司。1957年，IBM賣了第一套電腦主機給台糖公司，當時牛車載著主機拉進糖廠。  
(資料來源：台灣IBM/中國時報)

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# 現在



# 二十年後

?

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Thanks for your attention!

謝謝聆聽



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# 光學的歷史

劉源俊 / 東吳大學  
物理學史研習會（五）  
東吳大學物理學系  
2015年10月24日

1

## 大綱

光  
光源  
光速  
有關光的重要實驗  
光的學說

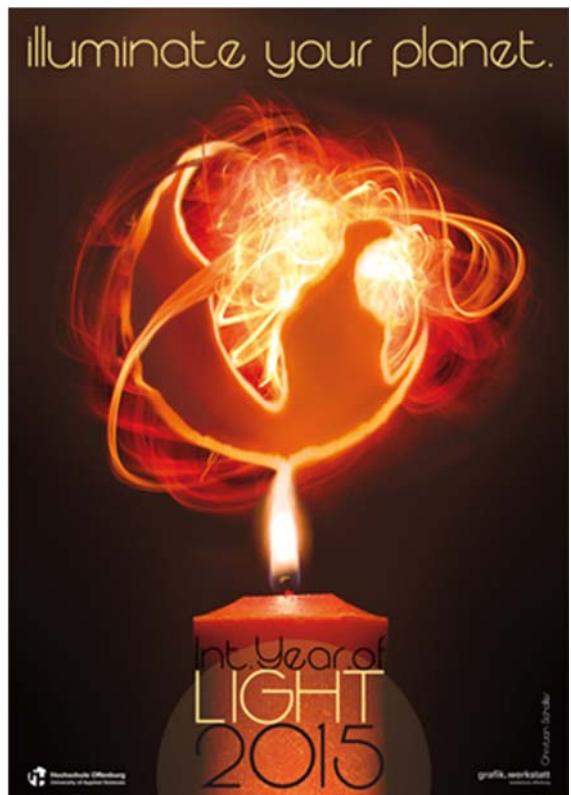
線光學  
波光學  
量子光學

2

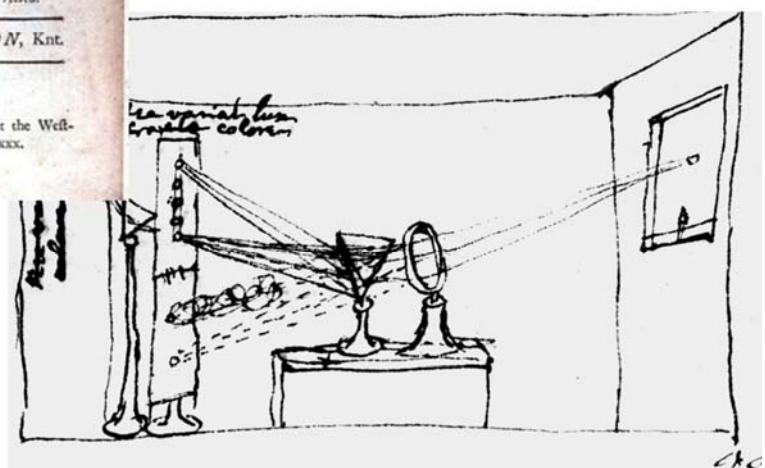
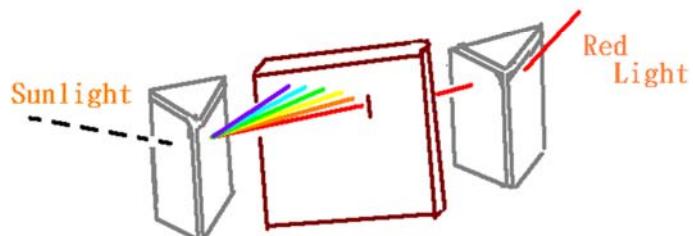
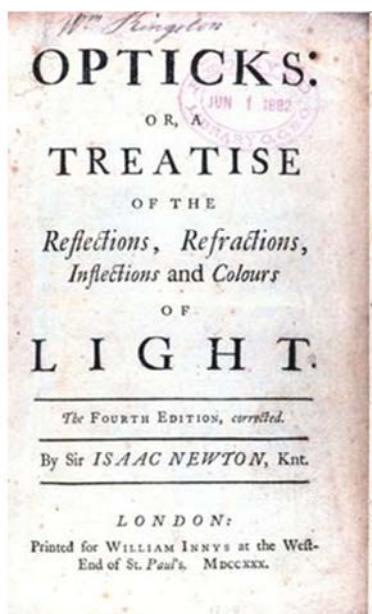
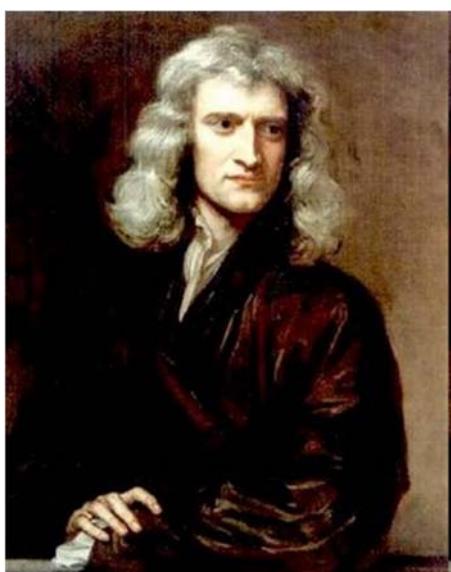


# 2015 國際光之年 紀念

- 1015年，阿拉伯 Ibn al-Haytham 著七冊《光學之書》（*Kitab al-Manathir, Works on Optics*），為人類首部光學研究著作。
- 1665年，Newton 研究光的色散。
- 1815年，Fresnel 提出光的波動說。
- 1865年，Maxwell 提出光波是電磁波。
- 1905年，Einstein 提出光量子說，解釋光電效應。
- 1965年，高錕提出光纖通訊理論。

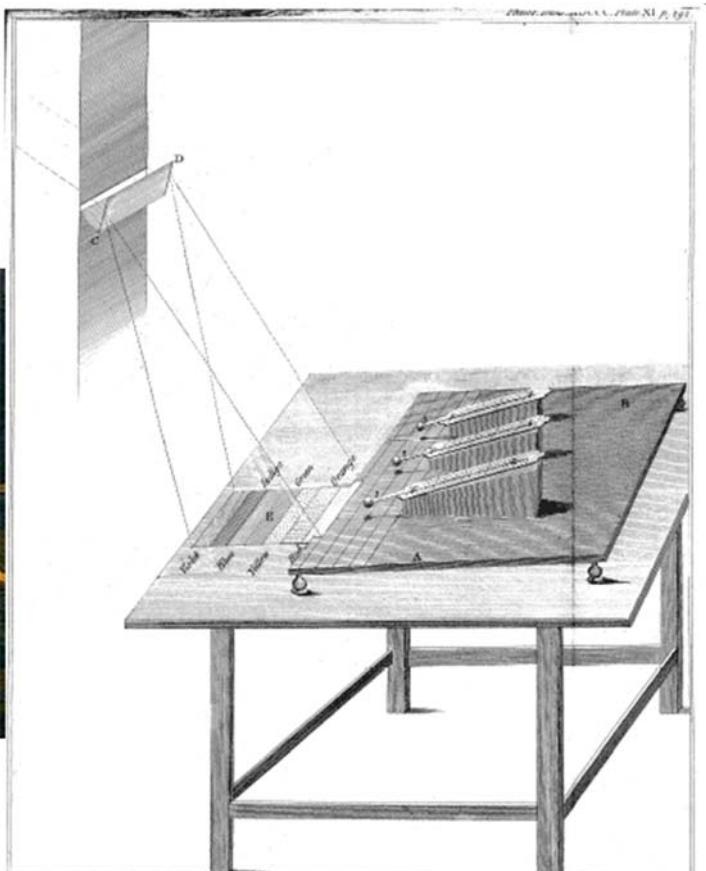
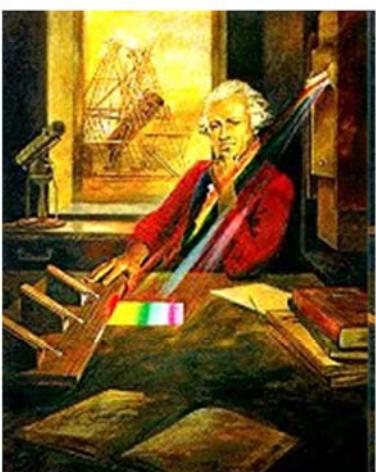


# 1665 Newton 光的色散



# 1800 Herschel 發現紅外線

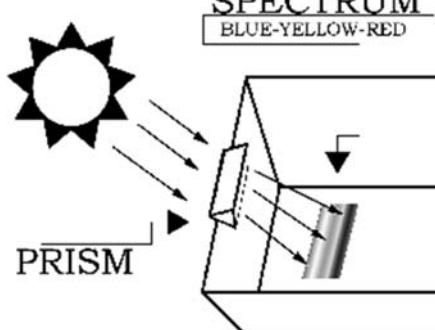
利用稜鏡與溫度計  
發現紅外線。



# 1801 Ritter 發現紫外線



紫外線能使氯化銀底片感光。

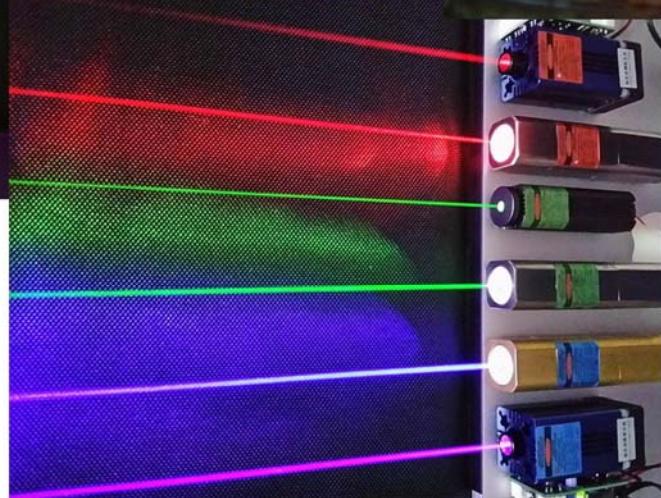


(circa early 1800s)

## 光源

- 太陽 月亮 星
- 閃電
- 火
- 磷光
- 螢火
- 電弧
- 電燈
- 放電管
- 發光二極體
- 光頻激射
- 同步輻射儀





# 光速的測定（訂定）

- Galileo
- Rømer
- Bradley
- Fizeau
- Foucault
- Michelson
- SI 訂定值

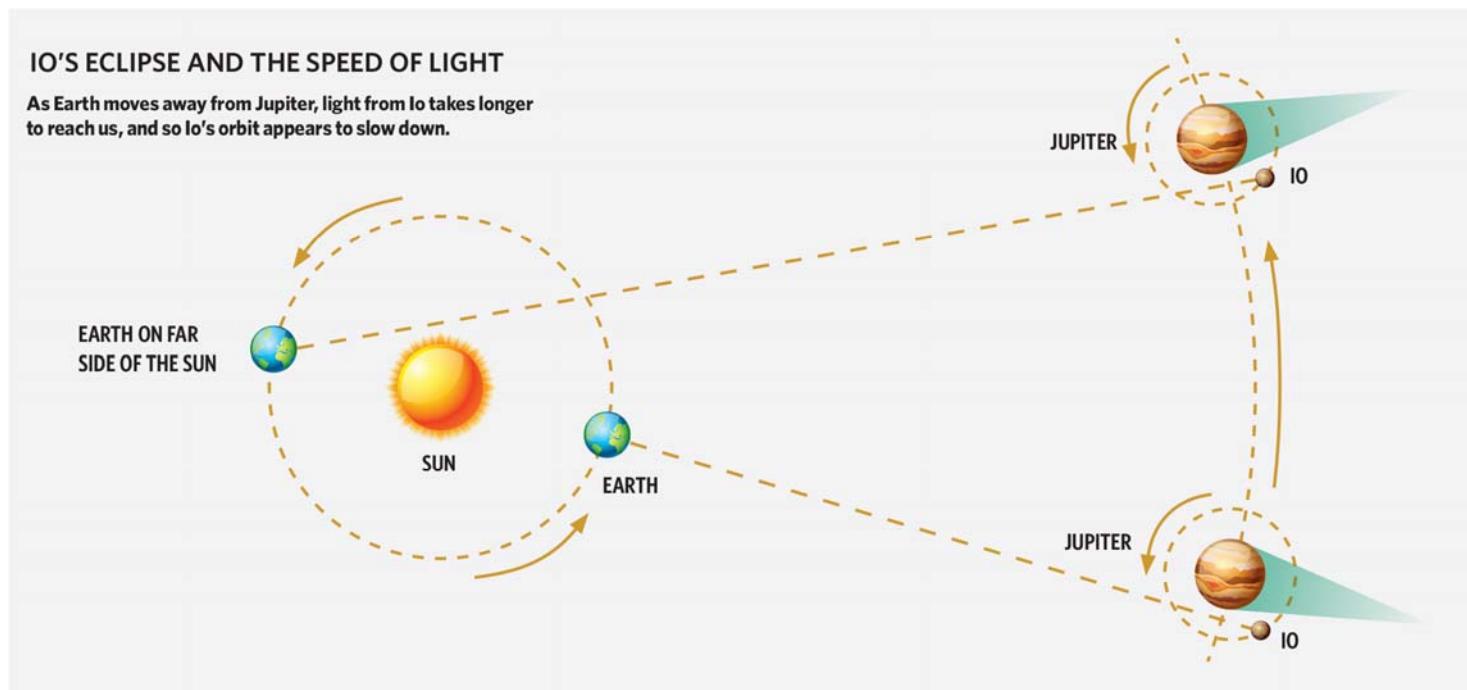


Galileo  
測不出光速



# 1676 Rømer

## 從木星衛星蝕的時間延遲推算光速



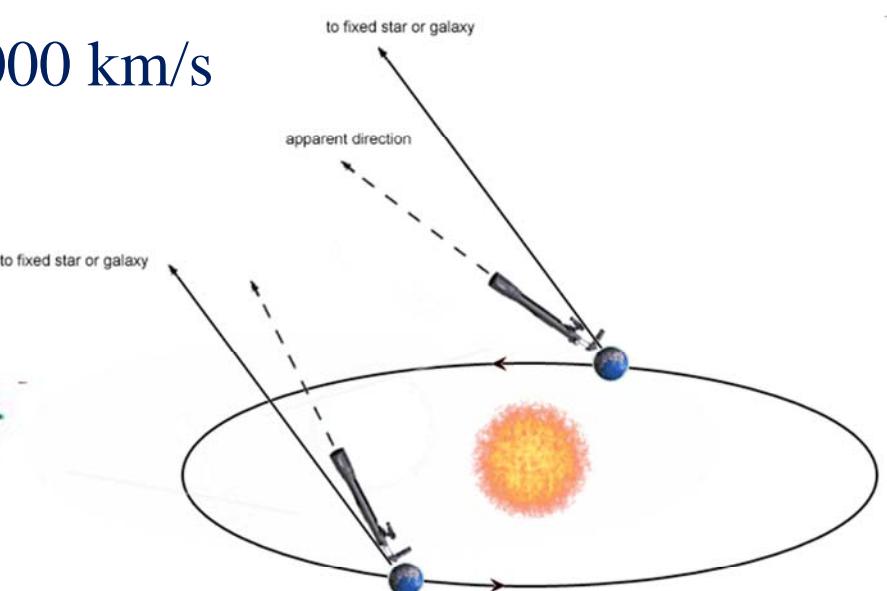
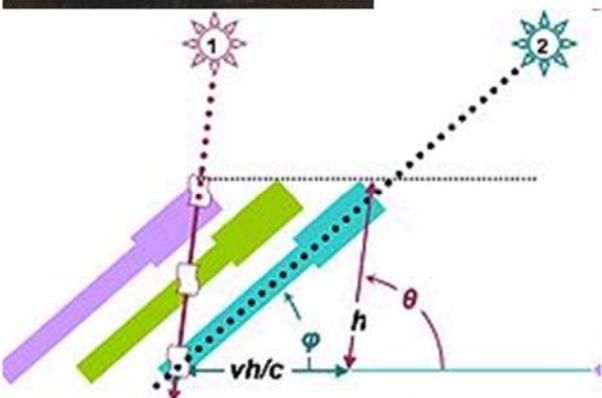
Huygens 估算得光速為 110,000,000 toises/s, 1 toise  $\approx$  1.949 m。

# 1729 Bradley

## 從星光的光行差測定光速



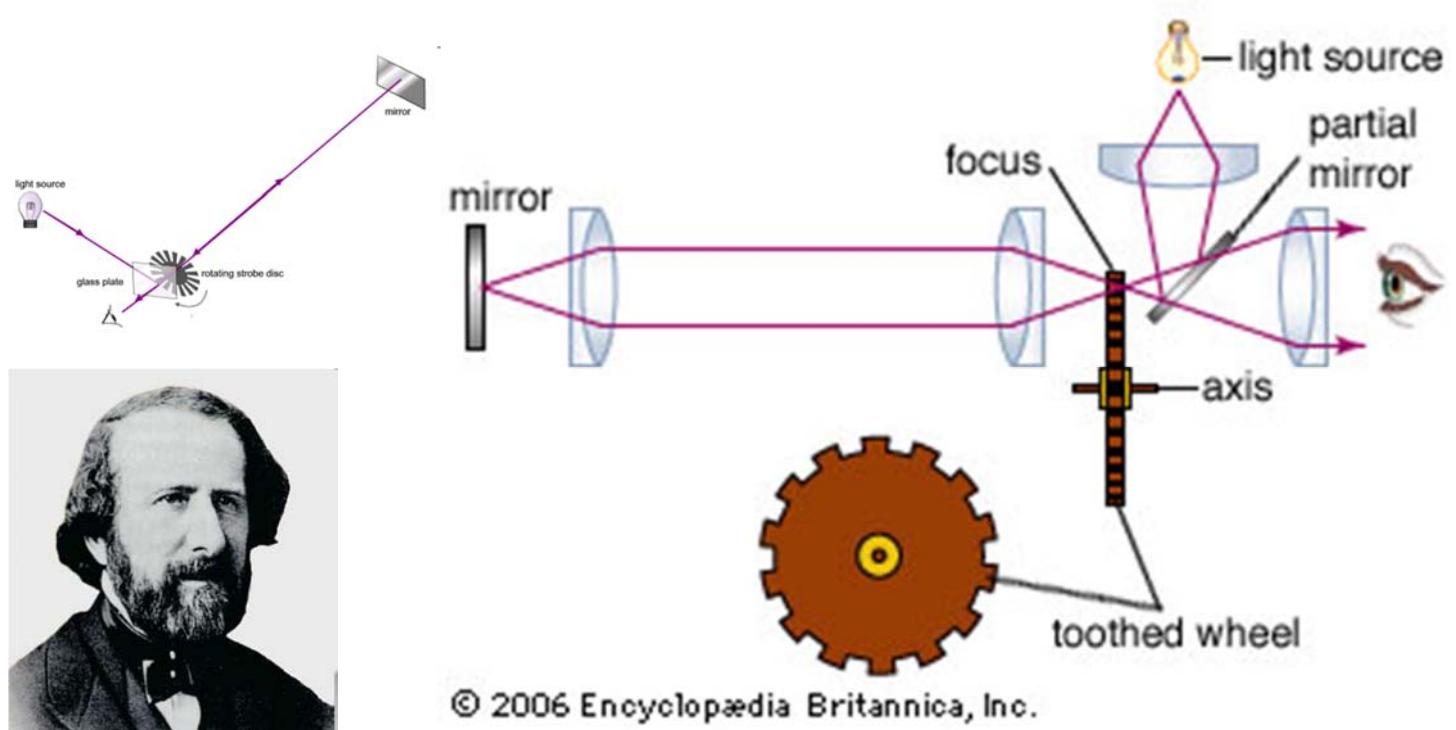
301,000 km/s



The apparent change in position of a fixed star or galaxy during an earth year is called aberration of starlight and its solution will be by means of derivation of relativistic aberration of starlight which Einstein accomplished in special relativity, 1905.

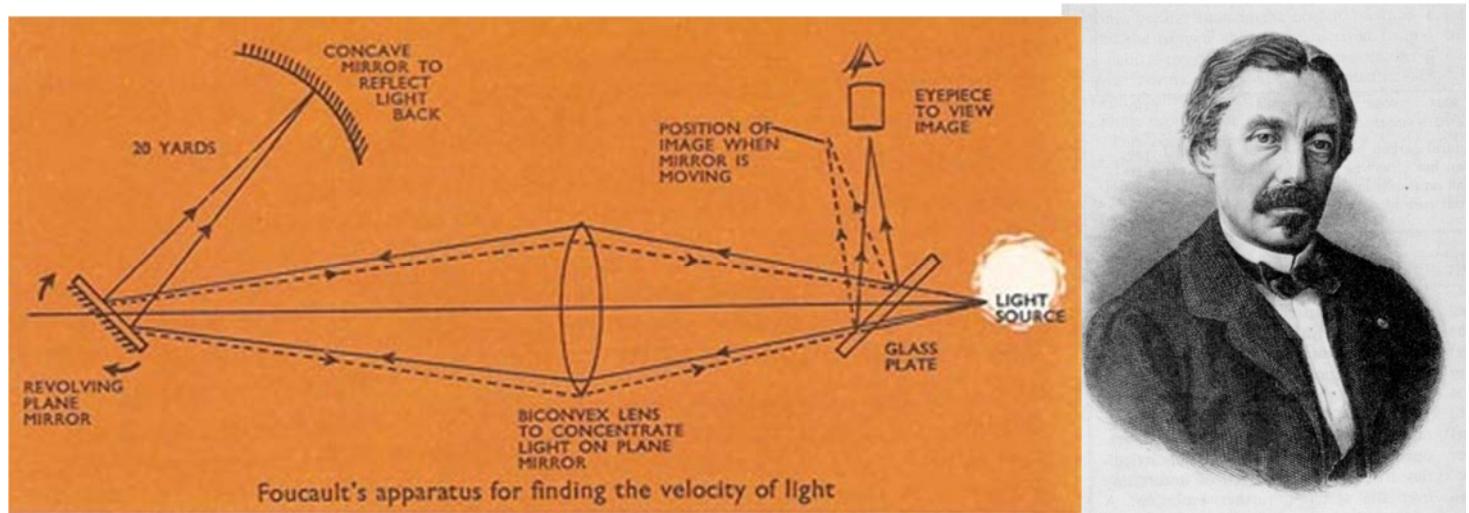
# 1849 Fizeau 地面上測定光速

- 空氣中光速：313,300 km/s



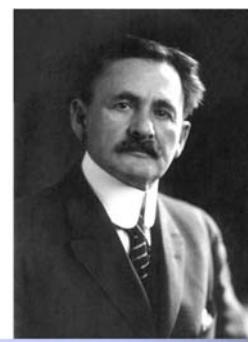
# 1850 Foucault 測定水中光速

- Foucault 用旋轉鏡方法更準確地測定了光速：298,000 km/s (1862)。
- 發現水中光速較小，支持波動說。

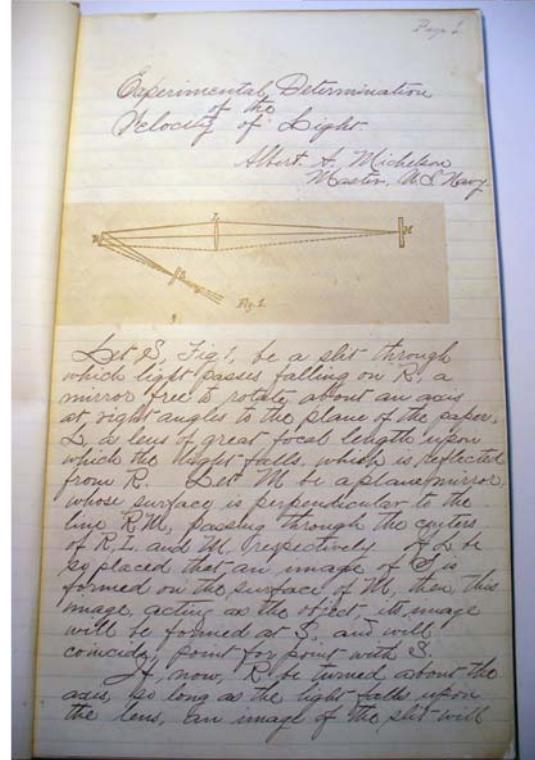


# Michelson 測量光速一生

1877-1931



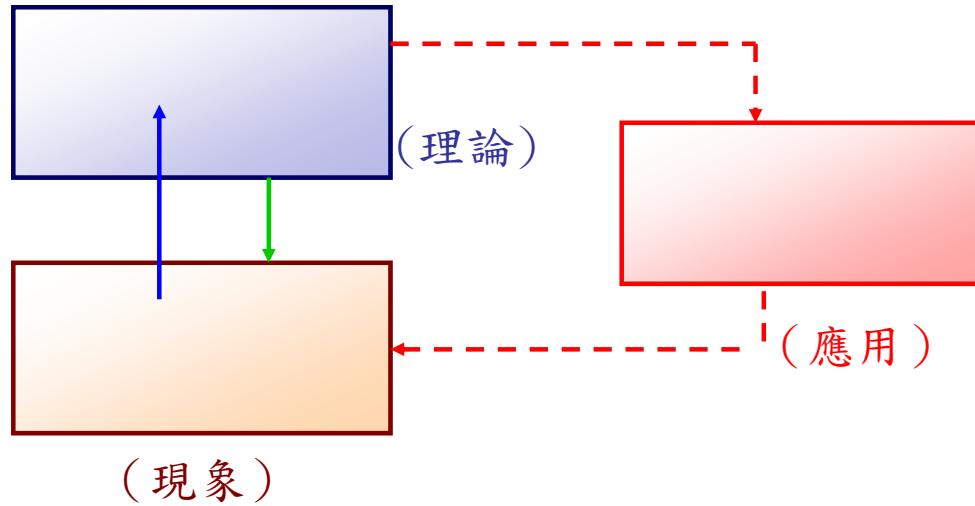
- 1879 測得  $299,910 \pm 50$  km/s。
- 1883 測得  $299,853 \pm 60$  km/s。
- 1926 測得  $299,796 \pm 4$  km/s。
- 1930 開始與 Pease 與 Pearson 合作；1931年逝世，未完成。1935年發表的數據為  $299,774 \pm 11$  km/s。



## 訂定值

- 1905 年，Einstein 提出相對論，其中假設真空光速恆定。
- 1975年，真空光速經測定為  $299,792,458$  m/s，誤差在  $4 \times 10^{-9}$  之內。
- 1983年，國際標準制（SI）訂定光速為確定值  $299,792,458$  m/s。

# 物理學

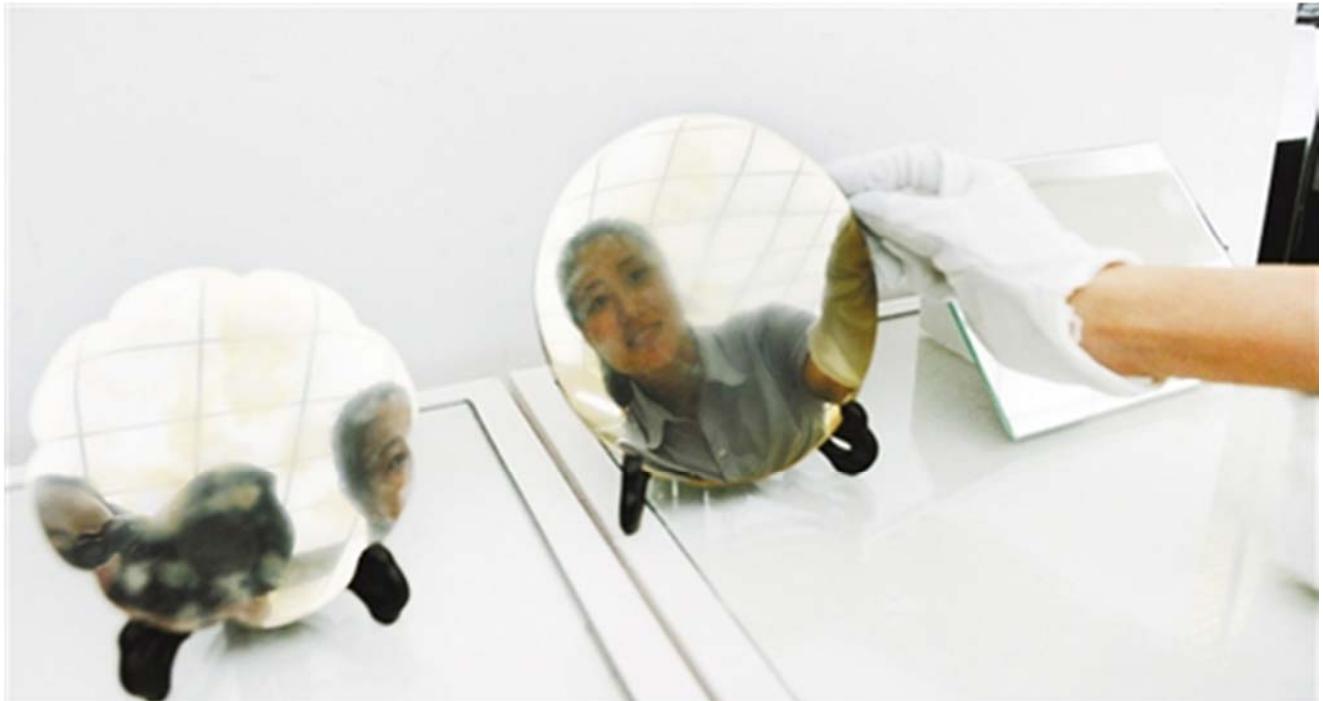


## 有關光的重要實驗

- 照鏡子
- 影
- 折射
- 雙折射
- 針孔成像
- 透鏡成像
- 分光
- 薄膜
- 狹縫干涉與衍射
- 色光三原色
- 偏振
- 光譜儀
- 都普勒效應



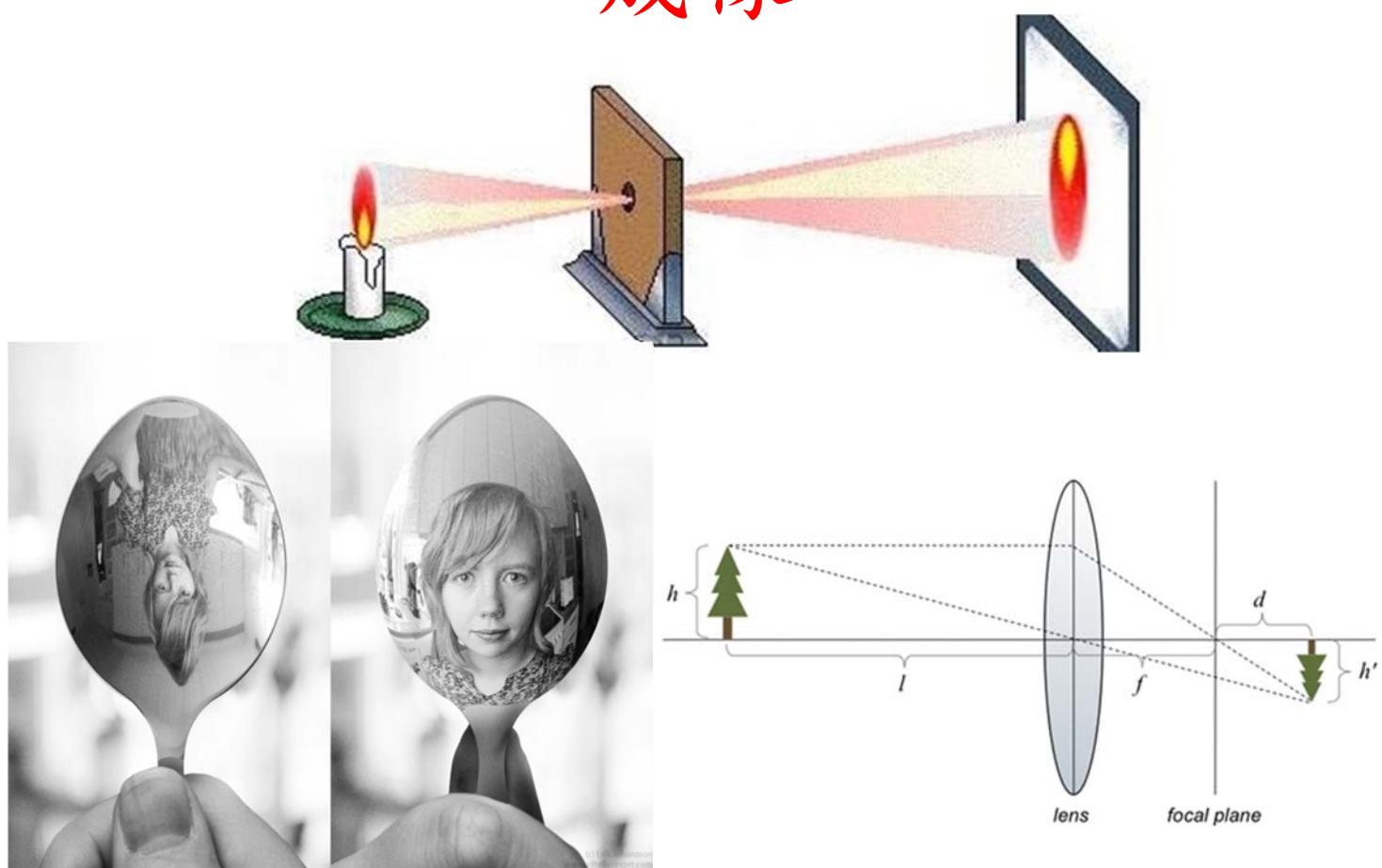
# 最古老的光學實驗——照鏡子



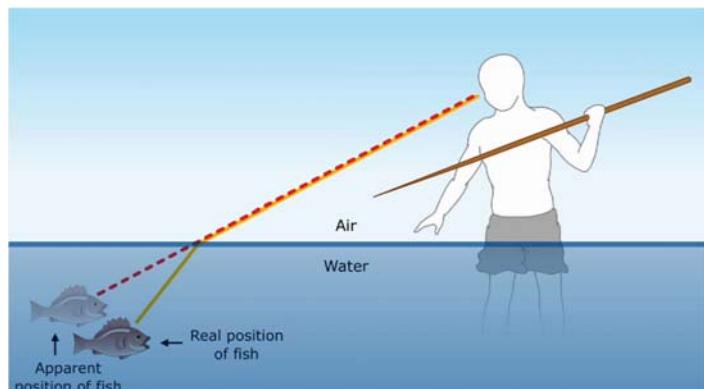
# 最古老的光學實驗——影



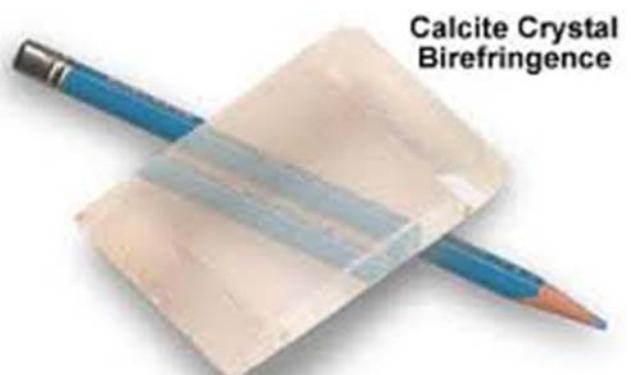
# 成像



# 折射

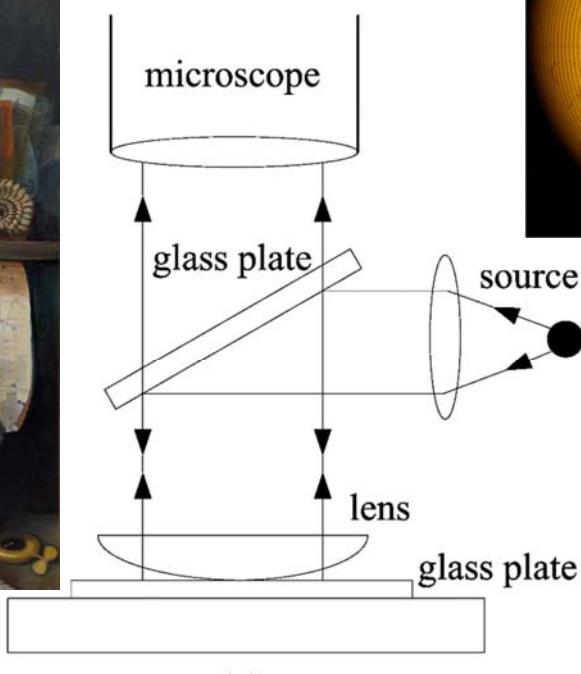


# 雙折射

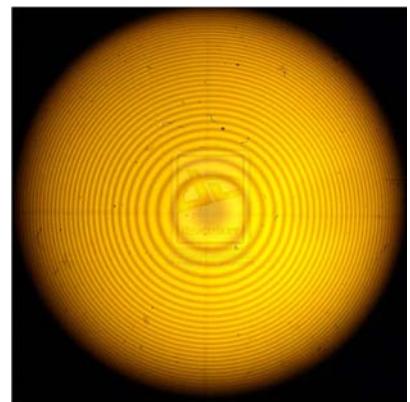


Calcite Crystal  
Birefringence

# 1660s Hooke 牛頓環

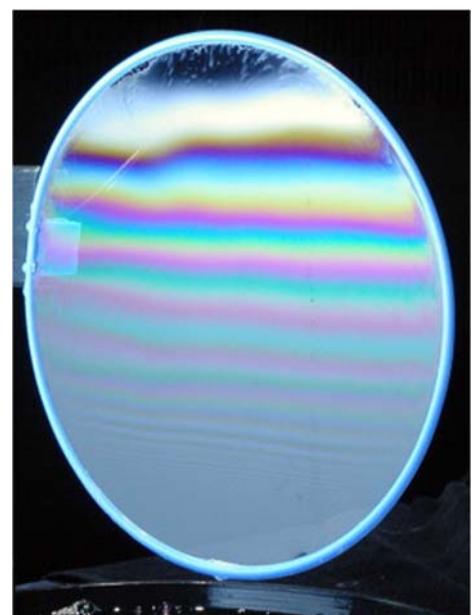


(a)

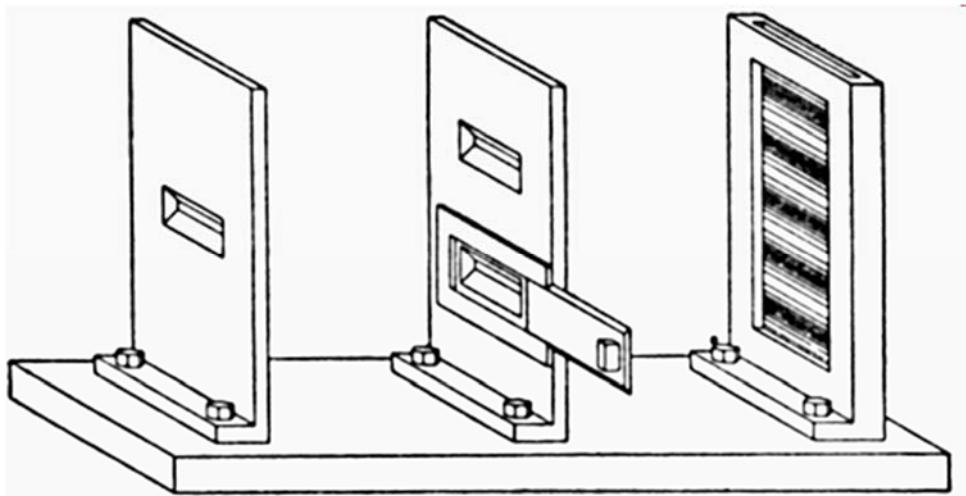


(b)

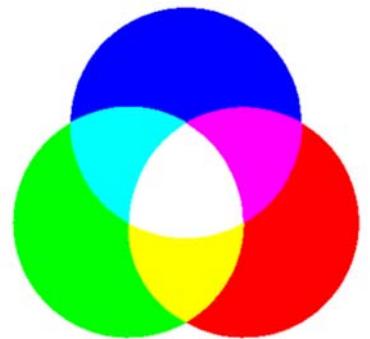
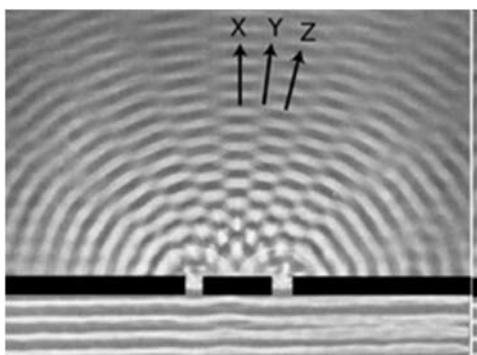
## 薄膜光彩



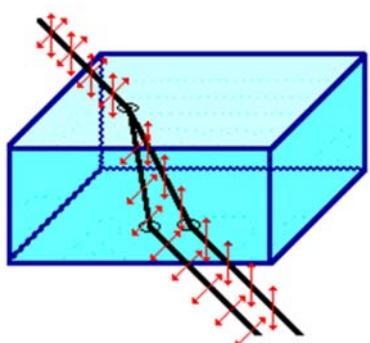
# 1802 Young 光的雙狹縫干涉



用水波槽譬喻  
光的波動說。

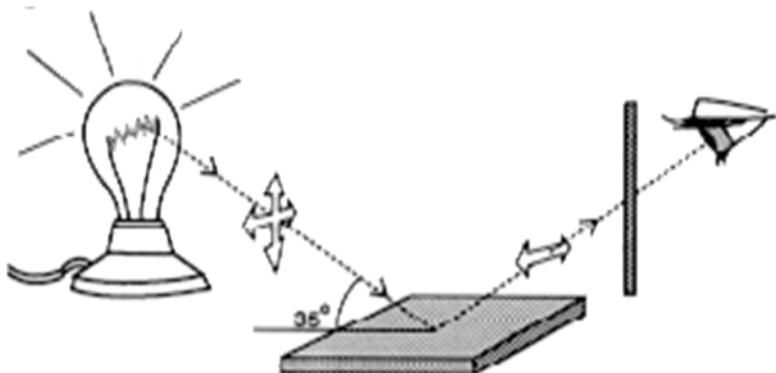


# 1808 Malus 光反射引致偏振



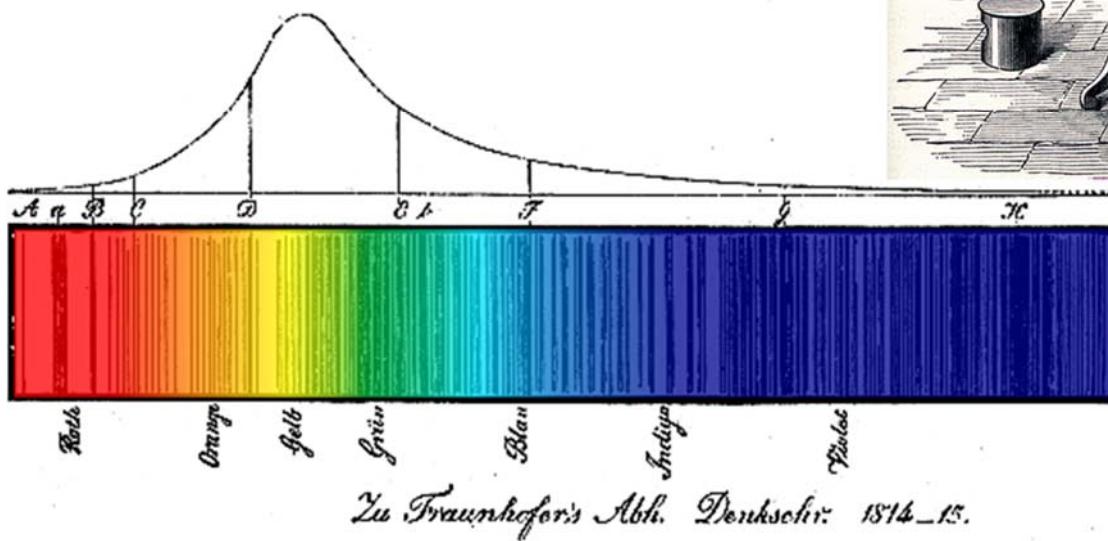
The two refracted rays passing through the Iceland Spar crystal are polarized with perpendicular orientations.

旋轉雙折射晶體（方解石），發現經玻璃反射的光可改變明暗。後經研究，光經反射可偏振化。



# 1814 von Fraunhofer 光譜儀與太陽暗線光譜

利用光譜儀發現太陽光譜裡的324條暗線，後經Bunsen與Kirchhoff解釋為吸收光譜。

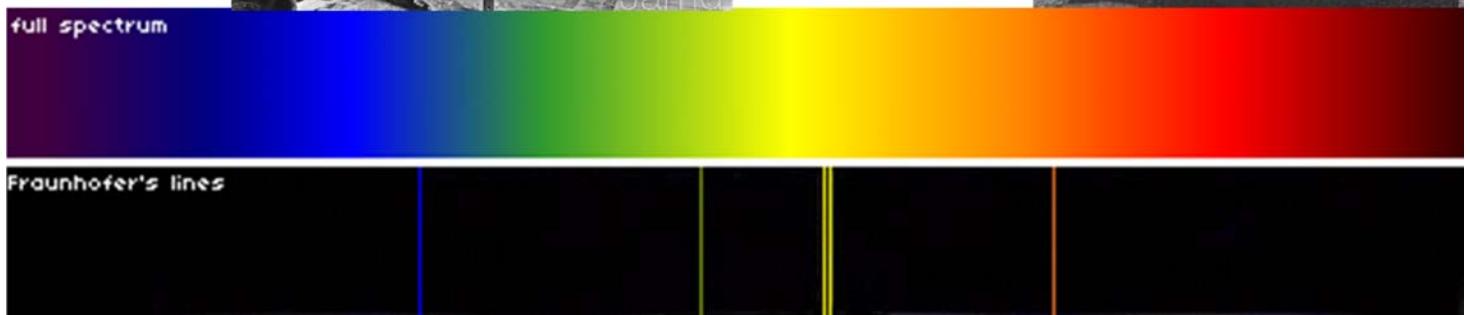


## 1821 Fraunhofer 絲線光柵

用260條絲線製成最早的光柵，可分辨出鈉的雙黃線。

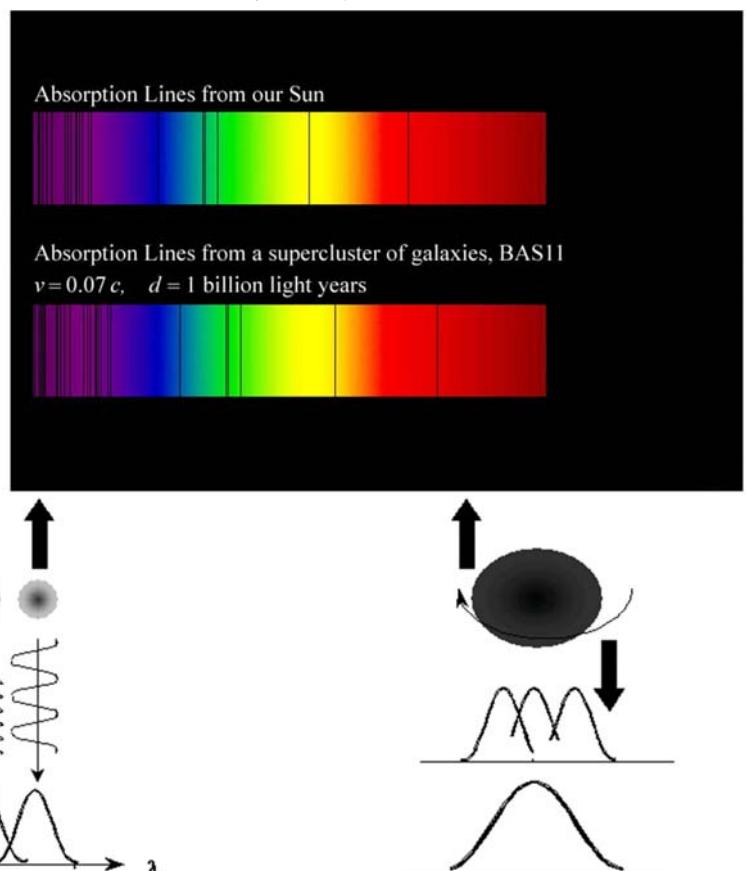
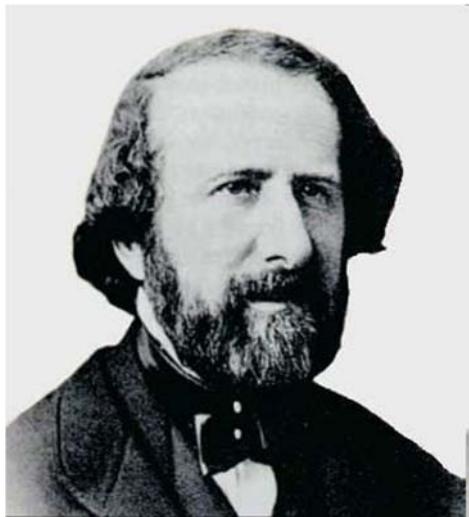


full spectrum



1848 Fizeau

光的都普勒效應



## 有關光的重要實驗（二）

- 散射
- 「相對以太運動」時的光速
- 光壓
- 黑體輻射光譜
- 星光行經太陽附近時的偏折



# 散射

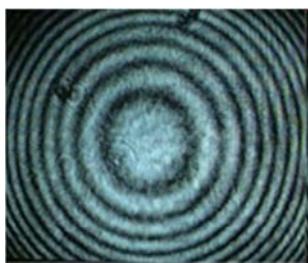


# Tyndall 效應



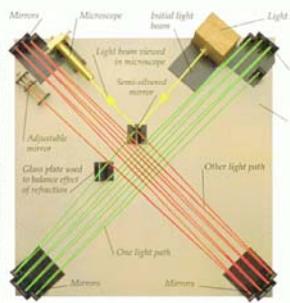
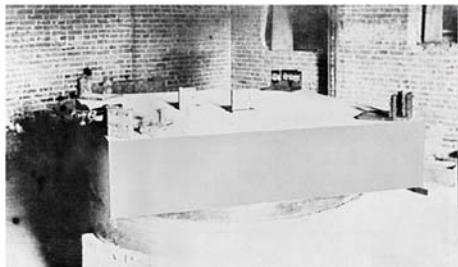
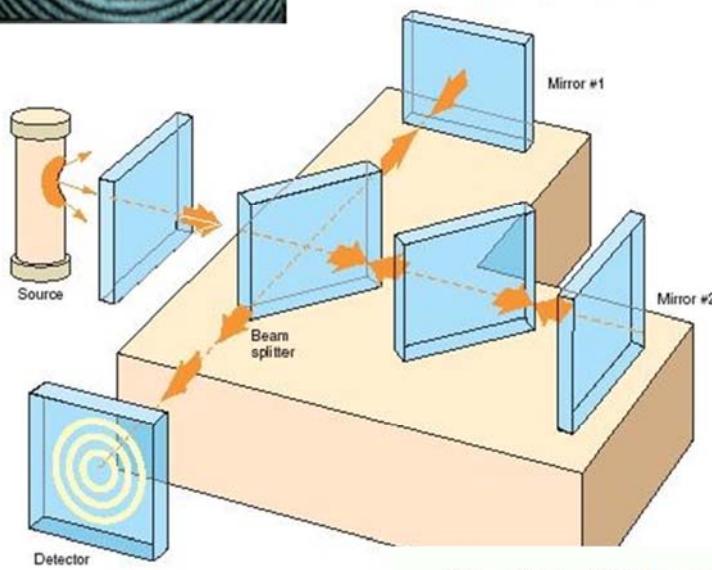
True solution  
(No scattering  
of light)

Colloidal sol  
(Scattering of  
light)

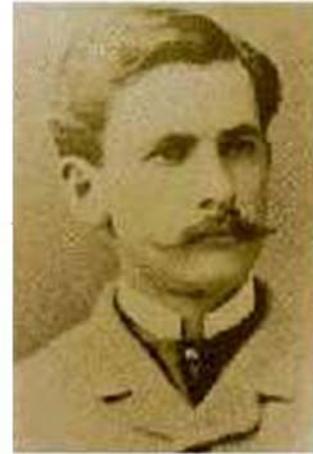


# 1887 Michelson/Morley

## 測不得以太效應



假如有以太，由於地球自轉，一天之間條文會會有週期性移位。結果沒有。



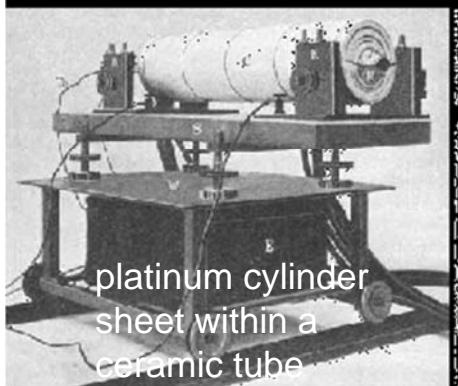
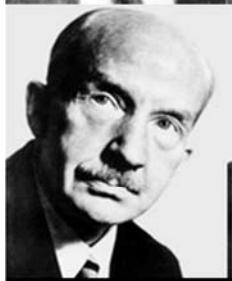
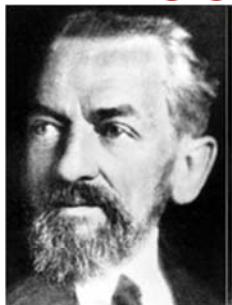
A.A. Michelson  
1852 - 1931



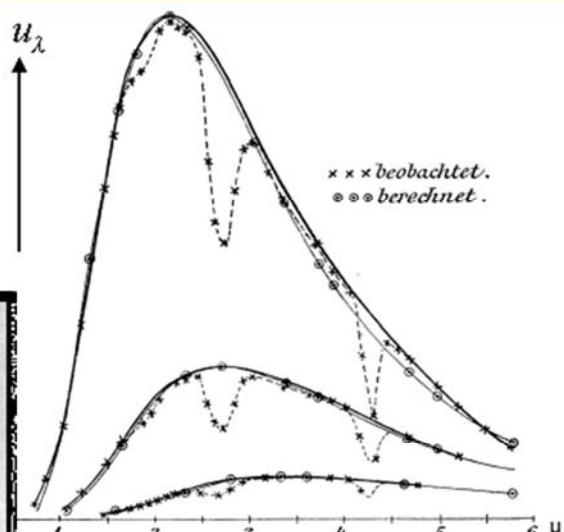
E.W. Morley  
1838 - 1923

# 1899 Lummer/Pringsheim

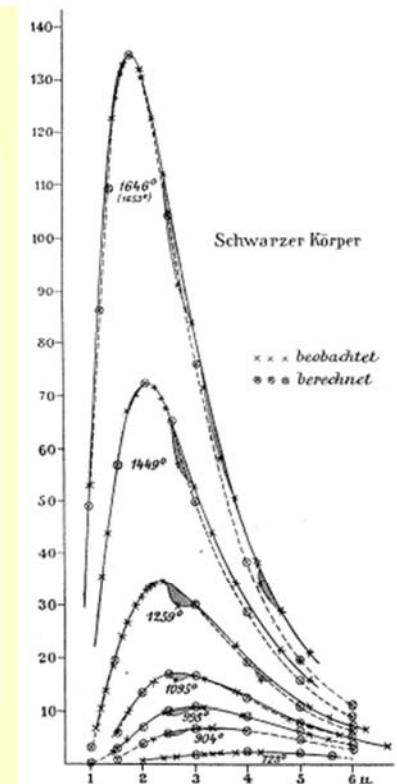
## 黑體輻射光譜



Die Messungen von Lummer und Pringsheim

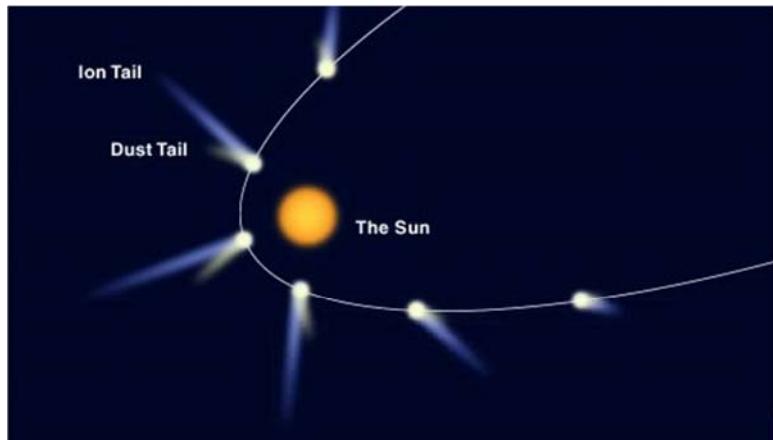


$\longrightarrow \lambda$

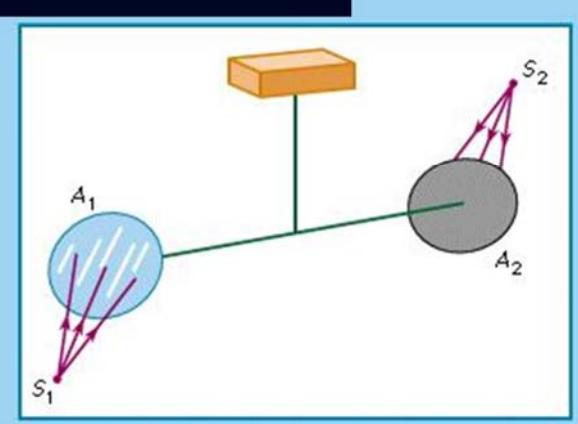
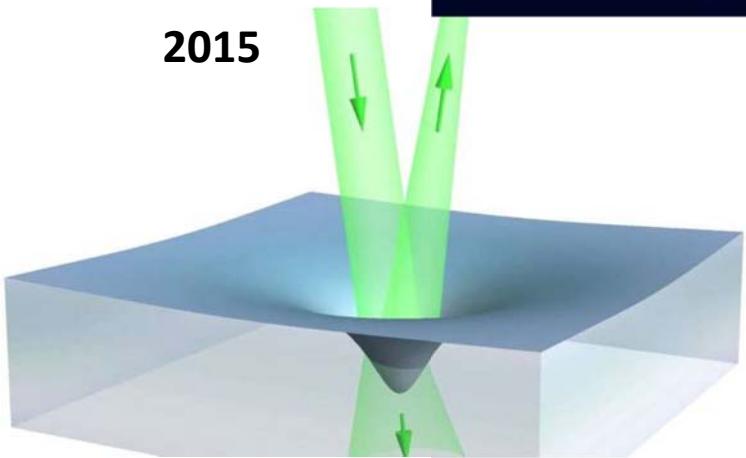


# 光壓

啟示

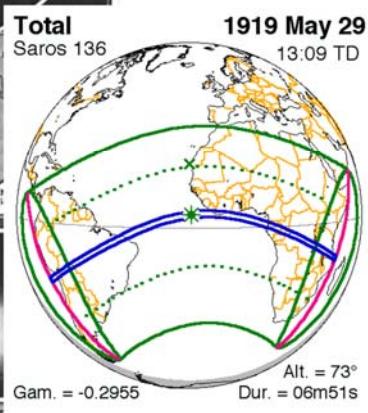
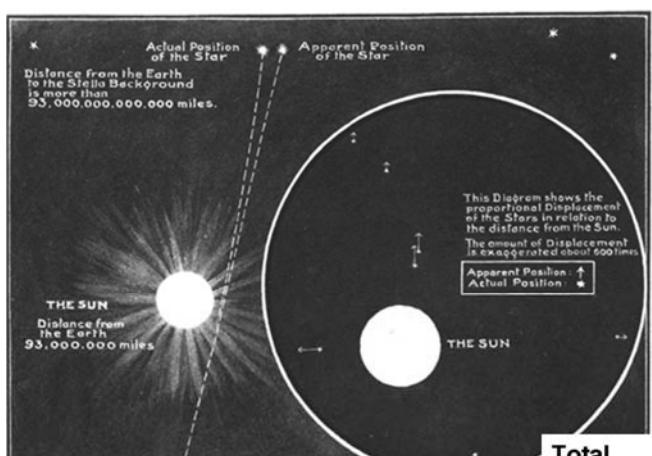


2015



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## 1919 Eddington 星光經太陽附近偏折驗證廣義相對論

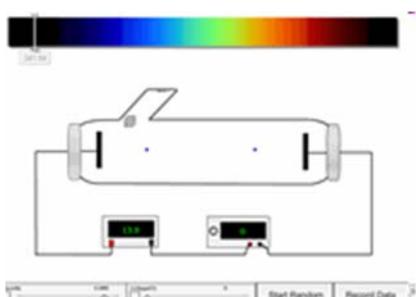


# 有關光的重要實驗（三）

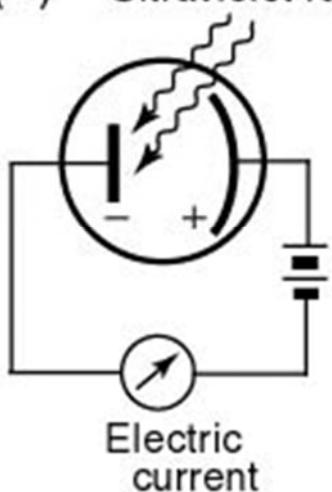
- 光電效應
- 微弱光的干涉
- Raman 效應
- 圓偏振光的角動量
- 光頻激射
- 全像術
- 孳生光子糾纏
- 非線性光學
- 近場光學



1902 von Lenard 光電效應

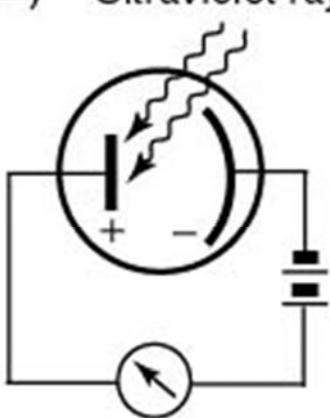


(A) Ultraviolet rays



Electric current

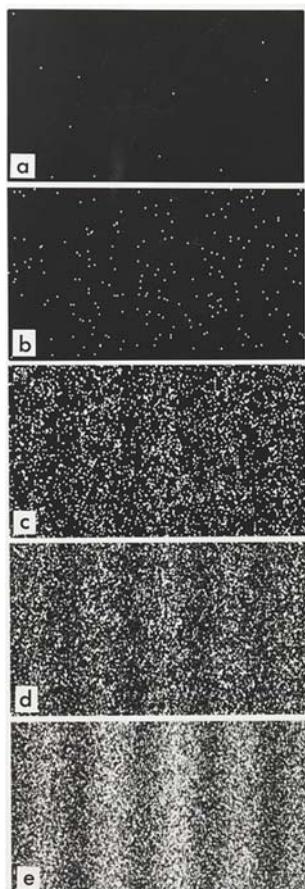
(B) Ultraviolet rays



No current



# 1909 Taylor 微弱光的干涉



*Interference fringes with feeble light.* By G. I. TAYLOR, B.A.,  
Trinity College. (Communicated by Professor Sir J. J. Thomson,  
F.R.S.)

[Read 25 January 1909.]

Photographs were taken of the shadow of a needle, the source of light being a narrow slit placed in front of a gas flame. The intensity of the light was reduced by means of smoked glass screens.

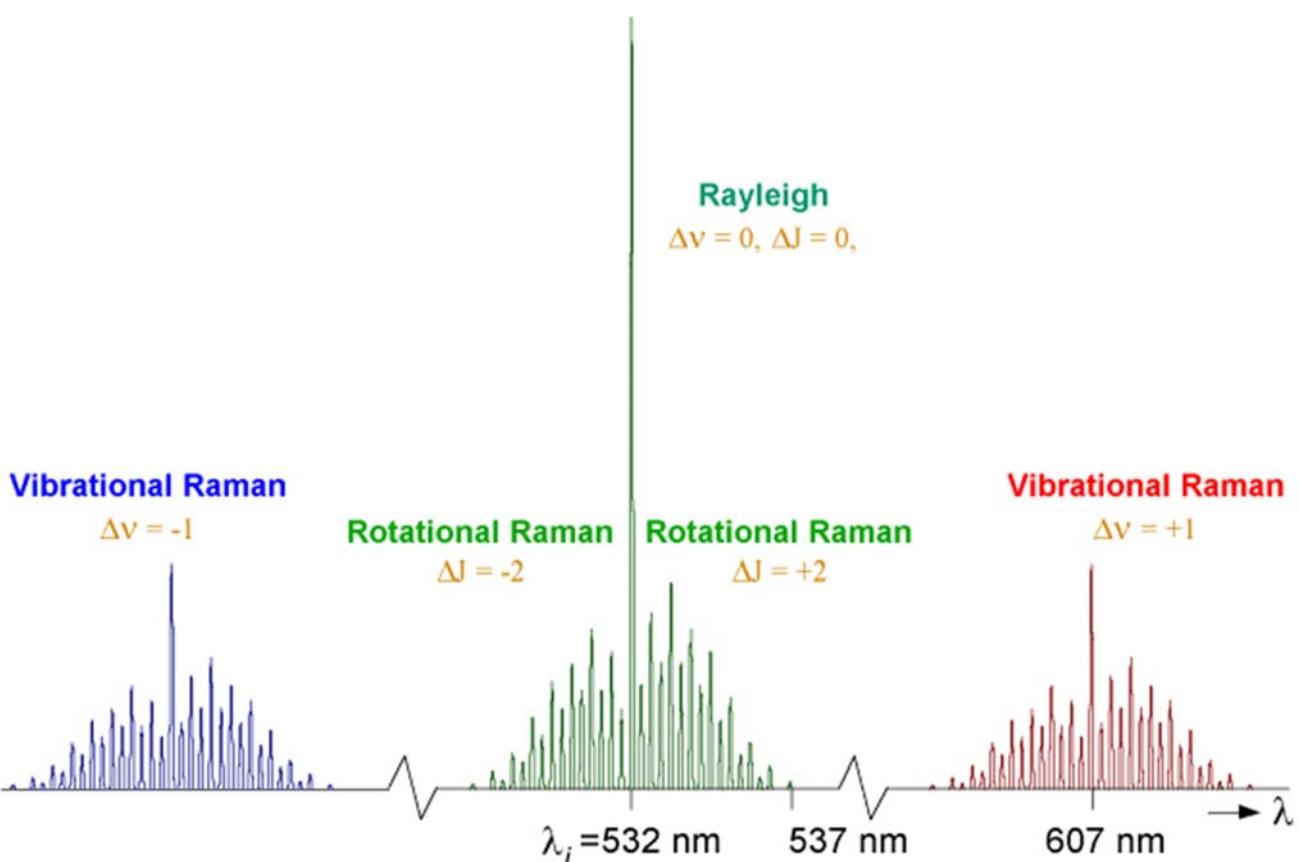
The time of exposure for the first photograph was obtained by trial, a certain standard of blackness being attained by the plate when fully developed.

The longest time was 2000 hours or about 3 months. In no case was there any diminution in the sharpness of the pattern although the plates did not all reach the standard blackness of the first photograph.

Proc. Camb. Phil. Soc. 15, 114 (1909)

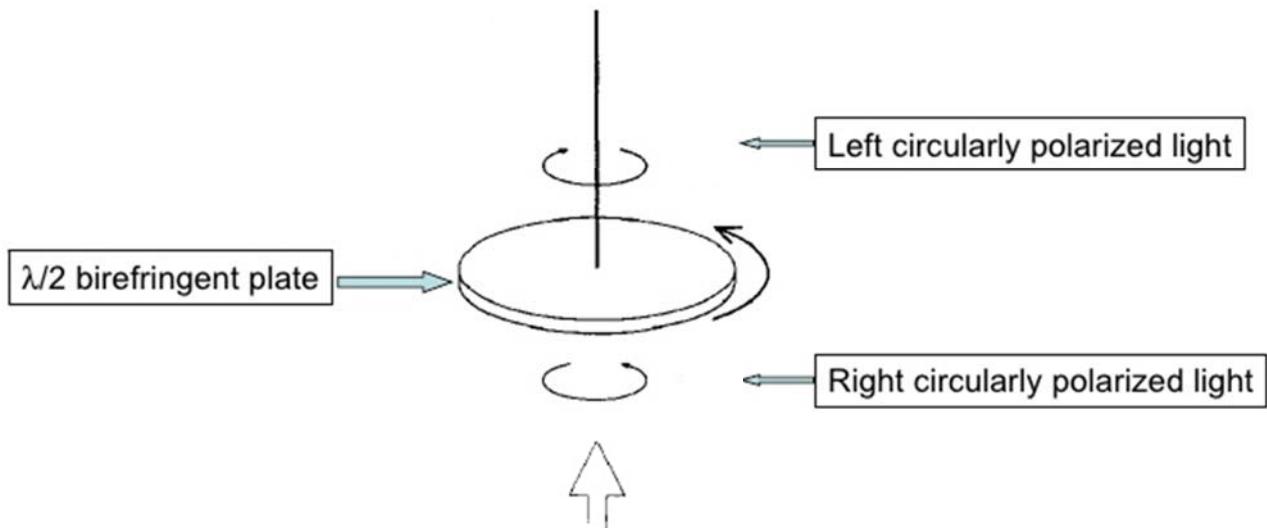


# 1928 Raman 強光經氣體散射頻率會加減



# 1936 Beth 圓偏振光的角動量

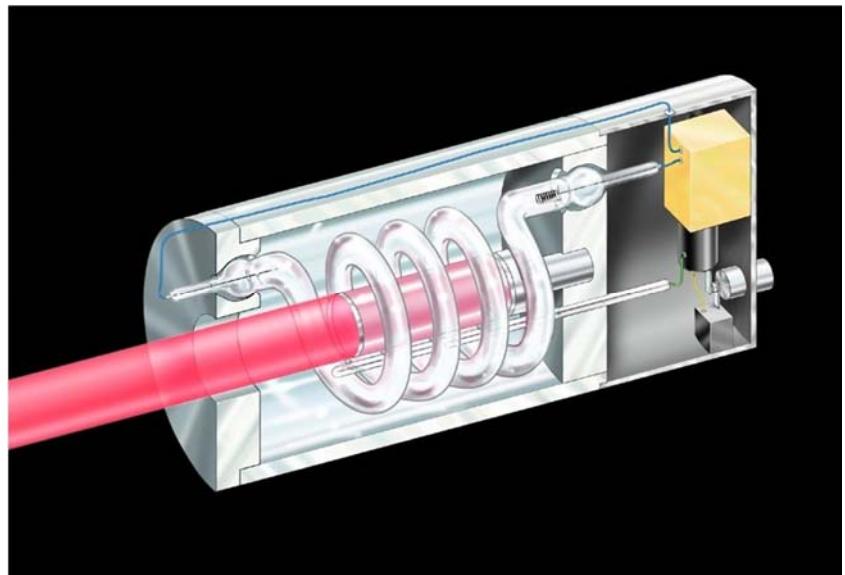
Beth Experiment in 1936 (Phys. Rev.)



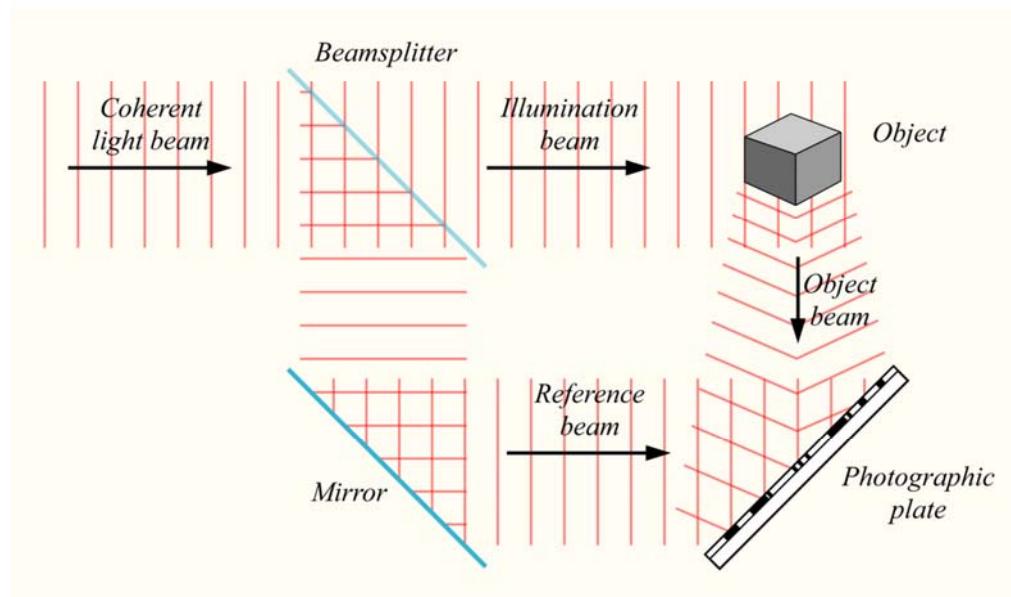
1954 Townes, 1960 Maiman 光頻激射



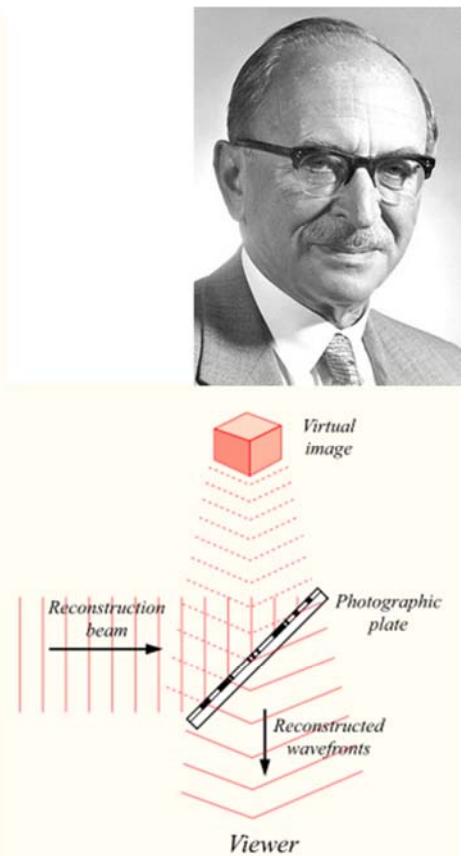
紅寶石雷射



# 1948 Gabor 全像術

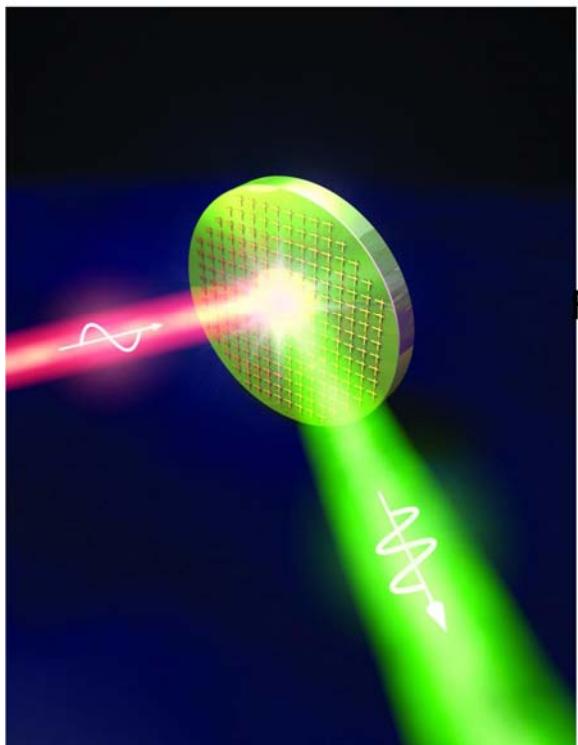


留像



重建

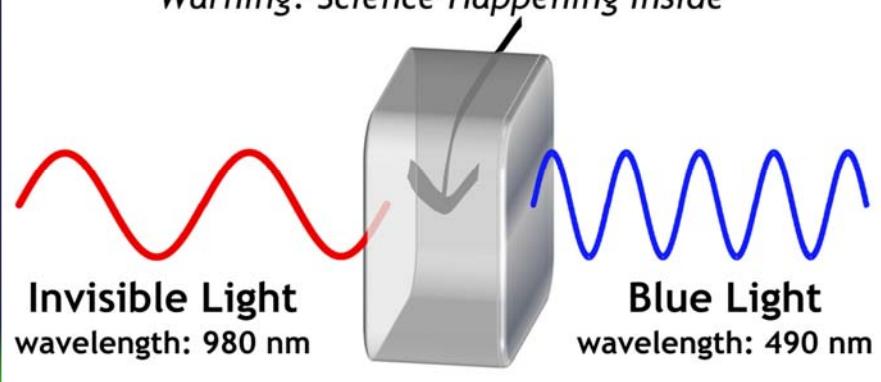
# 非線性光學



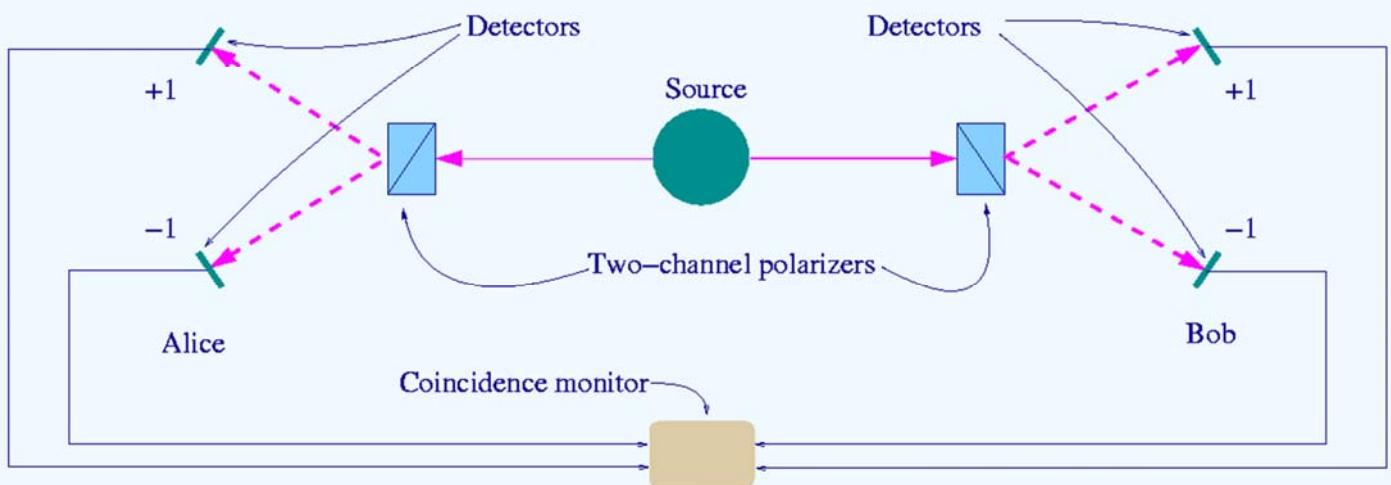
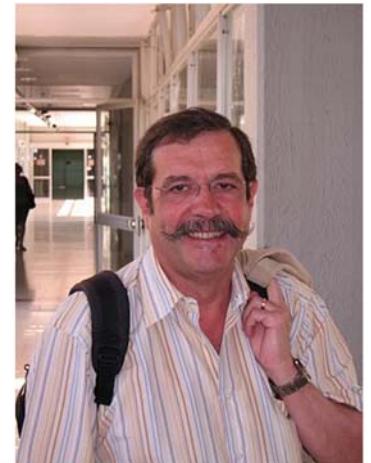
Bloembergen

Frequency Doubling Inside a Nonlinear Crystal

Warning: Science Happening Inside



# 1982 Aspect 孿生光子的越地糾纏



## 光的學說

- 線光學 (ray optics)  
Euclid, Ptolemy, Kepler, Snell, Descartes, Fermat, Newton.
- 波光學 (wave optics)  
Hooke, Huygens, Young, Fresnel, Arago, Hamilton, Fraunhofer, Maxwell, Rayleigh, Einstein, Born.
- 量子光學 (quantum optics)  
Einstein, Bohr, Dirac, Bose, Feynman, Glauber, Mandel, .....

# 線光學

- 光學是一門古老的科學，希臘時代 Euclid、Ptolemy都對此做出過貢獻。
- 到了17世紀，線光學基本上得以確立。線光學關注光線傳播的形學性質的研究，如光線傳播的直線性，光線的反射、折射性質等。由於製造光學儀器的需要，對光的折射性質的研究比較熱門。
- Kepler曾修正了Ptolemy關於入射角與折射角成正比的結論，並指出玻璃的折射角不會超過42度。



- 荷蘭數學家 Snellius (1591–1626) 在大量實驗的基礎上於1621年得出折射定律：入射角與折射角的餘割（正弦的倒數）之比為常數。
- Descartes 在1637年出版的《屈光學》(*Dioptrique*)一書中提出了折射定律的現代形式，即入射角與折射角的正弦之比為常數 $\sin\theta_1 = \frac{n_2}{n_1} \sin\theta_2$ 。
- 後來，法國數學家 Fermat 運用極值原理推出了光的反射定律和折射定律。
- 線光學利用形學 (geometry) 的點線面方法，成功地解釋了影、像的道理與虹、霓等的成因。



- Newton 的分光實驗以及牛頓環（Hooke's rings）的發現，使光學由線光學進入波光學。但牛頓本人認為光本質上是運動的微粒，所以他不能正確地解釋由他自己做出的偉大發現。
- 與牛頓同時代的Huygens等人主張光是一種波動，由此展開了近兩個世紀的光的本性之爭。
- 19世紀的光學以波動說的復興為先導，因此有必要先回顧一下微粒說與波動說之爭論



## 波動說與微粒說的對立

- Descartes 在光的本性方面的看法是不一貫的。在談到視覺問題時，他把光線比喻成脈衝波動，否認眼睛在看東西時有某種物質微粒進入。可是，他在解釋光的折射和反射時又運用物體的碰撞運動來進行比喻。
- Hooke 批評Newton 1672年提出的關於光與色的理論，認為光是波動。
- Huygens 最早比較明確地提出了光的波動說。在《光論》（1690）一書中，他認為光的運動不是物質微粒的運動而是介質的運動即波動，其理由是，光線交叉穿過而沒有任何相互影響。運用波動說，Huygens解釋了光的反射、折射以及方解石的雙折射現象。
- 不過，他的波動說並不完善。他誤認為光像聲音一樣也是縱波，所以在解釋光的干涉、繞射和偏振現象時遇到困難。



- Newton 傾向於微粒說。在《光學》（1704）中，他陳述了波動說的幾種不足：
  - ☆ 第一，波動說不能很好地解釋光的直線傳播現象。如果光是一種波動，它就應該有繞射現象，就像聲音可以繞過障礙物而傳播一樣，但我們並沒有觀察到光有這種現象。
  - ☆ 第二，波動說不能令人滿意地解釋方解石的雙折射現象。
  - ☆ 第三，波動說依賴於介質的存在，可是沒有什麼證據表明，天空中有這樣的介質，因為從天體的運行看不出受到介質阻力的跡象。
- 基於這些理由，Newton 懷疑波動說，而提出光是一種微粒的看法。
- 不過，Newton 也不完全排斥波動思想。比如，他就提出過光粒子可能在以太中激起週期性振動。但這些思想被後人有意無意地忘記，牛頓成了堅持微粒說的一面旗幟。



- 部分由於Huygens波動說的不完善，部分由於Newton 的崇高威望，微粒說在整個18世紀佔據主導地位。
- 但是，在折射問題的解釋上，波動說和微粒說之間出現了一個判決性的實驗。
- 微粒說認為，密介質中的光速大於疏介質中的光速，波動說則認為，密介質中的光速小於疏介質中的光速。
- 可是當時，在實驗室中測定光速還不可能，這個判決性實驗也起不了判決性作用。



# 波動說的復興



- 19世紀的光學是由英國醫生 Thomas Young 以復興波動說的論文揭開序幕的。
- Young 自小聰穎過人。他起先在愛丁堡大學學醫，後在德國 Göttingen 大學取得了博士學位，1799年開始在倫敦開辦診所。
- Young 的光學研究始自對視覺器官的研究。他第一個發現，眼球在注視距離不同的物體時會改變形狀。

- 1800年，Young 發表了《關於光和聲的實驗和問題》一文，對延續了一個世紀的微粒說提出異議。他說：「儘管我仰慕 Newton 的大名，但我並不因此非得認為他是萬無一失的。我遺憾地看到他也會弄錯。而他的權威也許有時甚至阻礙了科學的進步。」
- 在文章的光學部分，Young 提出了否定微粒說的幾個理由：第一，強光和弱光源所發出的光線有同樣的速度，這用微粒說不好解釋；第二，光線由一種介質進入另一種介質時，一部分被反射，而另一部分被折射，用微粒說解釋也很牽強。
- 在文章的聲學部分，Young 依據水波的疊加現象，提出了聲波的疊加理論。他把由疊加造成的聲音的加強和減弱稱為「干涉」。在聲波干涉中，「拍」現象即疊加造成的聲音時斷時強的效果，引起了 Young 的特別注意。他聯想到，如果光是一種波動，也應該有干涉和拍現象，即兩種光波疊加時，應該出現明暗相間的條紋。

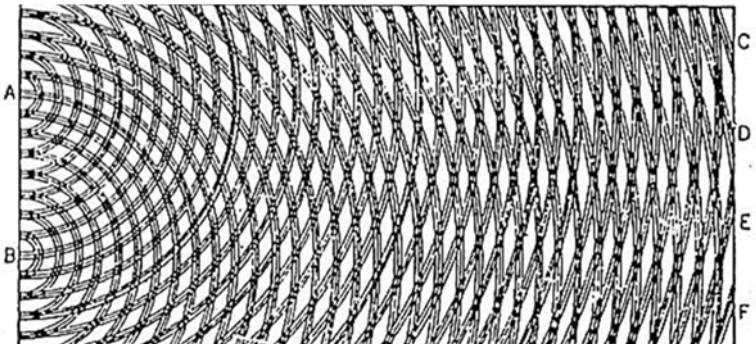
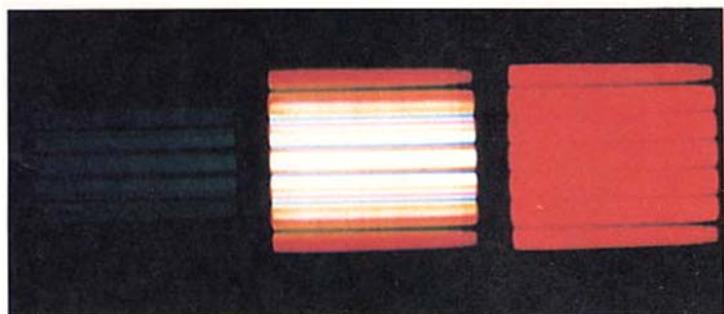


- 1801年，Young 向皇家學會宣讀了關於薄片顏色的論文。文中正式將干涉原理引入了光學之中，並且用這一原理解釋薄片上的色彩和條紋面的衍射。
- 在這篇論文中，Young 還系統提出了波動光學的基本原理，提出了光波長的概念，並給出了測定結果。楊指出，正是由於光波長太短，以致遇障礙物拐彎能力不大，人們才很難觀察到這類現象。
- Young 的論文在英國學界引起了敵視。當然，他的論文在闡述實驗方面不夠明晰。
- 儘管他本人實際上做過十分精確的實驗，但由於表述的問題使讀者感到干涉理論只是一些沒有實驗根據的理論推測。Young 沒有氣餒，繼續進行實驗研究，



## Thomas Young

- 於1803年發表《物理光學的實驗和計算》，對雙縫干涉現象進一步做出了解釋。
- 在1807年出版的《自然哲學講義》中，Young 系統闡述了他提出的波動光學的基本原理。



# Malus

- 1809年，法國物理學家Etienne-Louis Malus (1775–1812) 發現了光在雙折射時的偏振現象。  $I = I_0 \cos^2 \theta$
- 縱波不可能出現偏振現象，這使Young 新近復興的波動說遇到了極大的困難。微粒說的信奉者以此對波動說發起攻擊。
- Young 於1811年給Malus 寫信說：「你的實驗證明了我所採用的理論的不足，但是這些實驗並沒有證明它是錯的。」
- 1817年，Young 終於發現了擺脫這個麻煩的途徑。他在1月12日給法國物理學家Arago 的信中說，光波不是一種縱波，而是一種橫波，而偏振完全可以用橫波加以解釋。



# Augustin-Jean Fresnel



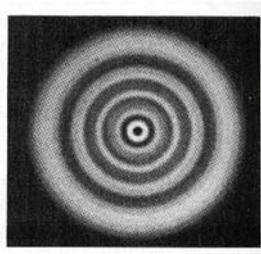
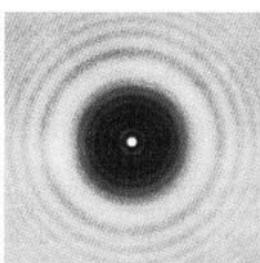
- 幾乎獨立提出光的波動學說的還有法國物理學家 Augustin-Jean Fresnel (1788–1827) 。
- 與Young 相反，他從小非常遲鈍，身體也不好，後來由於刻苦努力成了一名工程師。
- 由於反對拿破崙，他曾被關進監獄一段時間。
- 1814年，他對光學開始感興趣，次年便向科學院提交了第一篇光學論文。文中仔細地研究了光的繞射現象，並提出了光的干涉原理。

# Arago

- Fresnel 的論文實驗證據確鑿，很快在法國物理學界獲得支持。
- 本來信奉微粒說的Arago，在受命審查Fresnel的論文之後，第一個改信波動說。
- Fresnel 與 Arago 一起繼續進行實驗研究，於1819年證實了Young 關於光是一種橫波的主張。



# Poisson亮點



- 1814年，Fresnel開始研究小孔繞射問題。1817年，法蘭西學術院舉行了一次關於光的本性問題的最佳論文競賽，Fresnel 成功地提出了後人所謂 Huygens-Fresnel 原理，於1818年提交了論文。
- 科學院成立了一個評委會，儘管不少成員不相信Fresnel的觀點，但是最終授予他優勝獎。
- Poisson想推翻Fresnel的觀點，藉波動理論詳細分析，發現：用一個圓片作為遮擋物時，光屏的中心應出現一個亮點，令人難以相信。
- Fresnel和Arago精心設計了一個實驗，確認了這一亮斑的存在。Poisson當作謬誤提出來的，竟成了支持波動說的強有力的證據！

- Fresnel 在毫不瞭解Young 的工作的基礎上獨立地提出了光的波動理論。他與楊之間並未發生優先權之爭。當 Arago 將他的論文介紹給 Young 時，Young 對此進行了高度的評價。
- 由於他們的齊心協力，微粒說一統學界的局面被打破。在波動學說基礎上的光學實驗大量湧現，使19世紀在波光學方面取得了重大的進展。
- Hamilton闡明「波前」與「線」的算學關係。
- 波光學能導出線光學的所有結果。

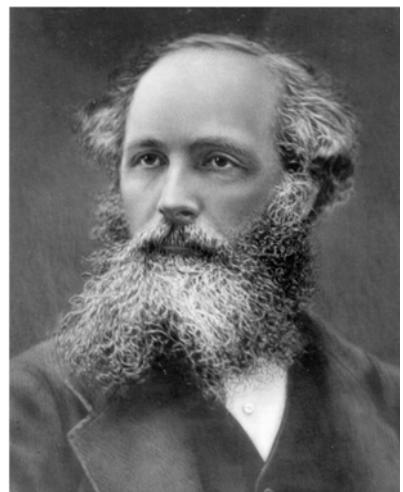


## 光學與電磁學的統一

- 波動說的確立使光傳播的載體問題變得突出。按照水波和聲波的類比，光波也應有它的傳播媒介。人們一般將這種看不見、摸不著的媒介稱為光以太 (luminiferous ether) 。
- 當 Young 和 Fresnel 發現光是一種橫波後，在光以太問題上遇到了困難。對於縱波而言，流體就可以充當媒介，但對橫波，其介質必須十分凝固，富有剛性。
- 可是，這樣十分堅固的光以太為何又沒有對天體運動產生阻礙呢？



- 物理學家們絞盡腦汁，對光以太的機械特徵進行各種各樣的修正和補充，但總是出現新的問題。這些做法均基於一個前提，即把光看成一種機械波。Maxwell 建立電磁統一理論之後，認為光就是一種波長極短的電磁波，從而在理論上統一了光學與電磁學。
- 光的電磁理論建立之後，光不再被看成機械波，因而光以太的機械特徵問題就不復存在。但是在經典理論中，電磁波的傳播同樣需要被稱為電磁以太（electromagnetic ether）的媒介。
- 光的傳播媒介不再是機械以太（mechanical ether），而是電磁以太。電磁以太又是什麼？這個問題留給了19和20世紀之交的物理學家們。



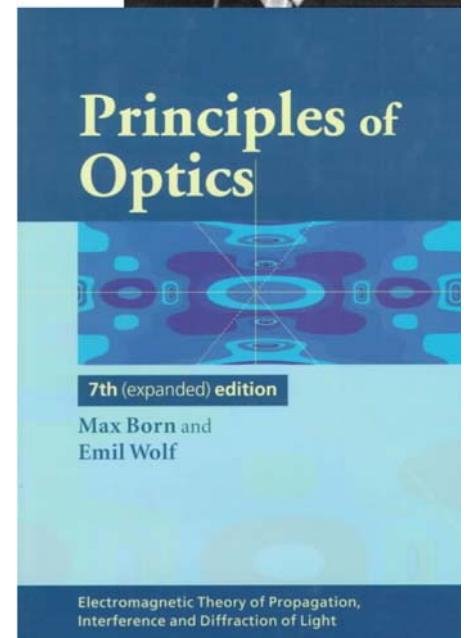
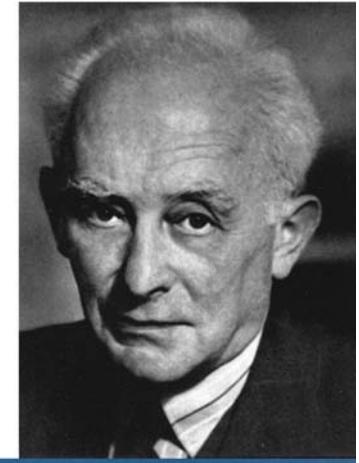
- Rayleigh 是研究波的大師。他的散射理論說，光被空氣分子散射時，散射強度與波長的四次方成反比；換言之，紅光遠比紫光難散射。這說明了為何天空在散射陽光後呈「天藍色」，也說明了為何黎明與黃昏時太陽呈「橘紅色」。



- Einstein 在 1905 年提出的後來稱之為「狹義相對論」的論文裡，揚棄了光以太，認為是「多餘的」（superfluous）。光的電磁波理論因而精鍊。



- Born的《光學》（*Optik: Ein Lehrbuch der elektromagnetische Lichttheorie*, 1933）是第一本用電磁學解釋光學的著作。
- 後來他與Wolf合著《光學原理》（*Principles of Optics: Electromagnetic Theory of Propagation, Interference and Diffraction of Light*, 1959），是為波光學的經典。



## 波光學裡光的

### 發射機制

- 電荷加速
- 電磁震盪
- 溫輻射

### 吸收機制

- 電荷受強迫震盪

### 傳播機制

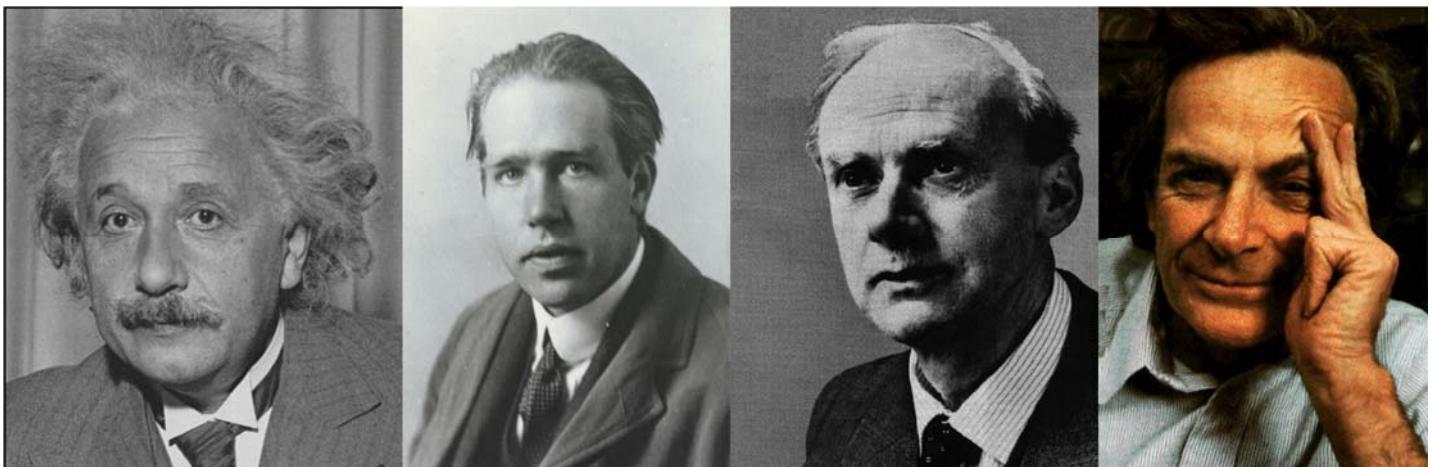
- 電磁波



# 量子光學

- Einstein是量子光學的開啟者。他在1905年提出的光量子假說改變頻率為 $\nu$ 的光的強度的意義： $I = n \cdot h\nu$ ,  $h\nu$ 是每個光量子的能量， $n$ 是光量子的數目通量密度。
  - 後來又清楚，光量子帶有動量與角動量。得到種種實驗的證實。
  - Bohr在1913年提出新的發光與吸收機制——能階躍遷  $h\nu_{nm} = E_n - E_m$ 。Einstein復於1917年指出光與物質作用的三種過程：自發放射、刺激放射與刺激吸收。
- 
- 光到底是波還是粒子，乃至電子到底是粒子還是波的疑惑，終於導致1925到26年間發展出量子力學，而有嶄新的看法——所謂波，是粒子在時空中「或然率分布」的「幅」（複數函）。
  - Bohr在1927年指出：波與粒子的「兩象」互補相成。
  - Dirac 於1928年開創量子電動力學，更以「場的量子化」統合粒子與波的兩種觀點。其後發展成「量子場論」。於是，與其用電場  $E$  與磁場  $B$  來描述光，不如用「四維勢」的算符  $\hat{A}^\mu$ 。
  - 又，Feynman 從「路徑積分」(path integral)的觀念對光學另有一套新說法。(QED: The Strange Theory of Light and Matter, 1985)

- 1924年，Bose 對於溫平衡下的光量子系統提出新的統計原理——光量子既不可分辨，又有合群性。
- 激射（maser, laser）出現後，引發從量子場論對同調性研究的新興趣。
- 1950、1960年代，Glauber, Sudarshan 與 Mandel等人提出「光子統計」（photon statistics）及「同調狀態」（coherent state）的新概念——激射光與溫輻射是兩個極端（前者同調，後者不同調），但其間還有各種可能的同調狀態（如反簇集 antibunching）。



# 量子光學裡光的

## 發射機制

- 能階躍遷
- 自發放射
- 刺激放射
- 制動輻射

## 吸收機制

- 能階躍遷

## 傳播機制

- 「量子場」



請指教



# The Story of Microscopy

顯微鏡的故事



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國立陽明大學

## The International Year of Light

and Light-based Technologies

2015



INTERNATIONAL  
YEAR OF LIGHT  
2015

Health

Communications

Economy

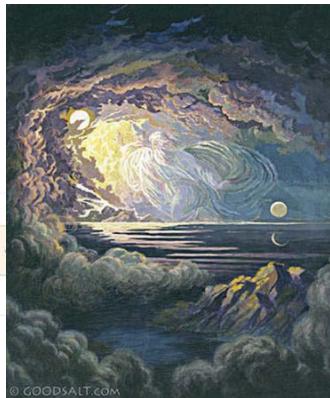
Environment

Social



# GENESIS 1:3

“And God said, Let there be light: and there was light.”



KING JAMES VERSION (KJV)

[▲ View Chapter](#)

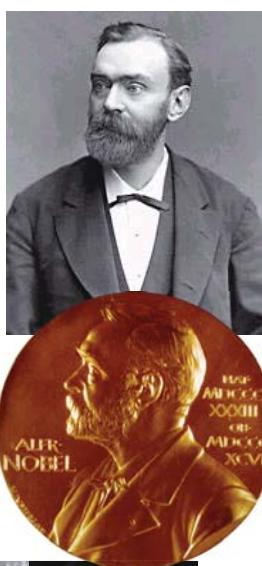


GENESIS 1:3 CONTEXT

<sup>1</sup>In the beginning God created the heaven and the earth. <sup>2</sup>And the earth was without form, and void; and darkness [was] upon the face of the deep. And the Spirit of God moved upon the face of the waters. <sup>3</sup>**And God said, Let there be light: and there was light.** <sup>4</sup>And God saw the light, that [it was] good: and God divided the light from the darkness. <sup>5</sup>And God called the light Day, and the darkness he called Night. And the evening and the morning were the first day.

[▲ View Chapter](#)

## Spectroscopy and Laser-Related Nobel Prizes





Arthur L. Schawlow



Charles Townes



Theodore H.  
Maiman.

## The Nobel Prize in Chemistry 2014



Photo: Matt Staley/HHMI

**Eric Betzig**

Prize share: 1/3



© Bernd Schuller, Max-Planck-Institut

**Stefan W. Hell**

Prize share: 1/3

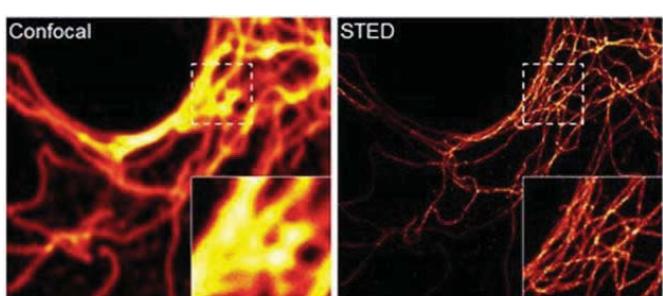
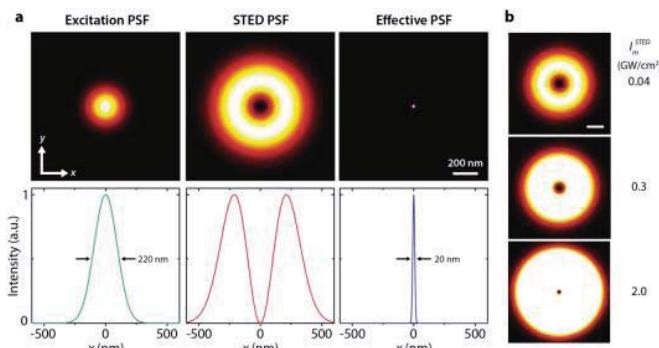
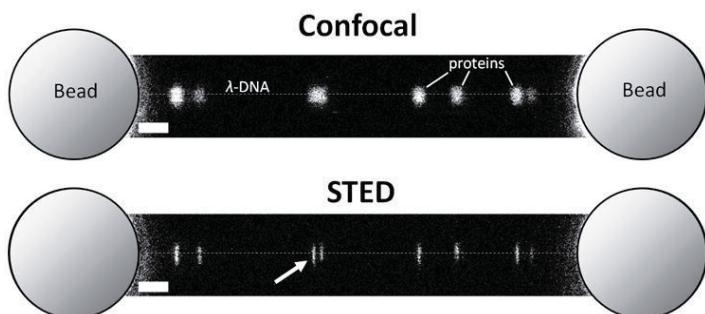


Photo: K. Lowder via Wikimedia Commons, CC-BY-SA-3.0

**William E. Moerner**

Prize share: 1/3

The Nobel Prize in Chemistry 2014 was awarded jointly to Eric Betzig, Stefan W. Hell and William E. Moerner "for the development of super-resolved fluorescence microscopy".



# The Nobel Prize in Physics 2014



**Isamu Akasaki**  
Meijo University, Nagoya, Japan  
Nagoya University, Japan



**Hiroshi Amano**  
Nagoya University, Japan



**Shuji Nakamura**  
University of California,  
Santa Barbara, CA, USA

Photo: Yasuo  
Nakamura/Meijo  
University

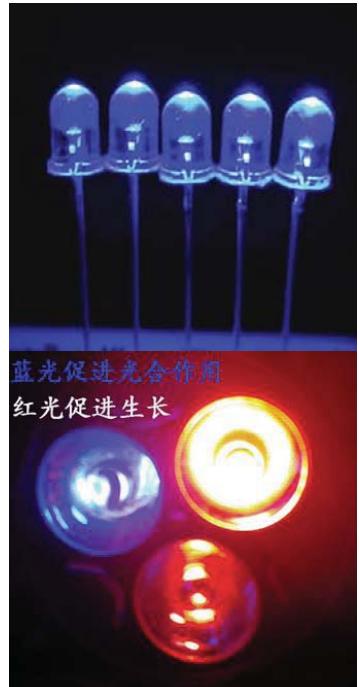
**Isamu Akasaki**  
Prize share: 1/3

III. N. Elmehed. © Nobel  
Media 2014

**Hiroshi Amano**  
Prize share: 1/3

III. N. Elmehed. © Nobel  
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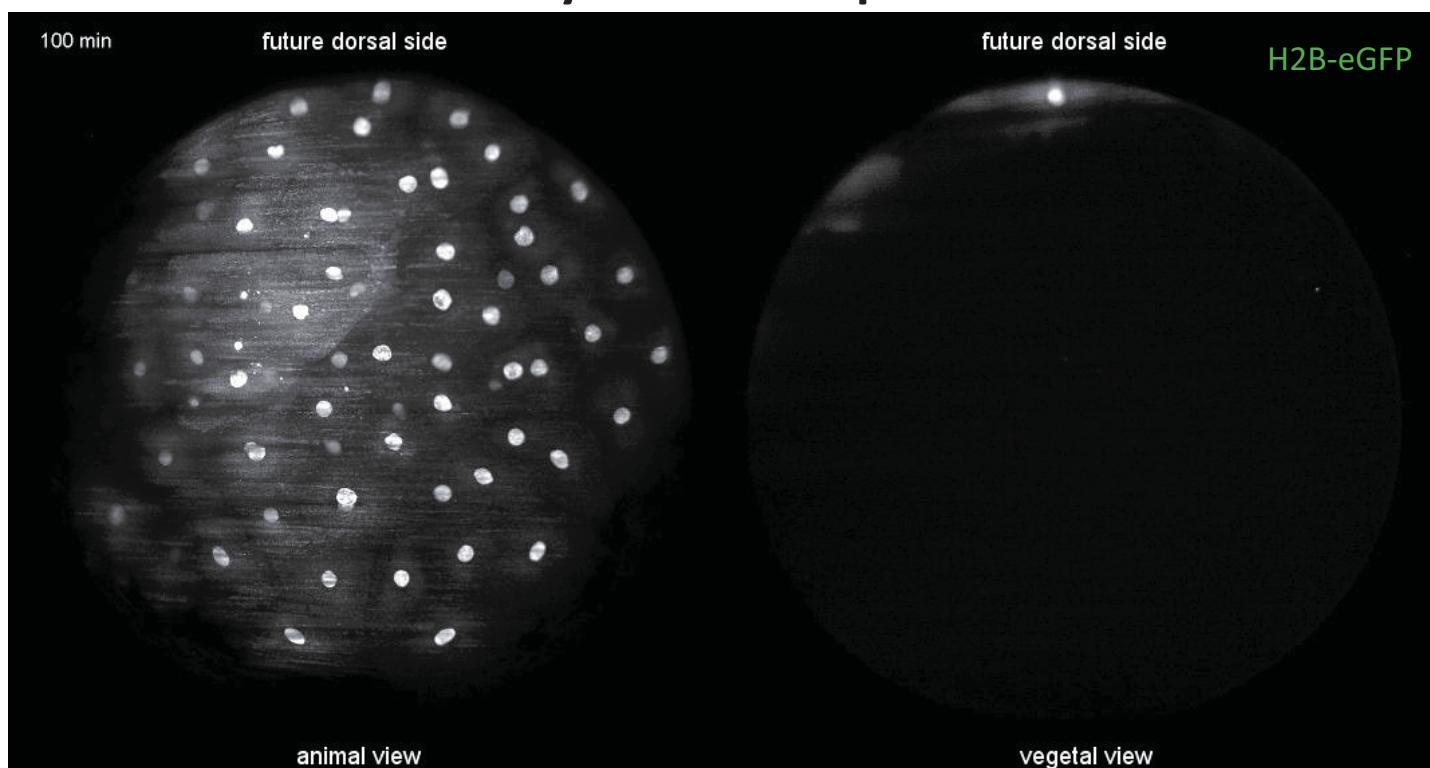
**Shuji Nakamura**  
Prize share: 1/3



The Nobel Prize in Physics 2014 was awarded jointly to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura *"for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources"*.



## Multi-view time-lapse recording of zebrafish embryonic development



The entire data set consists of 1,226 time points, recorded in 90 s intervals. At each time point, 370 images with 2048 x 2048 pixels each were recorded with a z-spacing of 2.96 µm.



**12th Century** - Salvino D'Armate from Italy made the first eye glass, providing the wearer with an element of magnification to one eye.



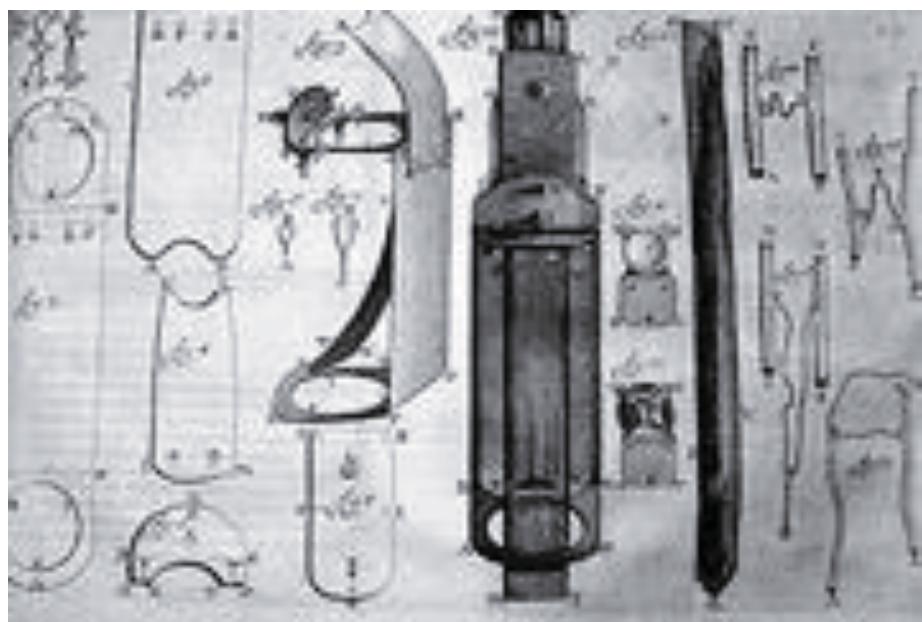
**1590** - Two Dutch spectacle makers, Zacharias Jansen and his father Hans started experimenting by mounting two lenses in a tube, the first compound microscope.



**1609** - Galileo Galilei develops a compound microscope with a convex and a concave lens.



## Anton van LeeuwenhoeK (1632 – 1723)



**Leeuwenhoek Microscopy**

1635 - 1703



Robert-Hooke

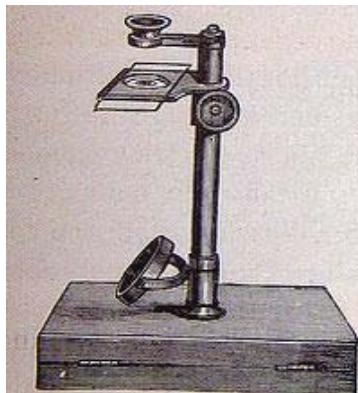


Fig. 227.—Microscopio simple

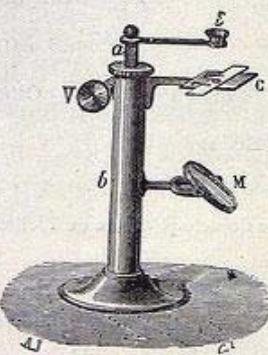


Fig. 228.—Otro microscopio simple

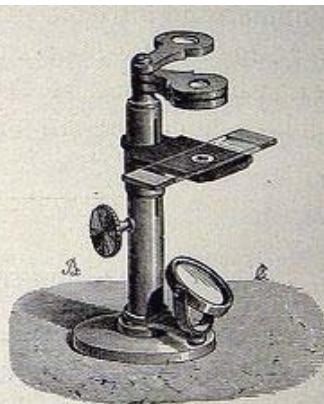
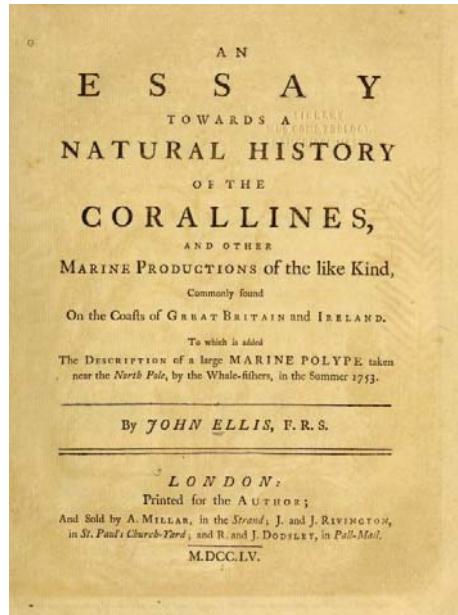


Fig. 229.—Anteojo compuesto

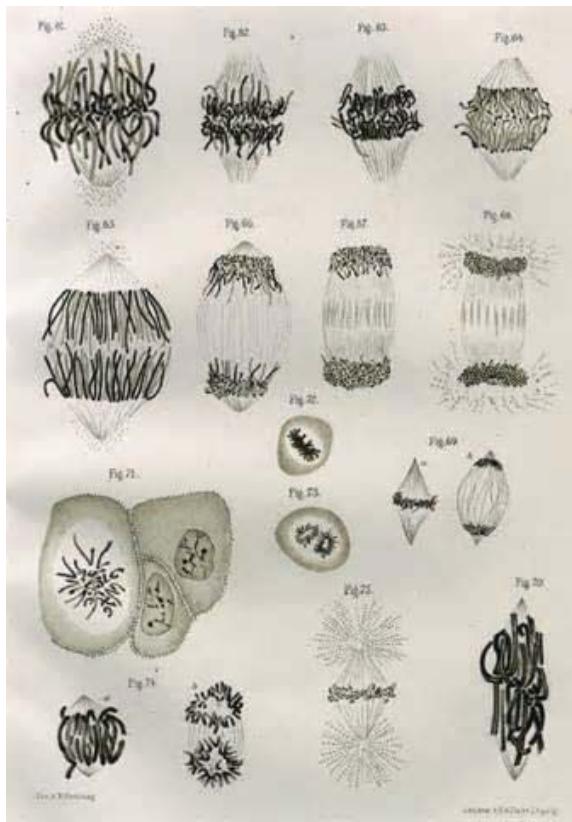


John Ellis' "Aquatic Microscope", as manufactured for him by John Cuff and described in Ellis' 1755 book, "An Essay Towards a Natural History of the Corallines".

The most notable feature of this pattern is the eyepiece that can be moved side-to-side and in-and-out, to view the entire field without touching the stage. This was important for Ellis' work on aquatic animals such as *Hydra*, which cease motion in reaction to stage movement. A photograph of a similar instrument is also shown. This is slightly different from Ellis' microscope, in having a round stem instead of square. <http://www.microscope-antiques.com/ellis.html>

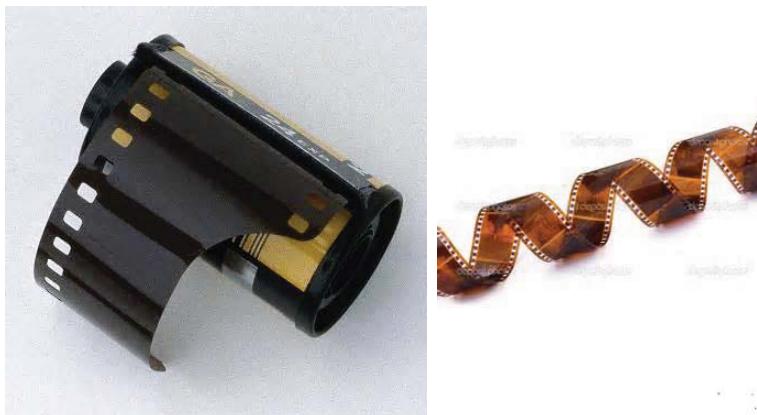


**Number 1 compound microscope by Powell and Lealand.** Signed and dated on the stage with the makers' name and address, 170 Euston Road, London, 1878. Accompanied by a case of lenses and other accessories. The objectives range in value between 1in. 30° and 1/50 150°. Sixteen of the lenses are signed by P & L and inscribed with a power matching their lids.  
 Sold at auction yesterday for £15600 (US\$ 25,000).



www.shutterstock.com · 102438631

## Drawing of mitosis by Walther Flemming.



### United States Patent [19]

Maruyama et al.

US005238796A

[11] Patent Number: 5,238,796  
[45] Date of Patent: Aug. 24, 1993

#### [54] SILVER HALIDE PHOTOGRAPHIC EMULSION AND PHOTOGRAPHIC LIGHT-SENSITIVE MATERIAL

[75] Inventors: Yoichi Maruyama; Shigeharu Urabe, both of Minami-ashigara, Japan

[73] Assignee: Fuji Photo Film Co., Ltd., Kanagawa, Japan

[21] Appl. No.: 788,536

[22] Filed: Nov. 6, 1991

#### [10] Foreign Application Priority Data

Nov. 14, 1990 [JP] Japan 2-346072

[31] Int. Cl. .... G03C 1/035; G03C 1/46; G03C 7/32

[52] U.S. Cl. .... 430/505; 430/543; 430/567; 430/569

[58] Field of Search .... 430/567, 569, 505, 543

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Hansen, Photo. Sci. and Eng., 11 (1967), pp. 57-68.

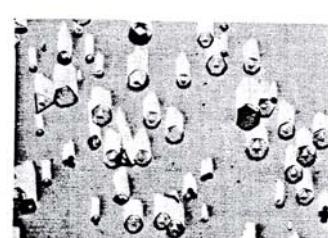
Berry, J. Appl. Phys., 27 (1956), pp. 636-639.

Berry, J. Appl. Phys., 35 (1964), pp. 2165-2169.

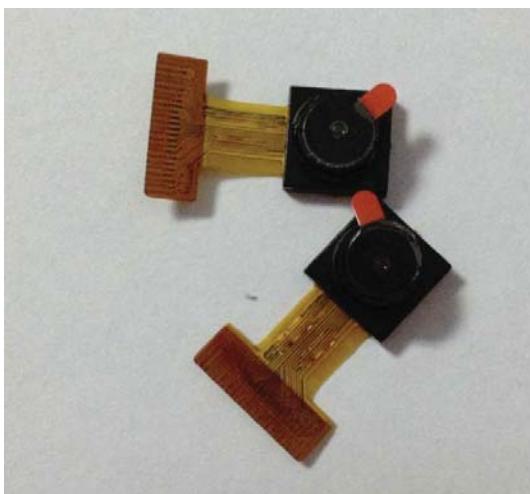
Primary Examiner—Janet C. Baxter  
Attorney, Agent, or Firm—Birch, Stewart, Kolasch & Birch

#### [57] ABSTRACT

A silver halide photographic emulsion containing tabular silver halide grains which have an aspect ratio of 2 or more and in which dislocations are localized in a center portion of each grain. The tabular silver halide grains have a thickness of less than 0.5 μm and a diameter of 0.3 μm or more and account for at least 50% of a total area of the silver halide grains. This emulsion has a high sensitivity and good reciprocity characteristics. In a photographic light-sensitive material having at least two light-sensitive silver halide emulsion layers having different color sensitivities on a support, the above tabular silver halide photographic emulsion is located on one of the couplet which is coupled with an oxidized or a color developer agent to develop a color added to at least one of the emulsion layers, thereby obtaining a photographic light-sensitive material having a high sensitivity and good reciprocity characteristics.



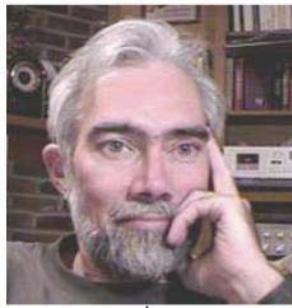
**Silver Halide Photographic Emulsion And Photographic Light-sensitive**



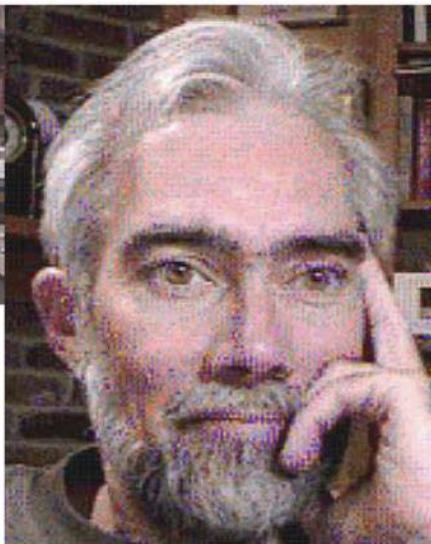
**CMOS 2 Meg.  
Pixels**



**CCD 1600 x 1200**



320x240 x 24



Zoom x 2

### Magnifying with inadequate information.

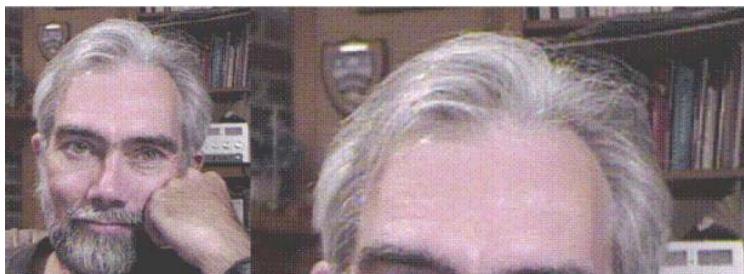
This is known as “empty magnification” because there are insufficient data points.



Zoom x 4

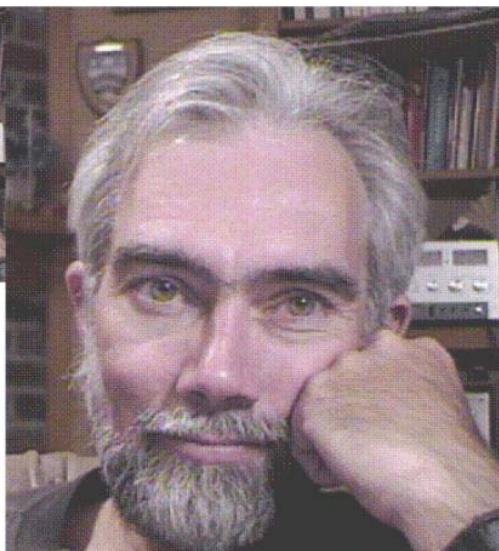
The final image appears to be very “boxy” this is known as “pixilation”.

Zoom x 8



180x200x8  
(288,000) 1X

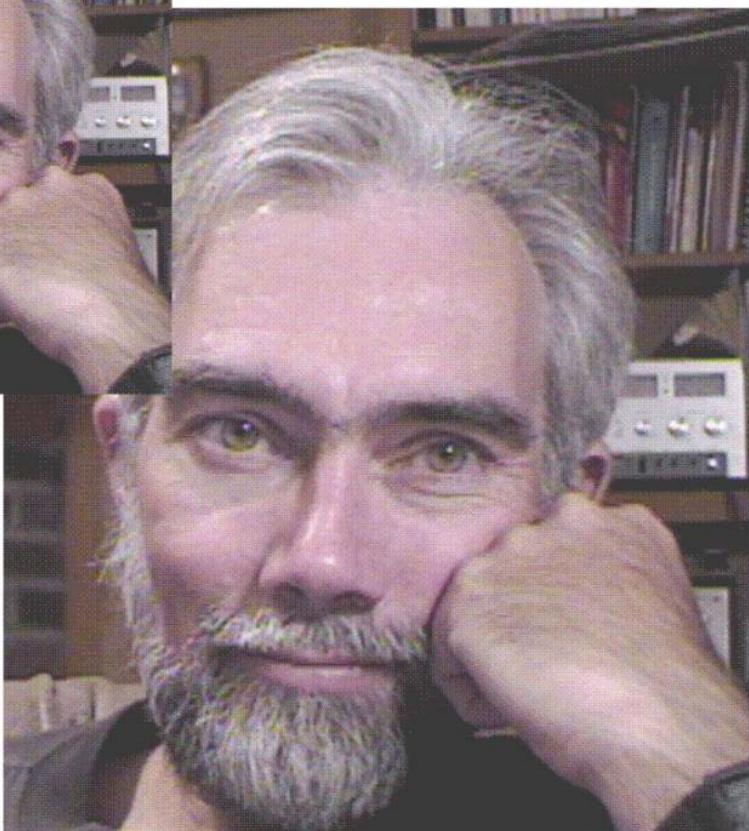
Socrates?....well perhaps not...

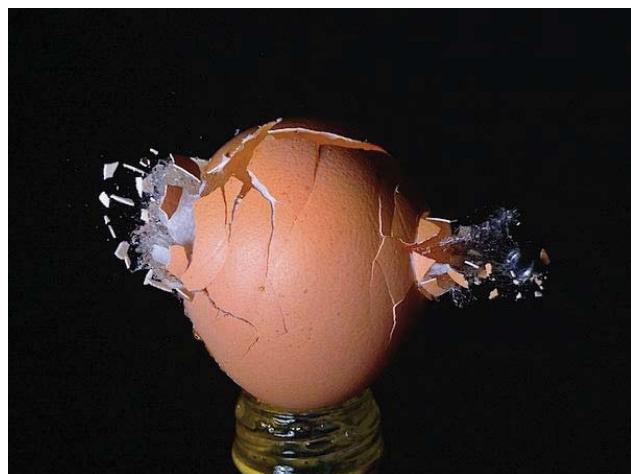


361x400x8  
(1,155,200) 2x

**Magnifying with adequate information.** Here, the original image was collected with many more pixels - so the magnified image looks better!

541x600x8  
(2,596,800) 1.5x





## High-Speed Camera



The Nobel Prize in Chemistry 1999  
Ahmed Zewail

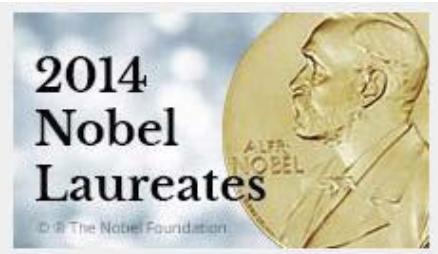
Share this:

# Nobel Lecture

## Femtochemistry: Atomic-Scale Dynamics of the Chemical Bond Using Ultrafast Lasers



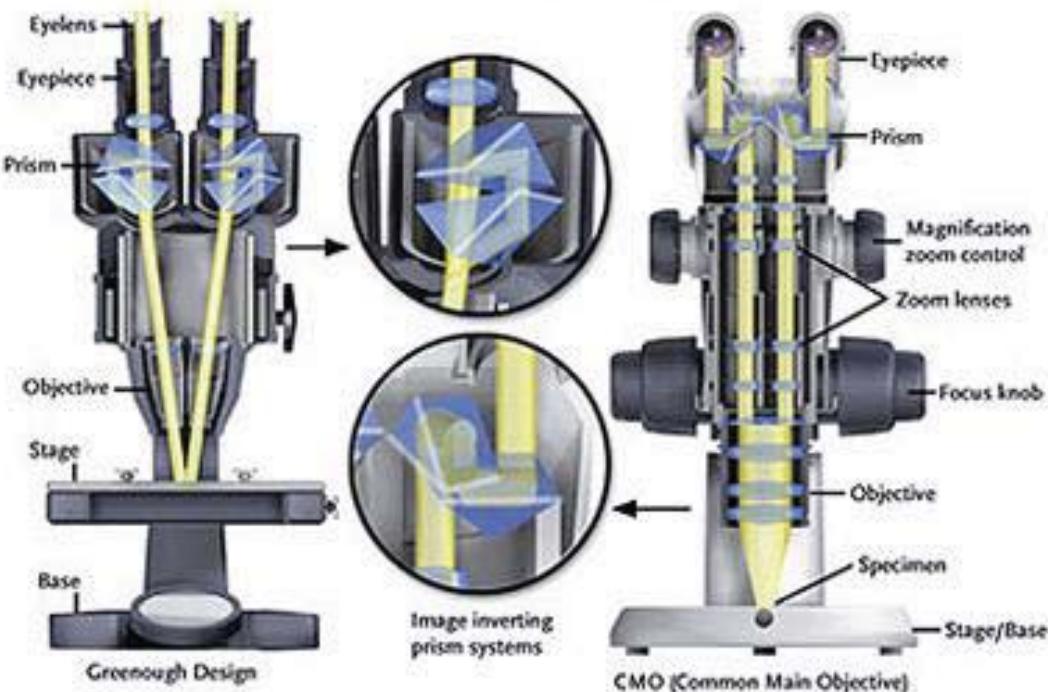
Ahmed Zewail held his Nobel Lecture December 8, 1999, at Aula Magna, Stockholm University. He was presented by Professor Bengt Nordén, Member of the Nobel Committee for Chemistry.



### NOBEL PRIZE QUIZ



### COMPARISON OF CMO AND GREENOUGH STEREOMICROSCOPE DESIGNS



## So, what's new!?

細: 空間解析度 (Spatial Resolution)

快: 時間解析度 (Temporal Resolution)

深: 透視深度 (Penetration Depth; *in vivo*)

多姿多彩: 多頻/多色 (Hyper-Spectral Imaging)

多維: Multi-Dimensional

多功能: Multi-Functional

記錄: Recording

展現: Display

量化: Quantifications

自動化: Automation

光源，光學材料與元件，架設，樣品，記錄器，  
電腦硬體和軟體

# 8-Dimensional Hyper-Spectral Microscopy

## 八維度超頻顯微

**Spatial: 3-D (空間 - 三維)**

**Temporal: 1-D (時間 - 一維)**

**Excitation & Detection Wavelengths: 2- D**

(激發與偵測波長 -二維)

**Excitation & Detection Polarizations: 2- D**

(激發與偵測偏振方向 - 二維)

**Multi-Functional (多功能):**

**Fabrication (三維微製造)**

**Manipulation (三維微操控)**

**Viscoelasticity Mapping (黏彈性影像)**

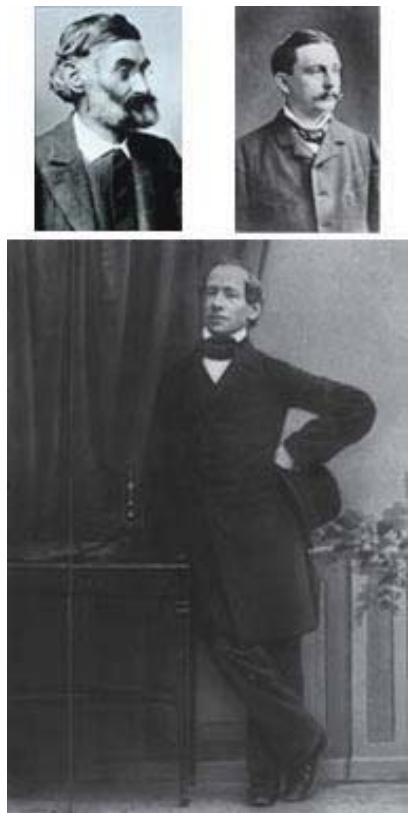
**Biochemical/Molecular Functional Mapping**

(生化及分子功能影像)

**Optics  
in Jena**

Ernst Abbe

$$d = \frac{\lambda}{2 \sin \theta}$$



Carl Zeiss



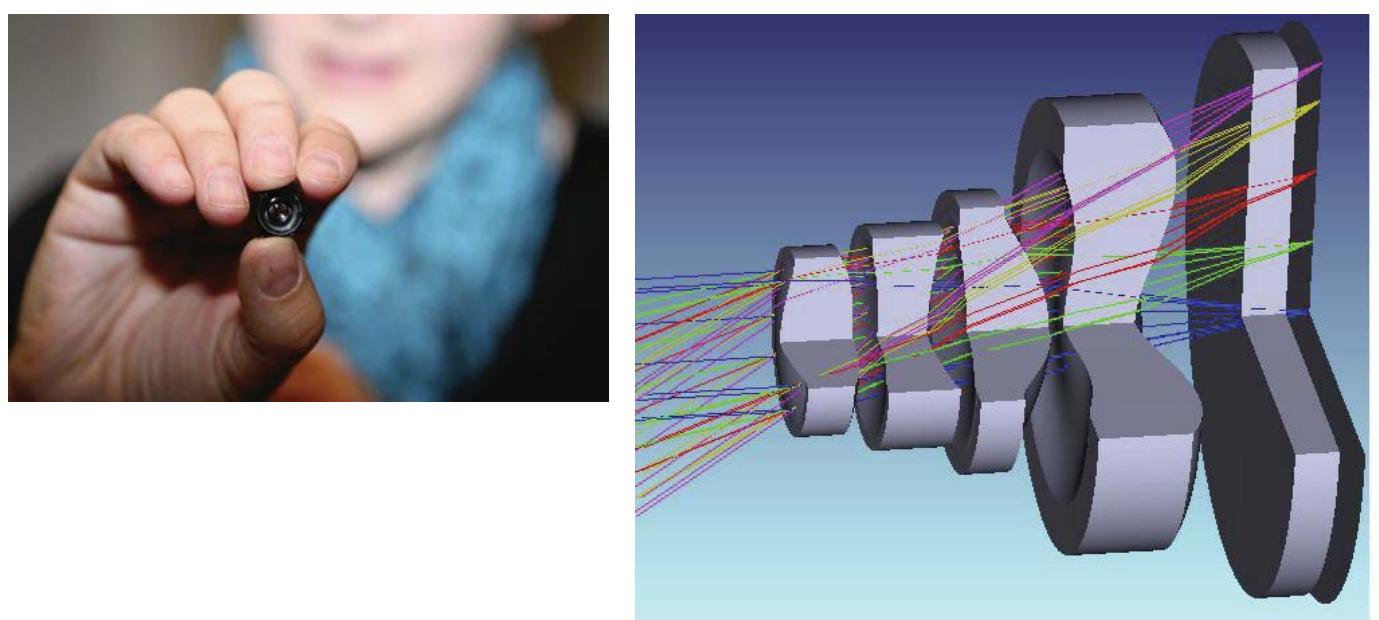
Otto Schott

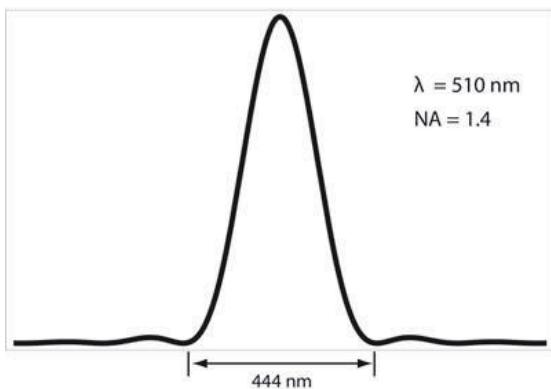
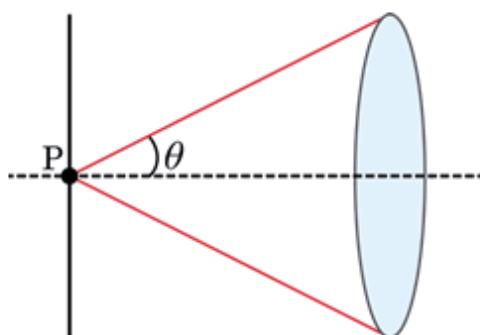
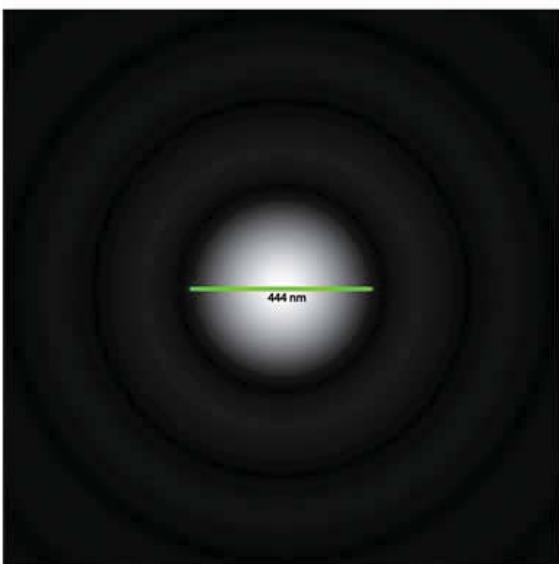
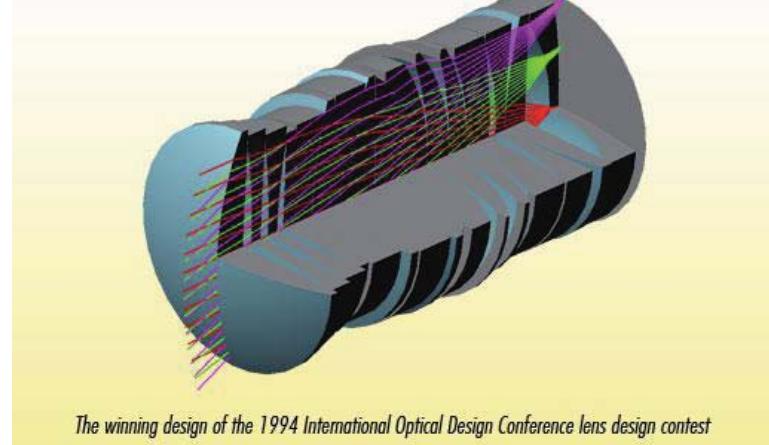
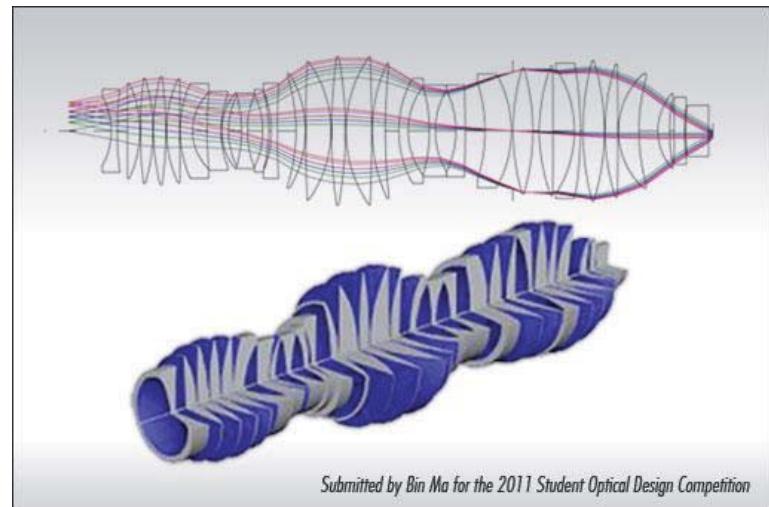


# Optics & Photonics in Jena, Germany



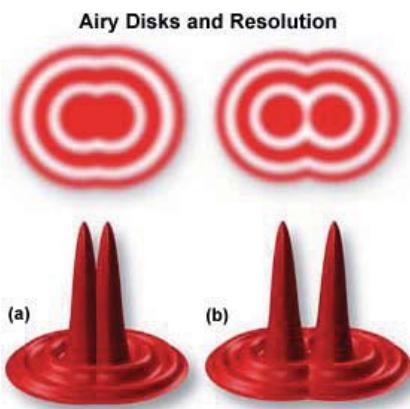
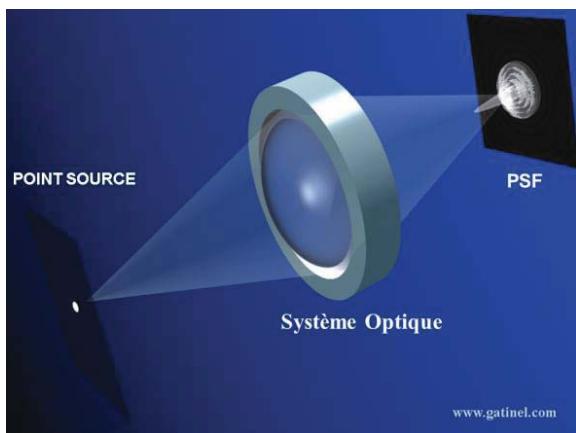
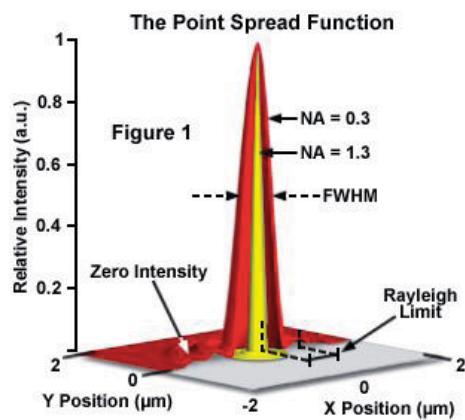
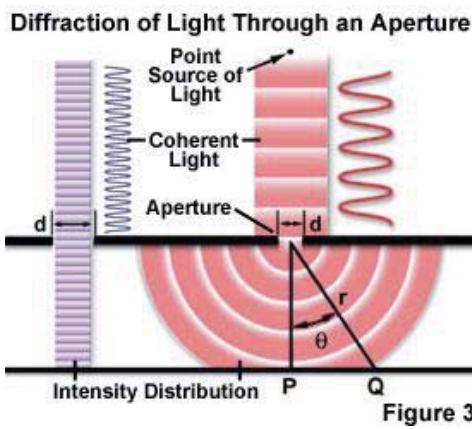
## Mobile Phone Camera



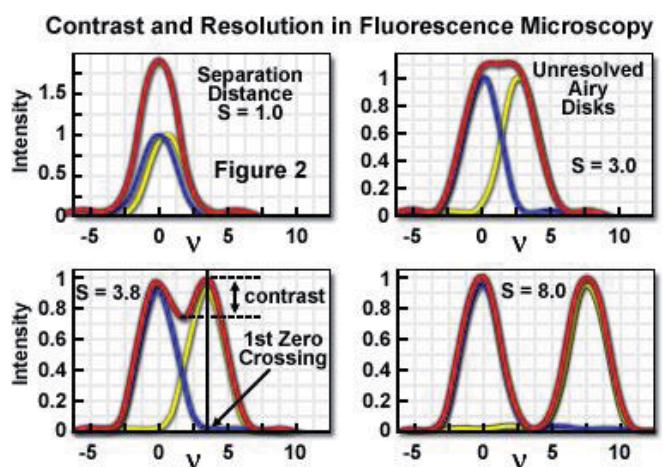
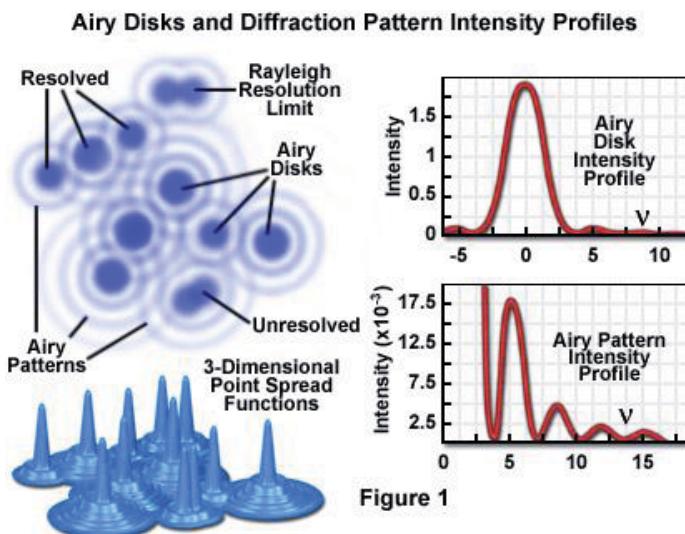


$$r = \frac{0.5 \lambda}{NA} = \frac{0.5 \lambda}{n \sin(\theta)}$$

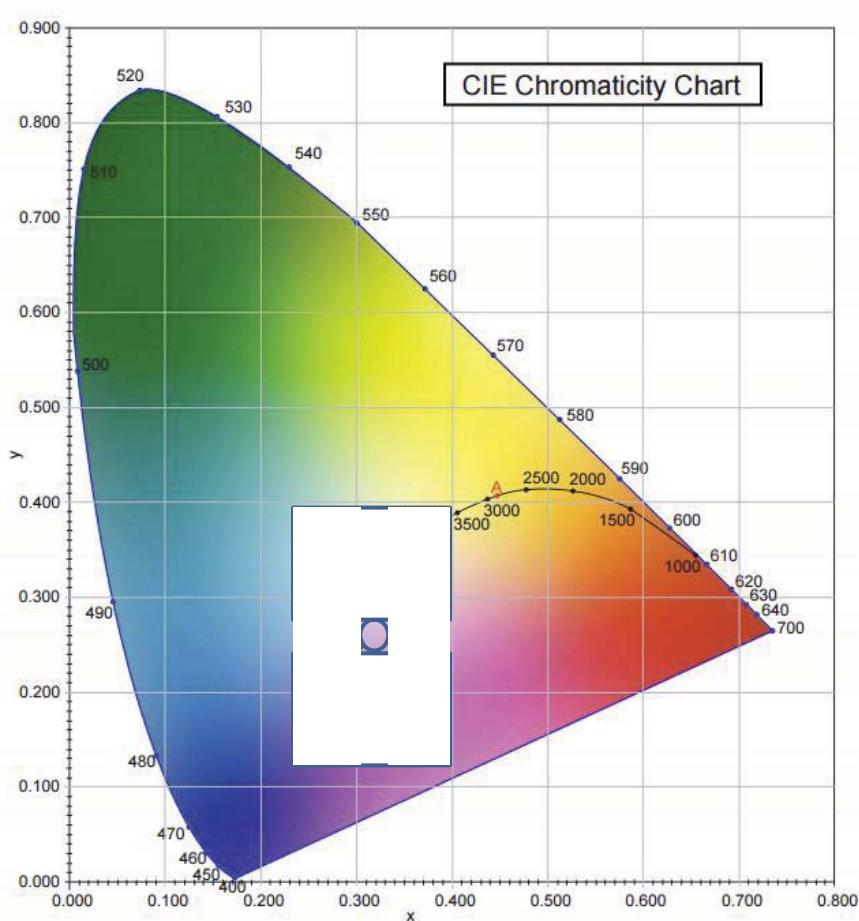
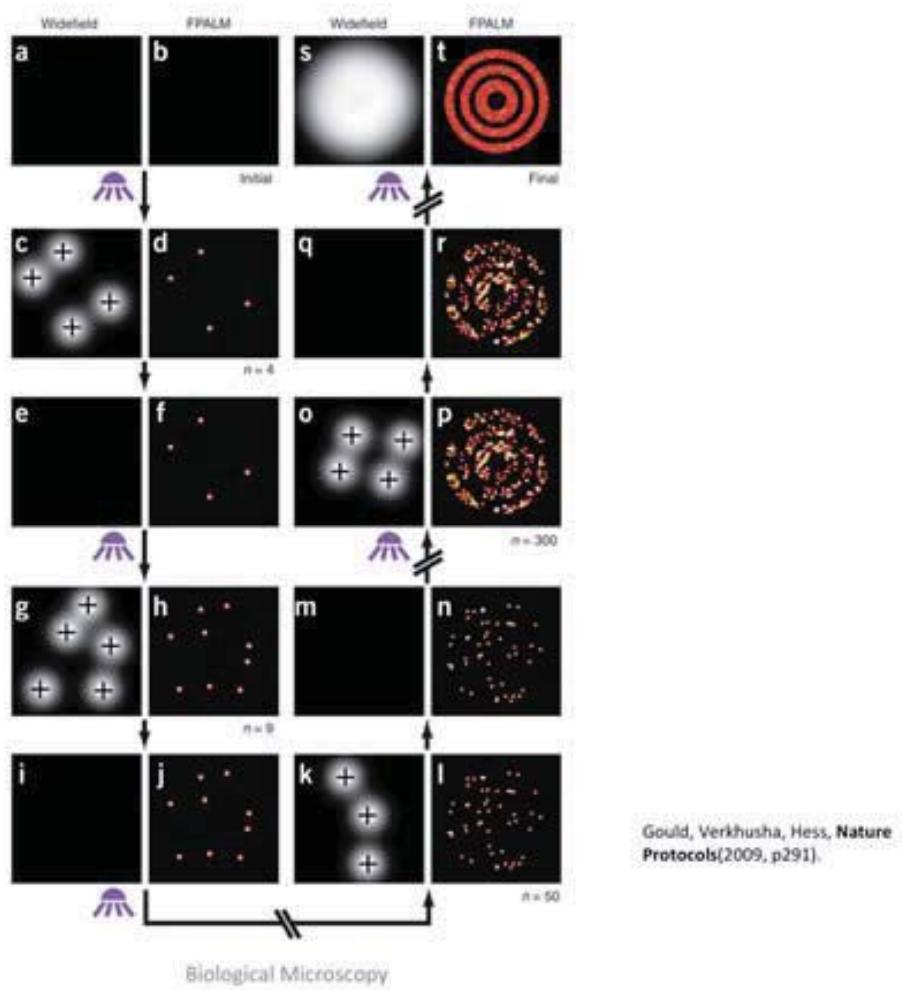
# Point-Spread Function & Two-Point Resolution



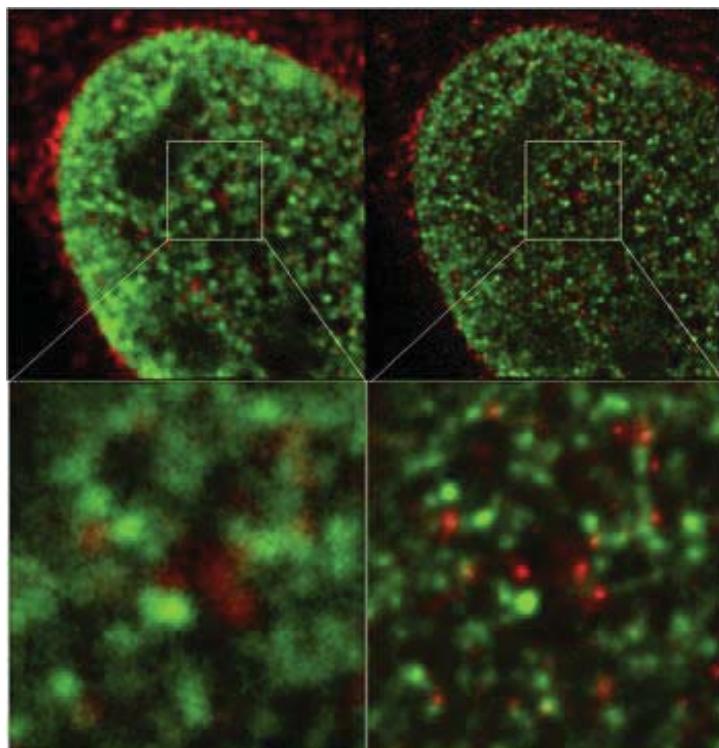
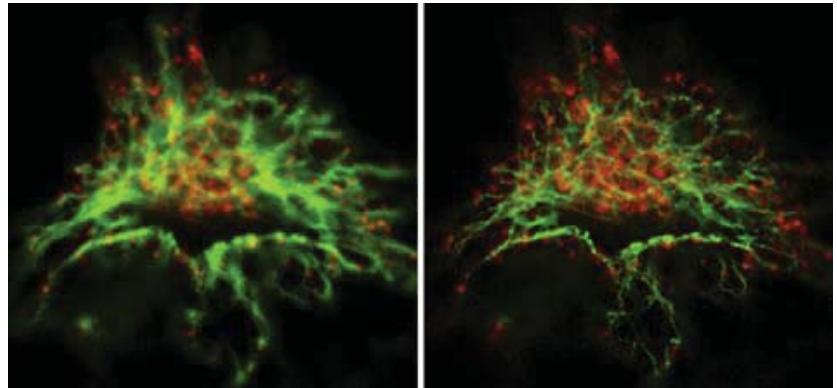
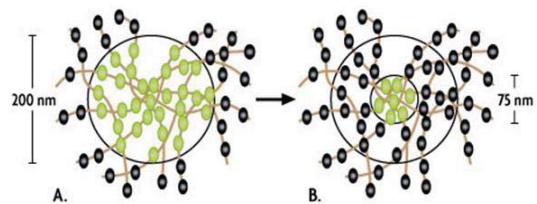
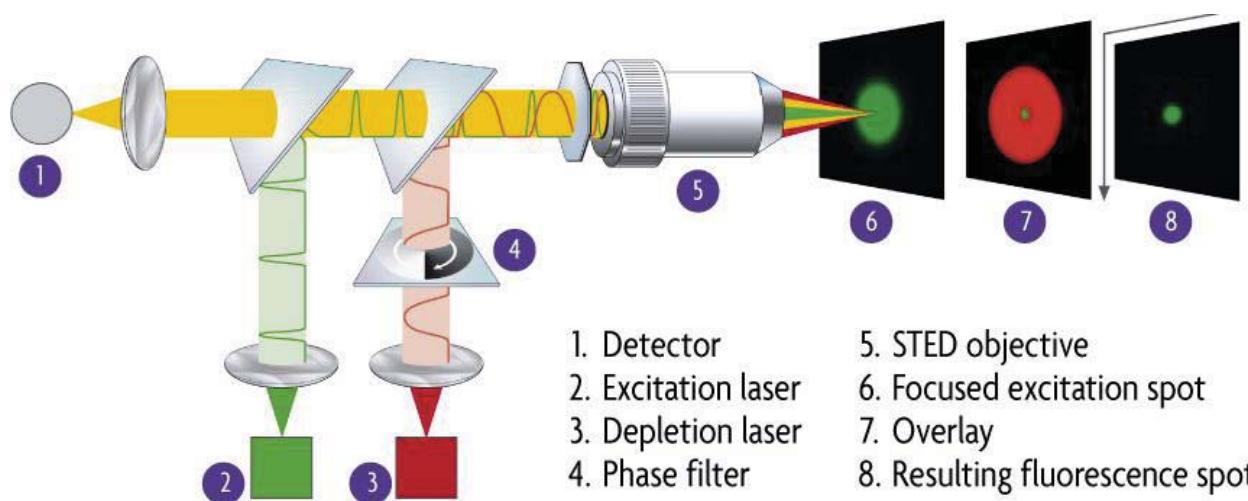
# Point-Spread Function & Two-Point Resolution



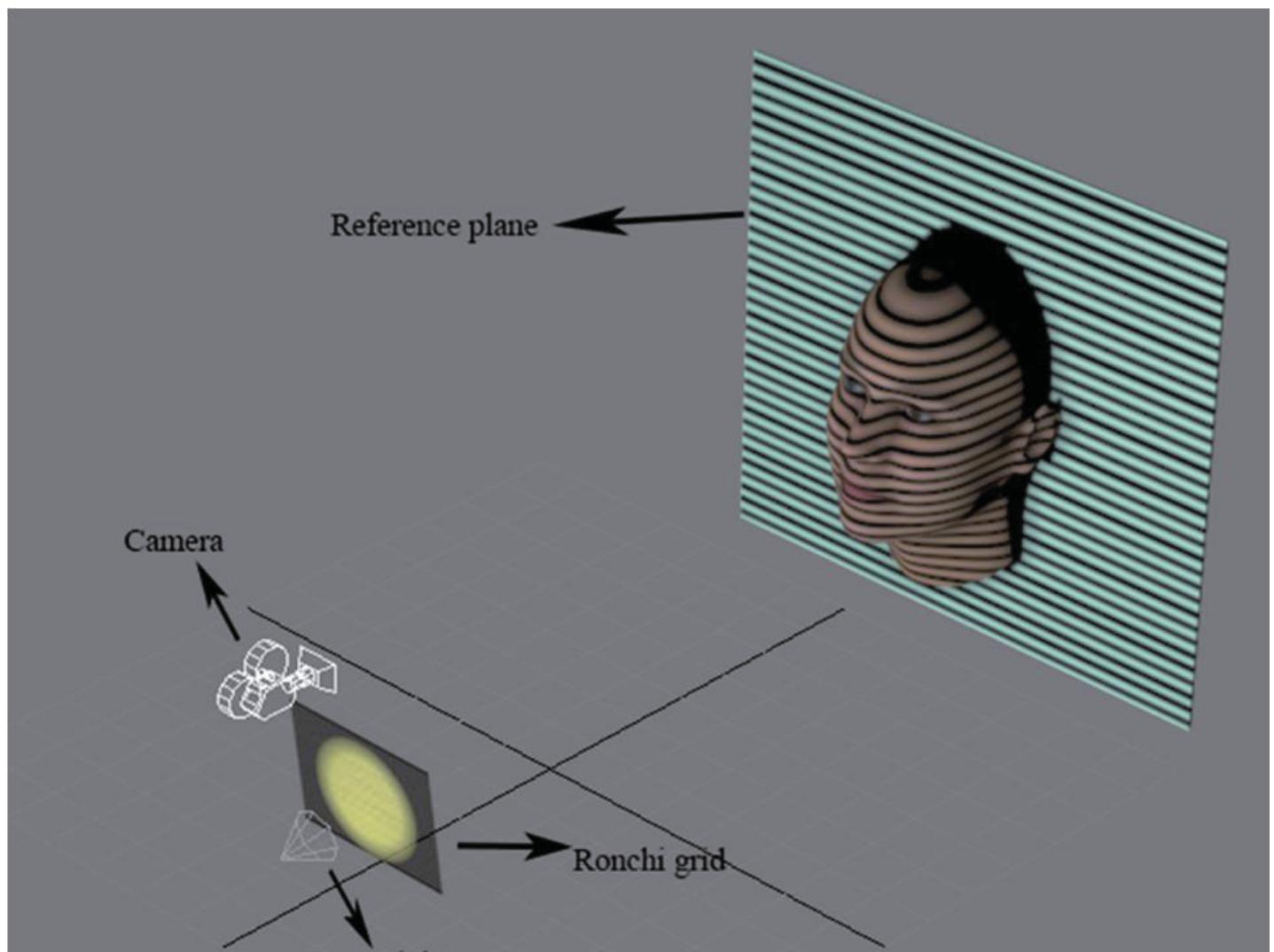
$$S = (2\pi/\lambda)w(r/L)$$



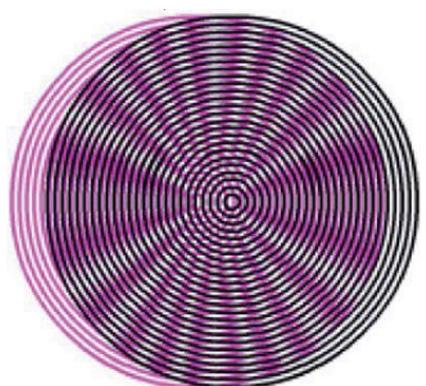
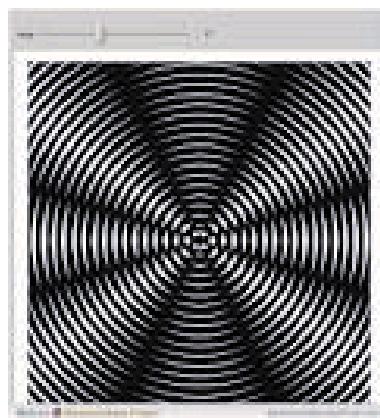
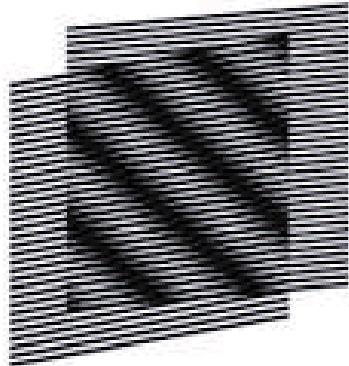
# Principle of STED Microscopy/Nanoscopy



**Figure 6: Nuclear structures visualized by dual color STED experiments.**  
The image on the left was prepared using a confocal microscope, while that on the right was produced using a STED microscope. The nuclear structures have been visualized with Chromeo 494 (green) and ATTO 647N (red). Images courtesy of Dr. L. Schermelleh, LMU Biozentrum Munich, Germany.

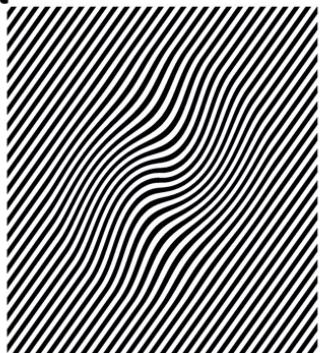


## Moiré Patterns

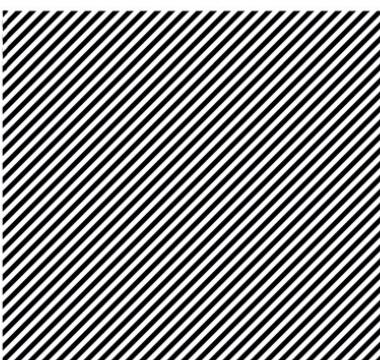


Moiré Pattern

a



b



c



# Advanced non-linear high-resolution microscopy

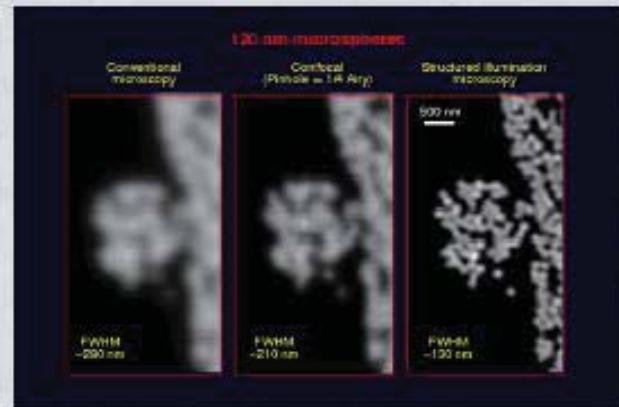
## Structured illumination microscopy The idea: Moiré fringes

Unknown pattern



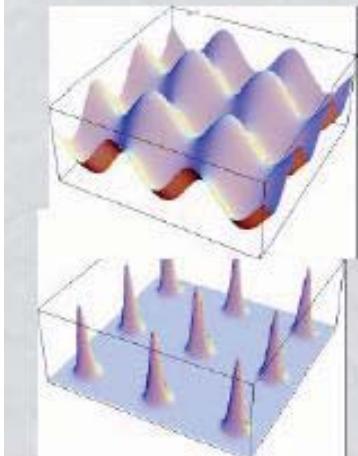
Superposed known pattern

Moiré fringes can be resolvable even if unknown pattern is not



Investigating non-linear imaging techniques both in scanning mode and periodic illumination geometries: on real biosamples (e.g. chromosome protein structure...)

- STED (stimulated emission depletion)
- SHG (second harmonic emission)
- CARS (Coherent anti-stoke Raman Scattering)



M. Gustaffson, J. Sedat UCSF

## Chemiluminescence in living animals = bioluminescence

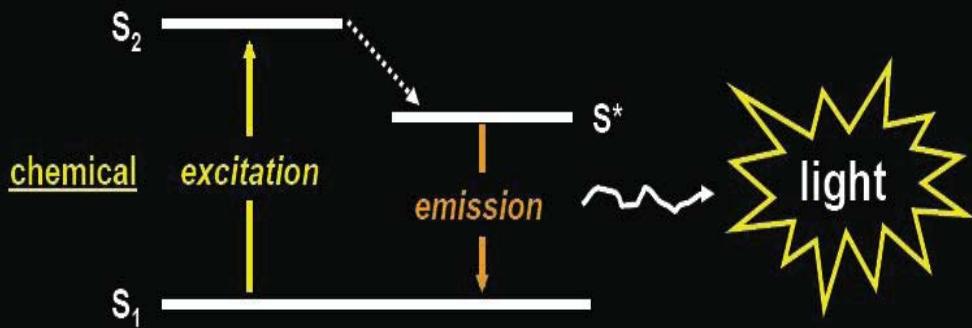
marine



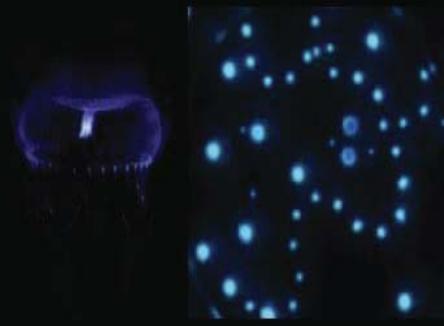
terrestrial



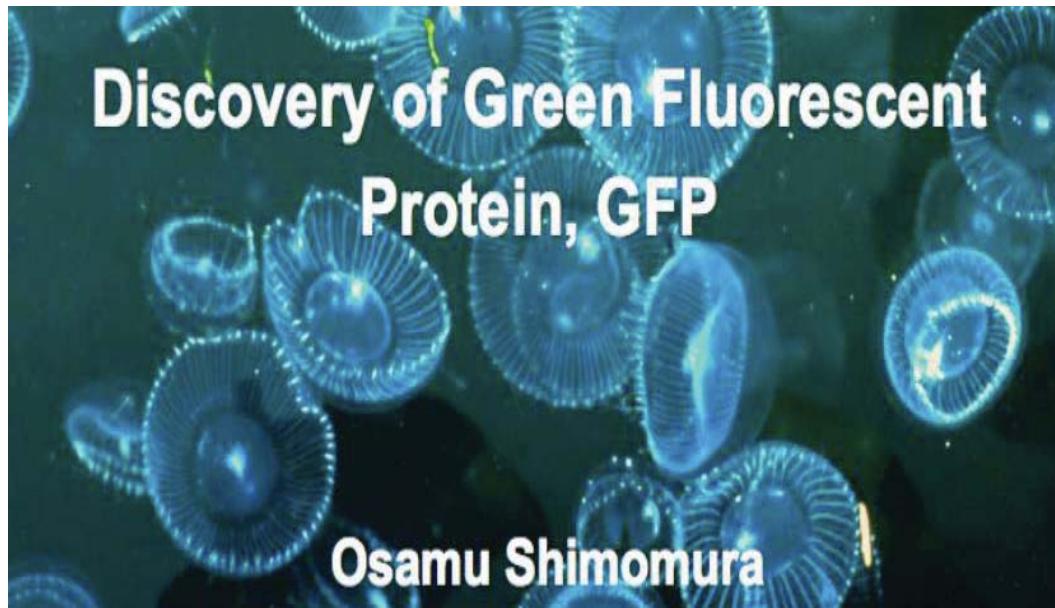
## Light can be produced in several ways



chemiluminescence



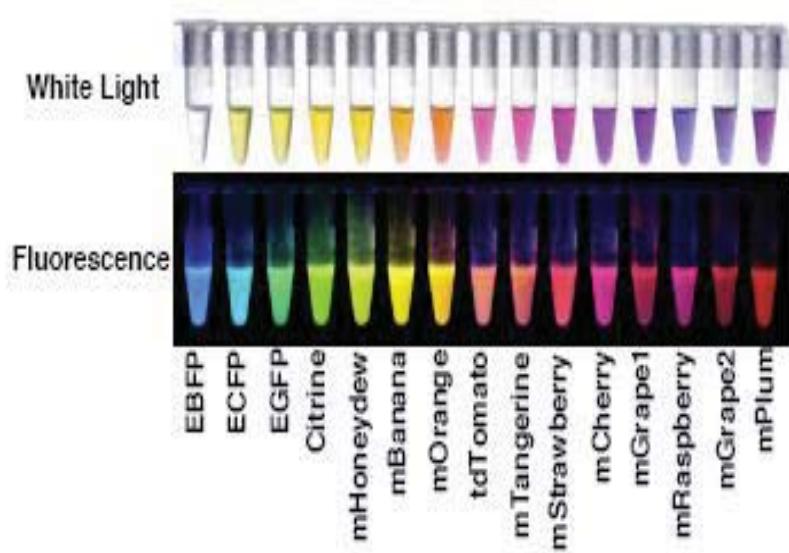
bioluminescence



Jellyfish collectors 1974 Shimomura and friends and family



## Fluorescence Proteins (FPs)





The Nobel Prize in Chemistry 2008

Osamu Shimomura, Martin Chalfie, Roger Y. Tsien

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# The Nobel Prize in Chemistry 2008

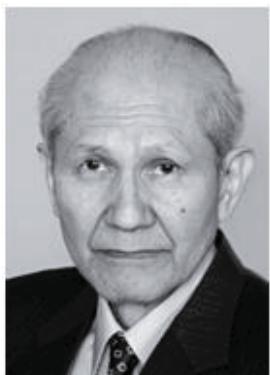


Photo: U. Montan  
Osamu Shimomura  
Prize share: 1/3

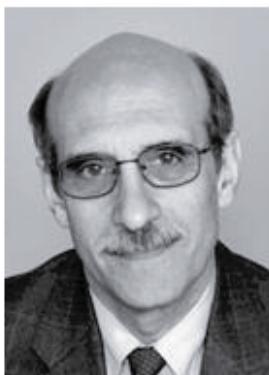
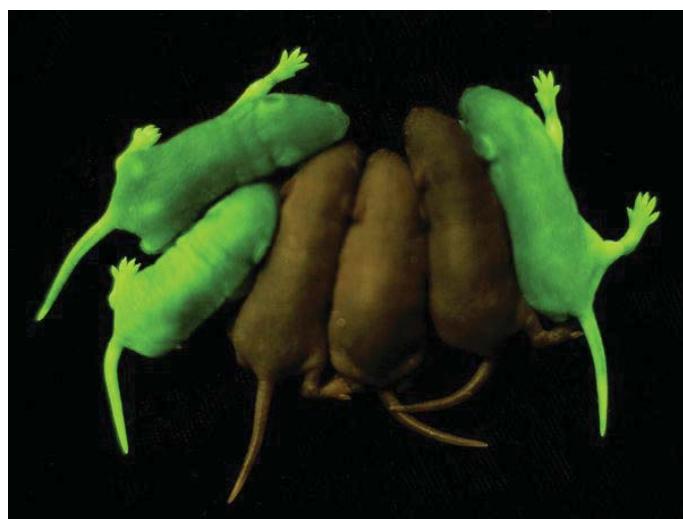


Photo: U. Montan  
Martin Chalfie  
Prize share: 1/3



Photo: U. Montan  
Roger Y. Tsien  
Prize share: 1/3

The Nobel Prize in Chemistry 2008 was awarded jointly to Osamu Shimomura, Martin Chalfie and Roger Y. Tsien "for the discovery and development of the green fluorescent protein, GFP".



## Principle of Excitation and Emission

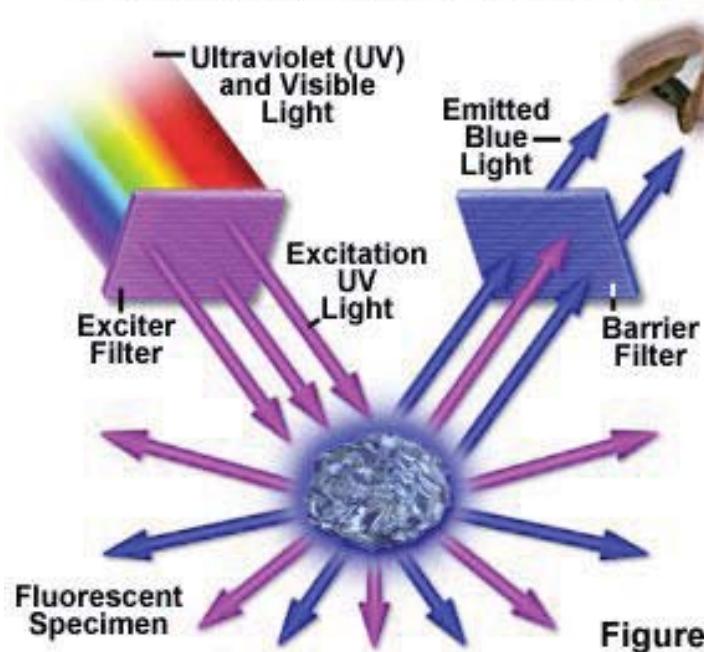
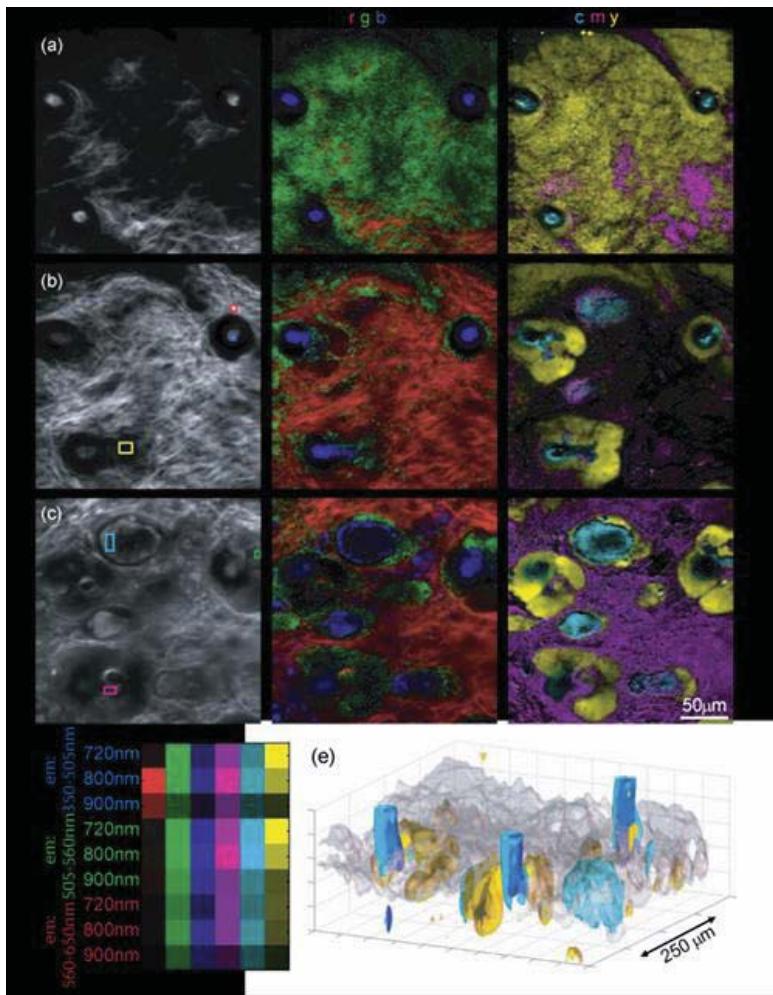


Figure 3



Hyper-Spectral Imaging  
or  
Spectro-Microscopy

3D Spectral Unmixing of 6 Components in Living Skin

# Observation of cell by TIRFM

- The schematic of our experimental platform
- The fluorescence molecules would be excited when transported toward the evanescent field
- The background is removed greatly

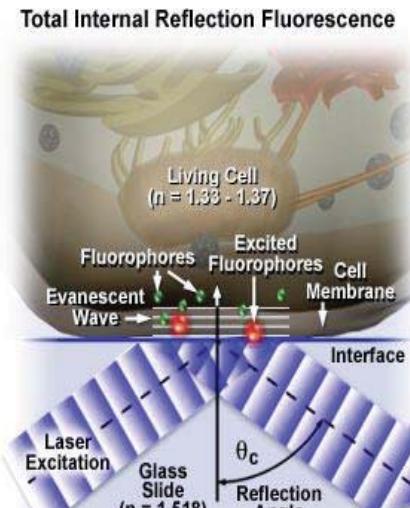
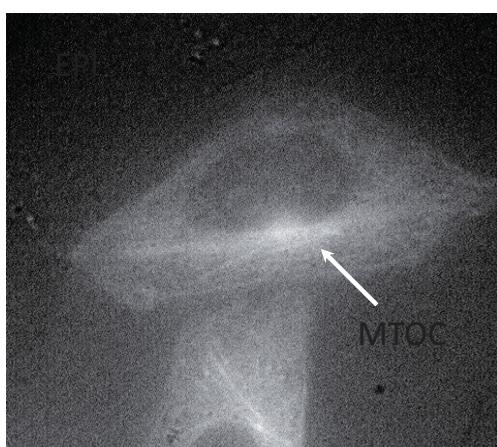


Figure 1

<http://micro.magnet.fsu.edu/primer/techniques/fluorescence/tirf/olympusaptirf.html>

P/NSTL@NTU

## Comparison between Epi-fluorescence and TIRFM image

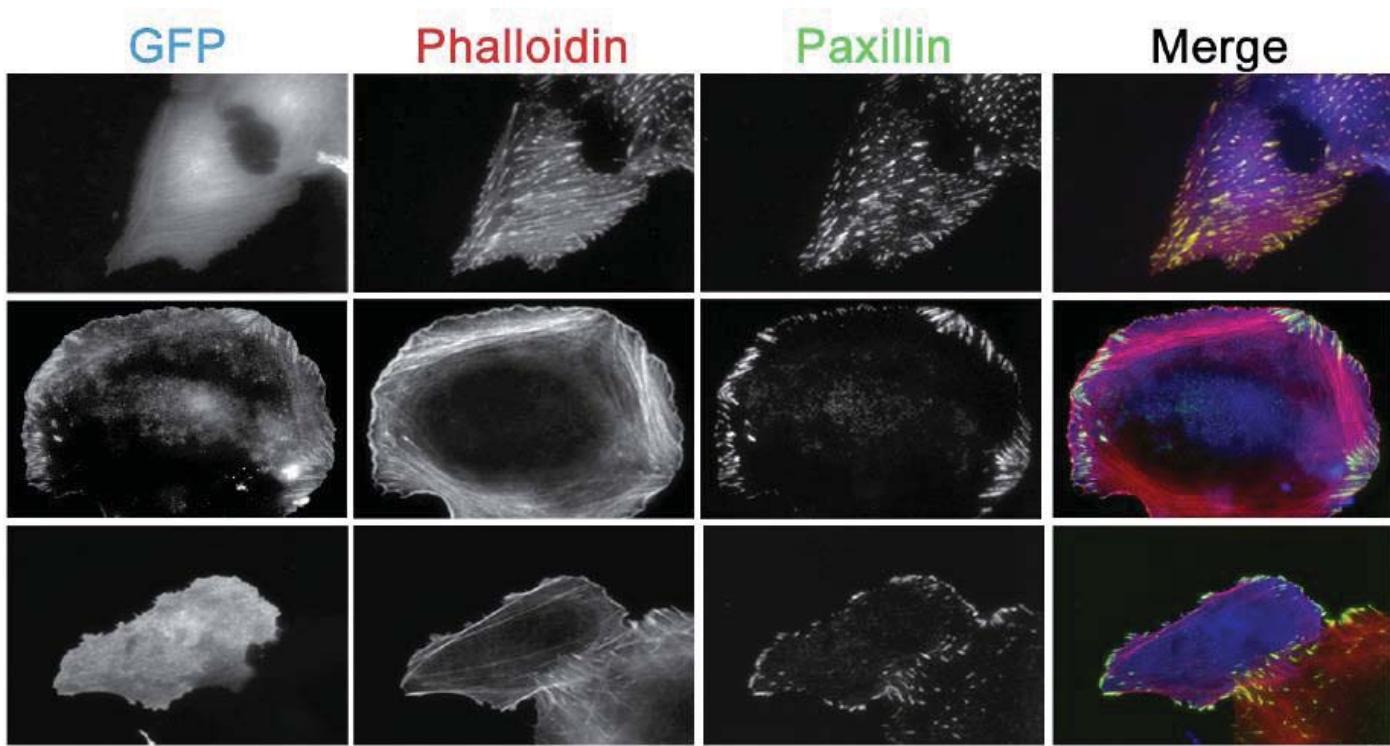


The relatively fuzzy picture of microtubule distributions under the epi-fluorescence microscope

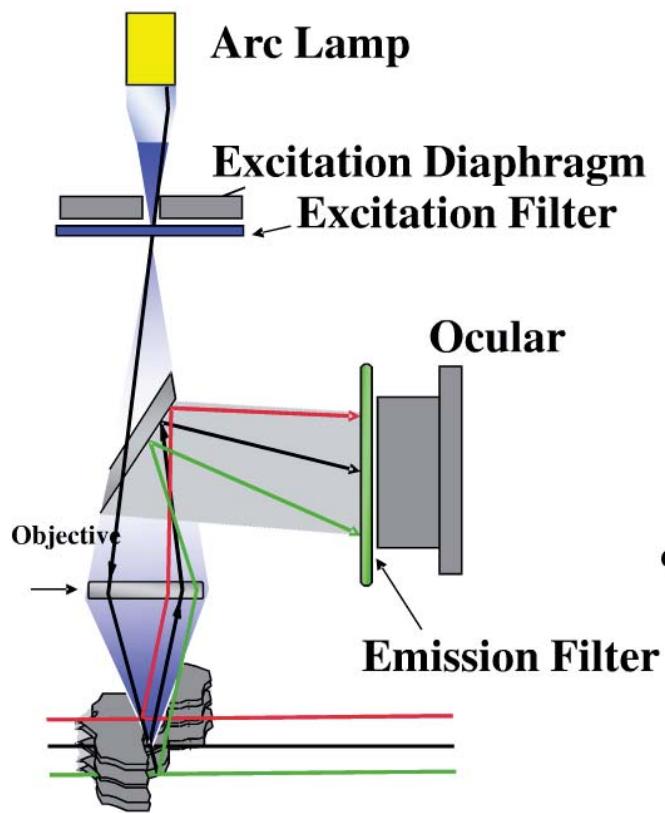


The same cell under TIRFM exhibited a much clearer picture where individual microtubules near the growth substrate could be resolved

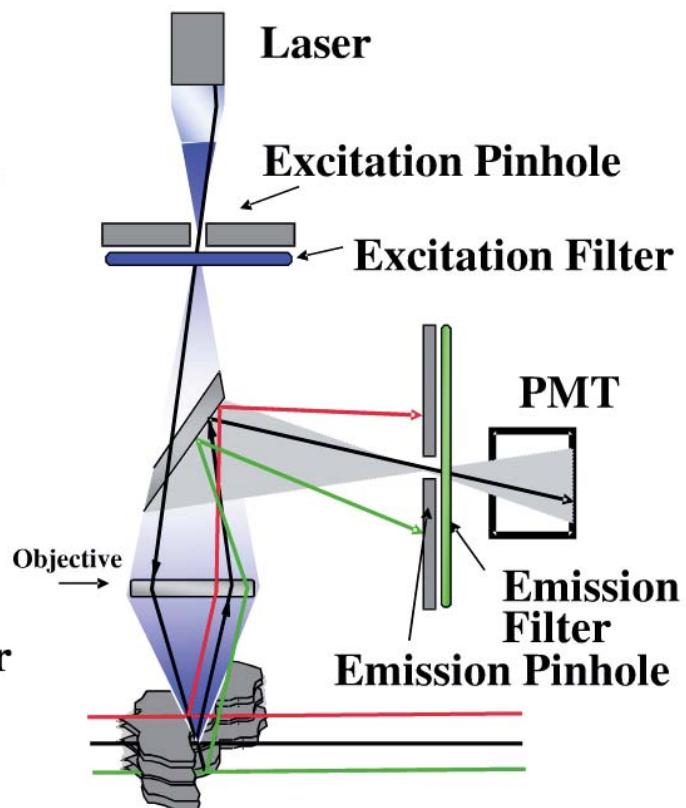
P/NSTL@NTU



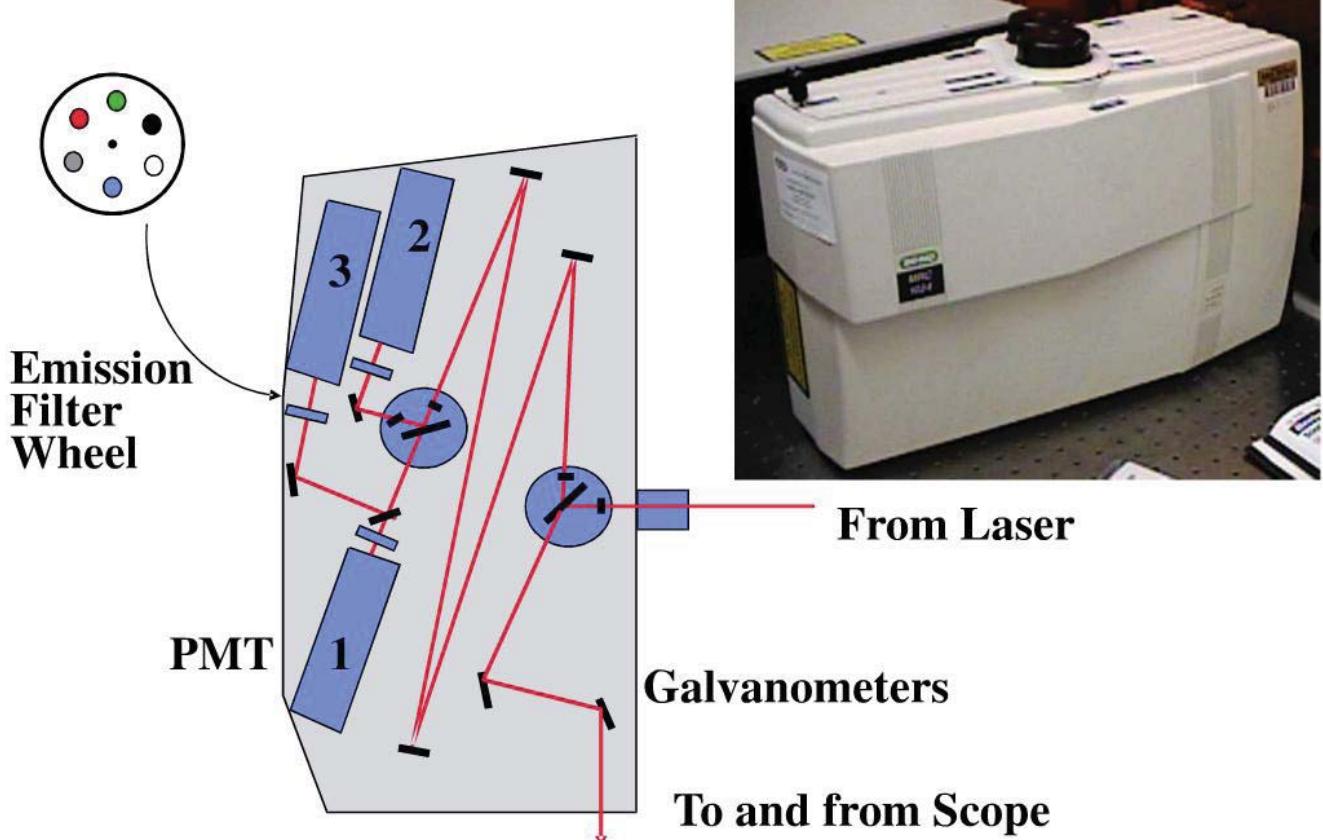
Fluorescent Microscope



Confocal Microscope

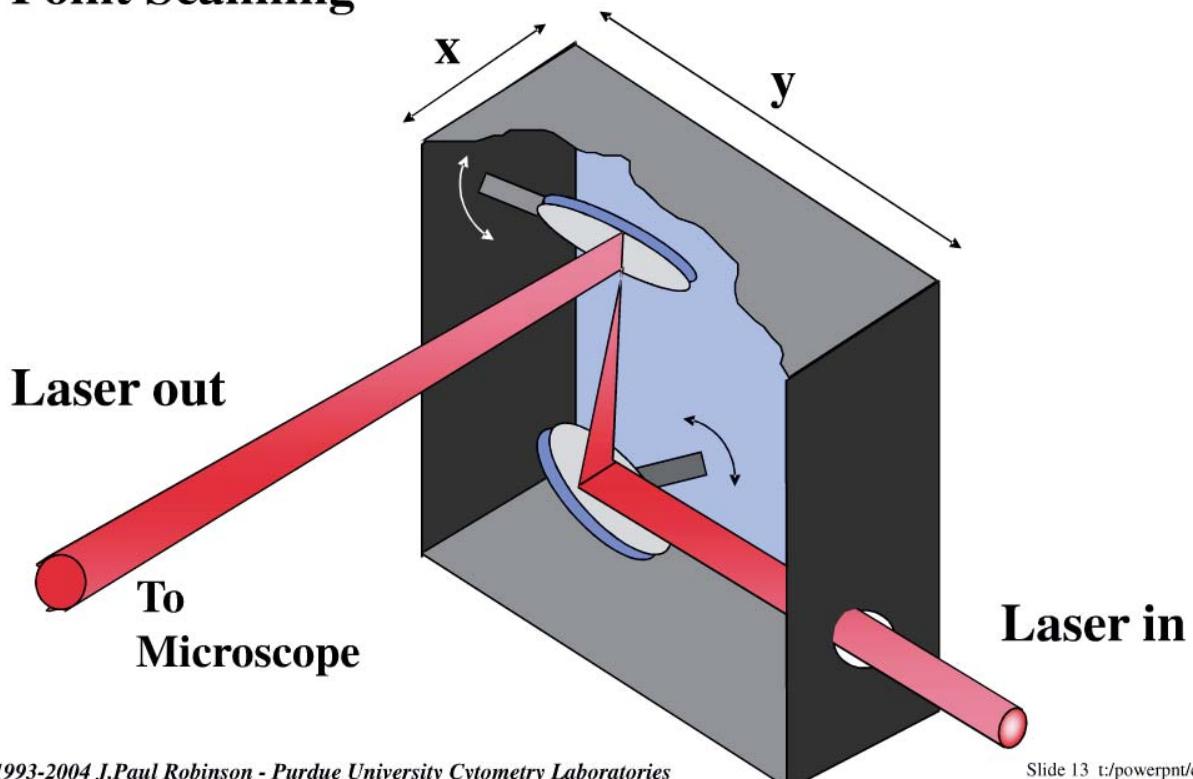


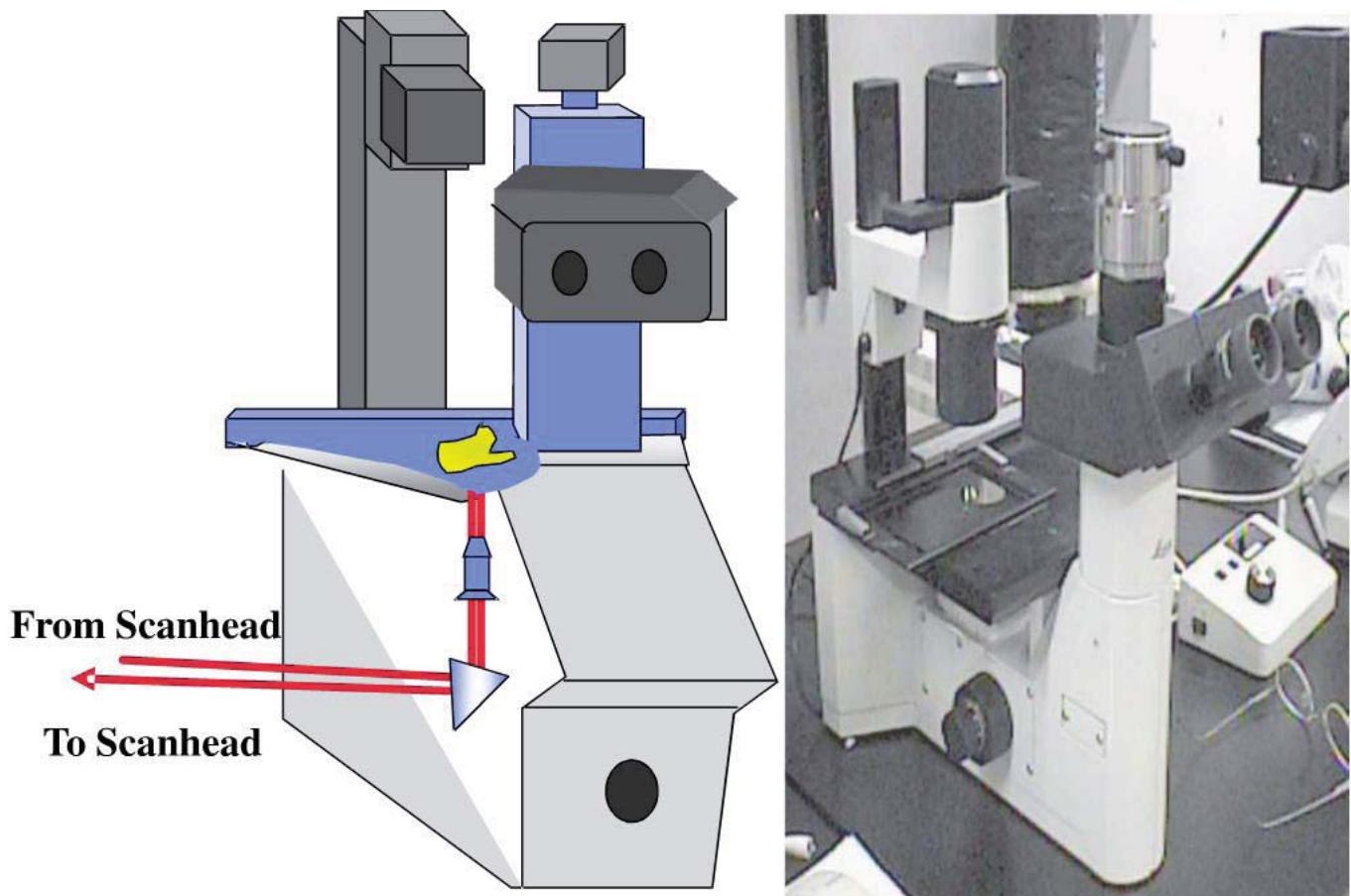
# MRC 1024 Scanhead



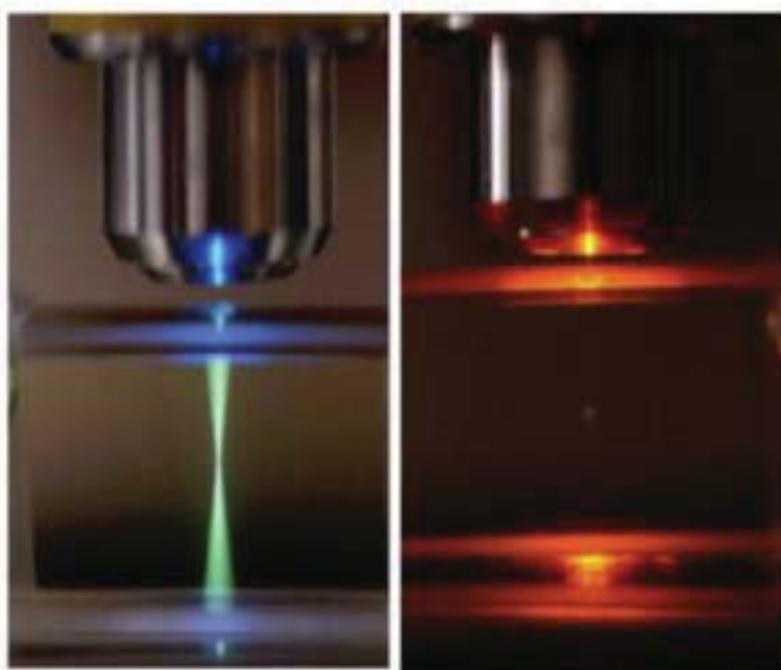
## Scanning Galvanometers

### Point Scanning





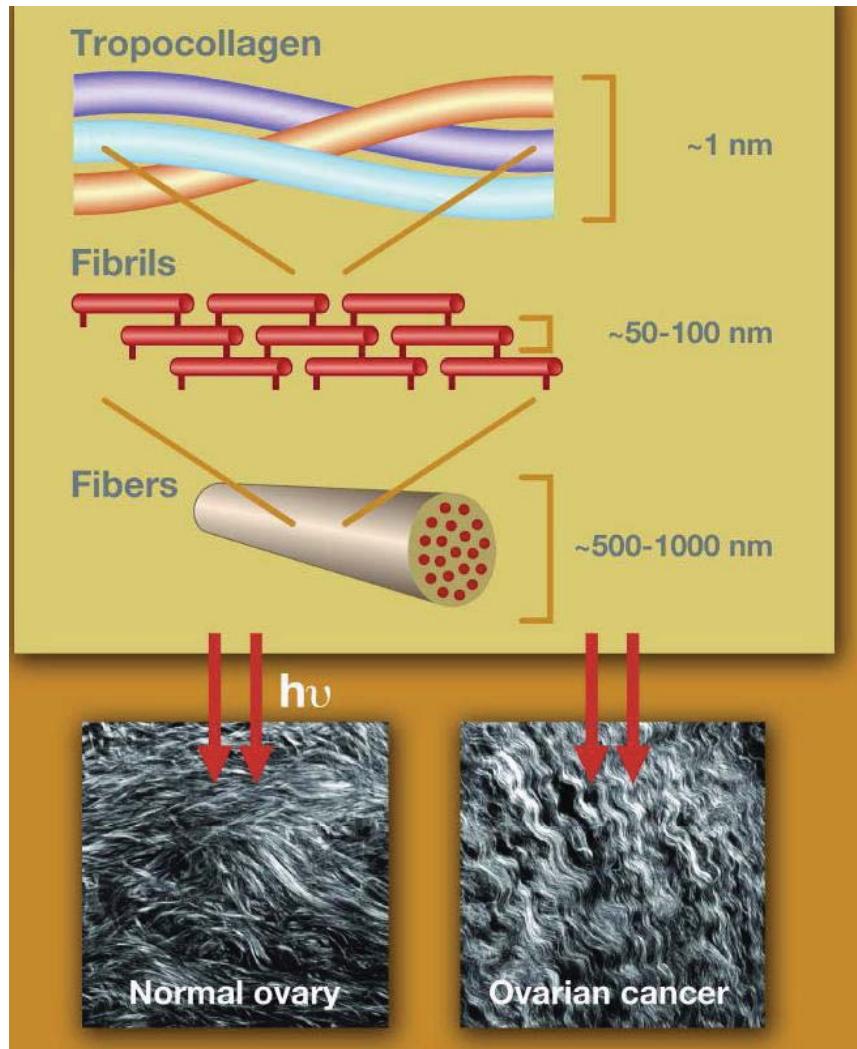
## 1-photon vs. 2-photon



Fluorescence from  
out of focus planes

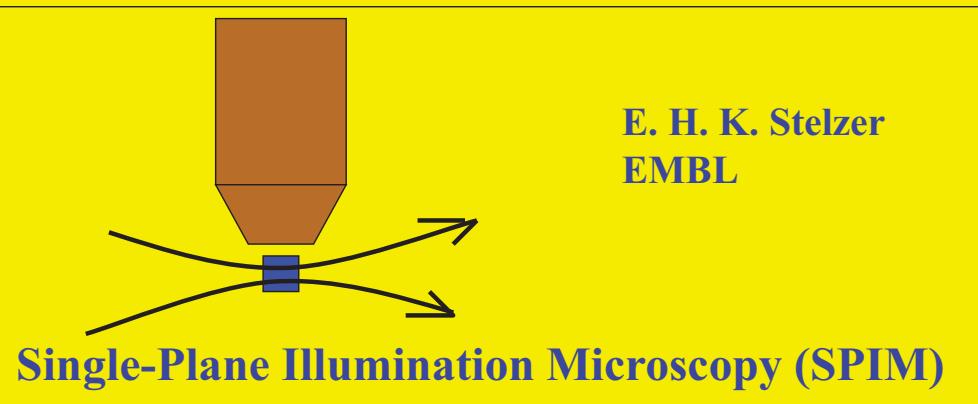
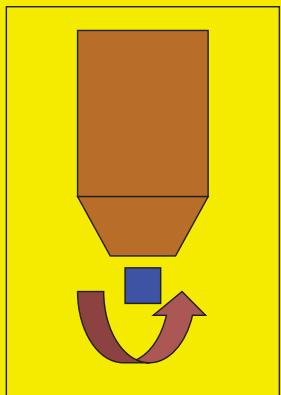
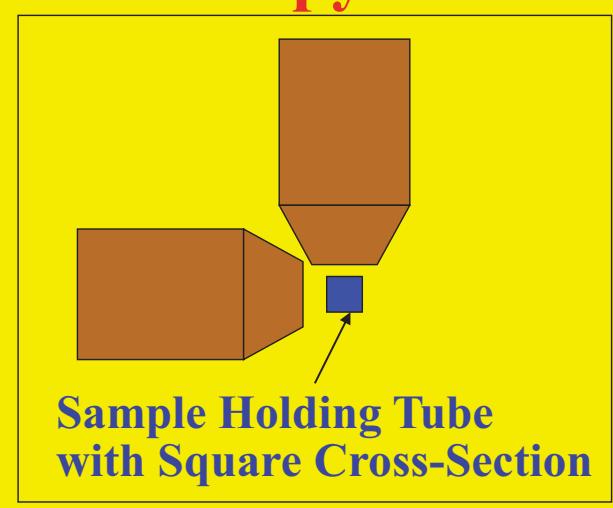
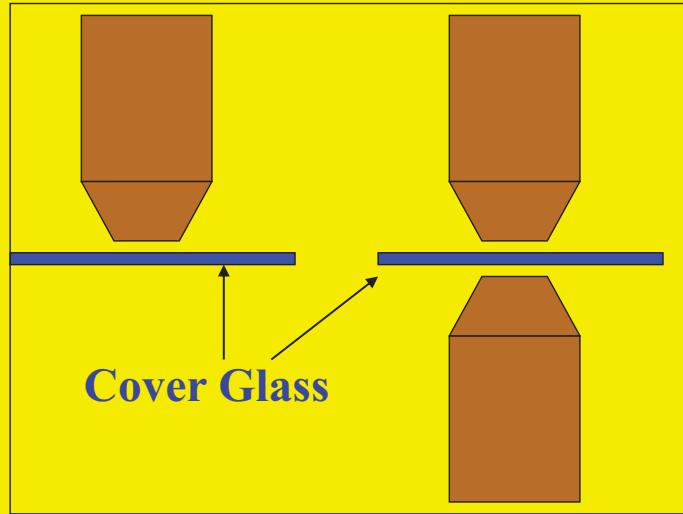
Fluorescence from  
focal spot only

# Second Harmonic Microscopy Images

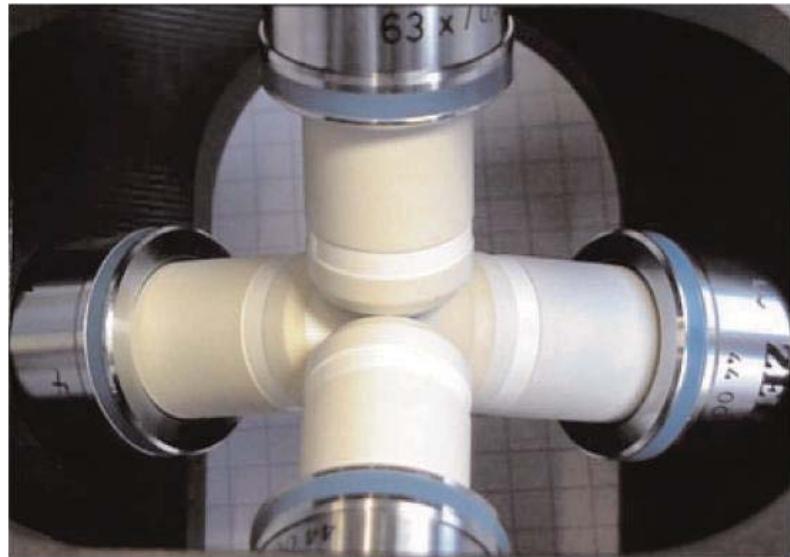


# Third Harmonic Microscopy

## What's New in Microscopy ?



# What's New in Microscopy ?



- Multi-Axis Imaging Microscopy (MAIM)
- Differential Active Optical Manipulator

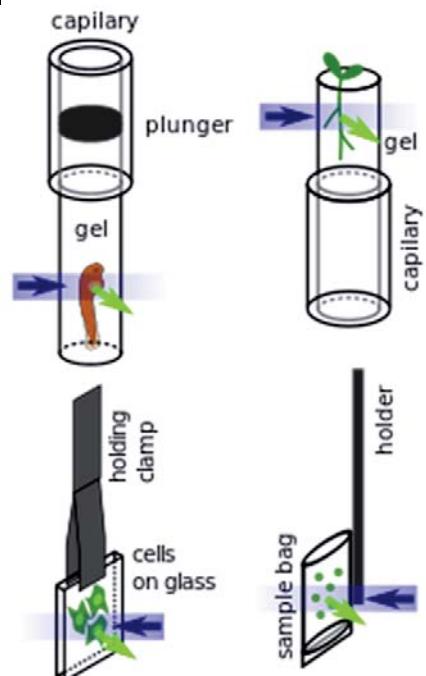
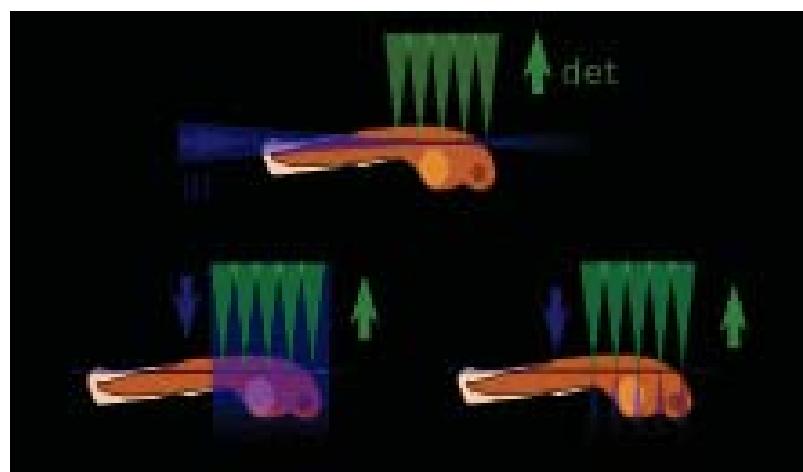
E. H. K. Stelzer, EMBL.

# What's New in Microscopy ?

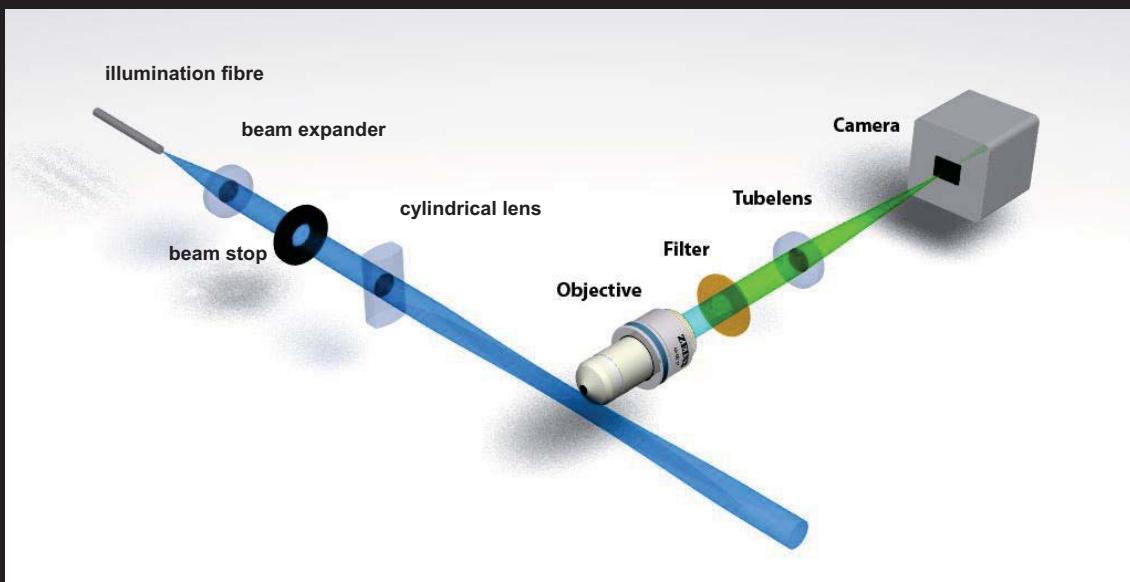


- Multi-Axis Imaging Microscopy (MAIM)
- Differential Active Optical Manipulator

E. H. K. Stelzer, EMBL.

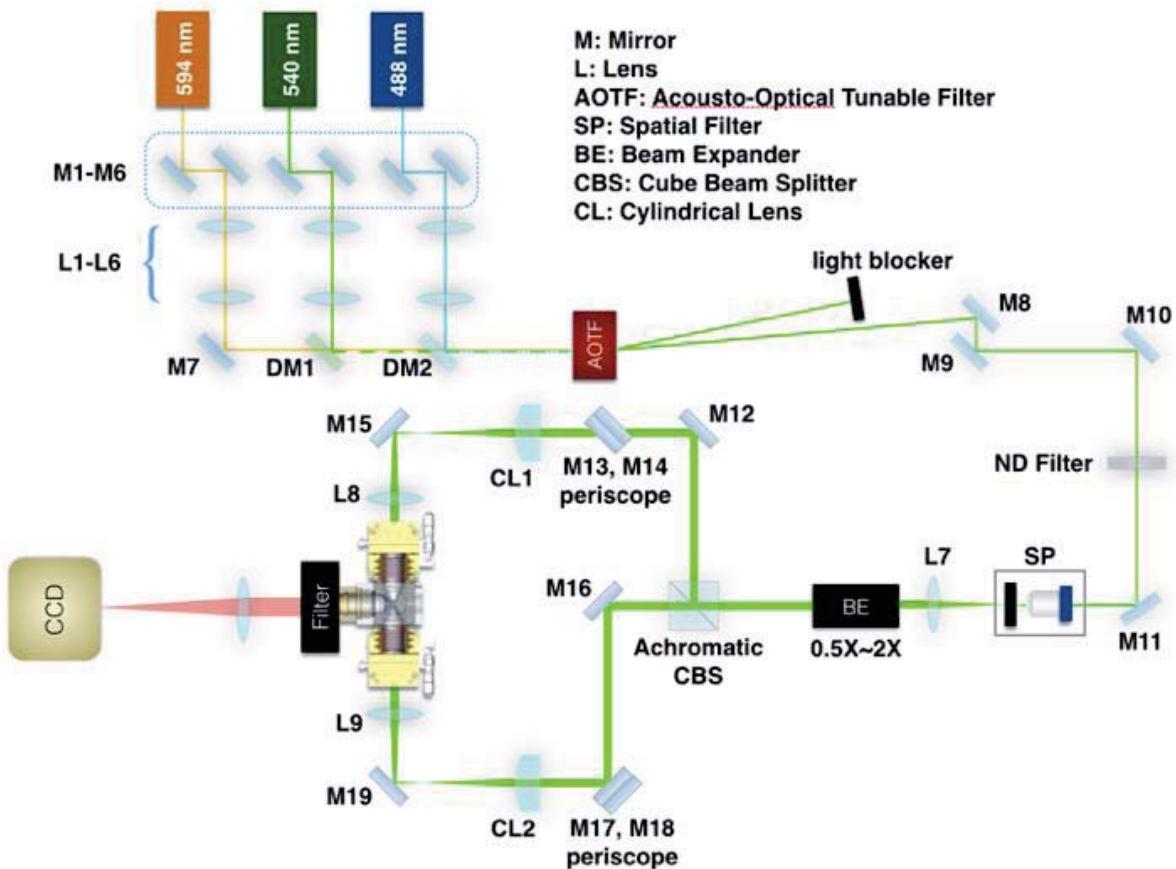


## Selective Plane Illumination Microscopy (SPIM) components & benefits

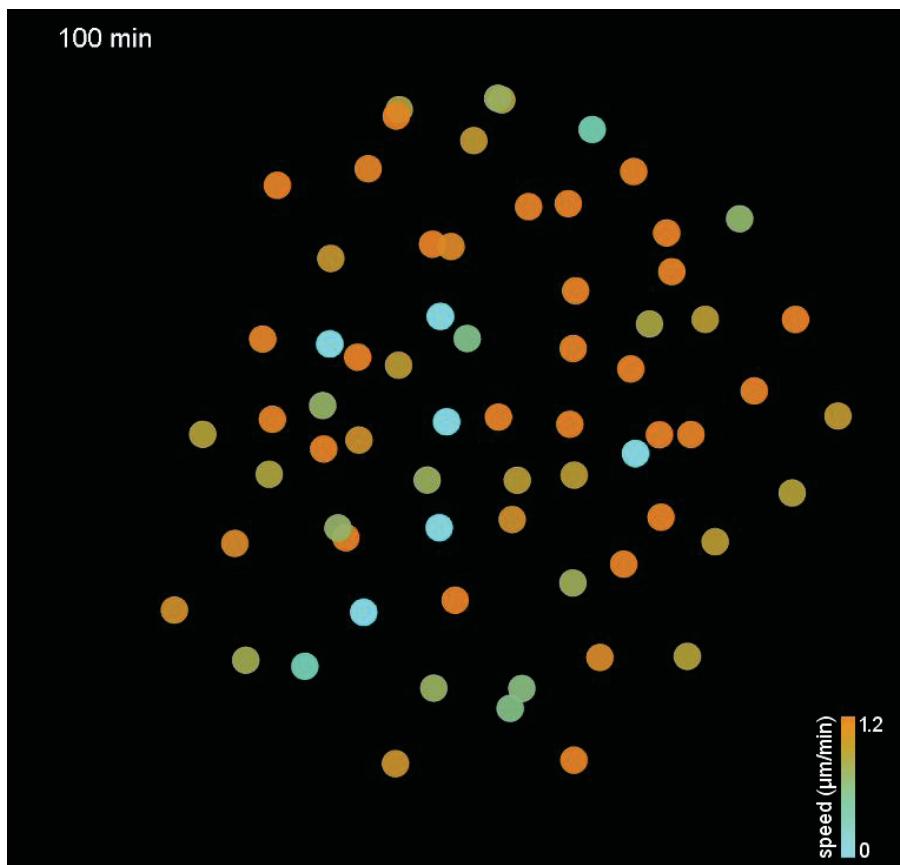


- Only focal plane is illuminated → Optical sectioning; reduced bleaching
- Translation stage → 3D stacks
- Water bath → Aberration reduction; “bio-friendly”

# Light-Sheet Microscopy

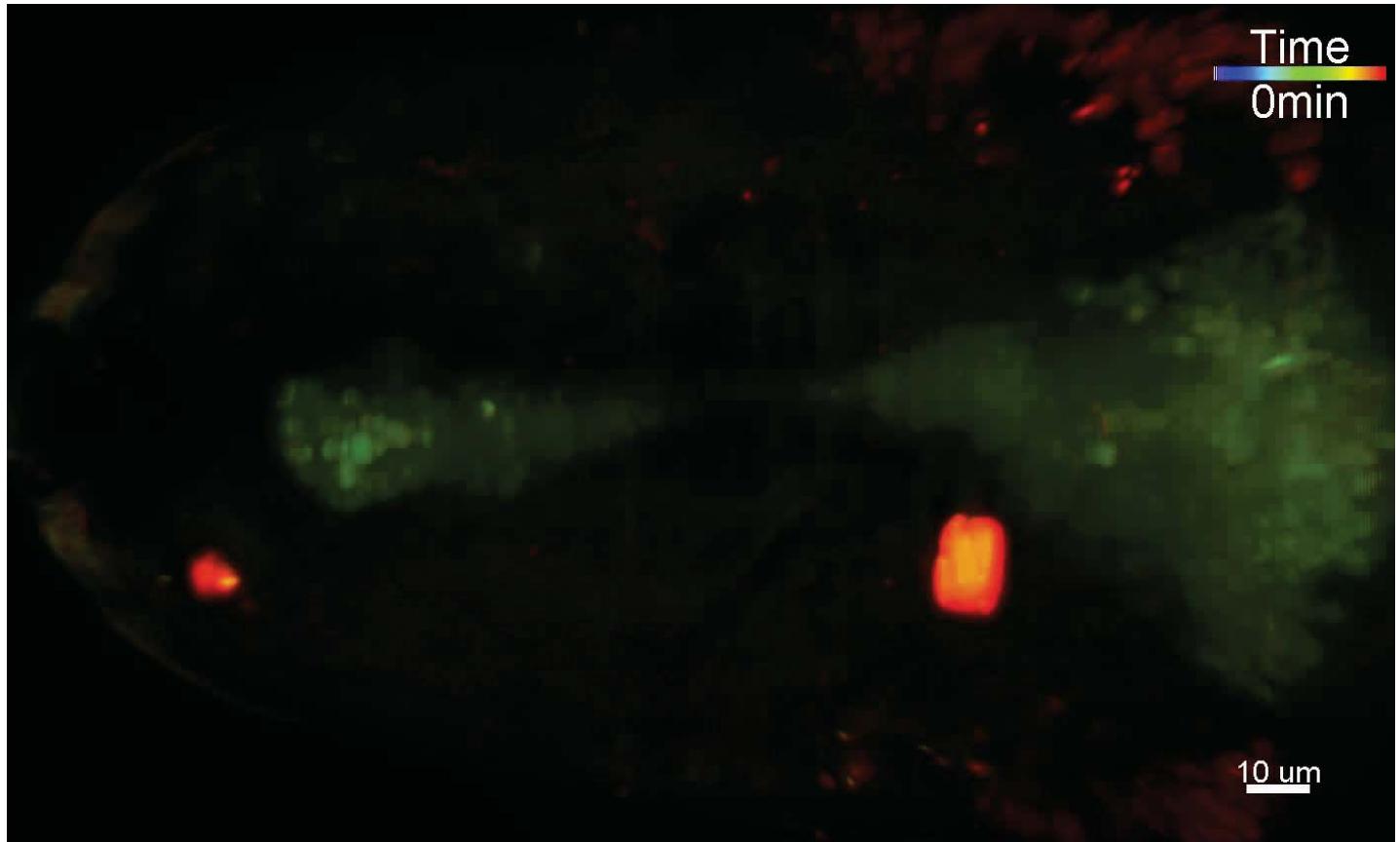


## Digital Zebrafish Embryo

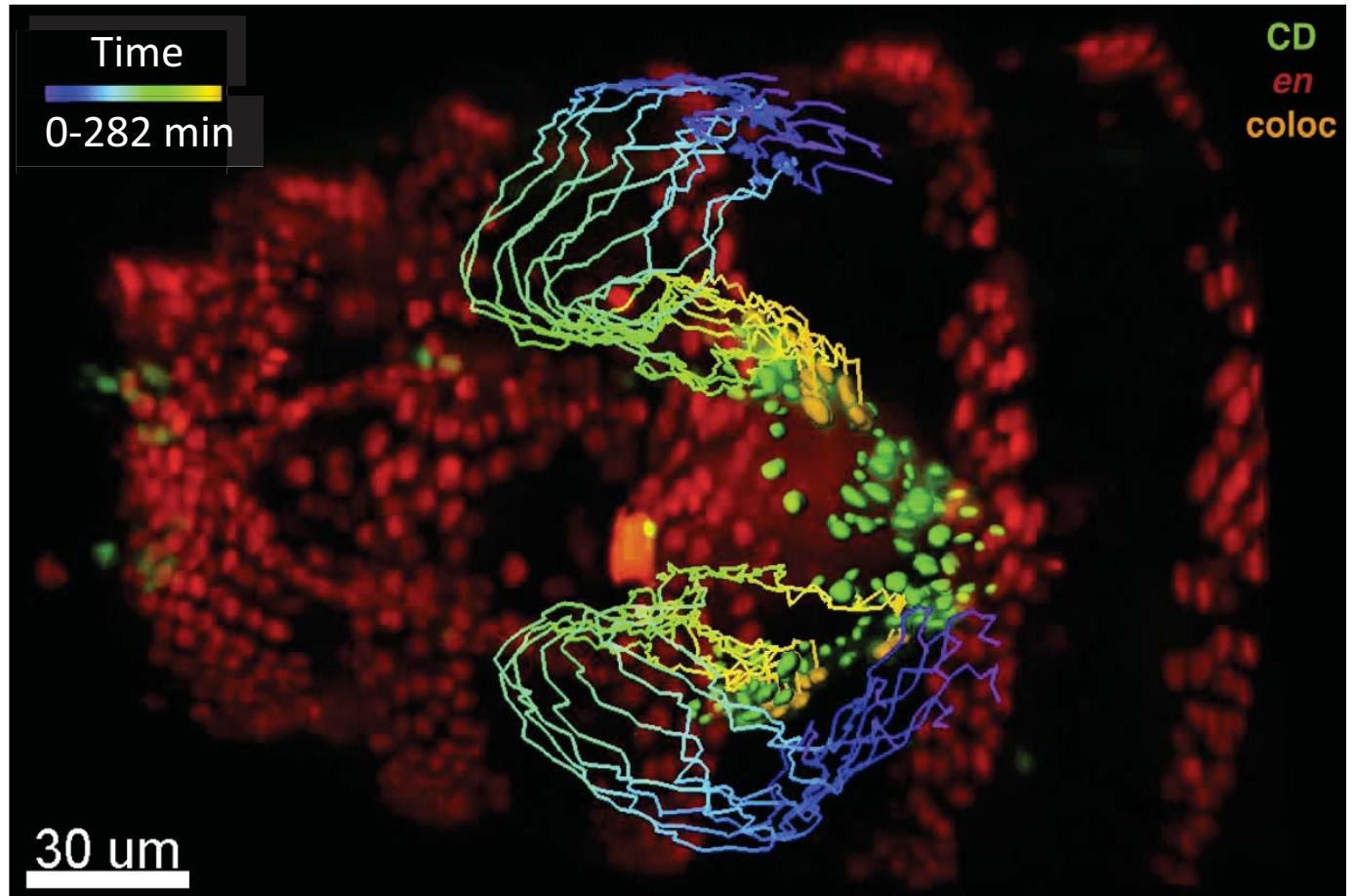


# The overview of the cell tracking result

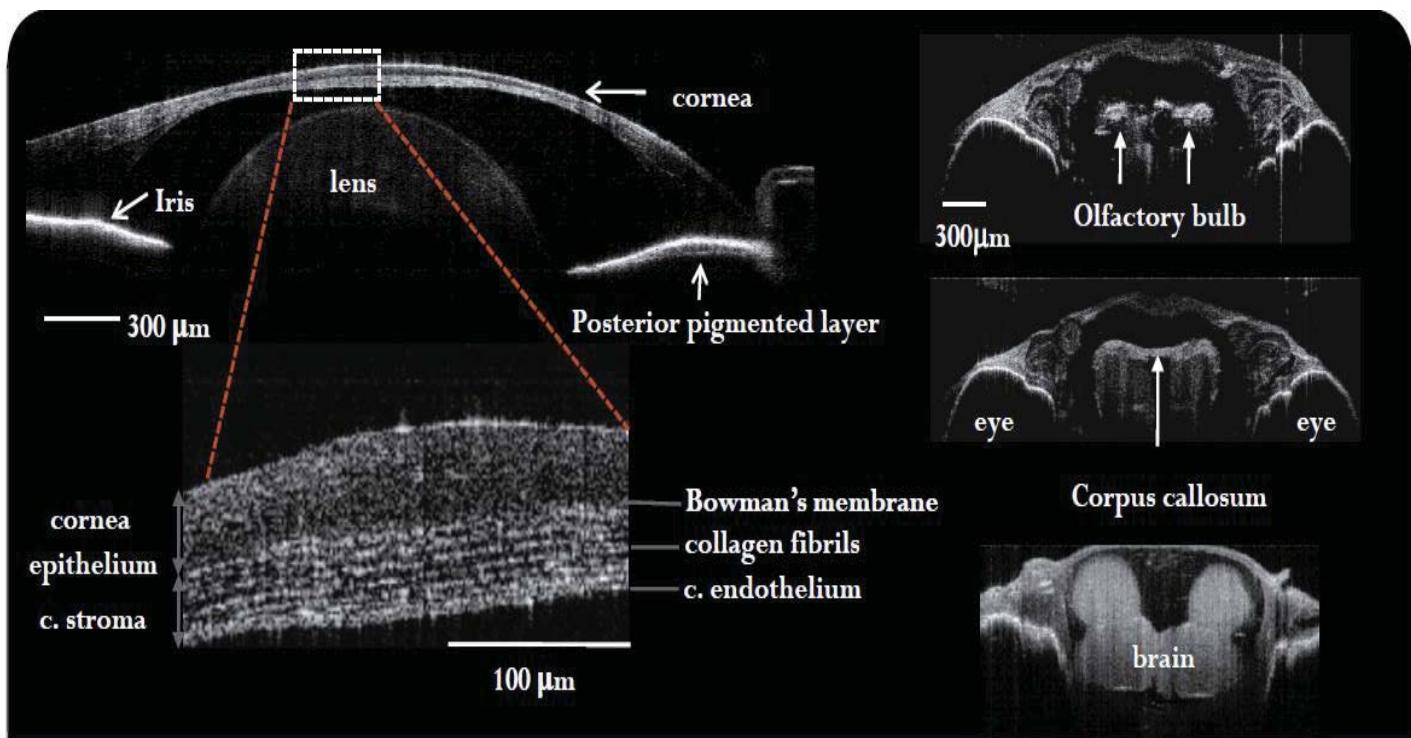
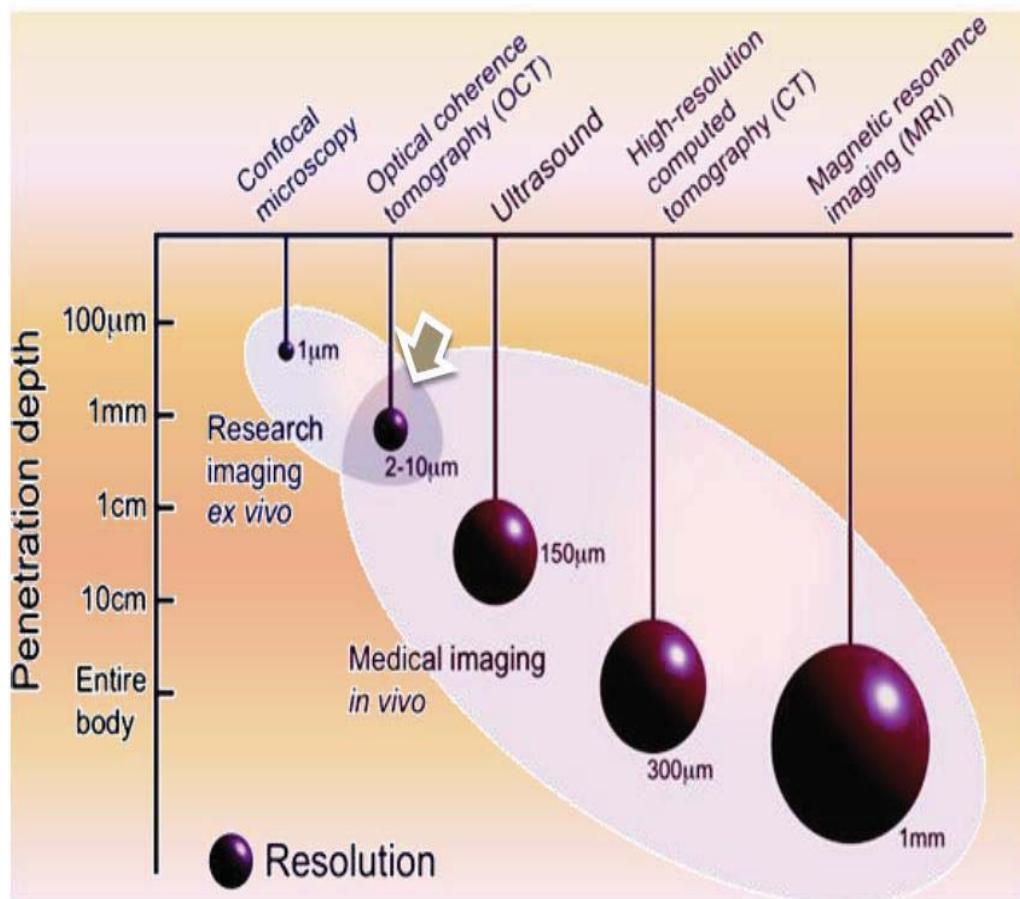
CD-GFP (II)/*en*-GAL4; UAS-H2B-RFP (III), dorsal view



## The Moving Trajectories of the Co-expressed Cells



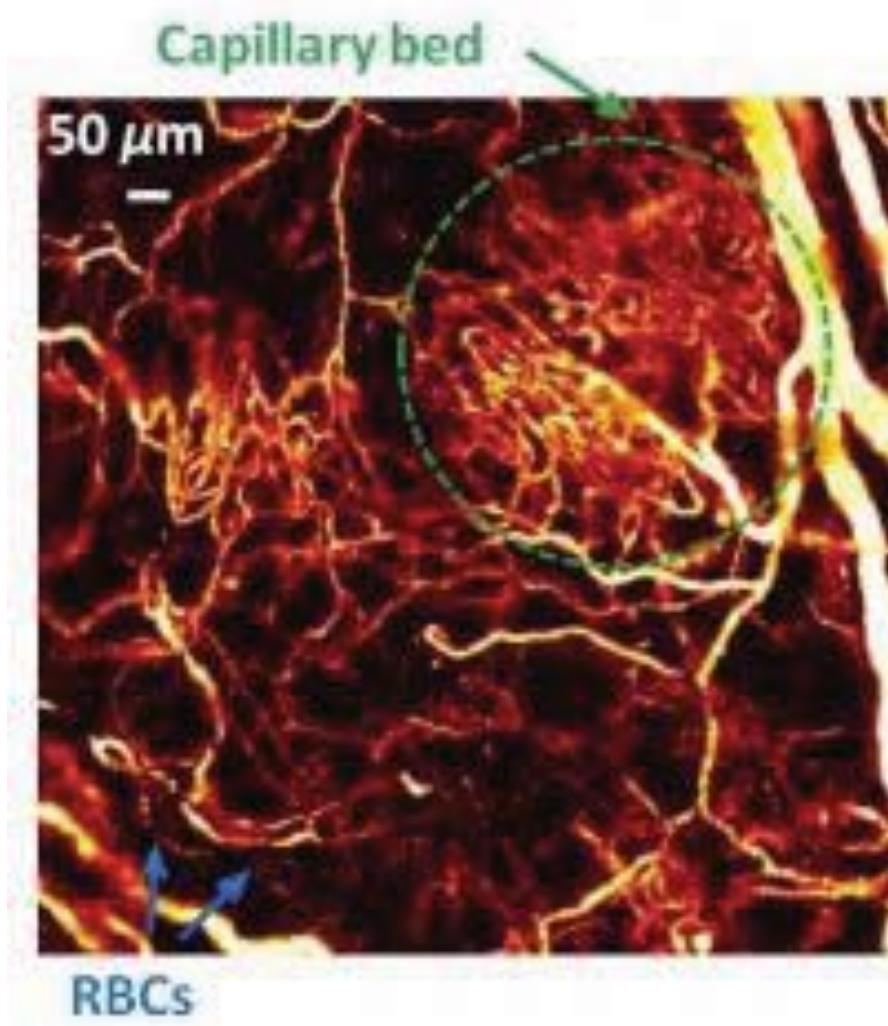
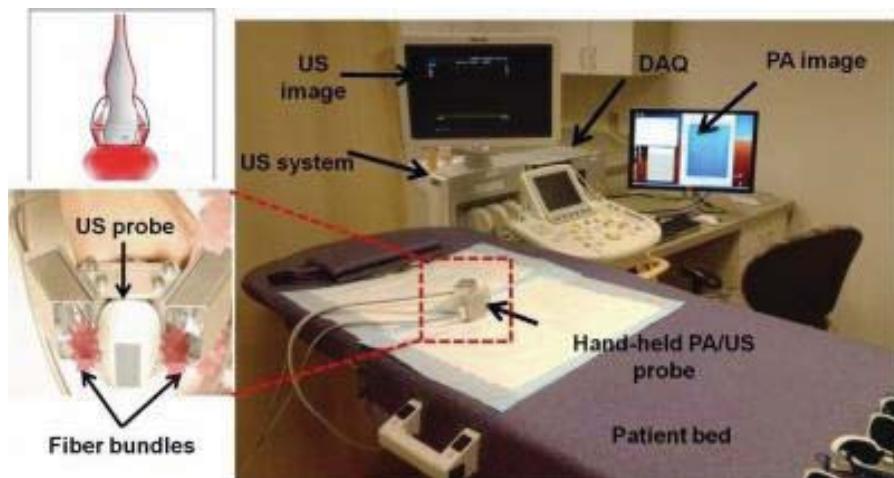
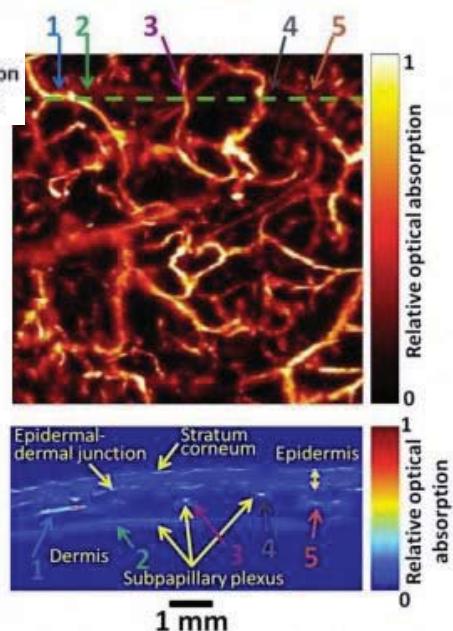
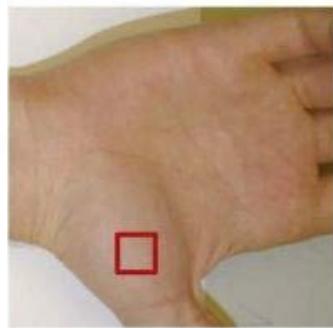
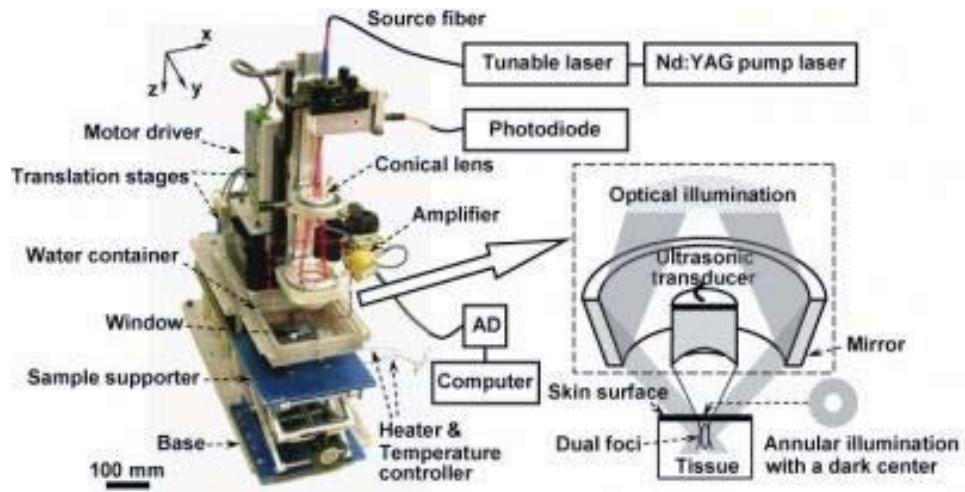
# Attractive features



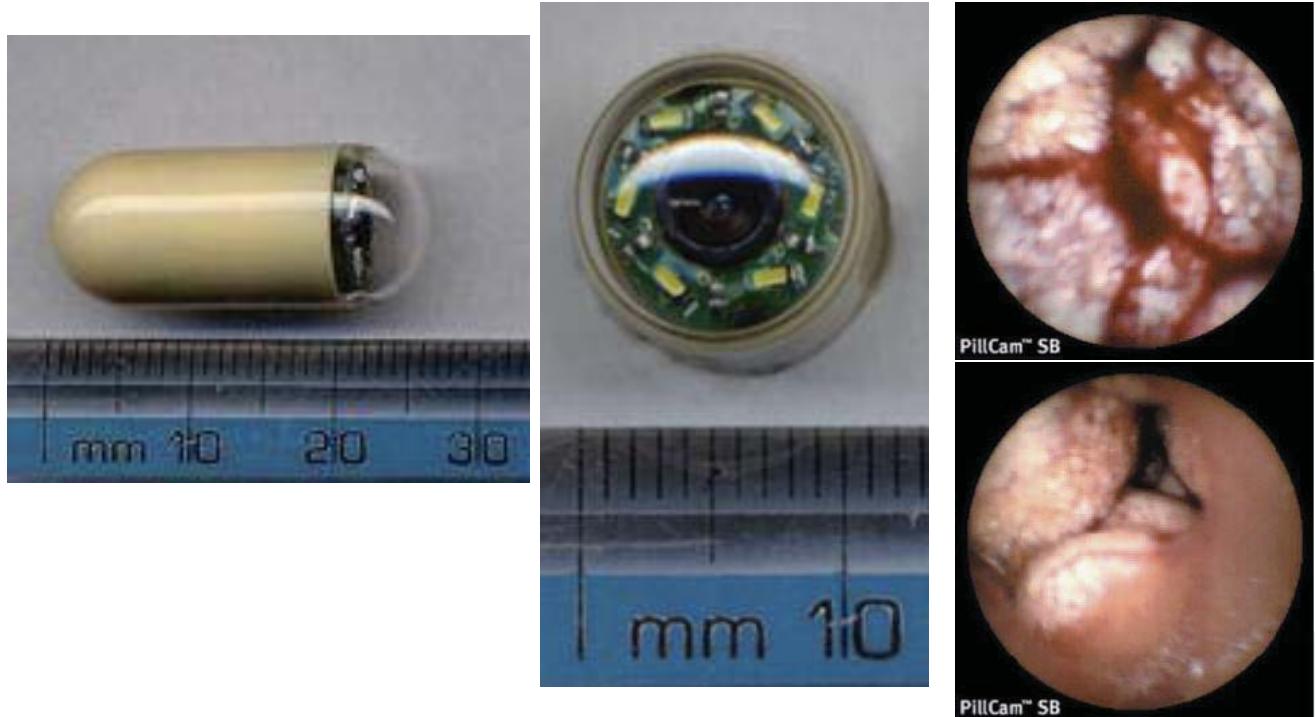
## Ultrahigh resolution OCT ( $2.6 \times 6 \mu\text{m}$ )

High speed (45 fps,  $1000 \times 4096$  pixels) *in vivo* eye and brain tomograms of a living fish.

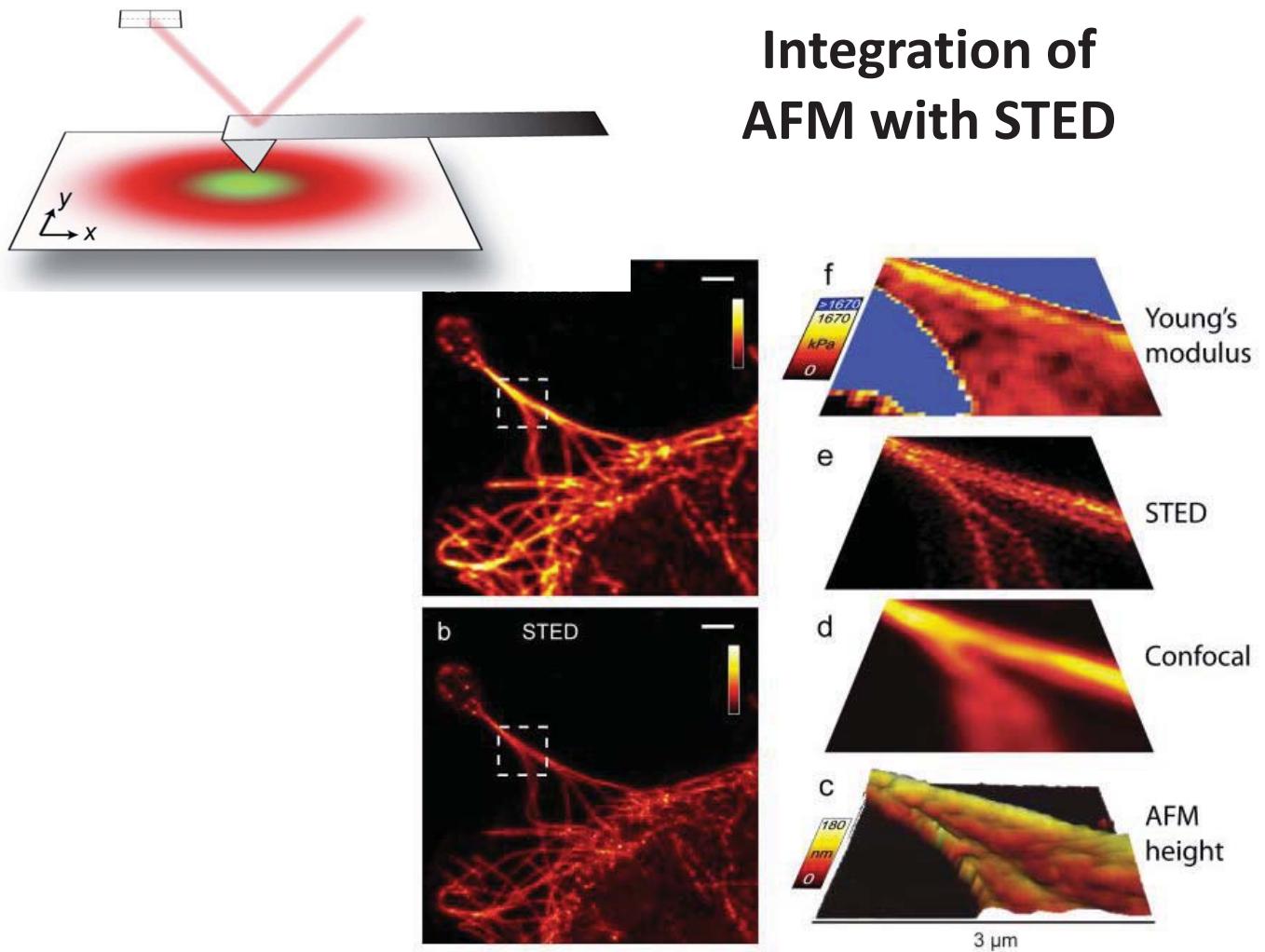
W.C. Kuo\* et al., Opt. Express 21, 2013



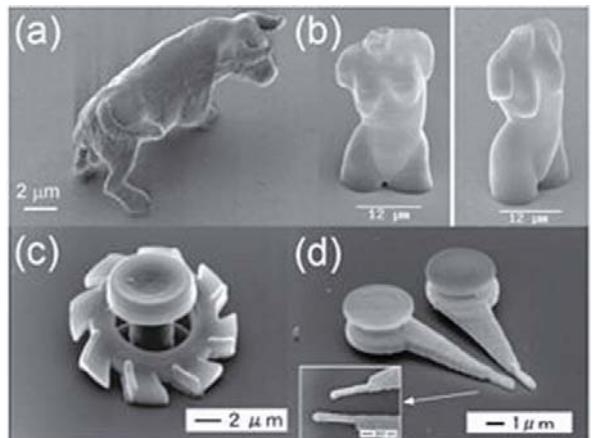
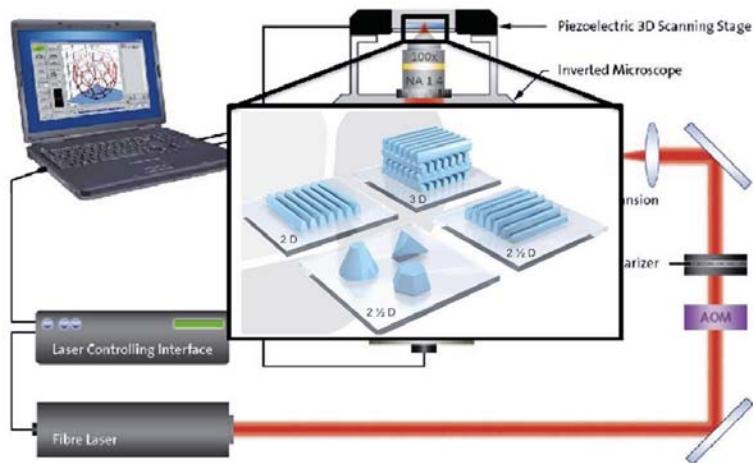
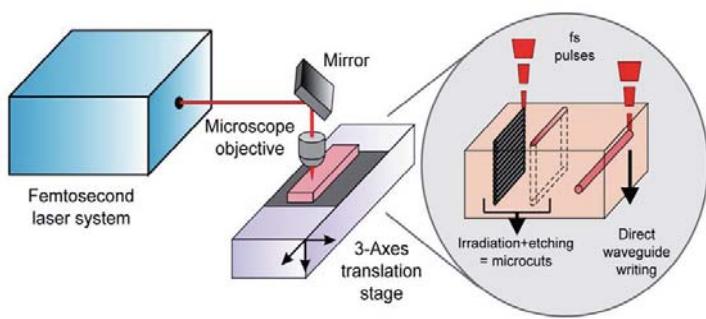
# Capsule Endoscopy



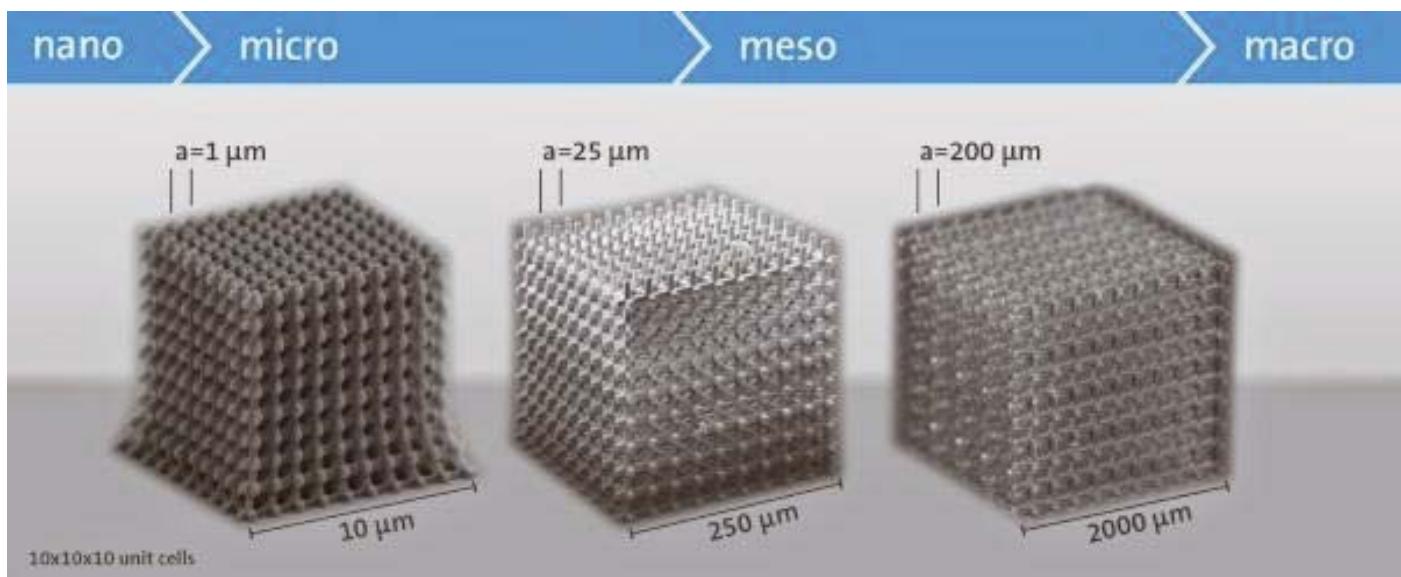
Endoscopic capsule end-on, showing six LEDs and camera lens.



# Laser 3-d Micro- and Nano- Fabrications

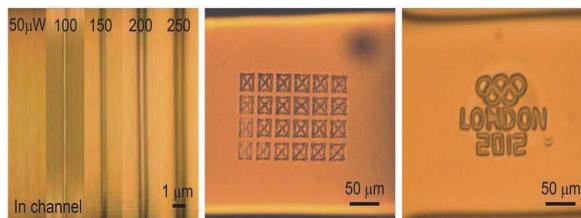


# Laser 3-d Micro- and Nano- Fabrications

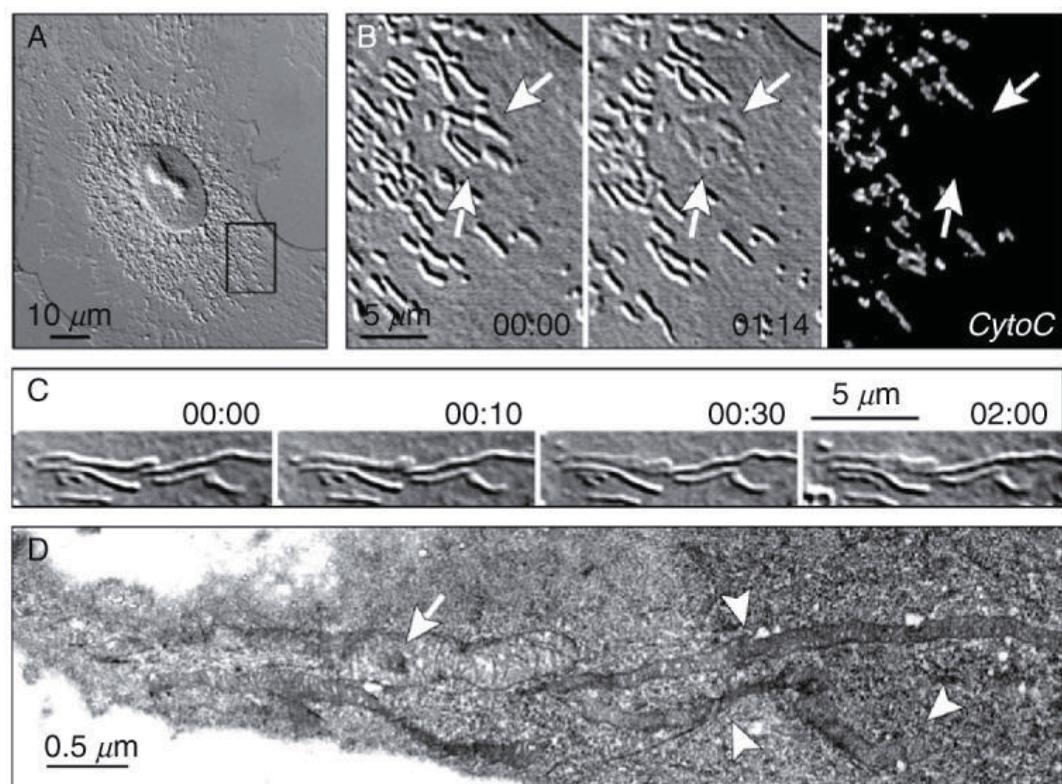
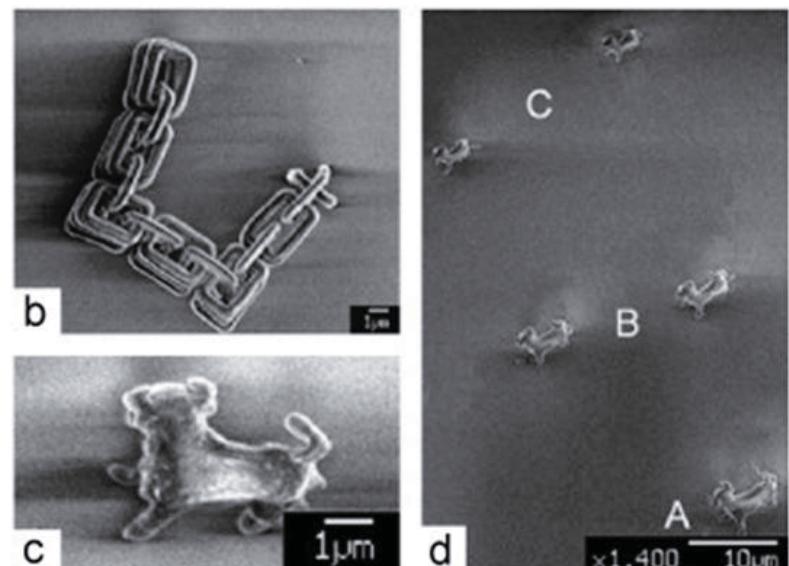
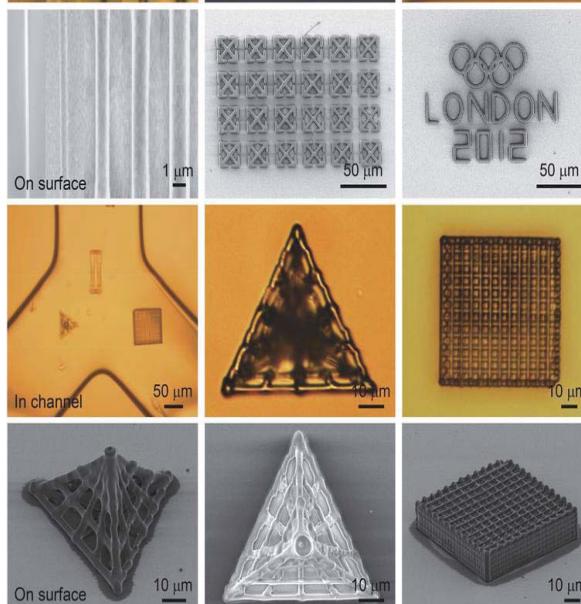


# Hybrid femtosecond laser microfabrication to achieve true 3D glass/polymer composite biochips with multiscale features and high performance: the concept of ship-in-a-bottle biochip

Dong Wu<sup>1</sup>, Si-Zhu Wu<sup>1,2</sup>, Jian Xu<sup>1</sup>, Li-Gang Niu<sup>2</sup>, Katsumi Midorikawa<sup>1</sup> and Koji Sugioka<sup>1,\*</sup>  
Article first published online: 27 MAR 2014; DOI: 10.1002/lpor.201400005



Laser & Photonics Reviews  
Volume 8, Issue 3,  
pages 458–467, May 2014



[Methods Cell Biol. 2007; 82: 239–266. ; doi: 10.1016/S0091-679X\(06\)82007-8](https://doi.org/10.1016/S0091-679X(06)82007-8)

Laser Microsurgery in the GFP Era: A Cell Biologist's Perspective  
[Valentin Magidson, Jadranka Lončarek, Polla Hergert, \\* Conly L. Rieder,](https://doi.org/10.1016/S0091-679X(06)82007-8)  
[and Alexey Khodjakov](https://doi.org/10.1016/S0091-679X(06)82007-8)

# TRANSORAL LASER MICROSURGERY

## Removing throat and neck tumors through the mouth minimizes risks and speeds recovery.

By Gwen Ericson Article originally appeared in the spring 2008 issue of Outlook magazine

- See more at:

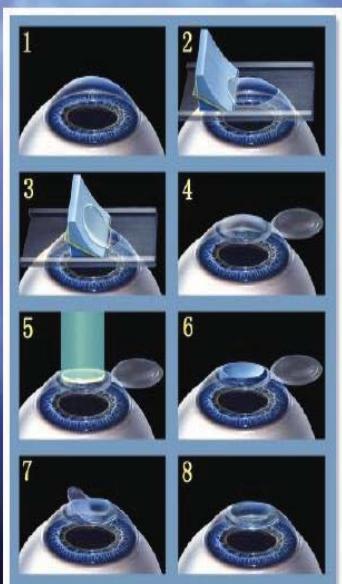
<http://www.siteman.wustl.edu/contentpage.aspx?id=2836#sthash.cl7SyS3n.dpuf>



## Laser and Tissue - Photoablative

UV 193 nm eximer laser. Exceeds molecular binding.  
Ablates cornea/ no heating

■ LASIK (laser-assisted in situ keratomileusis) - reshaping the cornea

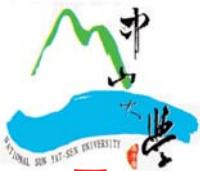


[www.kaytabas.com/refractive\\_procedures.html](http://www.kaytabas.com/refractive_procedures.html)

[www.eyeclinicpc.com/lasik/lasik.htm](http://www.eyeclinicpc.com/lasik/lasik.htm)

[http://www.augenportal.de/media/intemplate/12\\_fs-lasik-REM.jpg](http://www.augenportal.de/media/intemplate/12_fs-lasik-REM.jpg)





# Lasers:

## History, Basics, and Applications

台灣雷射五十年

李焜達

中山大學光電工程學系

chuckcklee@yahoo.com



National Sun Yat-Sen University  
Femtosecond & Quantum Modulation Lab.

## Outline

1. Laser Pioneers and the discovery of the laser
2. Ordinary light vs Laser Light
3. Basics principles of laser action
4. Properties of laser light
5. Examples of Typical Lasers

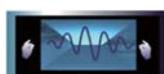


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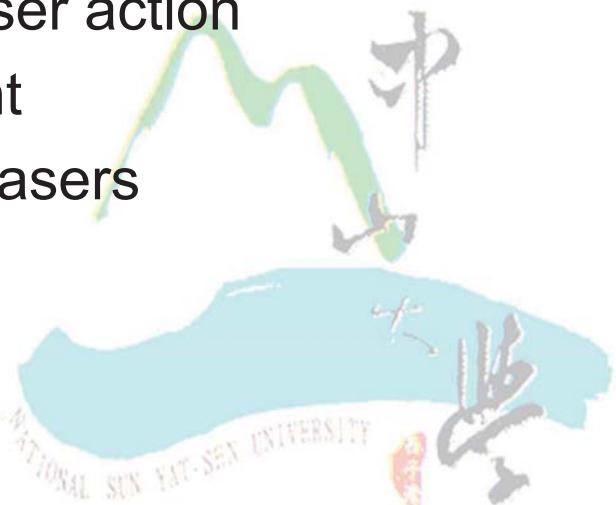


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## Noble Prizes Related to Lasers

1. A. Einstein (1917): Stimulated Emission
2. Townes, Basov, Prokhorov (1958): Masers and Laser Principles
3. Gabor (1971): Holography
4. Schawlow, Bloembergen (1981): Laser Spectroscopy
5. Chu (朱棣文), Cohen-Tannoudji, and Phillips (1997): Laser Cooling and Trapping of Atoms
6. Zewail (1999): Femtosecond Photochemistry
7. Alferov, Kroemer (2000): Semiconductor heterostructures for optoelectronics
8. Cornell, Ketterle, and Wieman (2001): Bose-Einstein Condensation
9. Glauber, Hall, and Hansch (2005): Quantum theory of optical and development of laser-based precision spectroscopy coherence
10. Amano, Nakamura and Akasaki(2014): invention of efficient blue light diode....

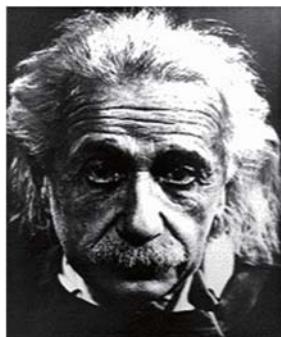
<http://nobelprize.org/nobel/>



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# Laser Pioneers



Einstein

1917

Stimulated  
Emission

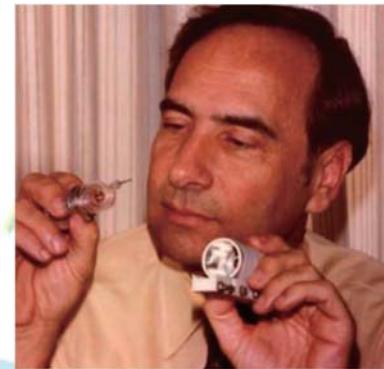


Gould  
1957

Laser  
Patent



Townes and Schawlow 1958 Optical Maser



Maiman 1960

The 1<sup>st</sup> Laser

## Before the MASER

- A theory of light emission proposed by Albert Einstein.
- Einstein's ideas primarily of academic interest until 1950s.
- After WWI, German Rudolf W. Ladenburg became interested in spectroscopic theory and energy level.

Study atomic absorption: huge absorption near resonant → negative dispersion/consequence of stimulated emission

(1928)



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# The MASER(I)

- After WWII, due to development of RADAR:
- MASER's idea: three group (Towns @ Columbia; Joseph Weber @ Maryland; Alexander M. Prokhorov and Nikolai G. Basov @ Moscow)
- 1st MASER by Towns and his postdoc and graduate student.



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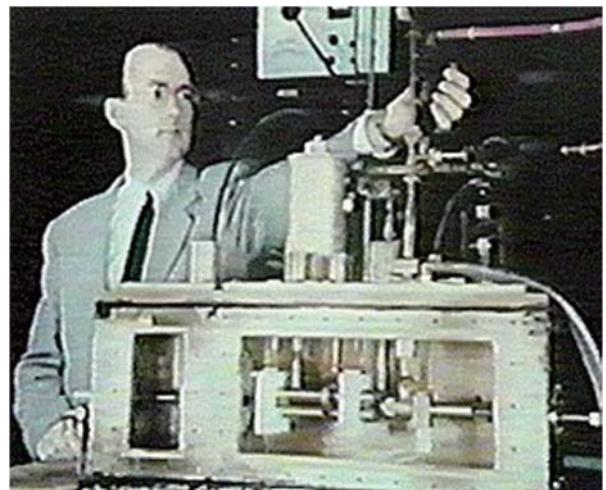
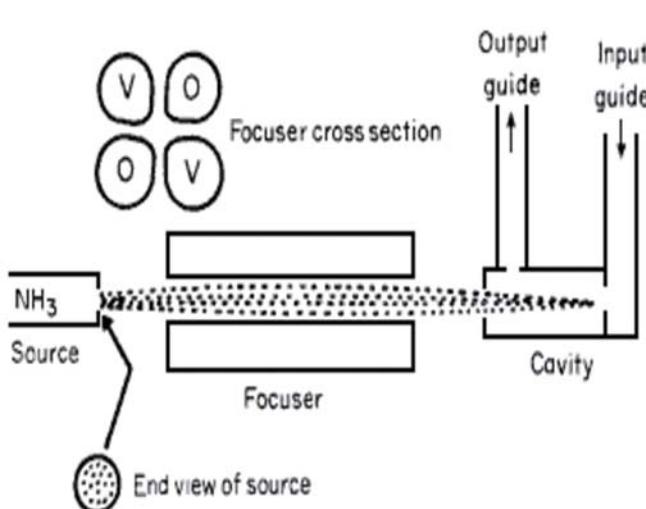
# The MASER(II)-Townes

- 1948, Join Columbia Univ. from Bell lab.  
Focus in microwave spectroscopy.
- Transfer to study maser because of delay  
in generation of new microwave source,  
1951.
- Idea in Franklin park.
- Calculation in envelope.
- Working on MASER peacefully.



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# Maser: Microwave Amplification by Stimulated Emission of Radiation



1st Maser:  $\text{NH}_3$  ( $\lambda = 1.25 \text{ cm}$ )

Townes and the 1st Maser 1954

Gordon,J.P., Zeiger,H.J., Townes,C.H.: 1954, *Phys.Rev.*, **95**, 282.



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## The MASER(III)-Others

- Weber's work: no operation due to lack of cavity. 1953
- Prokhorov and Basov @ Lebedev: plan to control population of various energy levels lead to enhance the sensitivity, 1950.
- Basov's doctoral thesis.

1st application: Ramesey; hydrogen maser in 1960  
→ 1989 Nobel prize



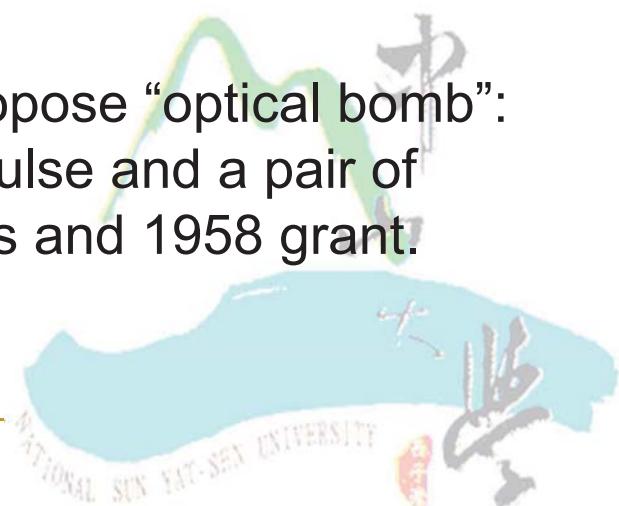
National Sun Yat-Sen University  
Femtosecond & Quantum Modulation Lab.

# Before the LASER

- Lots of scientist focus on this subject before 1st operation of maser.
- 1951, Fabrikant and his student file a patent “A method for the amplification of electromagnetic radiation.” But, rejected until 1959.
- 1954, Rober H. Dicke propose “optical bomb”: include short excitation pulse and a pair of parallel mirrors; 1956 files and 1958 grant.



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## The LASER(I)

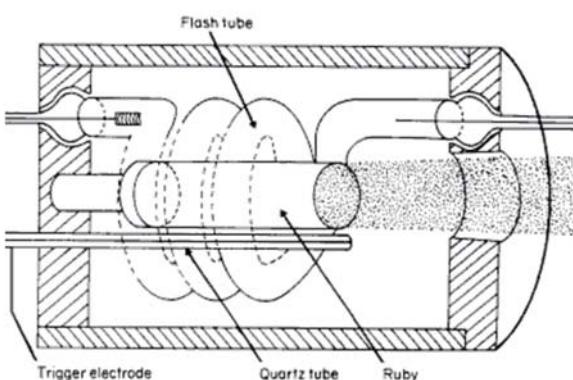
- 1st detailed proposal for building laser: “optical maser” by Townes and Schawlow (Town’s postdoc. Fellow and leave to Bell lab. In 1951)
- 1958, PR’s paper “Infared and Optical maser”.
- 1960, file patent from Bell lab.
- 1957, Gould defined laser. (Polykaro Kusch’s student; 1955’s Nobel prize)
- Cavity idea: Gould, Townes and Schawlow proposed Fabry-Perot interferometer.
- 1959, Schawlow and T. Maiman @ Hughes.
- 1960 May 16: silvered coated end inside a spring-shaped flashlamp.
- Rejected by PRL.



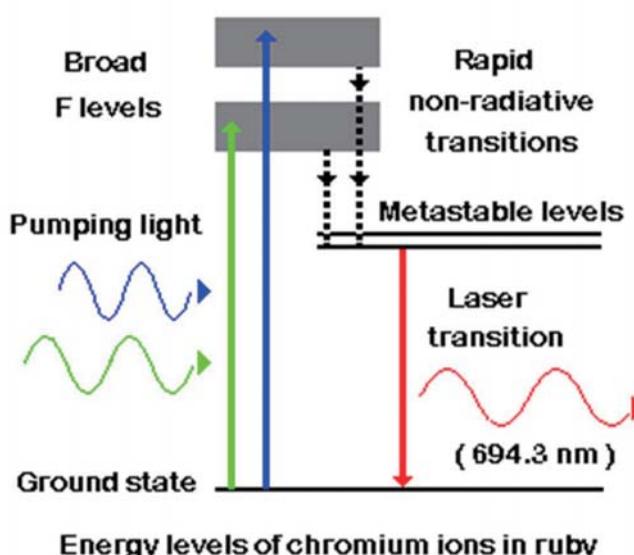
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# Ruby : The 1<sup>st</sup> Laser



Theodore Harold Maiman  
The Ruby Laser  
U. S. Patent No. 3,353,115



[http://www.invent.org/hall\\_of\\_fame/96.html](http://www.invent.org/hall_of_fame/96.html)

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## Ruby Laser: Mechanical Parts



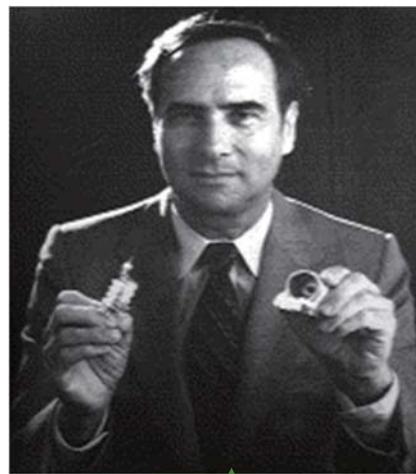
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# Maiman and his first Ruby laser

NY Times Picture of Maiman and the Ruby laser, July 8, 1960 It is not the first laser!



Nature, 187, 493, 1960



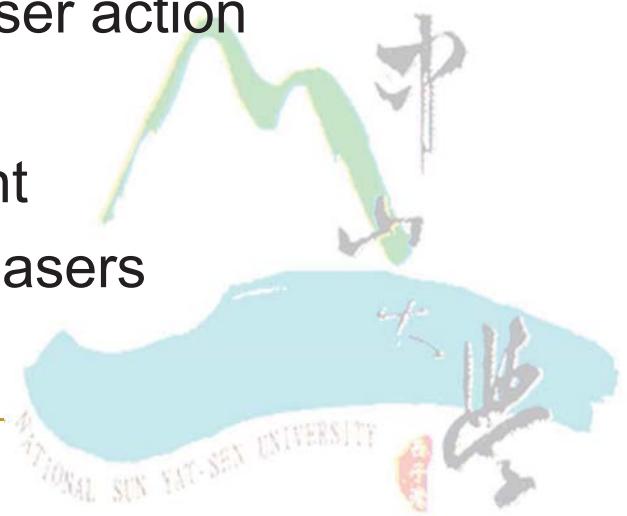
Maiman and his 1<sup>st</sup> Ruby Laser:  
Lasing observed on May 16, 1960

## Outline

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4. Types of lasers
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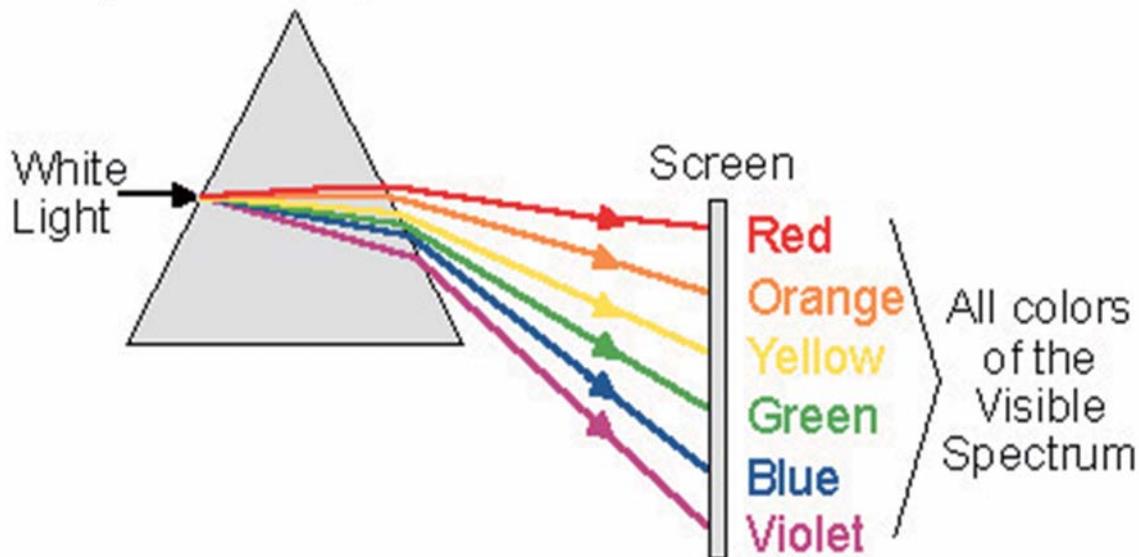


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# Solar Spectrum

Newton showed that sunlight is made up of many different “colors.”



<http://www.phys.ksu.edu/perg/vqm/laserweb/Java/Prism/Prisme.htm>

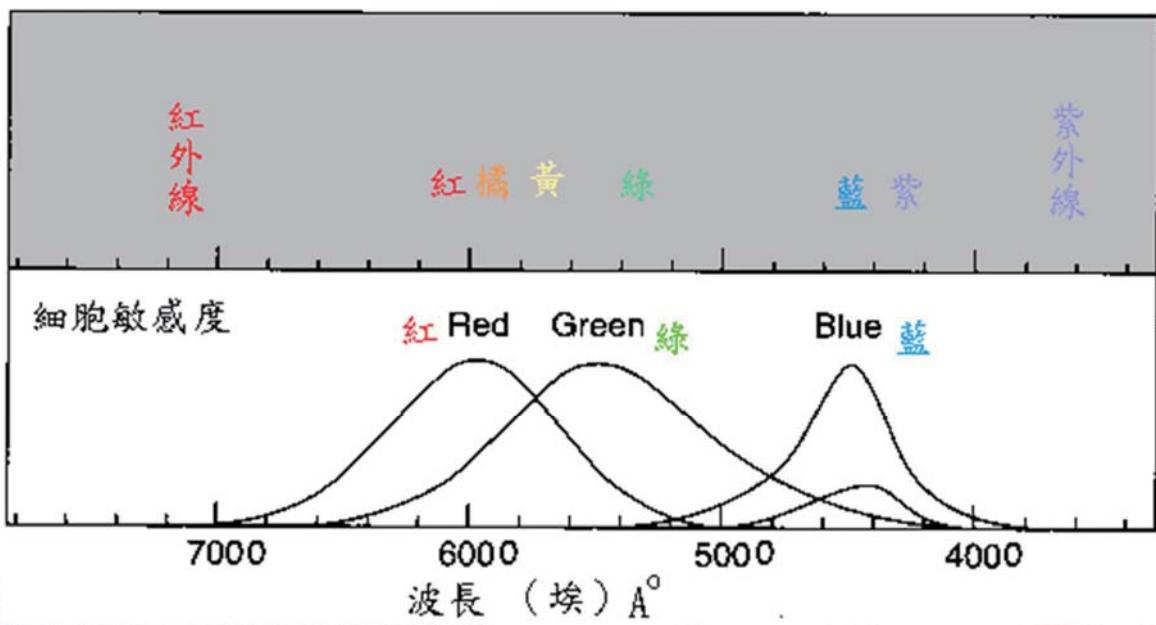


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# Solar Spectrum

How much “light” is present at wavelengths to which our eyes are not sensitive?



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# Blackbody Radiation

Every object absorbs radiation and emits radiation.

For an “ideal” object, these amounts are equal.

Sun:  $T = 10,000^{\circ} \text{ F}$

$$\lambda_{\text{peak}} = 500 \text{ nm}$$

Photo Flood Lamp:  $T = 5000^{\circ} \text{ F}$

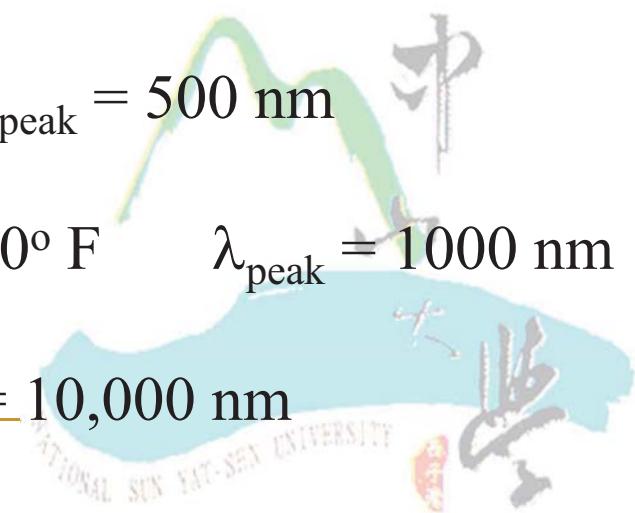
$$\lambda_{\text{peak}} = 1000 \text{ nm}$$

You:  $T = 100^{\circ} \text{ F}$

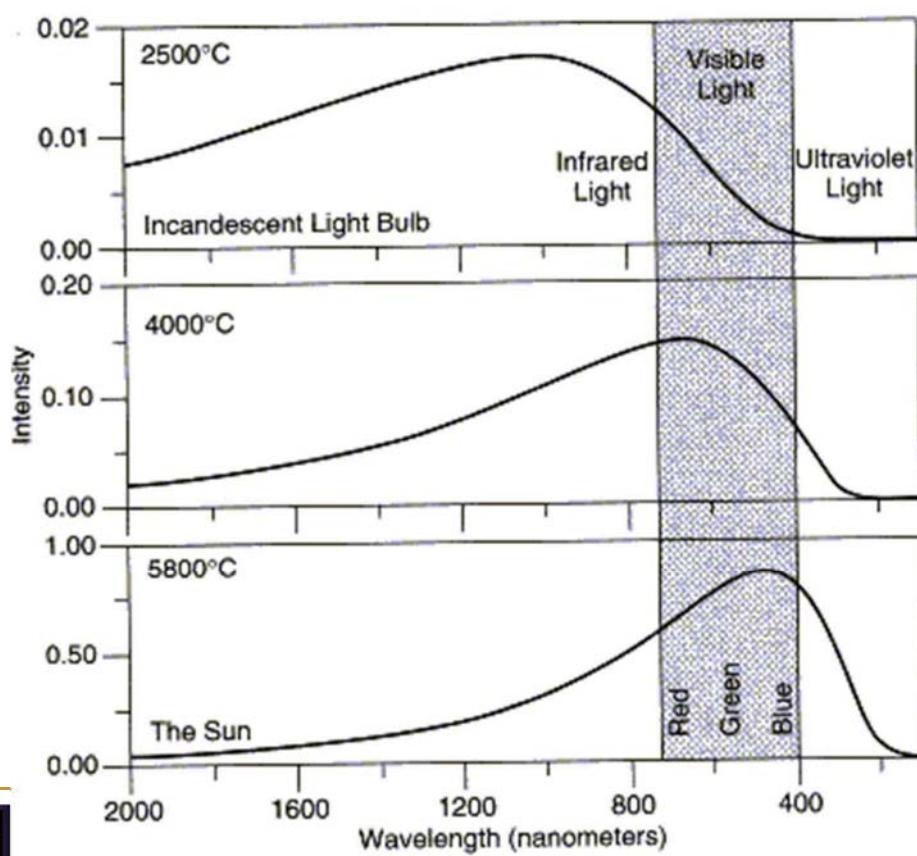
$$\lambda_{\text{peak}} = 10,000 \text{ nm}$$



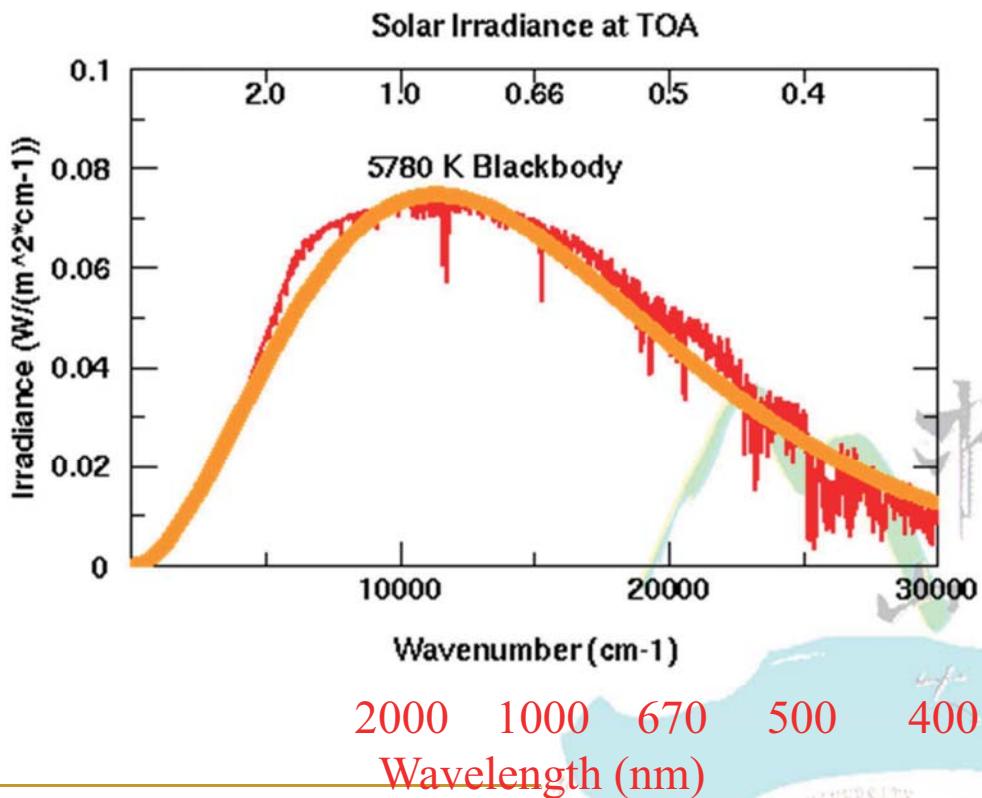
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## Blackbody Radiation Spectra



# Solar Spectrum



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## Common Light Sources

Light bulbs (including halogen)

- glowing filament at some temperature
- mostly infrared radiation (heat)
- very inefficient as a light source



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# Common Light Sources

## Fluorescent lights

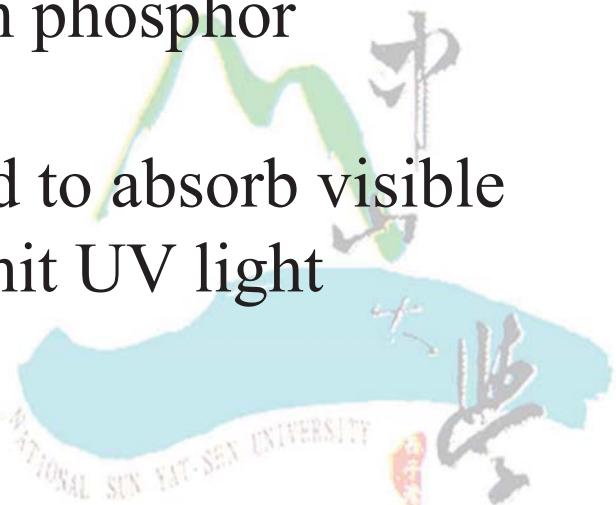
- glowing gas
- tube coated with phosphor

## Black lights

- same, but coated to absorb visible light and transmit UV light



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## Spectral Lamps and Atoms

### Street lamps (bluish-white or yellow/orange)

- glowing gas, either mercury vapor or sodium vapor
- identify using a spectrometer or diffraction grating

<http://phys.educ.ksu.edu/vqm/html/emission.htm>

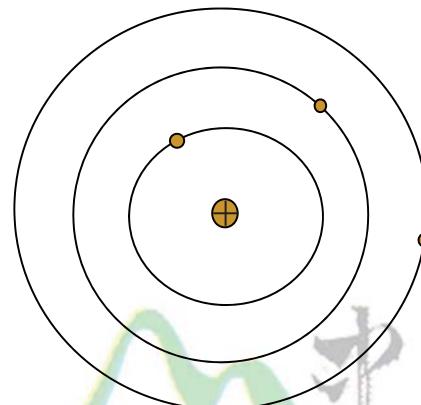


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# Spectral Lamps and Atoms

Planetary model of atom:  
electrons “orbit” around  
the central nucleus



Each atomic element has  
its own “fingerprint,”  
corresponding to the changes in orbit of  
electrons, and the resulting emitted  
photon energy



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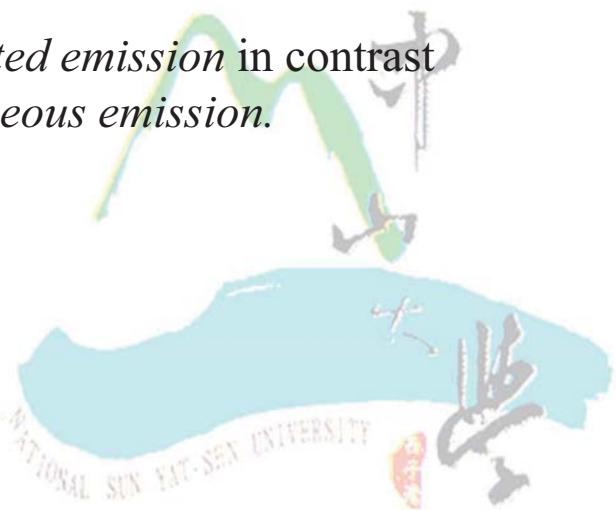


# What is a laser?

- **Laser is a coherent source of light.**  
Laser light is more **directional**, more **monochromatic**, and hence more **bright** compared with thermal sources (candle,sun, light bulb, etc.).
- **Why is laser light coherent?**  
It is produced through *stimulated emission* in contrast with ordinary light, or *spontaneous emission*.



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## What does the word “Laser” come from?

Laser: **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation

or

**L**ots of **A**pplied **S**cientists **E**ating **R**egularly

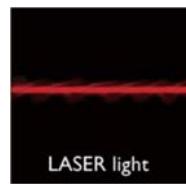
“1957 by Gould”



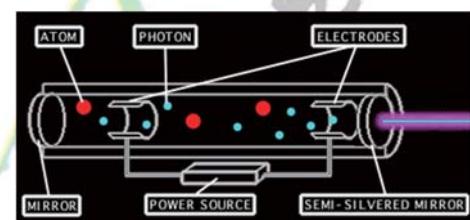
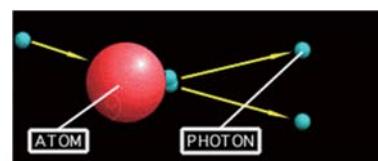
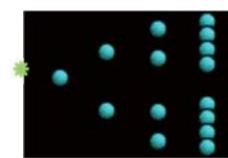
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Femtosecond & Quantum Modulation Lab.



The “L” in LASER stands for **Light**



The “A” in LASER stands for **Amplification**

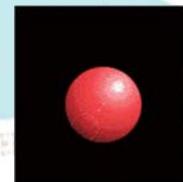


The “S” in LASER stands for **Stimulated**

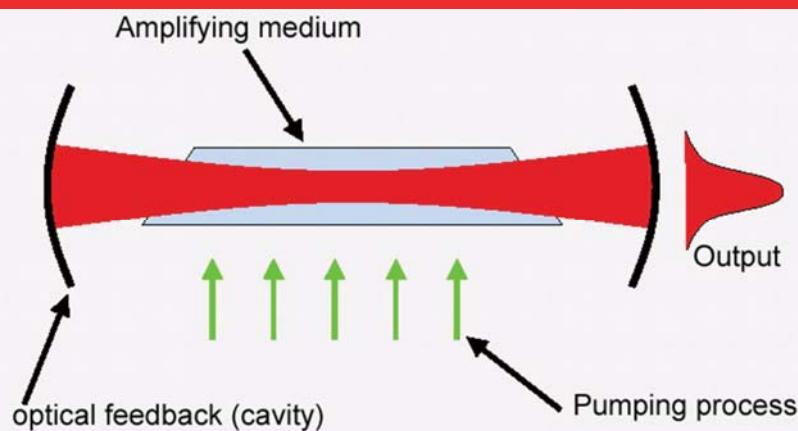
The “E” in LASER stands for **Emission**



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Femtosecond & Quantum Modulation Lab.



## Key Elements of a Laser

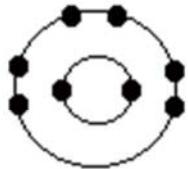


- Pumping process prepares amplifying medium in suitable state
- Optical power increases on each pass through an amplifying (gain) medium consisting of atoms, molecules in the form of gases, liquid or solids
- If gain exceeds loss, device will oscillate, generating a *coherent output*



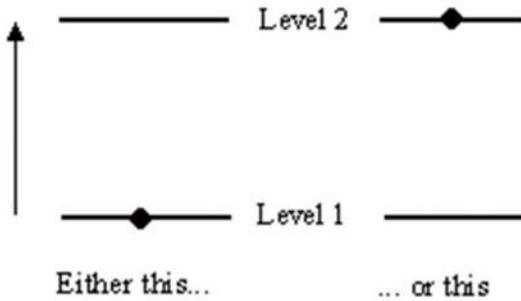
National Sun Yat-Sen University  
Femtosecond & Quantum Modulation Lab.

# Atoms and Energy Levels



• Electron

Energy



• Electron

“Shell Model” of  
the Atom

An “idealized” 2-level system

Photons are also  
“quantized”

$$E = \frac{hc}{\lambda}$$

E is the Energy  
 $\lambda$  is the Wavelength  
h and c are fundamental  
constants which just get the  
units correct



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Femtosecond & Qua



## Ground and Excited States



“Ground State”



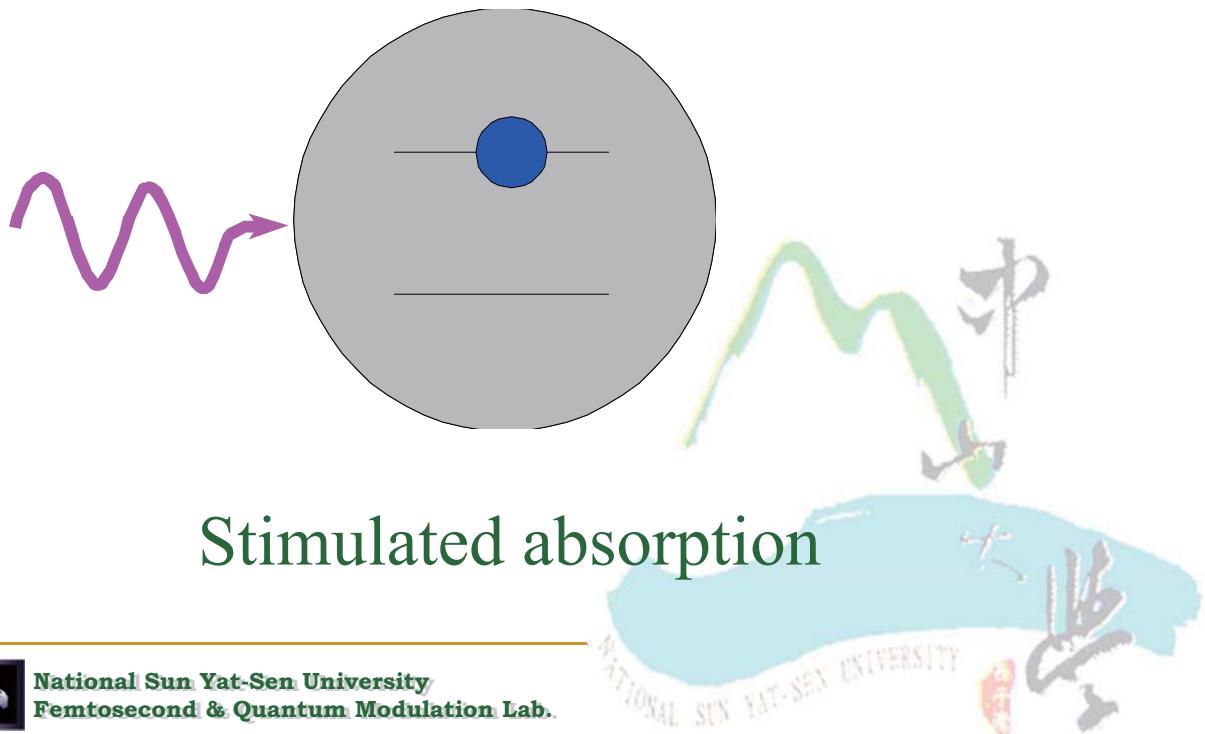
“Excited State”



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Femtosecond & Quantum Modulation Lab.

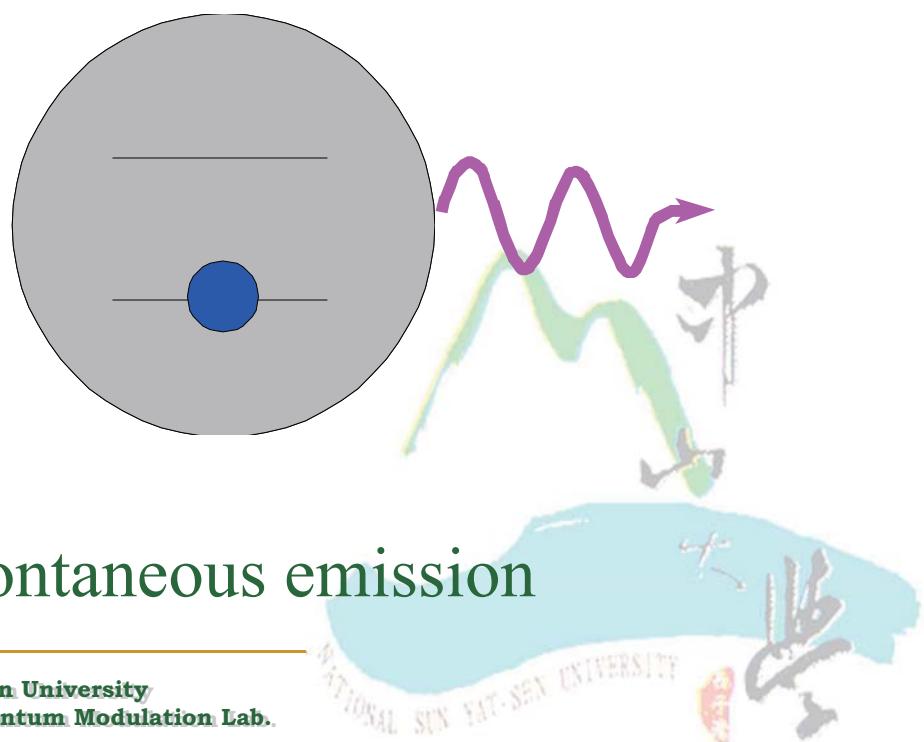


# Three Atomic Processes



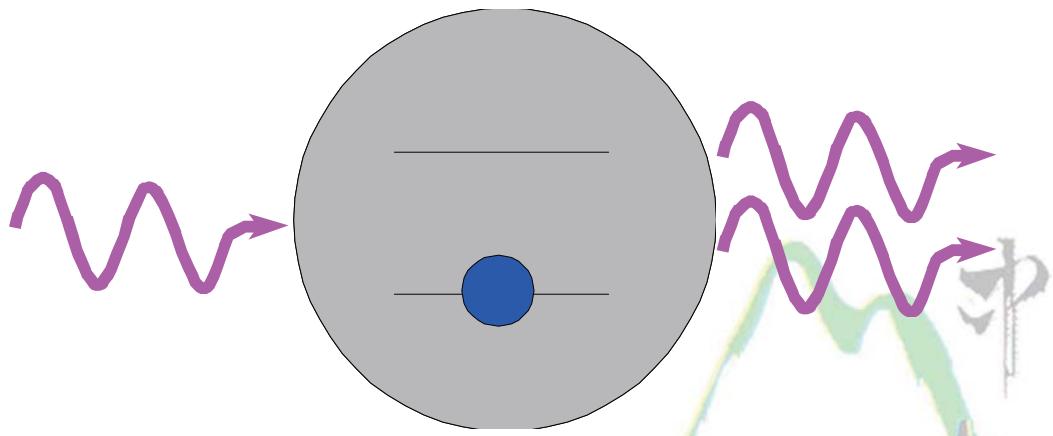
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# Three Atomic Processes



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# Three Atomic Processes



Stimulated emission



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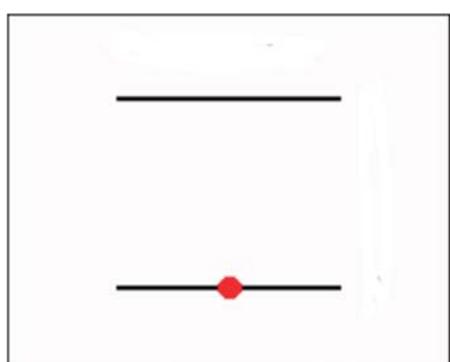


## Two types of emission processes

Absorption

&

Spontaneous  
Emission

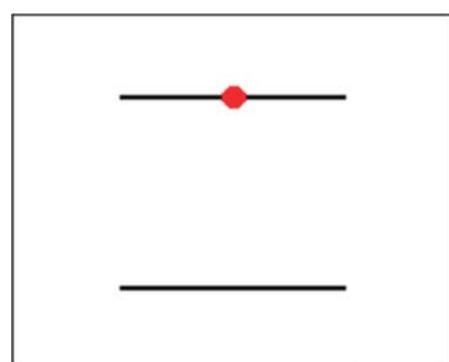


Two-level  
System

Absorption

&

Stimulated Emission



Laser light results from stimulated emission



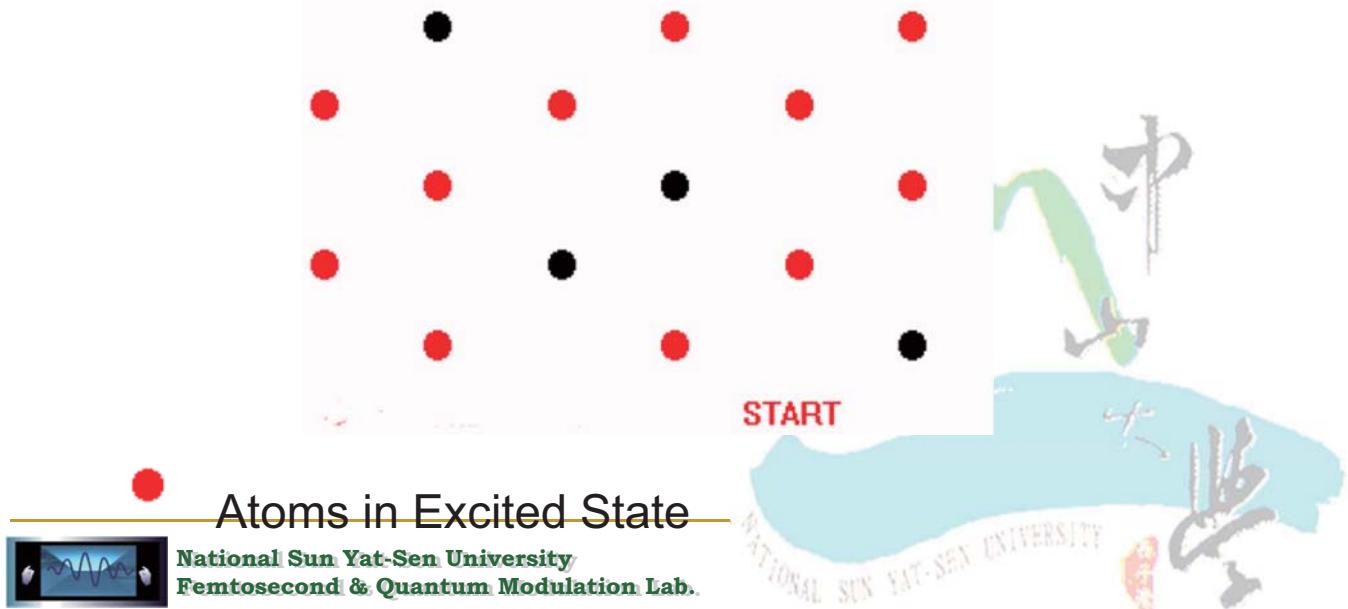
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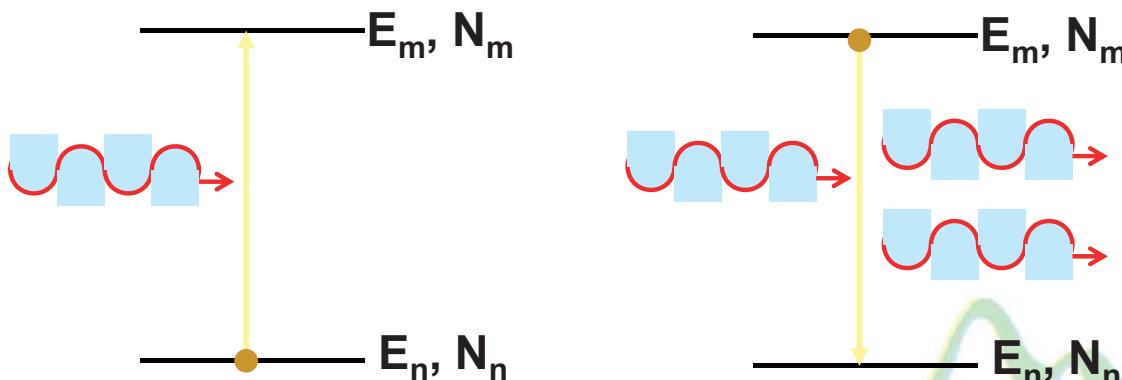


# A “Photon Slide”

## Photons in the Laser Environment



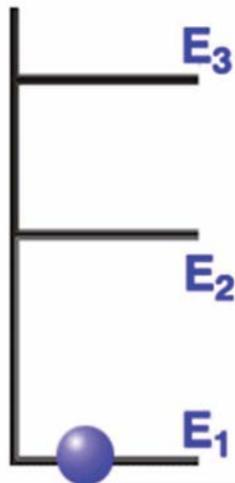
## Two Level System



Even with very a intense pump source, the best one can achieve with a two-level system is

**excited state population = ground state population**

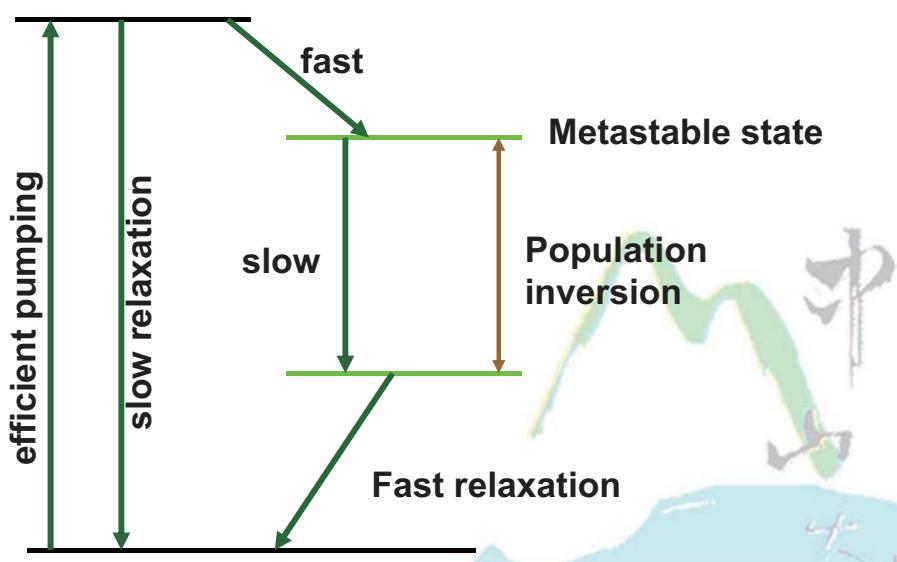
# Lasing in a 3-Level System



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## Lasing in a 4-level system

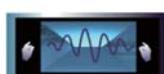


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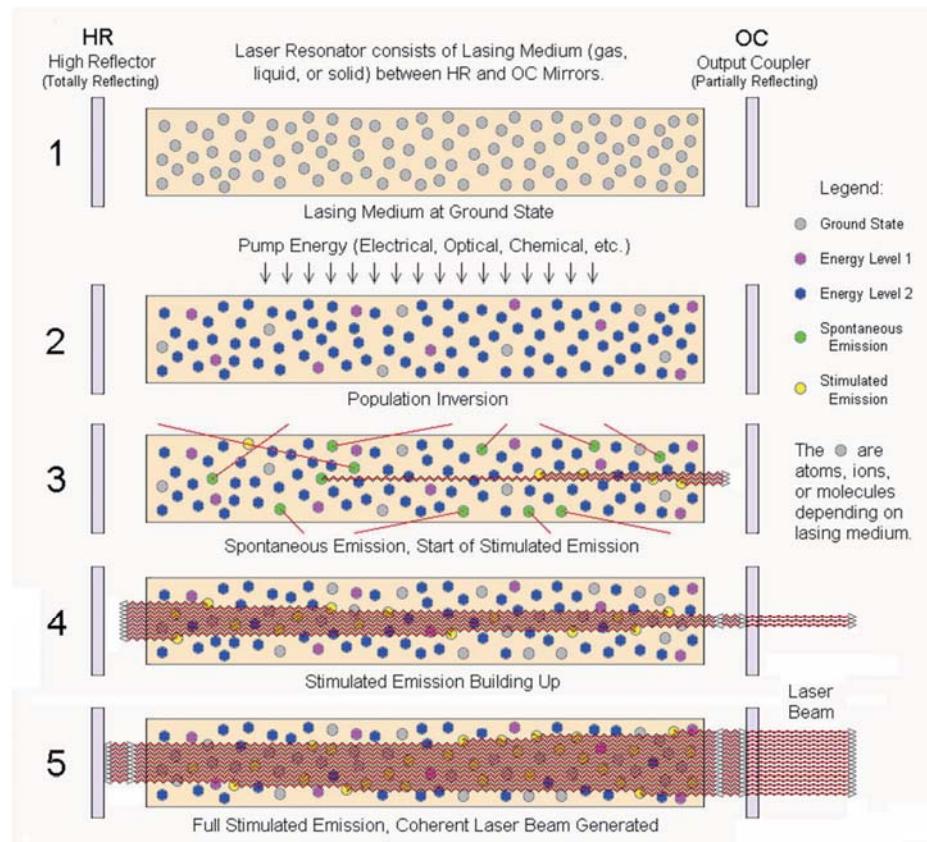


# The MASER(IV)-levels

- Two-level first.
- 1956, Basov and Prokhorov proposed in 3-level gas material
- 1956, Nicolas Bloembergen @ Harvard proposed 1st 3-level solid-state maser.
- Ali Jven also work in 3-level maser.



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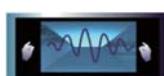
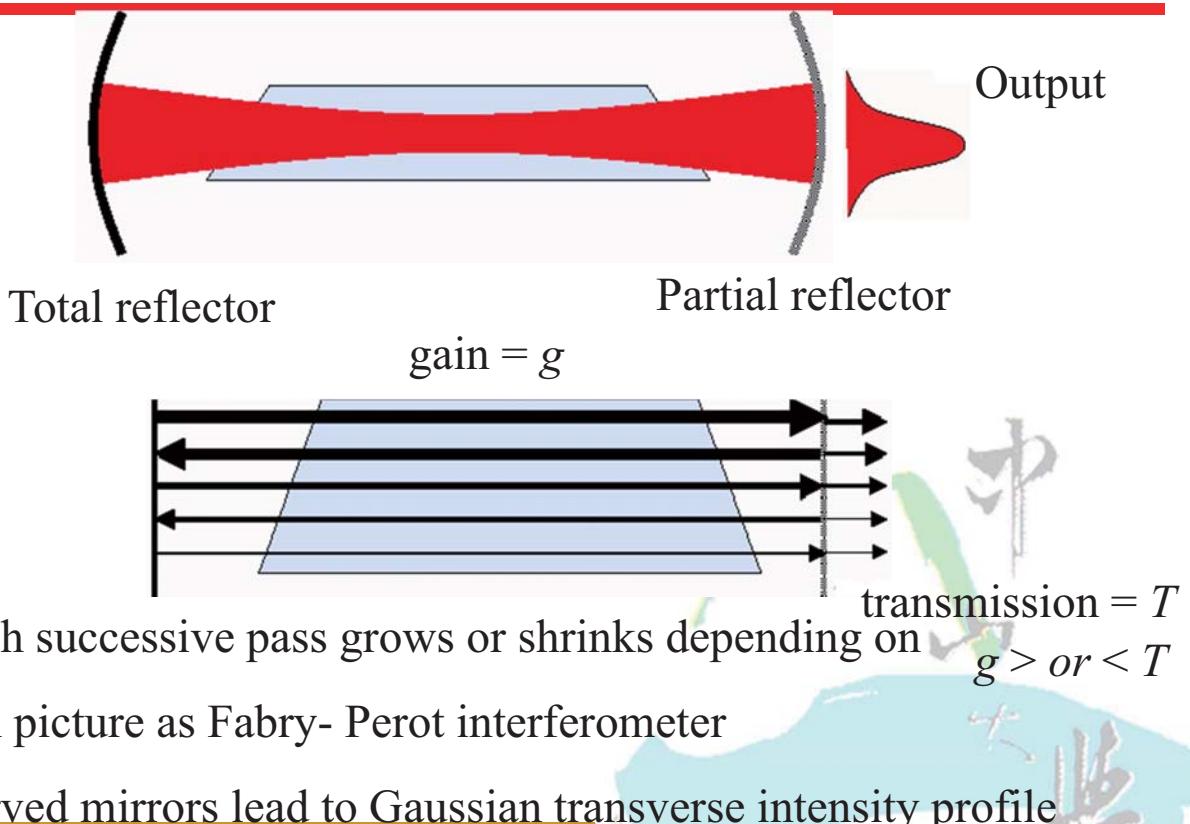
<http://www.phys.ksu.edu/perg/vqm/laserweb/Ch-3/F3s5p1.htm>



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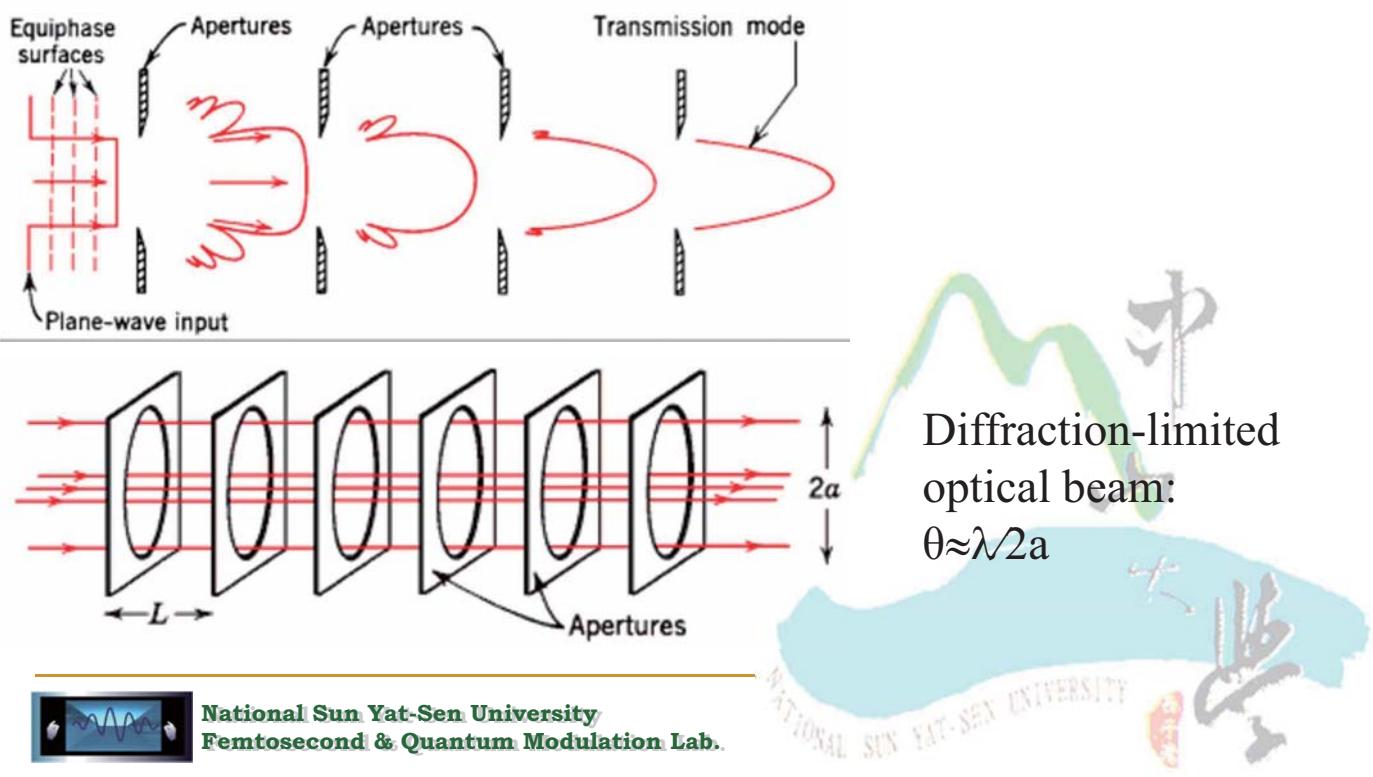


# Feedback in an Optical Cavity

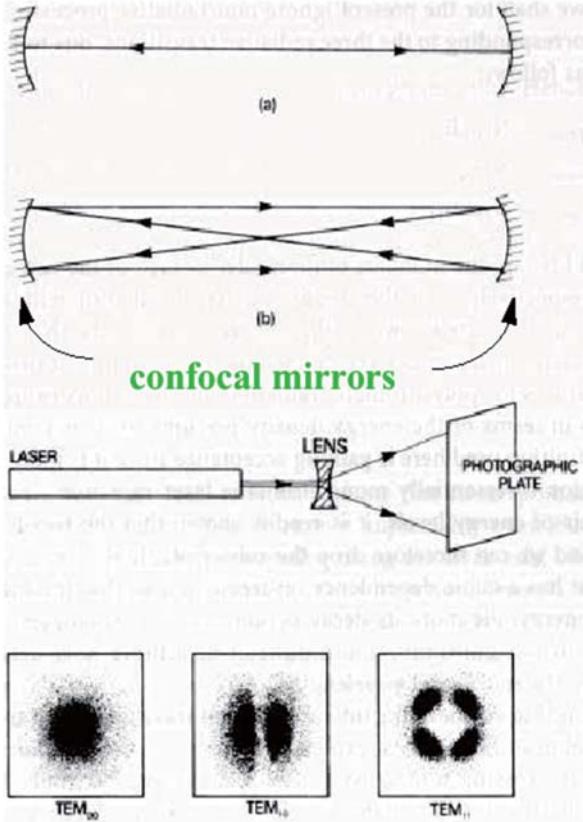


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## Optical Cavity and Directionality of the laser beam

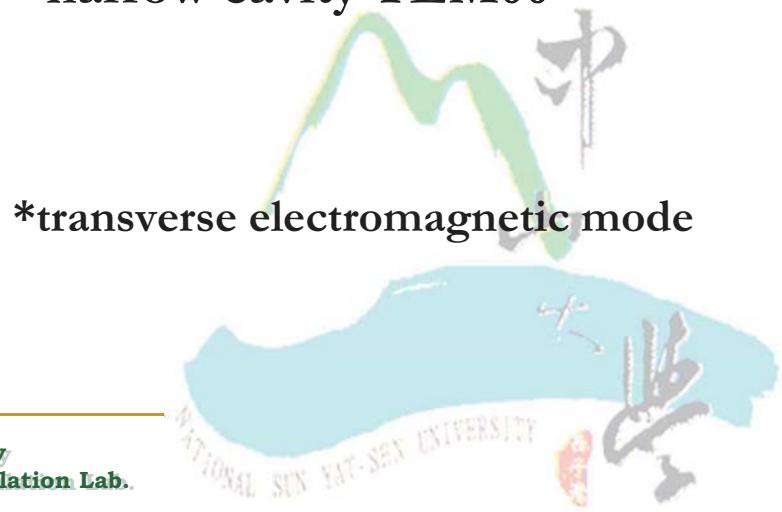


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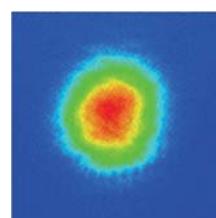
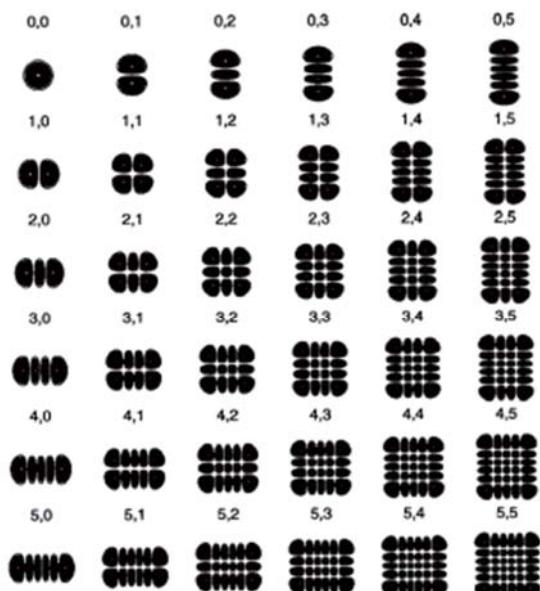


## TEM modes \*

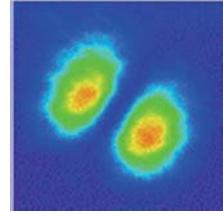
- a) on axis TEM00
- b) off axis TEM10
  - (TEM<sub>pq</sub>) confocal
  - p, q, # intensity min.
- multimode – less coherence
- narrow cavity TEM00



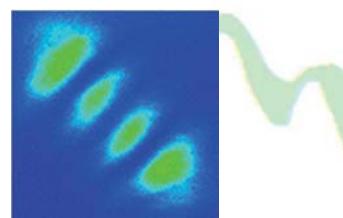
## Mode-Selection by the FP: Transverse Modes



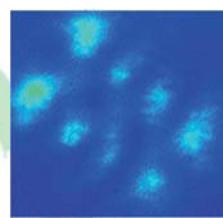
TEM00



TEM01



TEM03



TEM13

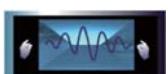
[http://www.iap.uni-bonn.de/lehre/ss01\\_laserphysics/optres.html](http://www.iap.uni-bonn.de/lehre/ss01_laserphysics/optres.html)



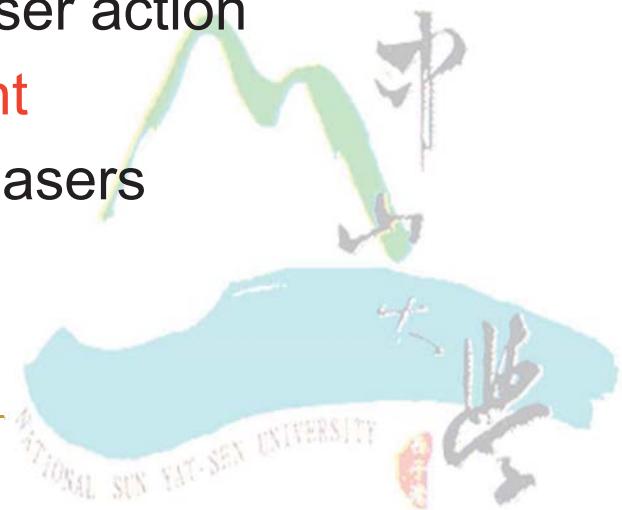
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Femtosecond & Quantum Modulation Lab.

# Outline

1. Laser Pioneers and the discovery of the laser
2. Ordinary light vs Laser Light
3. Basics principles of laser action
4. **Properties of laser light**
5. Examples of Typical Lasers



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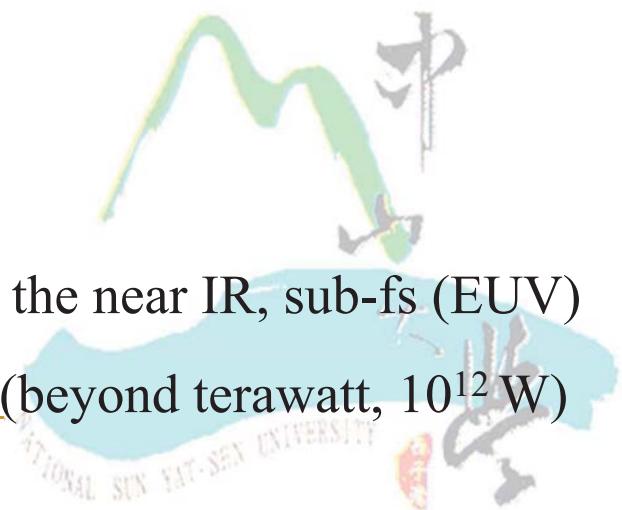


## What properties make lasers interesting/ useful?

- Compared to conventional “thermal” light source:
  - key difference is “coherence” of the laser output
  - highly correlated in space and time
- Spatial coherence
- Temporal coherence
- Extremely short pulses possible
  - $< 5$  fs ( $\sim$  one optical cycle) in the near IR, sub-fs (EUV)
- Extremely high power possible (beyond terawatt,  $10^{12}$  W)



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# Properties Of Laser Beams (I)

## Highly Monochromatic

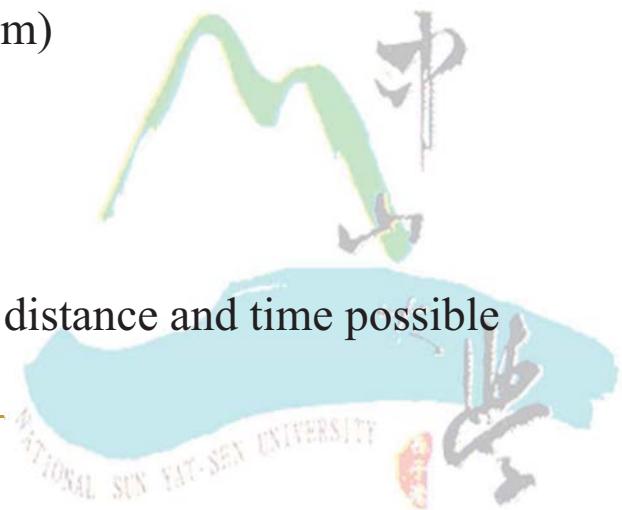
- Single-color output
- Narrow bandwidth:  $\Delta\nu/\nu_0 \sim 10^{-9}$  or even smaller
- Coherence time:  $\tau_c \sim \Delta\nu^{-1} \sim 1 \mu\text{s}$
- Coherent length :  $c \times \tau_c \sim 300 \text{ m}$ )

## Temporally coherent!

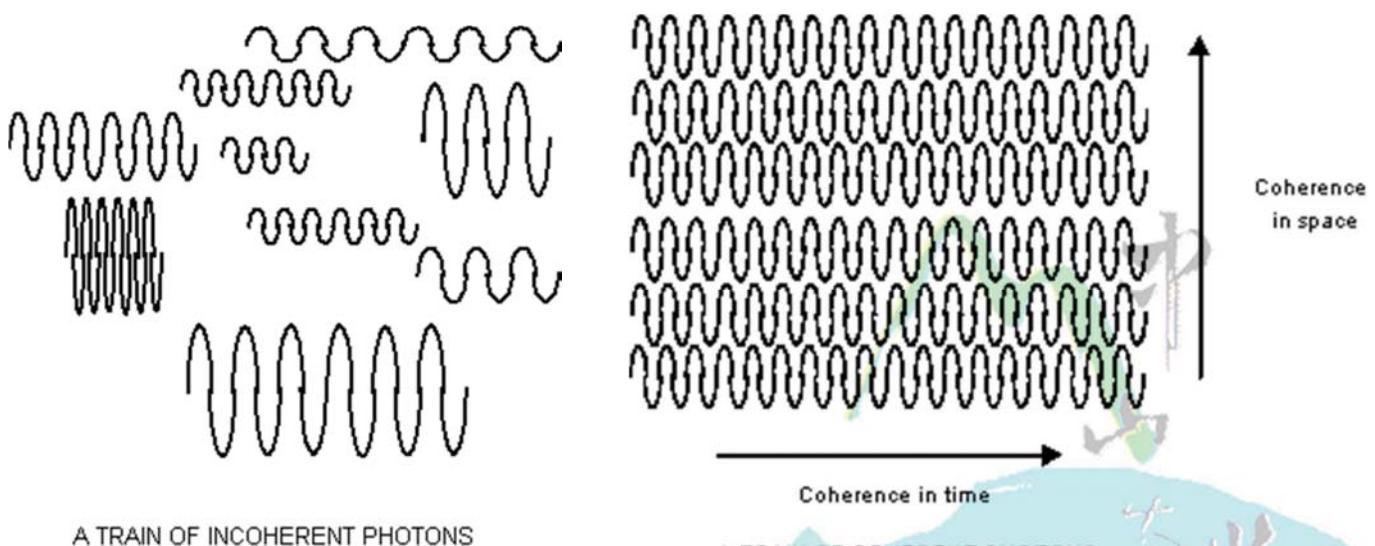
- nearly ideal sine wave
- very precise measurements of distance and time possible



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## Coherence



A TRAIN OF INCOHERENT PHOTONS

A TRAIN OF COHERENT PHOTONS



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# Properties of Laser Beams (II)

## Highly Directional

- Cavity provides feedback only along its axis.
- Diffraction-limited beam divergence:  $\theta_d \sim 1/D$

For a spot size  $D = 1$  mm,  $\theta_d \sim 0.03^\circ$ .

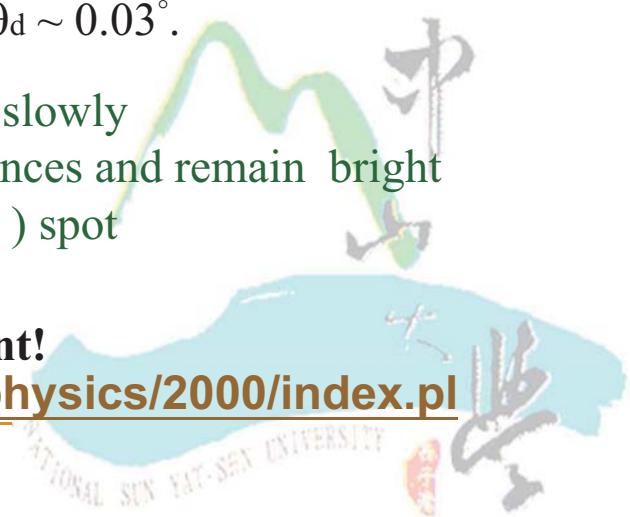
- laser beam diverges slowly
- propagate long distances and remain bright
- focus to small ( $\sim \lambda^2$ ) spot

Spatially Coherent!

<http://www.colorado.edu/physics/2000/index.pl>



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## Properties Of Laser Beams (III)

## Extremely Bright

- Brightness is defined as

$$B = \frac{\text{Power}}{\text{Area} \times \text{Solid} \cdot \text{Angle}}$$

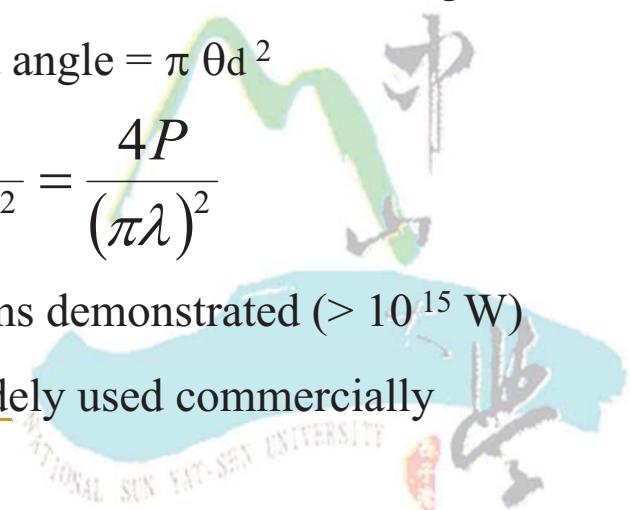
- For an optical beam of power  $P$ , diameter  $D$ , divergence,  $\theta_d$   
beam area =  $\pi D^2 / 4$ , solid angle =  $\pi \theta_d^2$

$$B = \frac{4P}{(\pi D \theta_d)^2} = \frac{4P}{(\pi \lambda)^2}$$

- petawatt peak power systems demonstrated ( $> 10^{15}$  W)
- kilowatt average power widely used commercially



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# Outline

1. Laser Pioneers and the discovery of the laser
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## Lasers: Big and Small Ones

National Ignition Facility  
1.8 MJ Nd:glass laser  
 $> \$10^9$



5 mW laser for CD player  
 $< \$0.50$



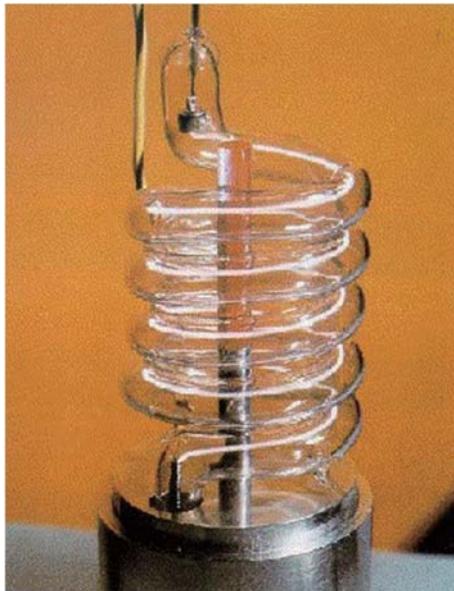
All operate on  
same general principles



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# Lasers: Big and Small Ones (II)



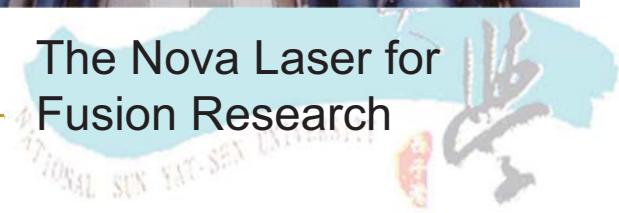
The 1st (Ruby) Laser



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The Nova Laser for  
Fusion Research



## Lasers: CW to Pulse



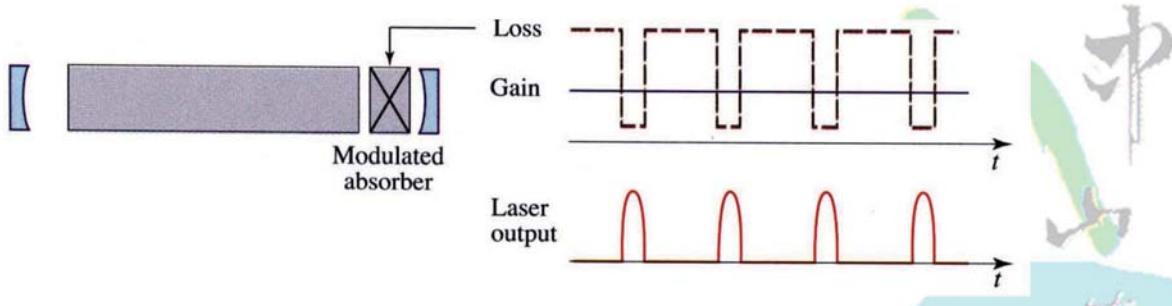
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# Lasers: CW to Pulse

## Methods of Pulsing Lasers

### Q-switching

Accumulating population difference during the high loss period,  
As Loss decreasing suddenly, the high power with short pulse duration releases  
due to the large accumulated population difference



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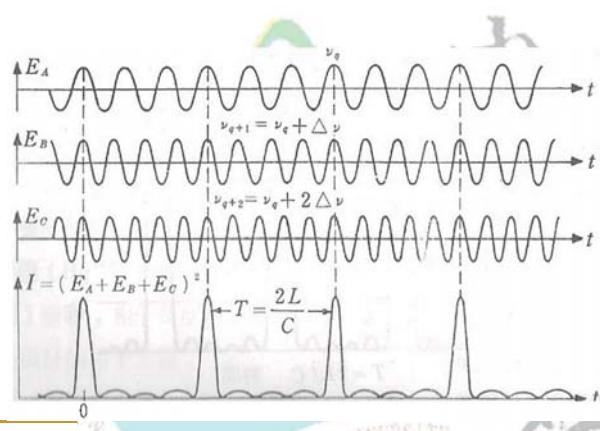
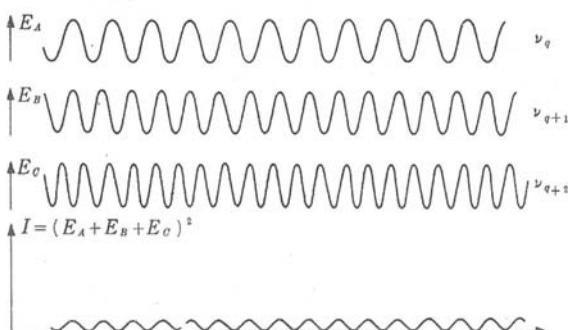
# Lasers: CW to Pulse

## Methods of Pulsing Lasers

### Mode Locking

For media with short lifetime, pulse operation with mode-locking

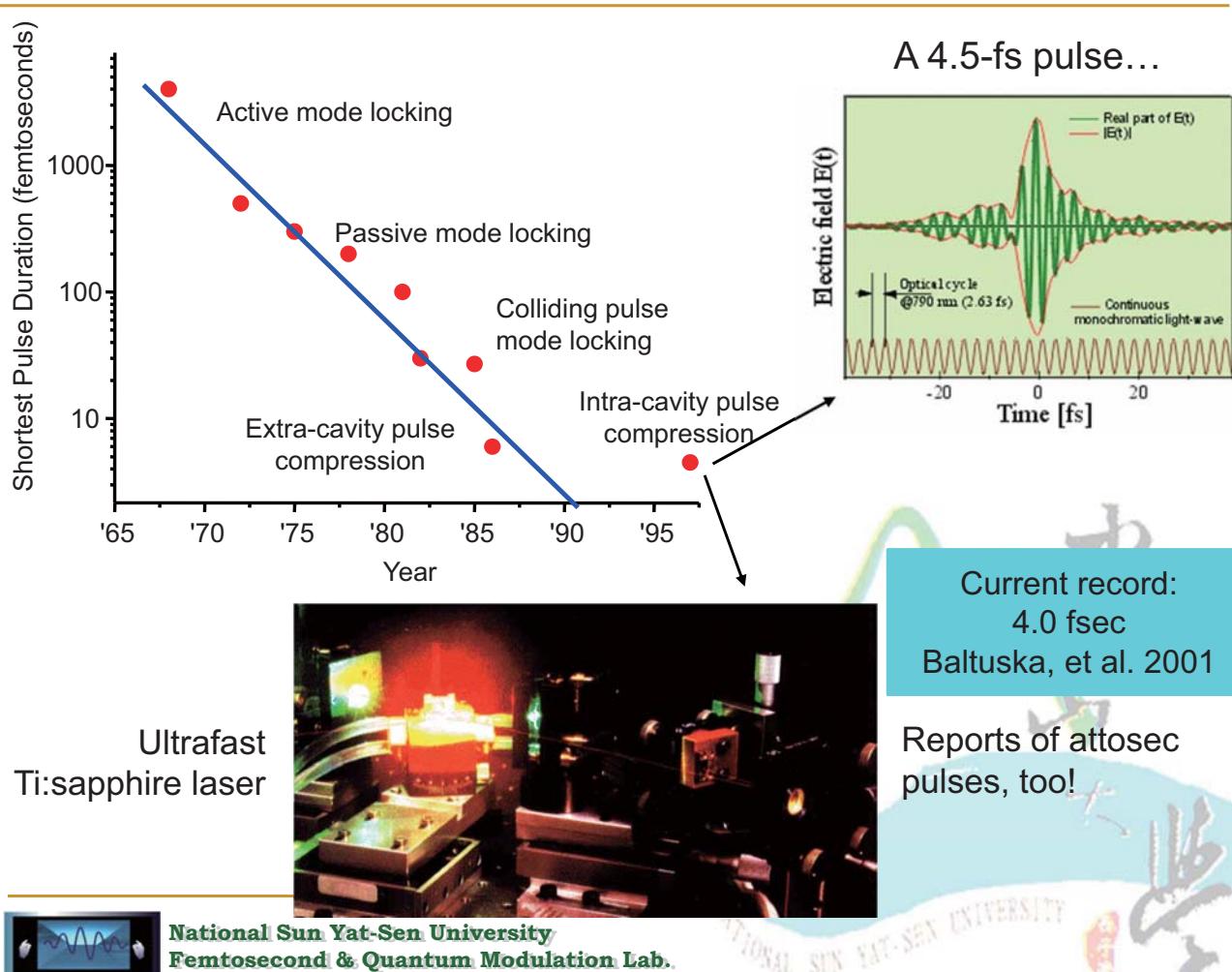
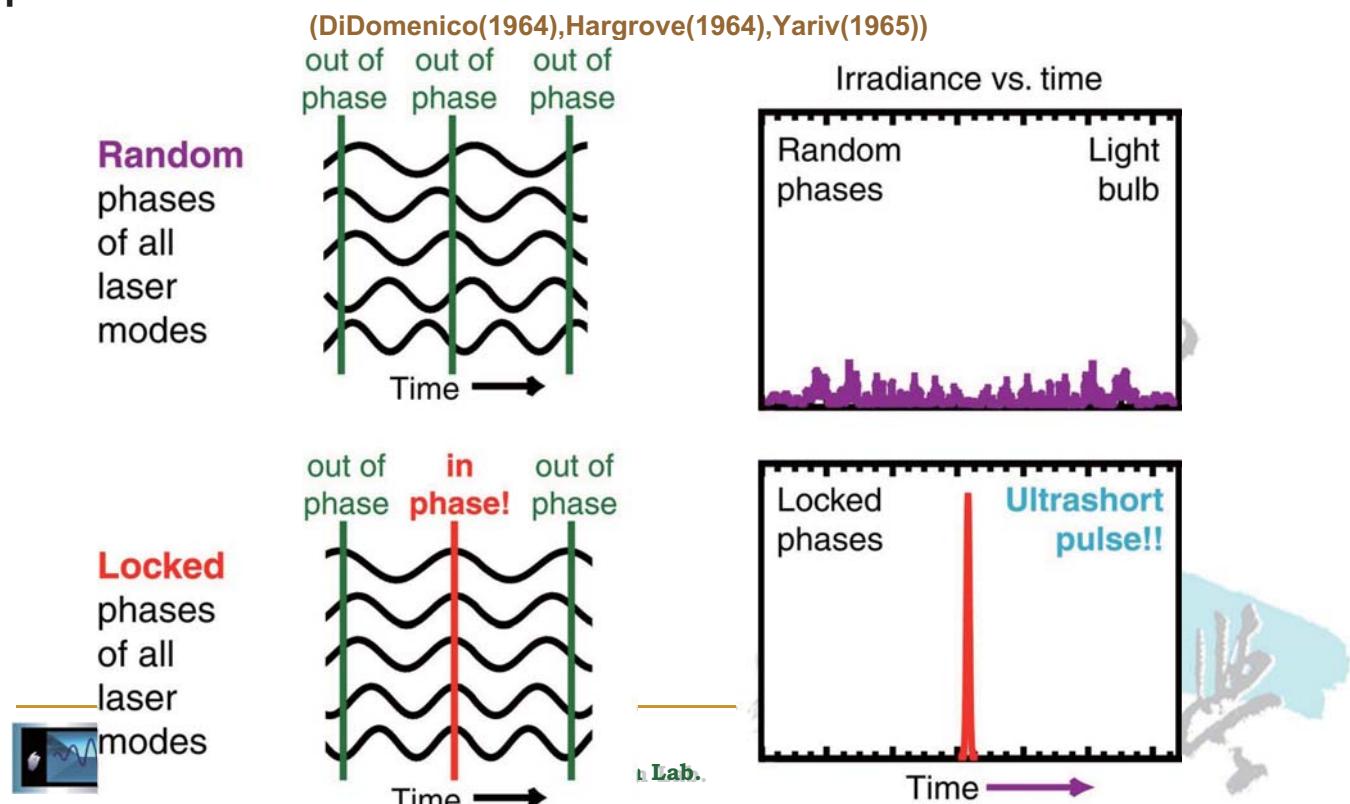
Definition: Phase lock the longitudinal modes



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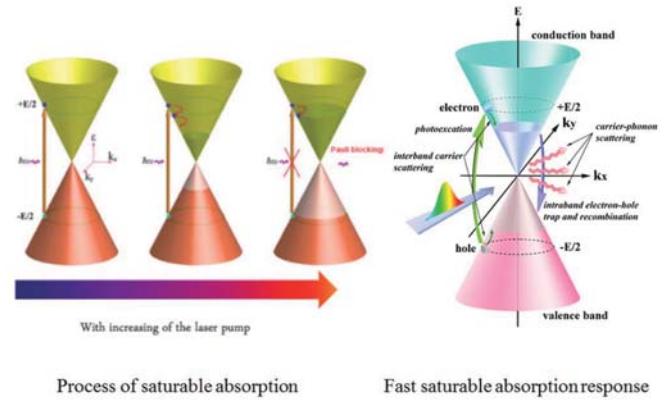
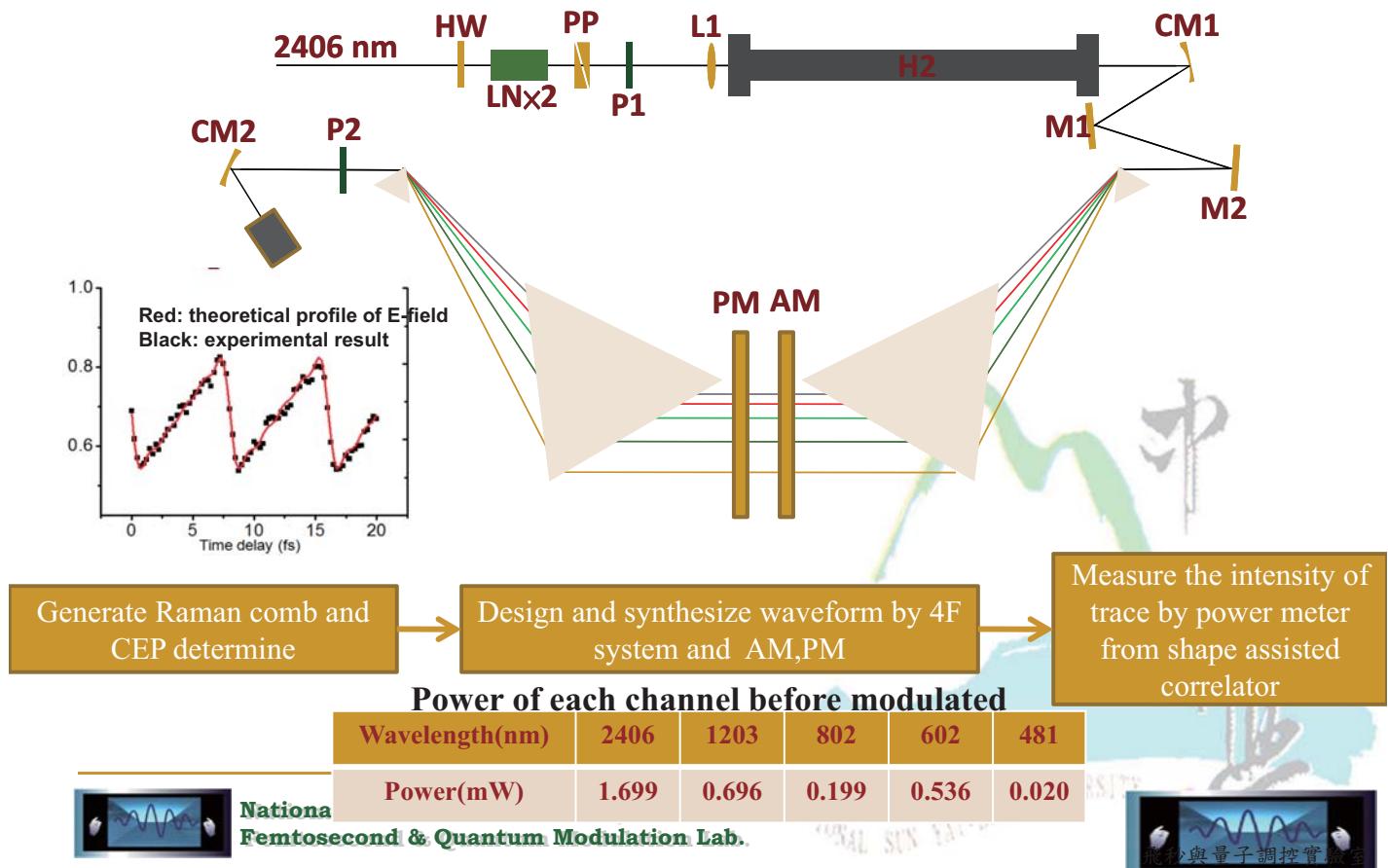
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## Locking the phases of the laser frequencies yields an ultrashort pulse.



# Exact E-field measurement of attosecond

Science 331, 1165 (2011)



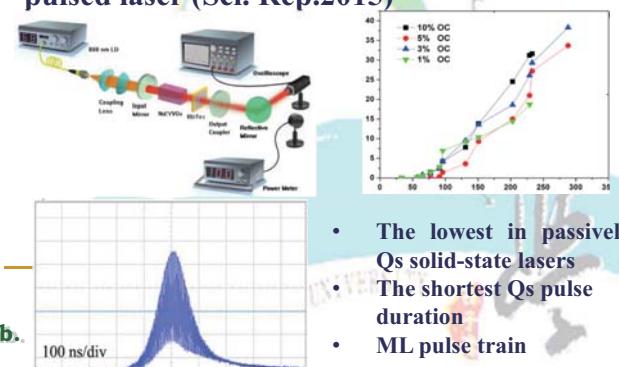
## Motivation

Compared with fiber lasers, solid-state bulk lasers have advantages of

- large mode areas
- high thermal conductivities
- low undesirable nonlinear effect

These make them more suitable for production of high-energy short pulses.

Sensitive saturable absorption response of large-size topological insulator and application in low-threshold solid-state pulsed laser (Sci. Rep. 2015)



# Types of Lasers : Classified by Gain Medium

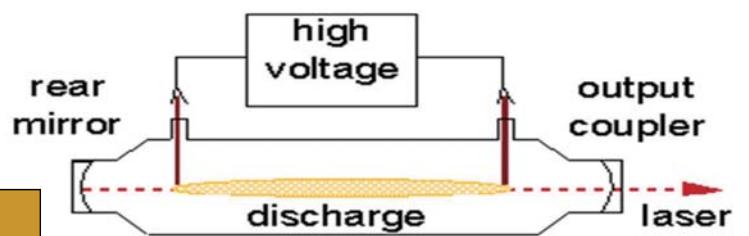
- Gas Lasers
- Dye Lasers
- Solid-state Lasers
- Semiconductor Diode Lasers
- Free Electron Lasers



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## Types of Lasers (I): Gas Lasers



### Excimer :

ArF\* - 248 nm,

XeCl\* - 308 nm (pulsed)

Nitrogen : 337 nm

(pulsed)(1963:1st UV laser)

He-Ne : 632.8 nm (cw) (1962;  
IR@1961)

Ar ion : 488, 541 nm(1964/CW)

CO<sub>2</sub> : 10.6 μm (1964) (cw or  
pulsed)

- electron impact excites atomic or molecular species
- low efficiency ( $10^{-4}$  typical), discrete wavelengths (UV – FIR)



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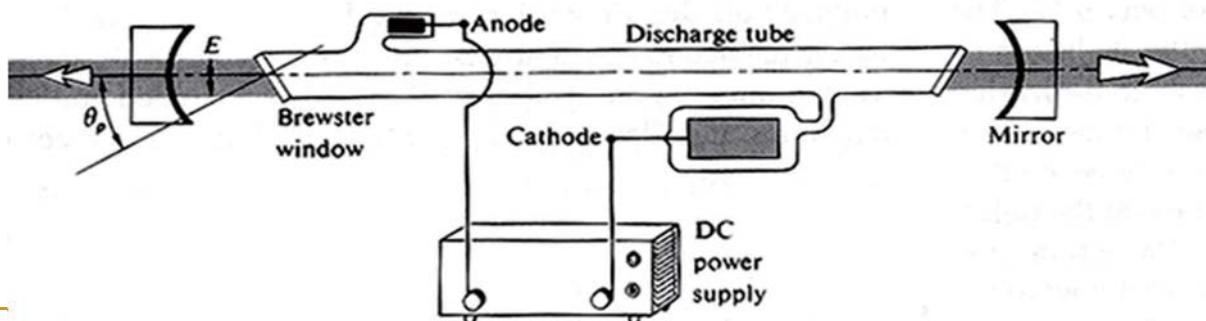
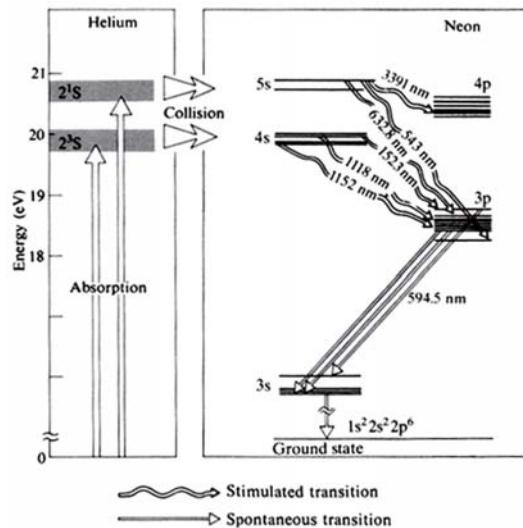


# The Helium-Neon Laser

“1st gas laser”

<http://phys.educ.ksu.edu/vqm/html/henelaser.html>

Energetic electrons in a glow discharge collide with and excite He atoms, which then collide with and transfer the excitation to Ne atoms, an ideal 4-level system.



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## Types of Lasers (II): Solid State Lasers

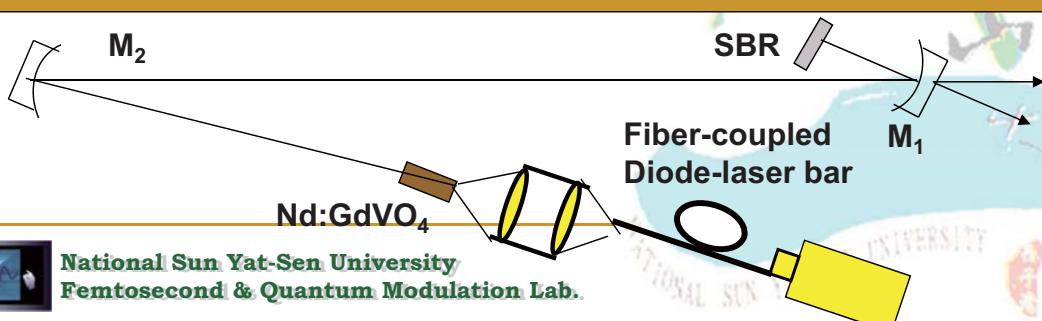
The gain medium in a solid-state laser is an impurity center (dopant) in a crystal or glass.

optical pumping (flashlamp, diode laser)

The first laser was a ruby crystal ( $\text{Cr}^{3+}$  in  $\text{Al}_2\text{O}_3$ ) that lased at 694 nm when pumped by a flashlamp

efficient, high power, often broadly tunable and/ or short pulses (typically NIR).

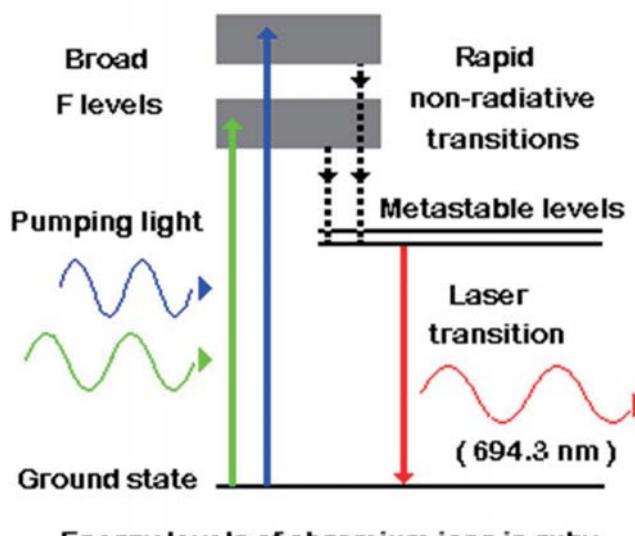
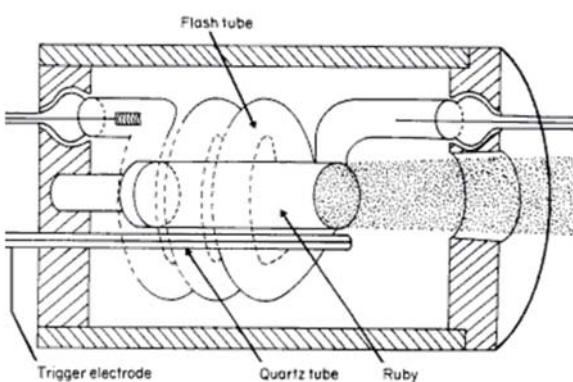
The most commonly used solid-state laser is one with  $\text{Nd}^{3+}$  in a  $\text{Y}_3\text{Al}_5\text{O}_8$  (YAG) or  $\text{YLiF}_4$  (YLF) crystal or in a glass.



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# Ruby : The 1<sup>st</sup> Laser



Theodore Harold Maiman

The Ruby Laser

U. S. Patent No. 3,353,115

<http://phys.educ.ksu.edu/vqm/html/rubylaser.html>



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Femtosecond & Quantum Modulation Lab.



## Types of Lasers (II): Dye Lasers

The gain medium in a dye laser is an organic dye molecule that is dissolved in a solvent.

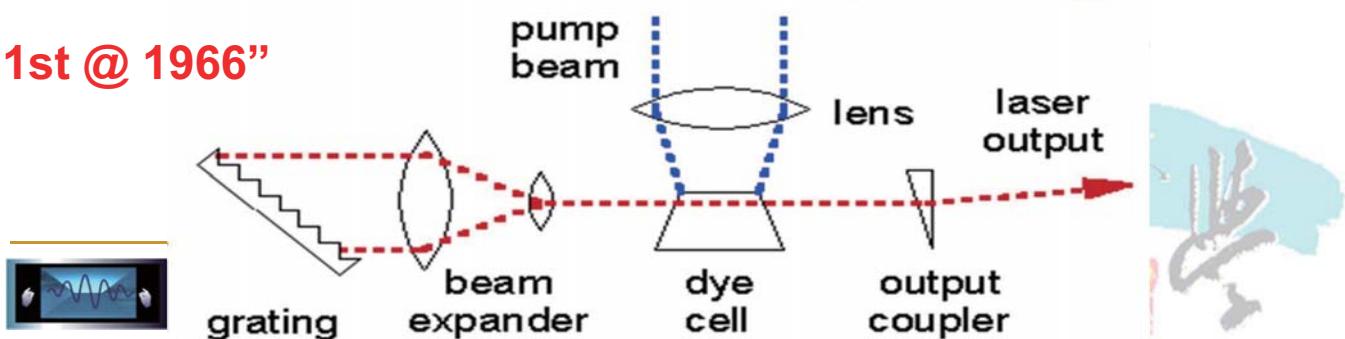
The dye and solvent are circulated through a cell or a jet, and the dye molecules are excited by flashlamps or other lasers.

Pulsed dye lasers use a cell and cw dye lasers typically use a jet.

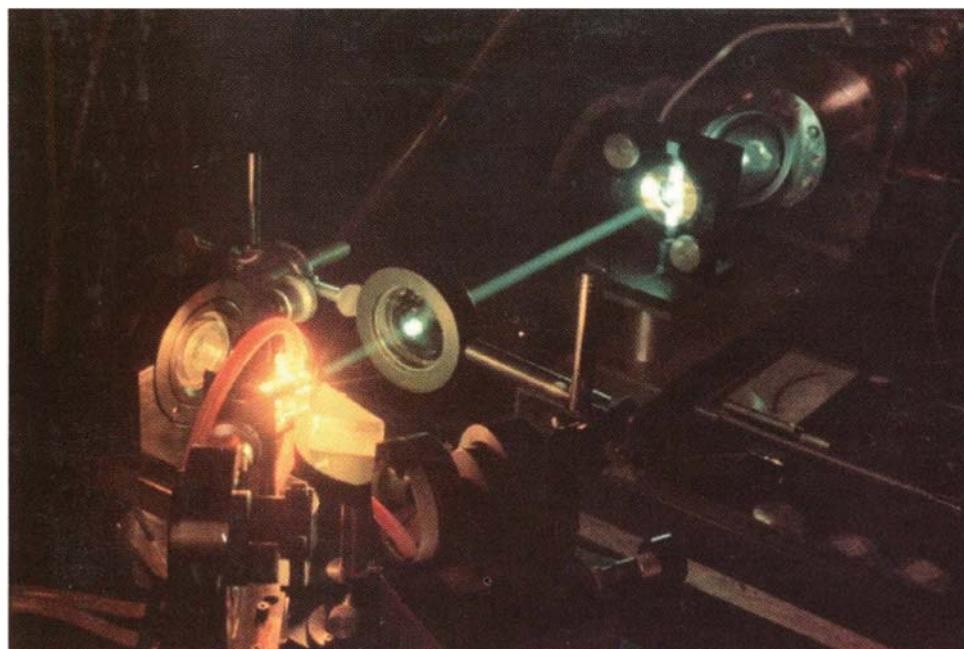
The organic dye molecules have broad fluorescence bands and dye lasers are typically tunable over 30 to 80 nm.

Dyes exist to cover the near-uv to near-infrared spectral region:  
330 - 1020 nm.

"1st @ 1966"



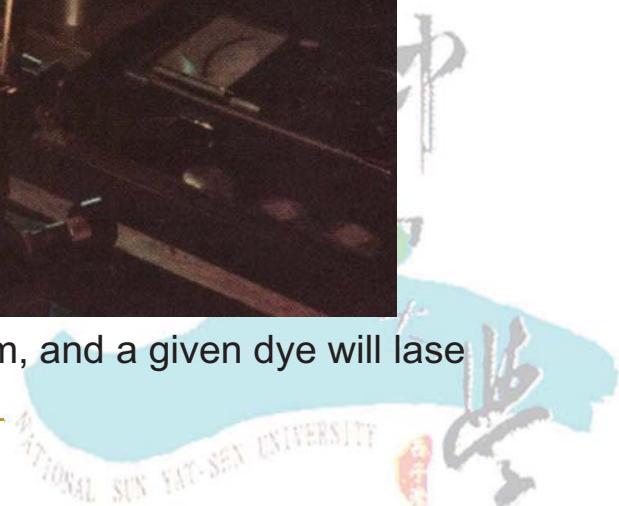
# Dye lasers



Dye lasers are an ideal four-level system, and a given dye will lase over a range of  $\sim 100$  nm.



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Femtosecond & Quantum Modulation Lab.



## Types of Lasers (III): Semicon. Lasers

Semiconductor lasers are light-emitting diodes within a resonator cavity that is formed either on the surfaces of the diode or externally.

An electric current passing through the diode produces light emission when electrons and holes recombine at the p-n junction.

Because of the small size of the active medium, the laser output is very divergent and requires special optics to produce a good beam shape.

These lasers are used in optical-fiber communications, CD players, and in high-resolution molecular spectroscopy in the near-infrared.

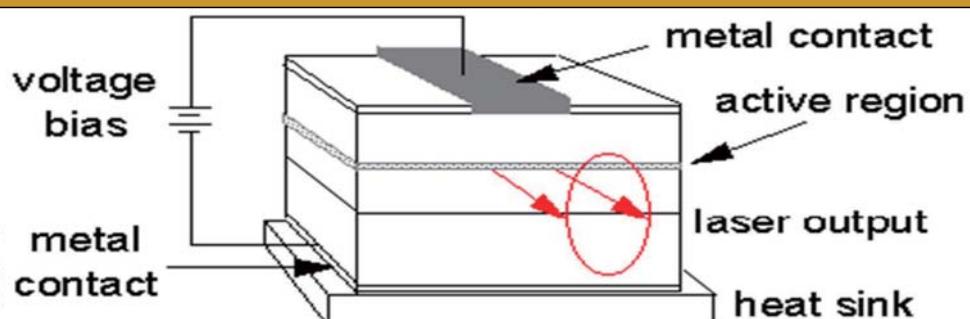
Diode laser arrays can replace flashlamps to efficiently pump solid-state lasers.

Diode lasers are tunable over a narrow range and different semiconductor materials are used to make lasers at 680, 800, 1300, and 1500 nm.

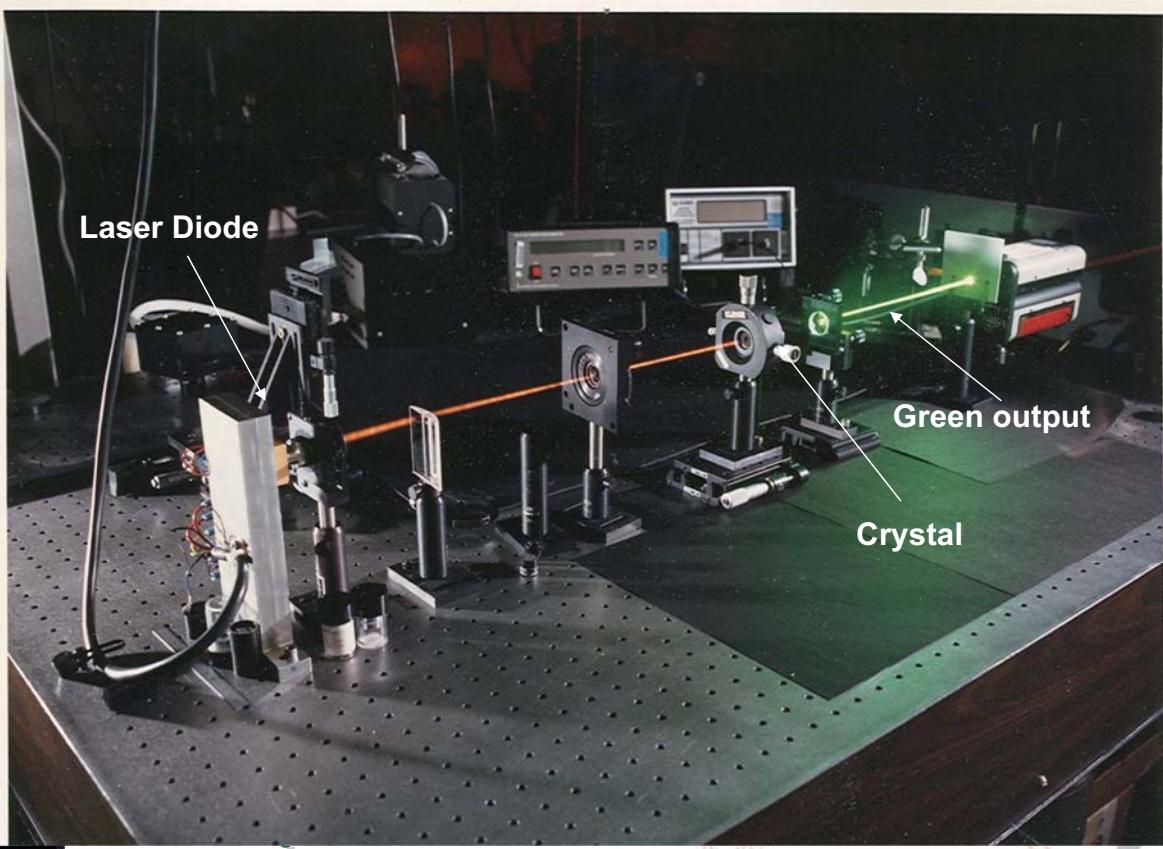
**"1st @ 1962"**



National S  
Femtosec



# DIODE PUMPED GREEN LASER



## Laser History in Taiwan

- 1963 年完成裝設國內第一部紅寶石(Ruby)雷射並測試成功(溫鼎勳、G. C. Dalman 教授)
- 1965 年建立國內第一氣體雷射製作設備及雷射實驗室(溫鼎勳、王興宗教授及王兆振博士)
- 1966 年自製成功國內首部氦氖(He-Ne)紅光氣體雷射(王興宗、溫鼎勳教授及王兆振博士)

1965年交大校友會訊“自由中國  
第一個自製的氣體雷射，已於七  
月二十九日.....”



# Laser History in Taiwan

- 1967 年完成測試低溫操作之砷化鎵(GaAs)半導體雷射(王興宗教授及研究生)/自製成功二氧化碳氣體雷射(王興宗教授、黃振中校友及碩士研究生)
- 1972 年國內第一部連續輸出二氧化碳雷射(黃廣志教授)
- 1974 年自製脈衝輸出二氧化碳雷射及展示雷射鑽孔(許根玉、許勝隆、黃廣志教授)



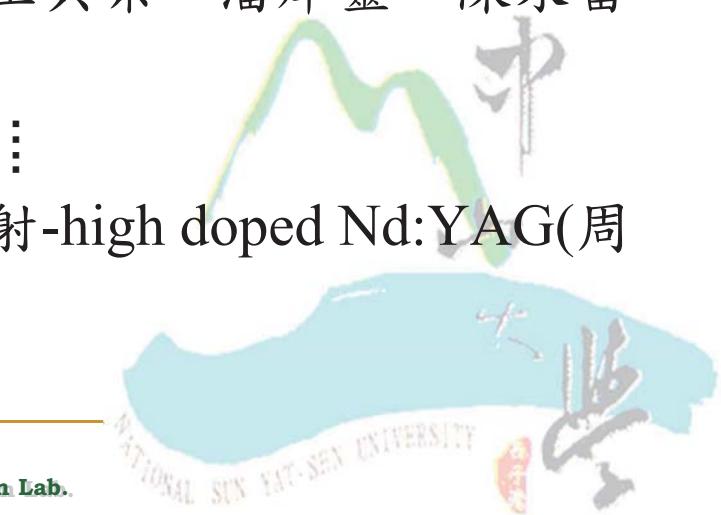
# Laser History in Taiwan

- 1977 年自製連續波輸出氬離子雷射成功(吳光雄、黃廣志教授)
- 1978 年自製脈衝式輸出氬離子雷射(許根玉、鄭有岩、吳光雄、黃廣志教授)
- 呂助增、施宙聰、劉海北、.....



# Laser History in Taiwan

- 1989 年自行裝設連續輸出鈦藍寶石雷射/飛秒級碰撞鎖模染料雷射（吳光雄、潘犀靈教授）
- 1995 年研發半導體雷射激發式固態雷射產生高功率綠色雷射光（王興宗、潘犀靈、陳永富教授）
- 2015 年自製全固態雷射-high doped Nd:YAG(周明奇、李晁達)



National Sun Yat-Sen University  
Femtosecond & Quantum Modulation Lab.

## Lasers: Light Extraordinary!



Laser machining



Barcode Scanner



Laser Surgery



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Picture courtesy of Fiorenzo Omenetto

# Laser Applications

Laser light shows

Art restoration

Laser Surgery

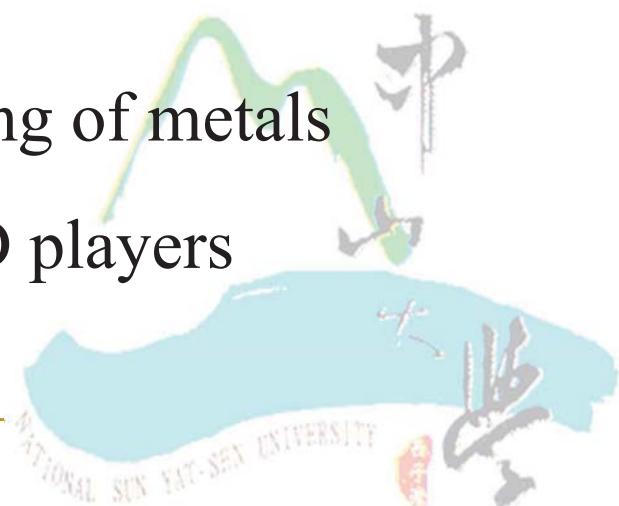
Cutting, welding, drilling of metals

Compact disc and DVD players

Dental cavity-finders



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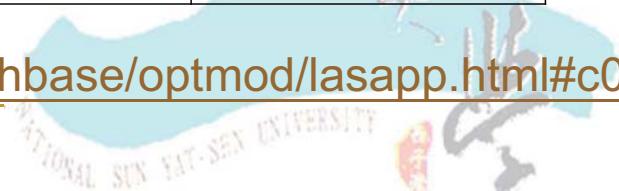
# Laser Applications

|                             |                              |                      |
|-----------------------------|------------------------------|----------------------|
| <u>Medical applications</u> | <u>Welding and Cutting</u>   | <u>Surveying</u>     |
| <u>Garment industry</u>     | <u>Laser nuclear fusion</u>  | <u>Communication</u> |
| <u>Laser printing</u>       | <u>CDs and optical discs</u> | <u>Spectroscopy</u>  |
| <u>Heat treatment</u>       | <u>Barcode scanners</u>      | <u>Laser cooling</u> |

<http://hyperphysics.phy-astr.gsu.edu/hbase/optmod/latapp.html#c0>



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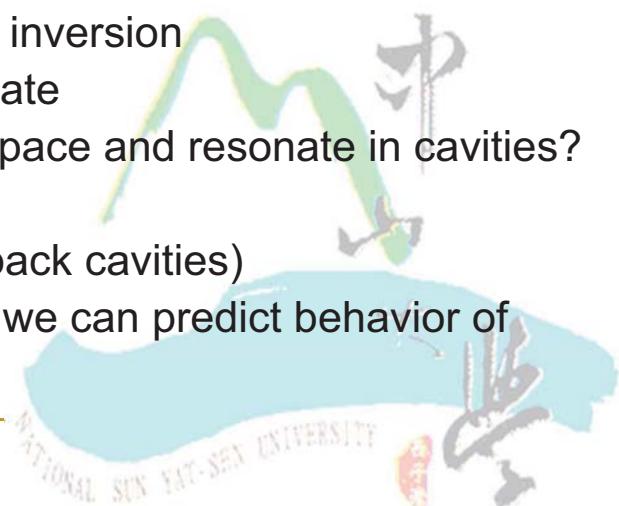


# What you should learn about lasers

- How does radiation interact with matter?
  - absorption and emission
  - stimulated and spontaneous events
  - conditions for amplification rather than absorption
- How do we prepare system to obtain gain?
  - dynamics of evolution of population between energy levels
  - pumping to obtain population inversion
  - saturation to reach steady- state
- How do EM waves propagate in space and resonate in cavities?
  - gaussian beams
  - interferometers (optical feedback cavities)
- Combining these basic elements, we can predict behavior of laser oscillators and amplifiers



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Femtosecond & Quantum Modulation Lab.



## Summary

- Lasers are among the most important inventions of the 20th century.
- Lasers are versatile tools for basic studies in science as well as day to day applications.
- Understanding the operation principles and properties of laser beams are important for photonics professionals.



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Femtosecond & Quantum Modulation Lab.





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Femtosecond & Quantum Modulation Lab.

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# 光電科技發展史 History of Photonics

劉容生

國立清華大學

Yung-sheng Liu (Professor Emeritus)

National Tsing Hua University

Hsinchu, Taiwan

Oct 24, 2015

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# Light Optics Photonics

# 光 光學 光電

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## 創世的第一天就有了光!

“起初神創造天地。地是空虛混沌，淵面黑暗。神的靈運行在水面上。**神說、要有光、就有了光。**神看光是好的，就把光暗分開了。神稱光為晝，稱暗為夜。有晚上、有早晨，這是頭一日。”

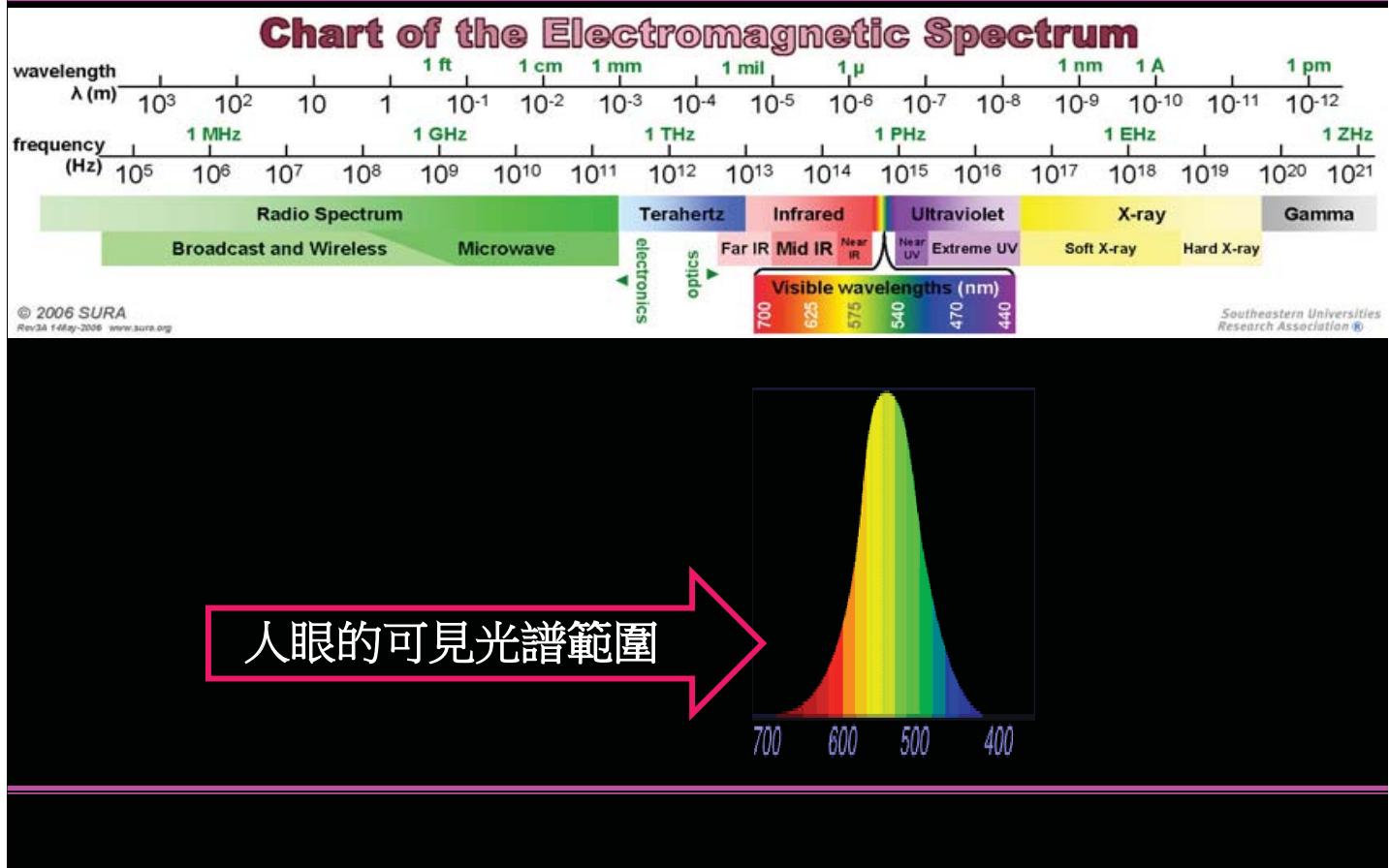
... 聖經，創世紀 (Genesis)

*In the beginning God created the heaven and the earth. At the first God made the heaven and the earth. And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters. And the earth was waste and without form; and it was dark on the face of the deep: and the Spirit of God was moving on the face of the waters. And God said, Let there be light: and there was light. And God said, Let there be light: and there was light. And God saw the light, that it was good: and God divided the light from the darkness. And God, looking on the light, saw that it was good: and God made a division between the light and the dark.*

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人眼的可見光譜範圍

## 光學的歷史

History of optics - From Wikipedia encyclopedia

- 光學和視覺 (~BC)
  - 古典光學 (~1600)
  - 近代光學 (~1900)
- The word *optics* is derived from the Greek “*τὰ ὄπτικά*” which refers to matters of *vision*. **Optics** began with the development of **lenses** by the ancient **Egyptians** (~750BC), followed by theories on light and vision developed by **Greek** (*Optics*, *Euclid*, c. 300 BC).
- Arab scholar, *Ibn al-Haytham*, published “*Book of Optics*” 1015.
- **Kepler** (1/1/1604) published as *Astronomiae Pars Optica* (*The Optical Part of Astronomy*), recognized as the foundation of modern optics (though the law of refraction is conspicuously absent). [22]
- Optics was significantly advanced in early modern Europe, where diffractive optics began, now known as "*classical optics*". And "*modern optics*" refers to areas of optical science and technology developed in the 20th century, which is referred as "*quantum optics*".



# 文藝復興及近代光學

## Renaissance and early modern optics

- **Snellius (1580–1626)** found the mathematical law of refraction, now known as Snell's law.
- **Huygens (1629–1695)** - Huygens' principle.
- **Newton (1643–1727)** - the refraction of light, demonstrated a prism could decompose white light into a spectrum of colours, known as Newton's theory of colour.
- In **Hypothesis of Light of 1675**, Newton proposed the existence of the ether to transmit forces between particles.
- In **1704, Newton published Opticks**, he expounded his corpuscular theory of light made up of extremely subtle corpuscles,
- **1803 Young** did double slit interferometer to explain the wave nature of light suggested by Hyugens.

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**World Year of Physics 2005**

Einstein in the 21st Century  
讓物理光耀世界

About WYP 2005 Projects Events Teachers International Press Room Downloads About Einstein

下載連線程式

The World Year of Physics 2005 is a United Nations endorsed, international celebration of physics. Events throughout the year will highlight the vitality of physics and its importance in the coming millennium, and will commemorate the pioneering contributions of Albert Einstein in 1905. Through the efforts of a worldwide collaboration of scientific societies, the World Year of Physics brings the excitement of physics to the public and will inspire a new generation of scientists.

News  
US House of Representatives Passes WYP Resolution

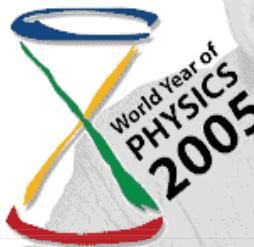
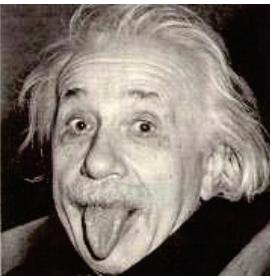
全球物理年 登入註冊手機密碼 挑戰愛因斯坦

Event Finder

Choose a state and/or date below to find World Year of Physics Events. You may also [submit an event](#).

All States All Dates  
 Include Nationwide Events

Find Events



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“100年前愛因斯坦對光電效應的闡釋及理論，揭開了近代量子物理的新頁，奠訂了現代量子光學的基礎，導引了20世紀光電科技璀璨的研發，進而帶動光電產業的蓬勃發展，徹底的改變了人類的生活 ... ”

- 劉容生- 科學人 “讓物理光耀世界”

“100 Years ago, Einstein developed the theory for the photo-electric effect which uncovered the modern quantum physics. The theory also lay the foundation of modern optics (coherent optics) and introduced the 20<sup>th</sup> century opto-electronics (photonics), that brought forth the huge optoelectronics industry which totally changed the life of modern world.”

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# 光電科技發展史 History of Photonics

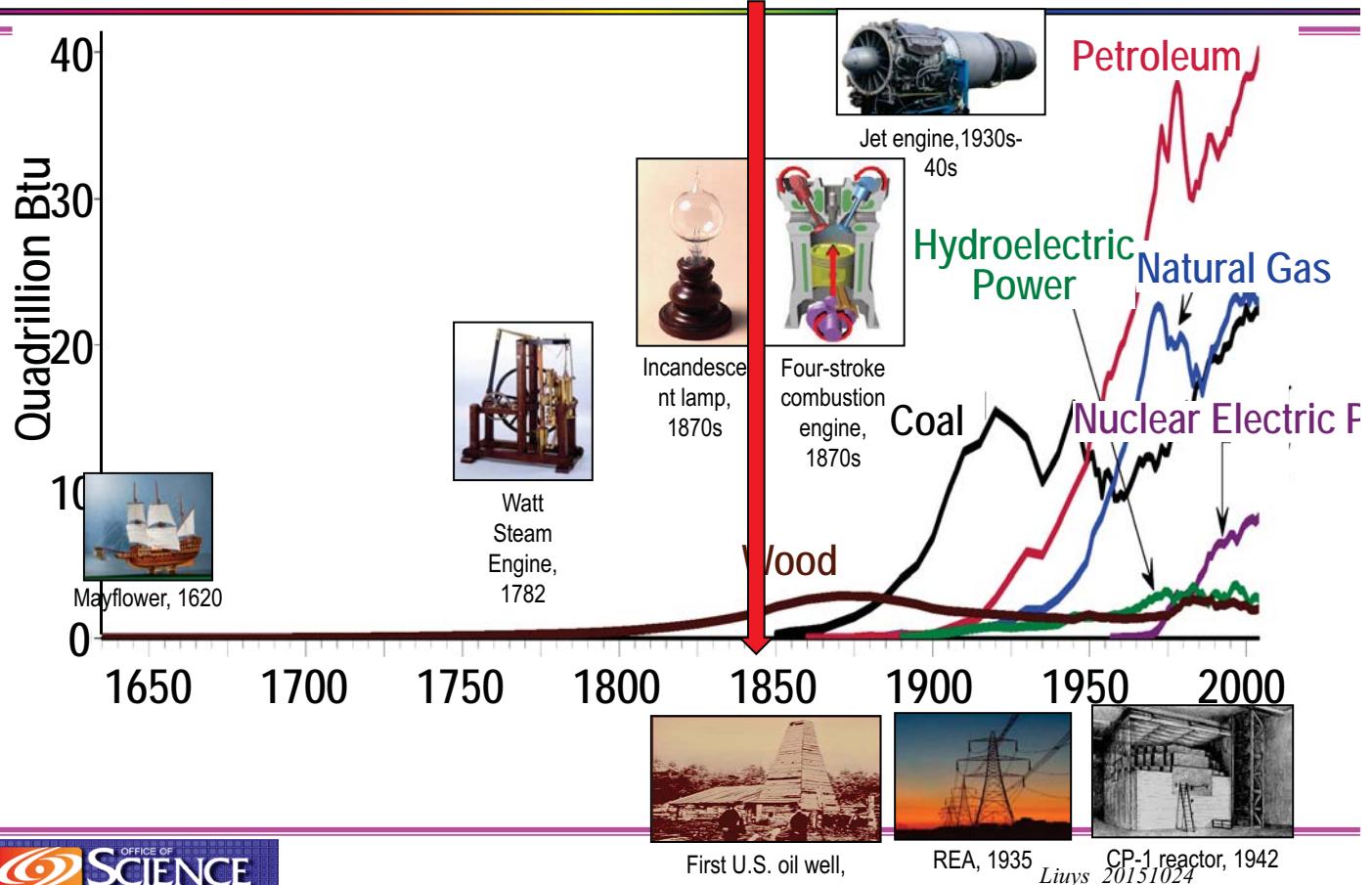
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## 17世紀以來人類 能源消耗的成長





# 五個故事

1. 愛迪生 ... (Thomas Edison, ~1880)
2. 愛因斯坦 ... (Albert Einstein, ~1890)
3. 肖洛、湯斯 .. (Arthur Schawlow & Charles Townes, ~1960)
4. 高錕 ... (Charles Kao, ~1970)
5. 中村修二 ... (Shuji Nakamura, ~1990)

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## 光電科技的主要里程碑 Major Milestones in Photonics

1. 愛迪生發明電燈炮  
(Edison's Invention of light bulbs ~1880)
2. 愛因斯坦的光電效應  
(Einstein's Discovery of Photo-electric Effect, ~1890)
3. 相干光輻射的發明  
(Invention of Coherent Radiation, LASER ~1960)
4. 光纖通訊的發明  
(Invention of fiber optics communication, ~1970)
4. 高亮度藍光/白光LED的發明  
(Invention of High Brightness White LED, ~1990)

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# 發明 vs 發現

# Discovery vs Invention

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附註：清楚了解每一個主要字的意義。

Milestone; 名詞 - 里程碑, landmark

Coherent; 形容詞-

- 相干
- 連貫 Coherent, consistent
- 通 Through, common, open, coherent, all, logical
- 接氣 Coherent, consistent

From Webster Online Dictionary:

**Co·her·ent;** *adjective \kō-\'hir-ənt, -'her-\'*

**Definition of COHERENT**

- 1 . *a:* logically ordered or integrated : consistent <*coherent style*> <a *coherent argument*>
- *b:* having clarity or intelligibility : understandable <a *coherent person*> <a *coherent passage*>
- 2 : having the quality of holding together or cohering; especially: cohesive, coordinated <a *coherent plan for action*>

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## 光電科技的主要里程碑 Major Milestones in Photonics

1. 愛迪生發明電燈炮  
(Invention of light bulbs ~1880)
2. 愛因斯坦的光電效應  
(Einstein's Photo-electric Effect, ~1890)
3. 相干光幅射的發明  
(Invention of Coherent Radiation, LASER ~1960)
4. 光纖通訊的發明  
(Invention of fiber optics communication, ~1970)
4. 高亮度藍光/白光LED的發明  
(Invention of High Brightness White LED, ~1990)

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## 光電科技的主要里程碑 Major Milestones in Photonics

- ### 1. 愛迪生發明電燈炮 (Invention of light bulbs ~1880)

電與光

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# 照明的一百多年發展史 - History of Lighting

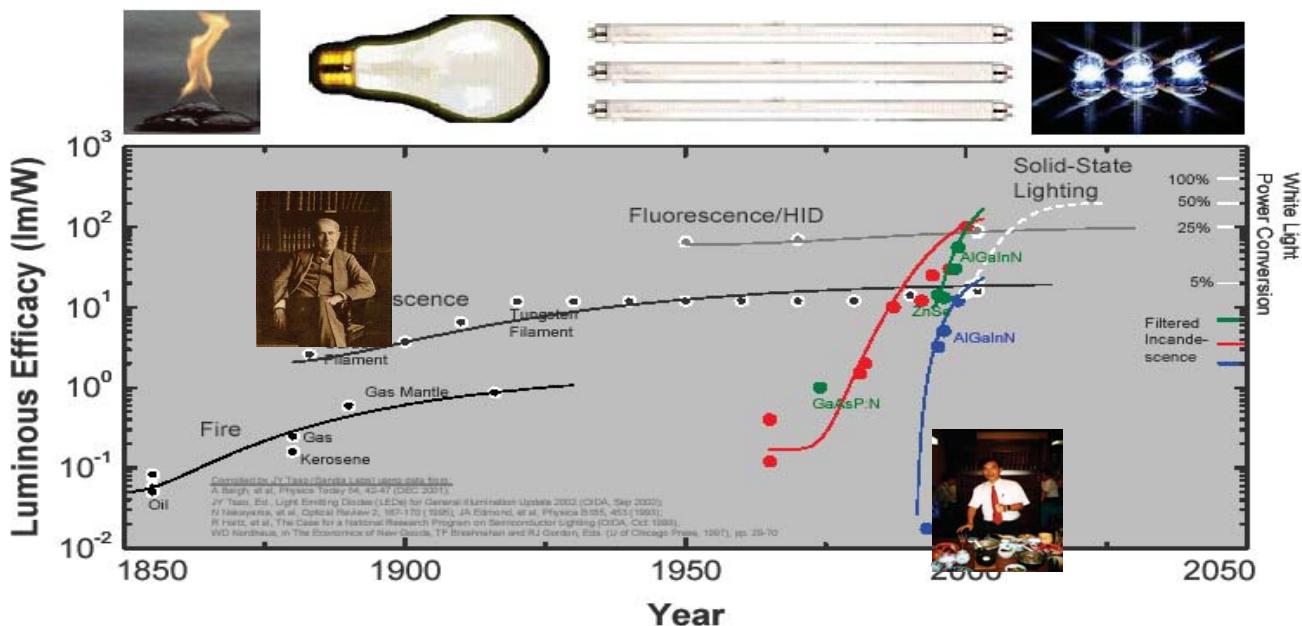
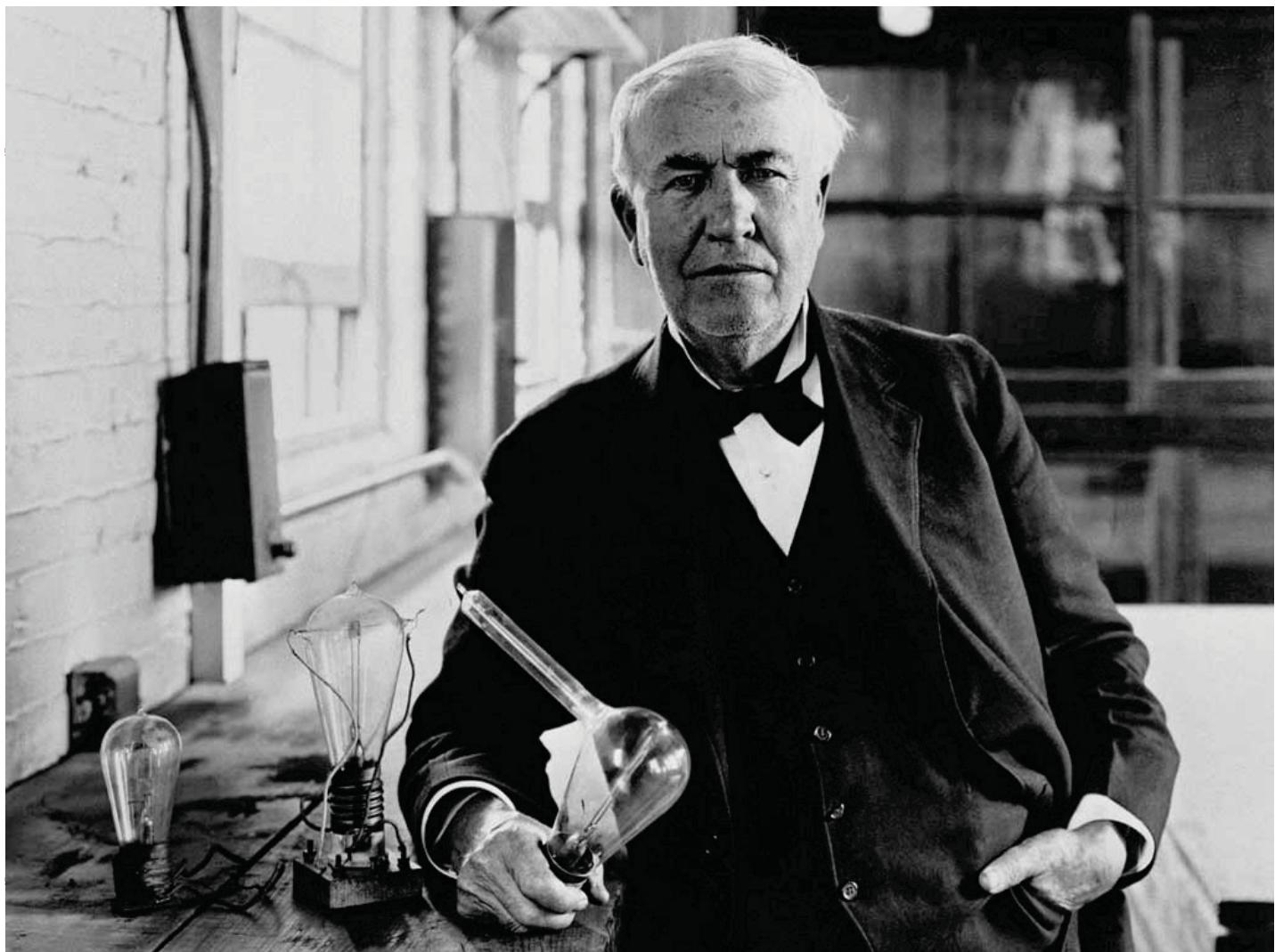


Figure 1: 200-year evolution of luminous efficacy for various lighting technologies.

2015/10/13 Jeff Y. Tsao, Sandia Labs., IEEE Electronic Circuits & Devices, May/June, 2004

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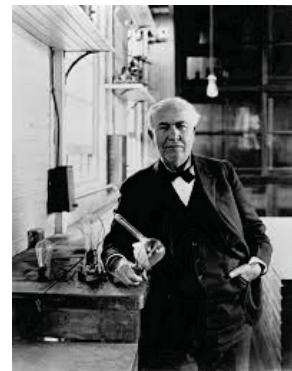
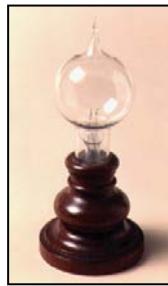
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# 白熾燈的誕生 Incandescence Light – Birth of Lighting

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National Tsing Hua University



Patent US#223,898,  
Jan. 27, 1880

← BC- 1880's

1879

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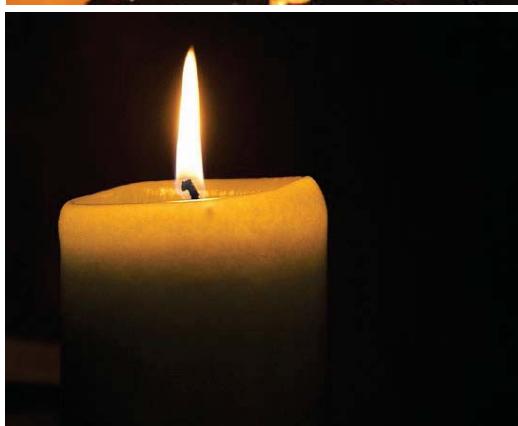
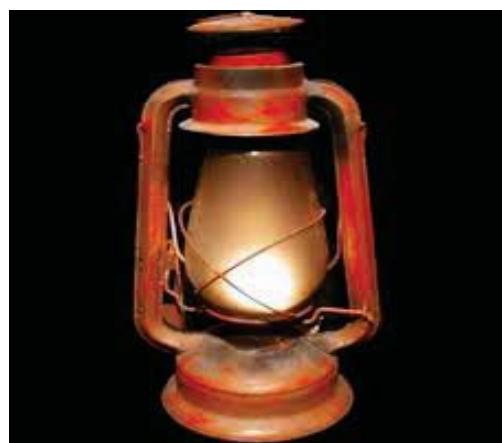
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## 沒有電燈以前的光源

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National Tsing Hua University

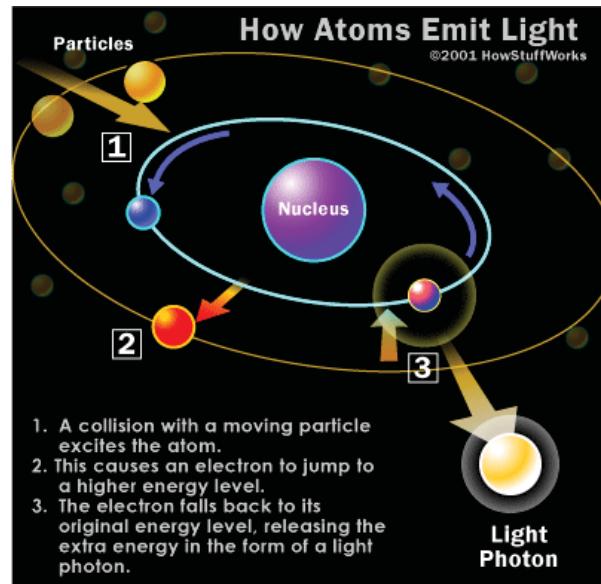
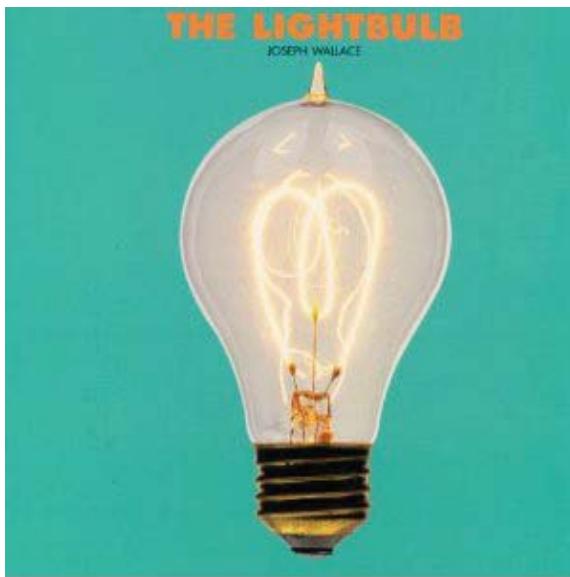


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# 白熾燈的原理



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## 白熾燈發光的原理-黑體輻射

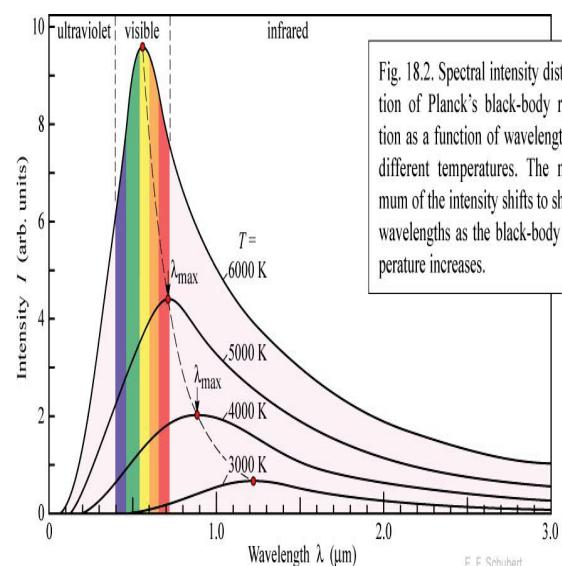
**PLANCK DISTRIBUTION- BLACKBODY RADIATION**

國立清華大學  
National Tsing Hua University

$$P_\lambda = \frac{8\pi hc}{\lambda^5} [\exp(hc/\lambda kT) - 1]$$

- $P_\lambda$  = Power per m<sup>2</sup> area per wavelength
- $h$  = Planck's constant ( $6.626 \times 10^{-34}$  J·s)
- $c$  = Speed of Light ( $3 \times 10^8$  m/s)
- $\lambda$  = Wavelength (m)
- $k$  = Boltzmann Constant ( $1.38 \times 10^{-23}$  J/K)
- $T$  = Temperature (K)

This is the black body radiation function for each temperature, i.e. the spectral power emitted at each wavelength.



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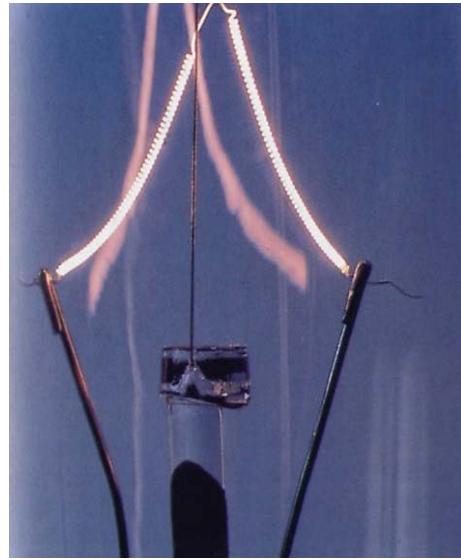
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## 早期的白熾燈泡

- Original Carbon Filament Incandescence Bulb

- 效率低、壽命短。

- **Low efficiency** - When a filament is heated (Incandescence), it releases mostly infrared light photons invisible to the human eye till to around 2,200C they will emit a good deal of visible light.
- **Short life** - The filament first invented by Edison was made of a long, thin length of carbon filament which lasted only tens of hours.



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## 挑戰的問題!

*Stop & Think*

- 假定你的老板是愛迪生、他叫你去改善剛剛發明燈炮的效率、你要從那開始?
- Now if Edison were your Boss, and asked you to improve the efficiency of the light bulb he just invented, what would you do?

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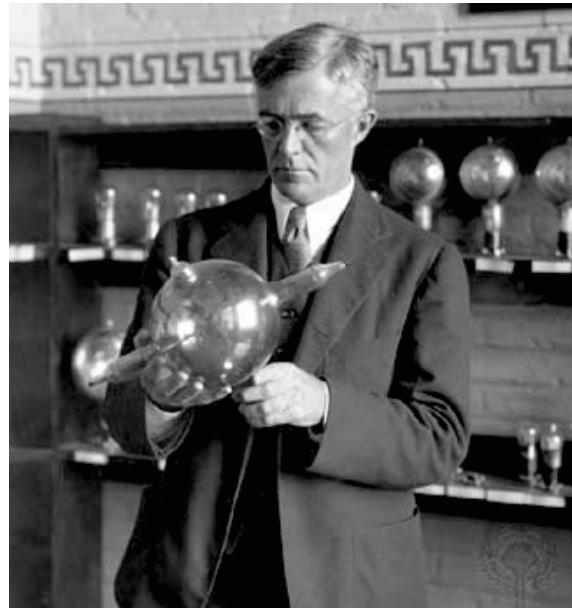
# 1932 諾貝爾化學獎

國立清華大學  
National Tsing Hua University

## *Langmuir- 1932 Nobel Prize in Chemistry*

"For his discoveries and investigations in surface chemistry"

- 歐文·朗繆爾 (1881-1957)
- 美國化學家、物理學家。1909年至1950年在通用電器(GE)工作，發明了氬氣焊接、在燈炮充入氣體的技術，因在表面化學的貢獻而獲得1932年諾貝爾化學獎。
- 獲獎紀錄：諾貝爾化學獎，修斯獎章，珀金獎章



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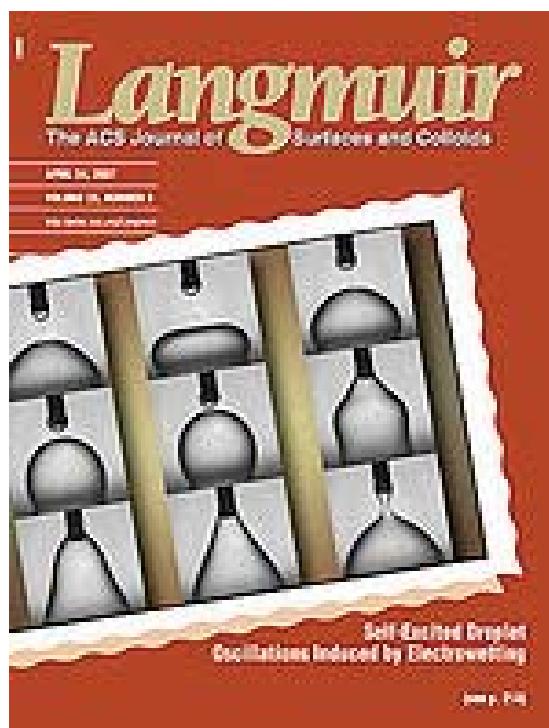
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# 朗繆爾化學期刊

國立清華大學  
National Tsing Hua University

- 《朗繆爾》是美國化學會出版的期刊之一，創刊於1985年，命名來源於1932年諾貝爾化學獎得主歐文·朗繆爾的姓氏。
- 主要發表表面化學和膠體化學領域的論文。2014年影響因子4.457，年出版論文2000餘篇。



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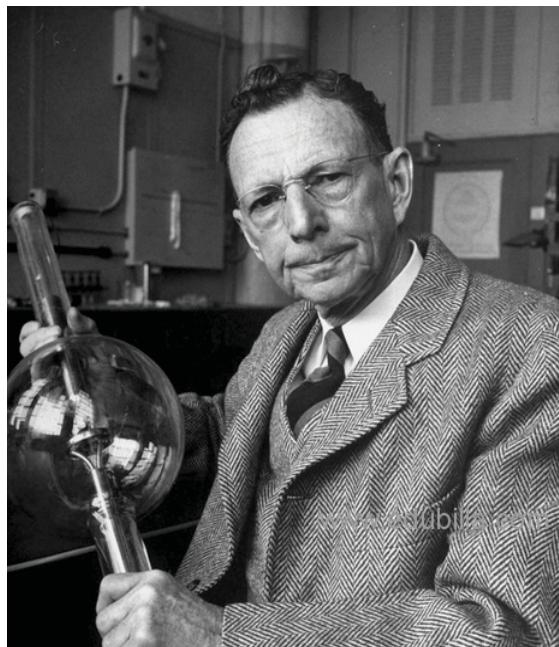


# 1909鎢絲燈的發明

國立清華大學  
National Tsing Hua University

## Coolidge's Tungsten Lamp at 10 LPW

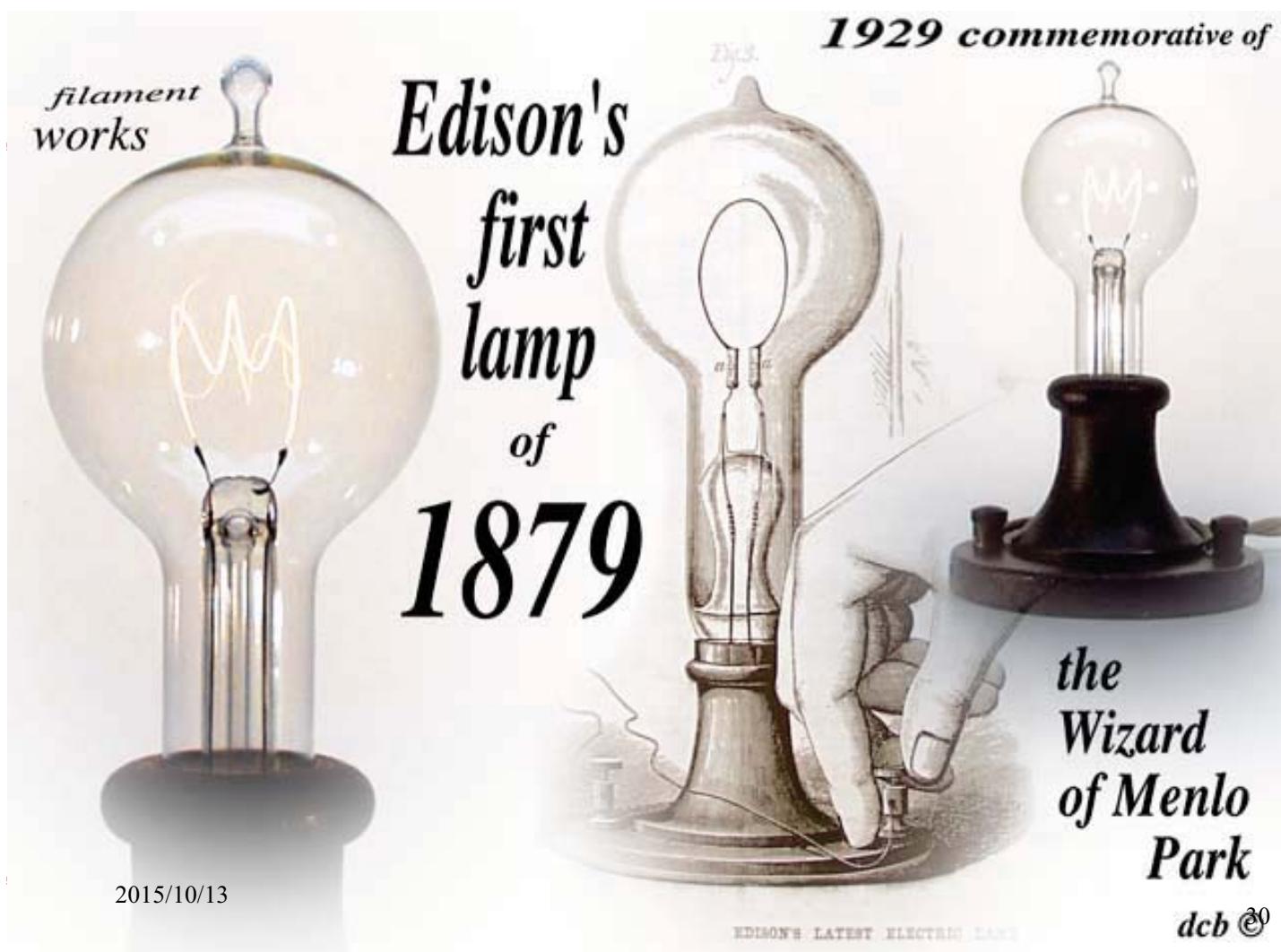
- 威廉·大衛·柯立芝（1873-1975）物理學家作出重大貢獻的X光機。他是通用電氣(GE)研究實驗室和公司的副總裁。也是著名的“韌性的發展鎢”(Ductile tungsten)發明人，對於白熾燈有重要貢獻。



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EDISON'S LATEST ELECTRIC LAMP

dcb ©



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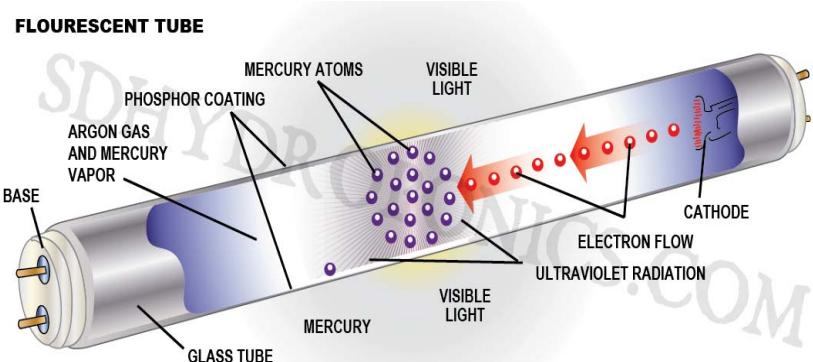
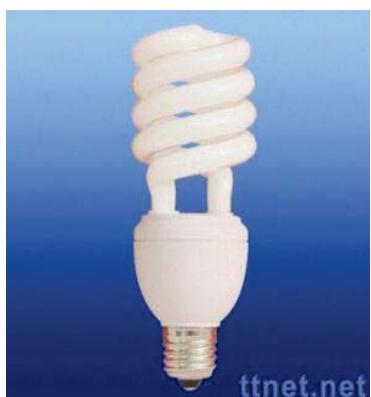
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## 螢光燈 - 利用放電和螢光粉轉換

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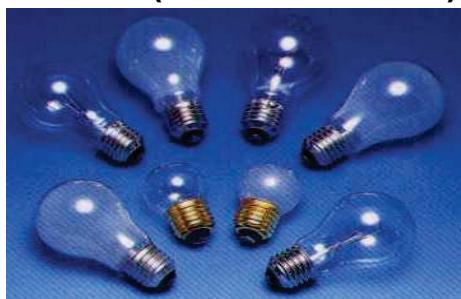


# 對人類的影響: 百年的照明技術

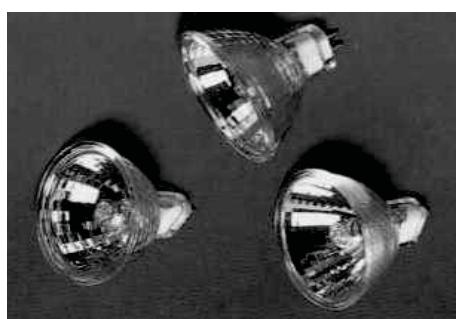
## Artificial Light Sources in the past century

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白熾燈(Incandescence)



螢光燈(Fluorescence bulbs)



鹵素燈(Halogen bulbs)

小型螢光燈 (Compact FB)

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## 光電科技的主要里程碑 Major Milestones in Photonics

1. 愛迪生發明電燈炮  
(Invention of light bulbs ~1880)
2. 愛因斯坦的光電效應  
(Einstein's Photo-electric Effect, 1890-1916)
3. 相干光幅射的發明  
(Invention of Coherent Radiation, LASER ~1960)
4. 光纖通訊的發明  
(Invention of fiber optics communication, ~1970)
4. 高亮度藍光/白光LED的發明  
(Invention of High Brightness White LED, ~1990)

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## 光電科技的主要里程碑 Major Milestones in Photonics

# 2. 愛因斯坦的光電效應 (Einstein's Photo-electric Effect, 1890-1916)

光與電

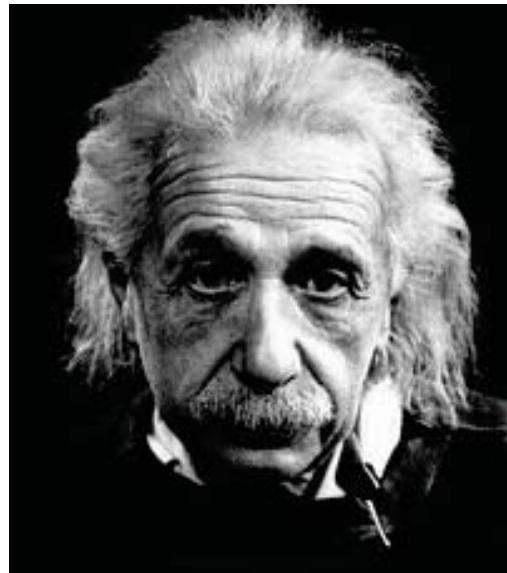
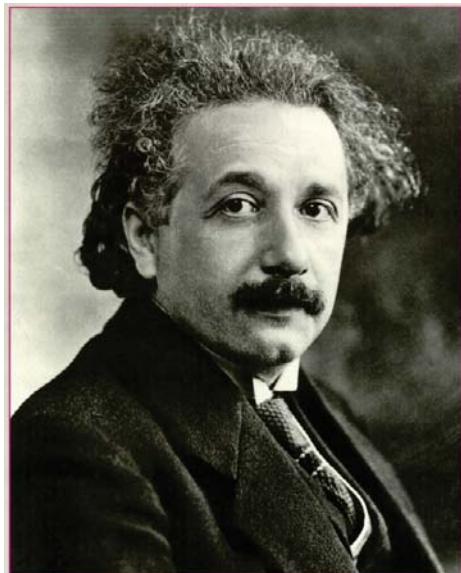
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# 愛因斯坦

(Albert Einstein - 1879-1955)



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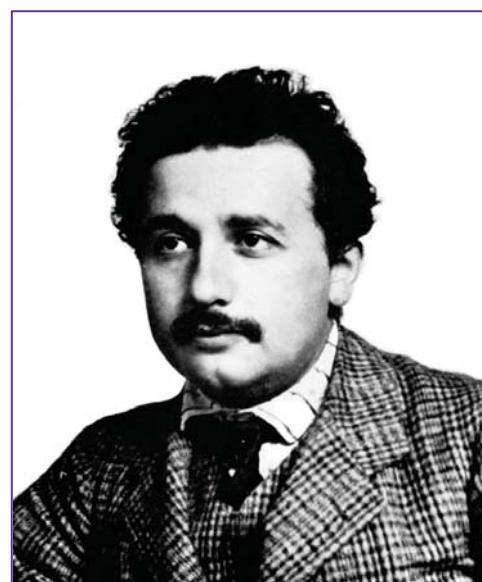
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## 阿爾伯特·愛因斯坦

**Albert Einstein (1879 -1955 )**

- 理論物理學家
- 20世紀猶太裔理論物理學家，創立相對論。發現質能方程式 $E = mc^2$ 著稱於世，他因為「**對理論物理的貢獻，特別是發現了光電效應**」而獲得**1921年諾貝爾物理學獎**，這個發現為量子理論的建立踏出了關鍵腳步。（維基百科）



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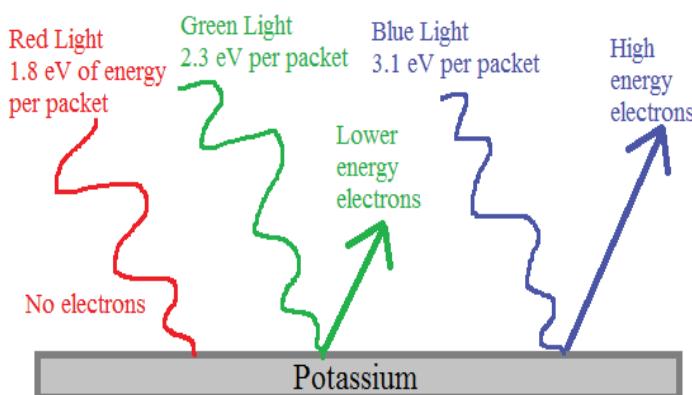
- **光電效應** “On a Heuristic Viewpoint Concerning the Production and Transformation of Light”, (June 9)
  - 解釋光電效應，能量是量子化 (Quantized)。揭開了量子力學的基本奧密，開啟現代量子光學的紀元
- **布朗動則** “On the Motion of Small Particles Suspended in a Stationary Liquid, as Required by the Molecular Kinetic Theory of Heat”, (July 18)
  - 開闢了基本熱力學對分子動力的定律
- **狹義相對論** “On the Electrodynamics of Moving Bodies”, (Sept 26)
  - 提出了對時空及質量關係革命性的新理論
- **物質與能量的轉換** “Does the Inertia of a Body Depend Upon Its Energy Content”, (Nov. 21)
  - 建立  $E = mc^2$

- 劉容生- 科學人95/4月份 “讓物理光耀世界”



## 菲利普·萊納德 光電效應

Philip Lenard (1862-1947)



Potassium electrons need 2 units of energy to escape (2 eV).

- 德國物理學家，1905年諾貝爾物理學獎獲得者。研究陰極射線時曾獲得卓越成果。實驗發現了光電效應的重要規律。



# 尼爾斯·玻爾

(1885-1962) 維基百科

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- 物理學家
- 波耳是一位丹麥物理學家
  - 他因**對於原子結構與舊量子論的研究做出的基礎性貢獻而榮獲1922年諾貝爾物理學獎**。波耳還是一位哲學家，並積極促進科學研究的發展。波耳發展出原子的波耳模型。



Niels Bohr  
(1885-1962)

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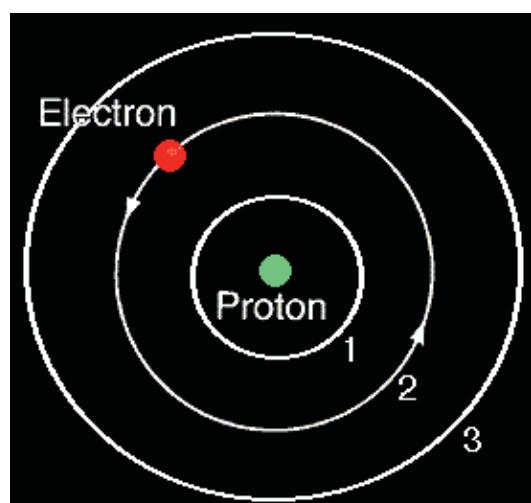
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## 尼爾斯·玻爾的原子模型

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- 1911 - Rutherford's model of the atom with electrons orbiting a central nucleus (The so-called planetary model) was theoretically unstable. Unlike planets orbiting the Sun, electrons are charged particles, which should radiate energy and spiral in toward the nucleus.
- 1913 - Bohr published, "*On the Constitution of Atoms and Molecules*," He used the **quantum of energy,  $\hbar$ , introduced into physics by Max Planck** in 1900, to explain Rutherford's atomic structure and to account for the line spectrum of hydrogen.



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# 尼爾斯·玻爾的原子模型 (cont)

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- Bohr assumed there were '**stationary**' orbits for the electrons in which the electron did not radiate energy.
- He further assumed such orbits occurred when the electron had definite values **of angular momentum, with specifically values of  $h/2\pi, 2h/2\pi, 3h/2\pi, \dots$  where  $h$  is Planck's constant.**
- He further postulated that **emission** of light occurred when an electron moved from one orbit to a lower-energy orbit; **absorption** occurred a change to a higher-energy orbit. **In each case the energy difference produced radiation of energy  $hv$ , where  $v$  is the frequency.**
- In 1913 he realized that, using this idea, he could obtain a formula similar to the empirical formula of **Balmer for a series of lines in the hydrogen spectrum.**

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## 馬克斯·普朗克 Max Planck (1858-1947)

- 德國國籍德國
- 研究領域: 物理學家
- 任職於基爾大學, 柏林洪堡大學, 哥廷根大學
- 母校慕尼黑大學
- 著名成就普朗克常數、普朗克黑體輻射定律、舊量子 諾貝爾物理學獎 (1918年)





# 黑体幅射

## Black-body radiation

- Planck was commissioned in 1894 by electric companies to create maximum light from light bulbs with minimum energy.
- 1895, Kirchhoff stated : "how does the intensity of the electromagnetic radiation emitted by a black body (a perfect absorber, also known as a "cavity radiator") depend on the frequency of the radiation (i.e., the color of light) and the temperature of the body?".
- The question, explored experimentally, but no theoretical treatment agreed with experimental values.
- Wien's law correctly predicted the behavior at high frequencies, but failed at low frequencies. The Rayleigh–Jeans law, another approach to the problem, created what was later known as the "ultraviolet catastrophe", but contrary to many textbooks this was not a motivation for Planck.[\[13\]](#)

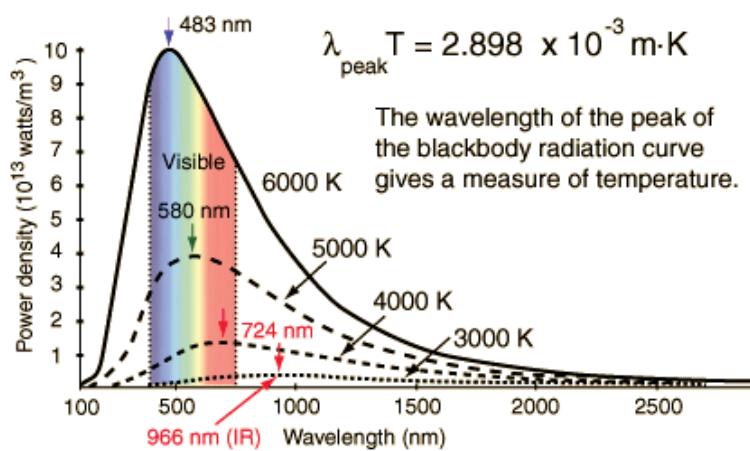
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## PLANCK ENERGY DISTRIBUTION FORMULA



Max Planck  
(1858-1947)

$$P_\lambda = 8 \pi h c / \lambda^5 [\exp(hc/\lambda kT) - 1]$$

Where,  $P_\lambda$  =Power per m<sup>2</sup> area per m wavelength;  $h$  = Planck's constant ( $6.626 \times 10^{-34}$  J.s);  $c$  = Speed of Light ( $3 \times 10^8$  m/s);  $\lambda$ = Wavelength (m);  $k$  = Boltzmann Constant ( $1.38 \times 10^{-23}$  J/K);  $T$  = Temperature (K)

# 科學家的精神

## - 理智(邏輯)戰勝信仰



Max Planck  
(1858-1947)

- **Max Born wrote about Planck:** "He was, by nature, a conservative mind; he had nothing of the revolutionary and was thoroughly skeptical about speculations. Yet his belief in the compelling force of logical reasoning from facts was so strong that he did not flinch from announcing the most revolutionary idea which ever has shaken physics."<sup>[2]</sup>

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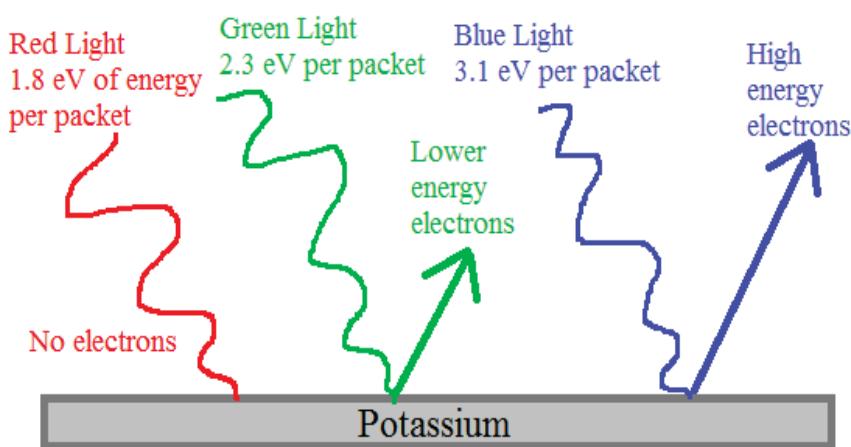
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# 菲利普·萊納德 光電效應

Philip Lenard (1862-1947)



Potassium electrons need 2 units of energy to escape (2 eV).

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- 愛因斯坦在〈一個關於光的產生與轉換的啟發性看法〉這篇論文裡，解釋為什麼當光束照射到金屬的表面會產生電子，同時說明光電效應中電子飛離金屬表面的速度與光波長的關係。更重要的是，他提出的一個革命性基本光子(photon)的觀念：
  - 光子是一個帶有能量的粒子，每個光子所帶的能量等於光的頻率乘上一個普朗克常數 ..

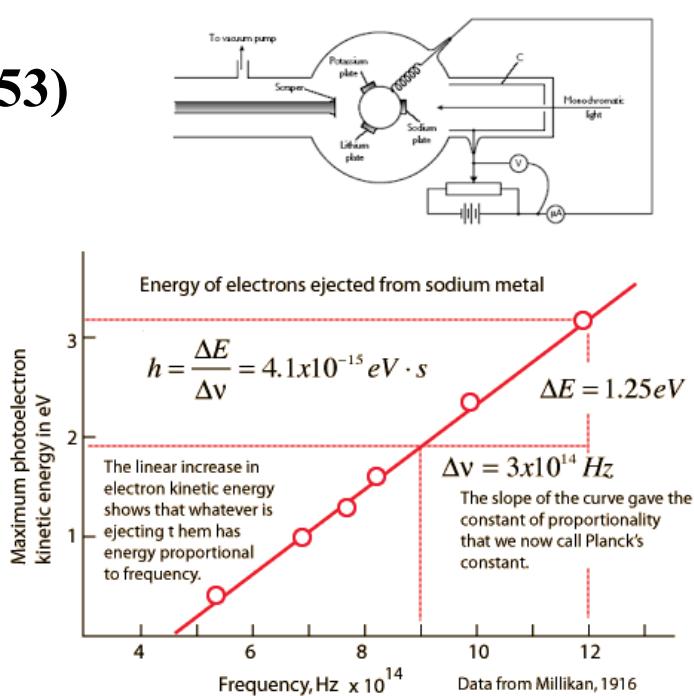
$$\epsilon = h \nu$$

- 當時另一位德國物理學家普朗克 ( Max Planck ) 剛發表了近代物理上最重要的量子理論、他提出一項具革命性能階觀念，其中導衍出一個基本且非常微小的常數、也就是愛因斯坦用來解釋光子所帶能量的普朗克常數。

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## Robert Millikan 羅伯特·密立根 (1868-1953)





## 羅伯特·密立根兩個小故事 (1) -科學(物理)興趣的培養

- In my sophomore year, my Greek professor asked me to teach the course in elementary physics in the preparatory department during the next year. To my reply that I did not know any physics at all, his answer was, "Anyone who can do well in my Greek can teach physics." "All right," said I, "I will try and see what I can do with it." I at once purchased an Avery's *Elements of Physics*, and spent the greater part of my summer vacation of 1889 at home – trying to master the subject. I doubt if I have ever taught better in my life than in my first course in physics in 1889. I was so intensely interested in keeping my knowledge ahead of that of the class that they may have caught some of my own interest and enthusiasm.[\[7\]](#)

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## 羅伯特·密立根兩個小故事 (2) -科學(物理)精神的培養

- When Einstein published his seminal 1905 paper on the particle theory of light, Millikan was convinced that it had to be wrong, because of the vast body of evidence that had already shown that light was a wave.
- He undertook a decade-long experimental program to test Einstein's theory, which required building what he described as "a machine shop *in vacuo*" in order to prepare the very clean metal surface of the photo electrode.
- His results published in 1914 confirmed Einstein's predictions in every detail, but Millikan was not convinced of Einstein's interpretation, and as late as 1916 he wrote, "Einstein's photoelectric equation... cannot in my judgment be looked upon at present as resting upon any sort of a satisfactory theoretical foundation," even though "it actually represents very accurately the behavior" of the photoelectric effect.

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# 路易·德布羅意

(1892-1987)

國立清華大學  
National Tsing Hua University

- 物理學家
- 路易·德布羅意，第七代布羅意公爵，法國物理學家，法國外交和政治世家布羅意公爵家族的後代。1929年因發現了電子的波動性，以及他對量子理論的研究而獲諾貝爾物理學獎。維基百科



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## 德布羅意的假設 De Broglie's Hypothesis

- In his 1923 doctoral dissertation, Louis de Broglie made a bold assertion. Considering Einstein's relationship of wavelength  $\lambda$  to momentum  $p$ , de Broglie proposed that this relationship would determine the wavelength of any matter, in the relationship, called the “*de Broglie wavelength*”.

$$\lambda = h/p \text{ (} h \text{ is Planck's constant)}$$

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# 光電效應的產品 IMACTS:

- 感光器件、太陽電池、數位相機、CCD

...



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## 光電科技的主要里程碑 Major Milestones in Photonics

- 愛迪生發明電燈炮  
(Invention of light bulbs ~1880)
- 愛因斯坦的光電效應  
(Einstein's Photo-electric Effect, ~1890)
- 相干光輻射的發明  
**(Invention of Coherent Radiation, LASER ~1960)**
- 光纖通訊的發明  
(Invention of fiber optics communication, ~1970)
- 高亮度藍光/白光LED的發明  
**(Invention of High Brightness White LED, ~1990)**

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# 1958 – 相干光幅射的發明的故事 - 雷射的發明

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## 第一個相干光幅射的光源 The First Maser and the First Laser

- A. L. Schawlow and C. H. Townes,  
“Infrared and Optical Masers,” Phys.  
Rev. 112, 1940 (1958)
- T. Maiman, “Stimulated Optical  
Radiation in Ruby,” Nature (London)  
187, 493 (1960)

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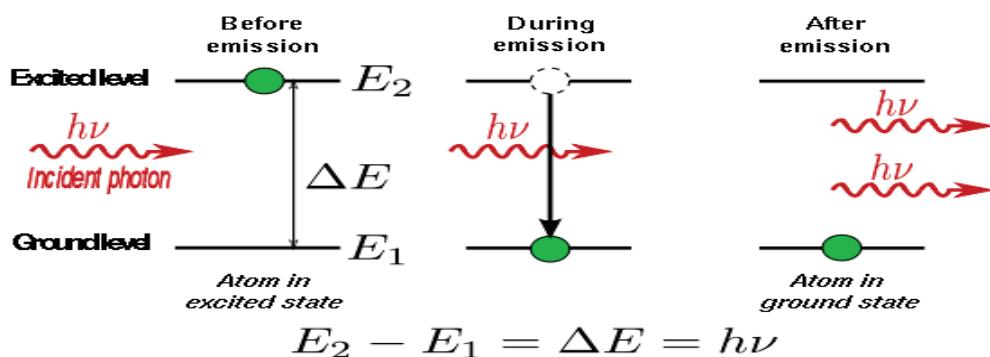
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# 受激發射: 激光

## (Light Amplification Stimulated Emission Radiation)

- 受激發射 (Stimulated emission) 是雷射的主要光源。受激發射的光放大 (Light Amplification by Stimulated Emission of Radiation) 縮寫就是「LASER」。受激發射概念是由阿爾伯特·愛因斯坦 (Einstein) **他在1917年發表的論文《關於輻射的量子理論》中提出的**；大約10年後，英國著名物理學家、劍橋大學教授保羅·狄拉克 (Dirac) 首次實驗證明受激發射的存在。



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(Ref: 維基百科)

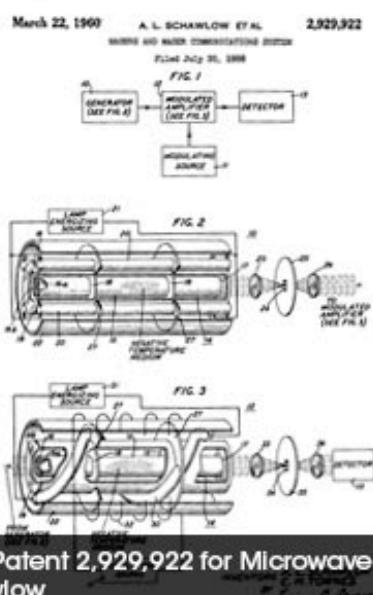
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# 發明雷射的科學家

阿瑟·肖洛(1921-1999)查爾斯·湯斯(1915-2015)



(from left to right) Charles Townes, Patent 2,929,922 for Microwave Amplification by Stimulated Emission of Radiation, Arthur Schawlow

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## Infrared and Optical Masers

A. L. Schawlow and C. H. Townes

Phys. Rev. 112, 1940 – Published 15 December 1958

- ABSTRACT
- The extension of maser techniques to the infrared and optical region is considered. It is shown that by using a resonant cavity of centimeter dimensions, having many resonant modes, maser oscillation at these wavelengths can be achieved by pumping with reasonable amounts of incoherent light. For wavelengths much shorter than those of the ultraviolet region, maser-type amplification appears to be quite impractical. Although use of a multimode cavity is suggested, a single mode may be selected by making only the end walls highly reflecting, and defining a suitably small angular aperture. Then extremely monochromatic and coherent light is produced. The design principles are illustrated by reference to a system using potassium vapor.
- A. L. Schawlow and C. H. Townes, \* Bell Telephone Laboratories, Murray Hill, New Jersey; \*Permanent address: Columbia University, New York, New York.; Received 26 August 1958

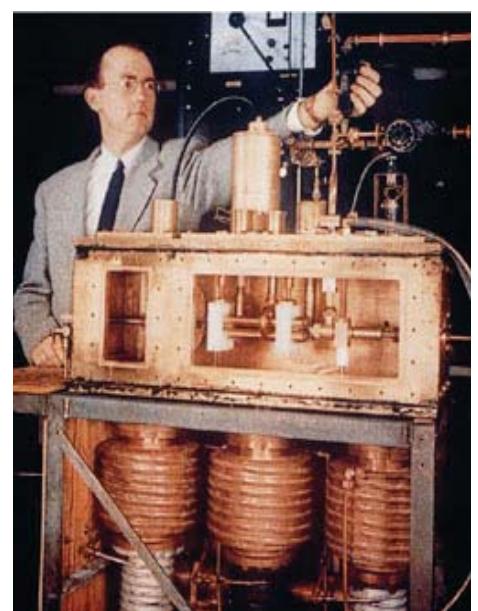
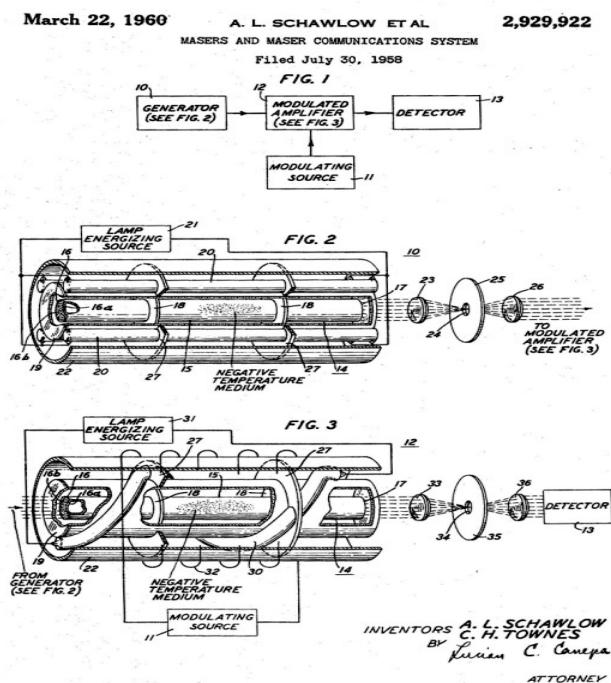
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## 1958, 相干光的發明 Invention of Coherent Light

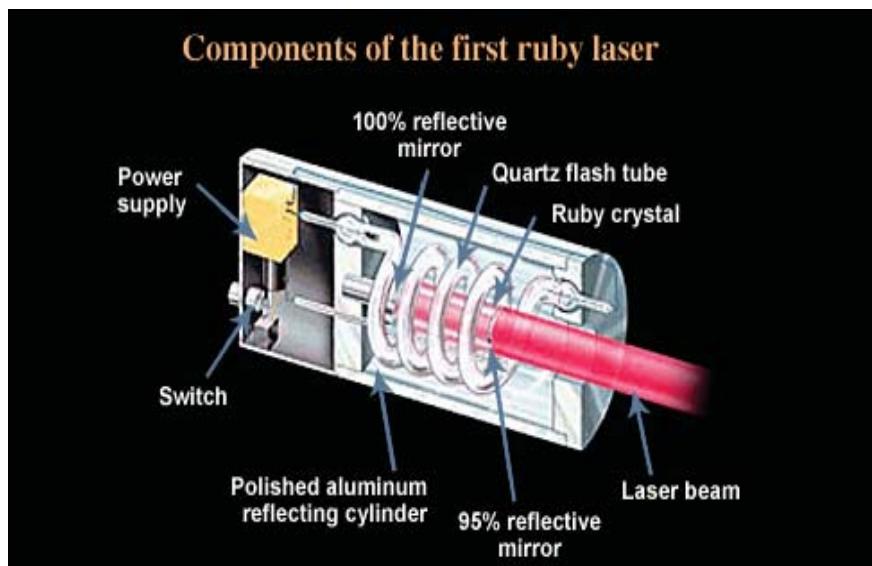


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# 西奧多·梅曼的第一個紅寶石雷射



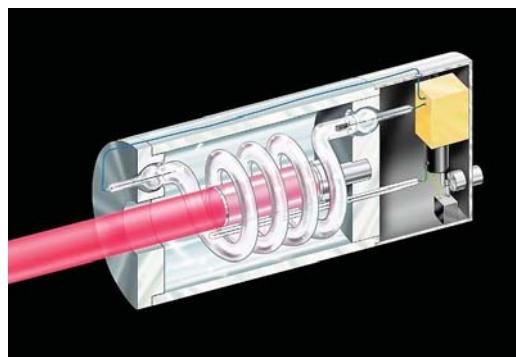
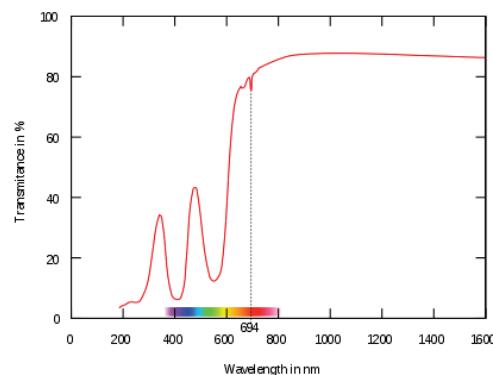
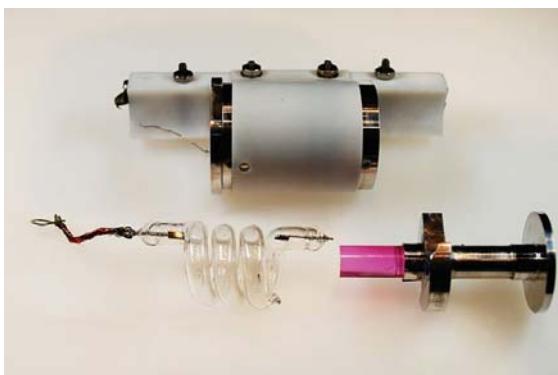
Theodore Maiman developed the first working laser at Hughes Research Lab in 1960, and his paper describing the operation of the first laser was published in Nature three months later

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# 梅曼的第一個紅寶石雷射



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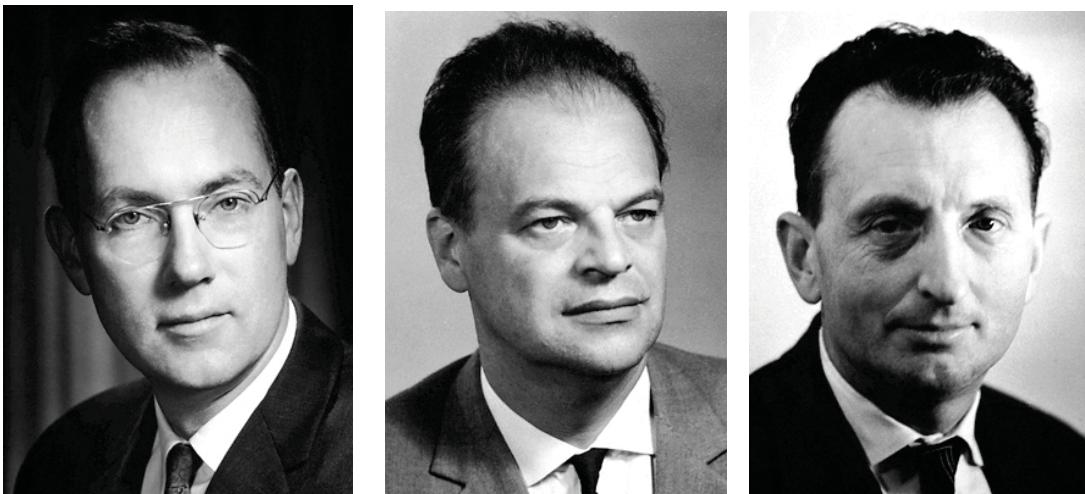
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## 1964諾貝爾物理獎

Nobel Prize in Physics- Townes, Basov, Prokhorov



“for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser-laser principle”

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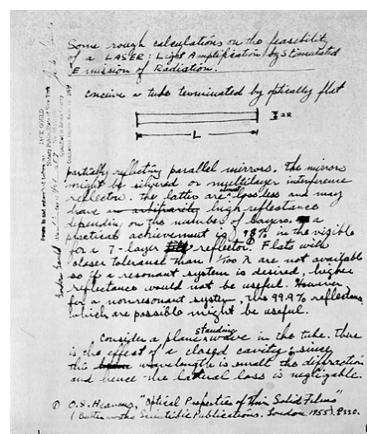
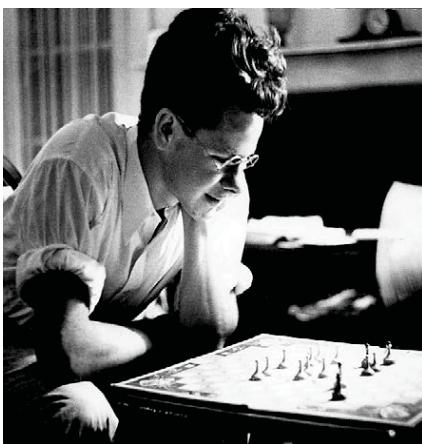
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## 雷射發明專利的戰爭 Gould's Patent and Patent War!

**Laser Inventor: Gordon Gould (1920-2005)**



The Patent War Gould ca. 1985 In 1957 Townes talked over some ideas about pumping light-energy into atoms with Gordon Gould, a graduate student who had been thinking along similar lines. Worried that he might be scooped, Gould wrote down his ideas for the record. He developed many more ideas of how lasers could be built and used, and in April 1959 he filed patent applications with his employer, the high-tech research firm TRG. Nine months earlier Schawlow and Townes had applied for a patent on behalf of Bell Laboratories, which employed Schawlow on staff and Townes as a consultant.

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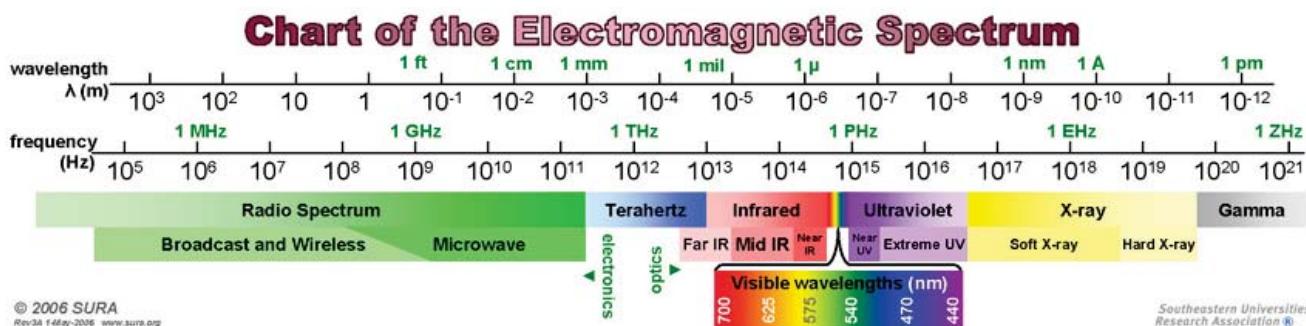
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# 雷射光的特殊性質

## Properties of Laser Radiation



- 同相 (Coherent)
- 集束 (Collimated)
- 高亮度 (High Brightness, Watt/cm<sup>2</sup>/Ω)
- 瞬時脈衝 (Short pulse, ~ $10^{-18}$  sec)
- 高功率 (High Power, Watt=J/s)
- 單色 (Spectrally Pure)

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## 光電科技的主要里程碑

### Major Milestones in Photonics

1. 愛迪生發明電燈泡  
(Invention of light bulbs ~1880)
2. 愛因斯坦的光電效應  
(Einstein's Photo-electric Effect, ~1890)
3. 相干光輻射的發明  
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4. 光纖通訊的發明  
**(Invention of fiber optics communication, ~1970)**
5. 高亮度藍光/白光LED的發明  
(Invention of High Brightness White LED, ~1990)

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## 4. 光纖通訊的發明

- 半導體雷射 (1962~)
- 低損耗的光纖 (1970~)

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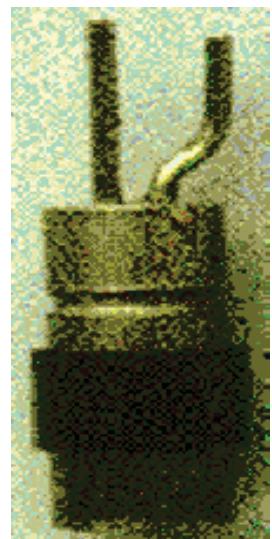


## 電晶体的發明 – 革命性改變了電子科技和產業

青華大學  
National Tsing Hua University

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### Nobel Prize in Physics 1956



- **William B. Shockley John Bardeen Walter H. Brattain**
- The Nobel Prize in Physics 1956 was awarded jointly to William Bradford Shockley, John Bardeen and Walter Houser Brattain "for their researches on semiconductors and their discovery of the transistor effect".

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# 電晶体的發明和電腦的進展

- 1946 ENIAC 1 Computer 20,000 vacuum tubes later...
- **1947/48 Bardeen, Brattain & Shockley invented The Transistor.**
- 1951 Eckert & Mauchly UNIVAC Computer First commercial computer.
- 1953 IBM 701 EDPM Computer IBM enters into 'The History of Computers'.
- 1954 IBM FORTRAN Computer Programming Language The first successful high level programming language.
- 1955 ERMA and MICR The first bank industry computer - also MICR (magnetic ink character recognition) for reading checks.
- **1958 Jack Kilby & Robert Noyce invented The Integrated Circuit (IC) "The Chip"**
- 1962 Steve Russell & MIT Spacewar Computer Game The first computer game.
- 1964 Douglas Engelbart Computer Mouse & Windows
- **1969 ARPAnet** The original Internet.
- 1970 Intel 1103 Computer Memory The world's first available DRAM chip.

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## 奇異公司發明第一個半導體雷射 (1962)

**Dr. R. N. Hall : inventor of the semiconductor injection laser.**

**"For the first realization of the semiconductor injection laser:  
A basic element of optical fiber communications."**

- 1962 GE's Research Center.

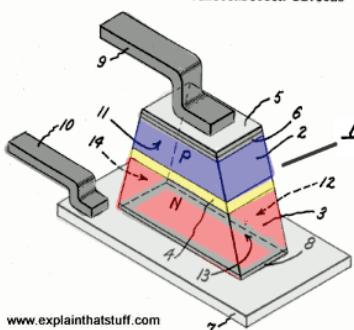
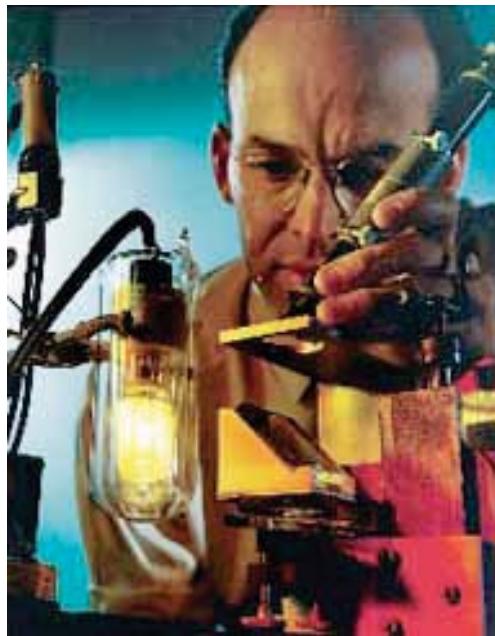
- Invented magnetrons used in microwave ovens,
- Discovered alloyed p-n junctions, the fundamental elements of power rectifiers.
- **1962, first developed the semiconductor injection laser**
  - used in all CD, DVD, laser printers
  - fiber-optic communications systems.



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## 發明半導體雷射的競賽

- GE Research Labs., - Hall, R N, Fenner, G. E, Kingsley, J. D, Soltys, T. J and Carlson R. O. Phys. Rev. Lett. 9, 366–369 (1962) . [\[1\]](#)
- IBM Research Labs. - Nathan M,I, Dumke W.P, Burns G, Dill F, H Jr, and Lasher G Appl. Phys. Lett. 1, 62 (1962).
- MIT Lincoln Labs.- Nathan M,I, Dumke W.P, Burns G, Dill F, H Jr, and Lasher G Appl. Phys. Lett. 1, 62 (1962).

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# 若列斯·伊萬諾維奇·阿爾費羅夫

## Zhores I. Alferov

- 若列斯·伊萬諾維奇·阿爾費羅夫-俄羅斯物理學家，生於白俄羅斯維捷布斯克，**2000年獲諾貝爾物理學獎**。
- **1930年3月15日（85歲）**



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## 阿爾費羅夫的奇妙設計使得半導體雷射實用

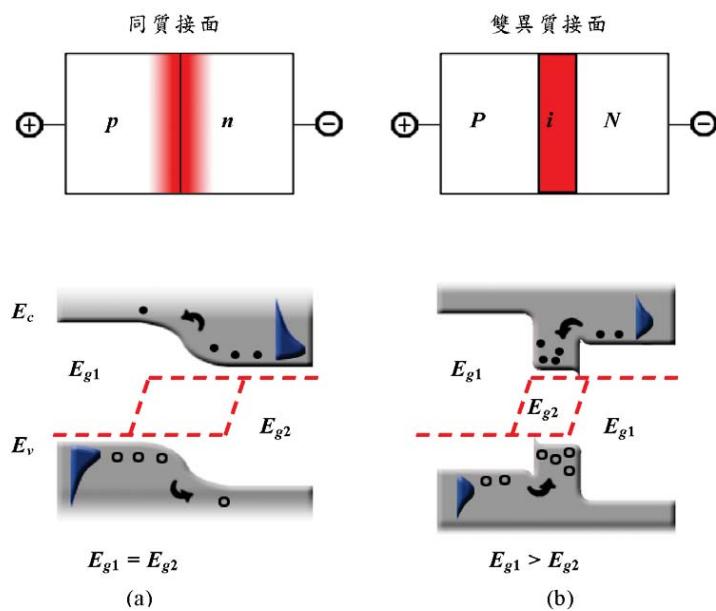
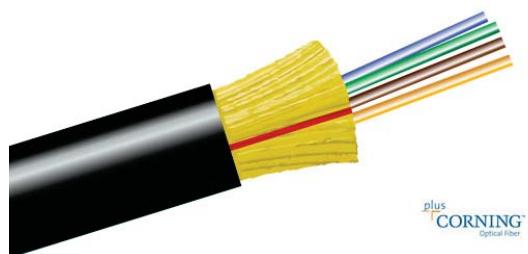
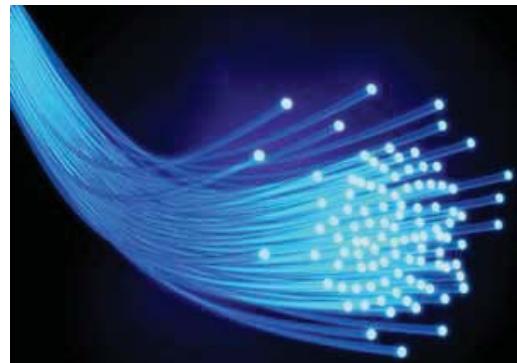
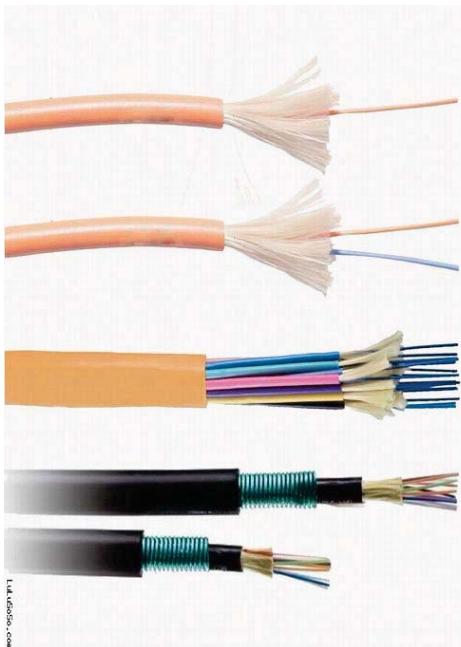


圖 3-1 (a)同質接面結構圖；(b)雙異質接面結構圖

# 現代通訊的傳輸介質 - 光纖



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## 光纖之父- 偉大的先知

### 高錕

Charles Kao (1933- )

- 高錕爵士，華裔電機工程師及物理學家，生於中國上海。1949年移居香港，赴英留學。



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## World's First Low-Loss Optical Fiber for

Telecommunications announced by Corning - 1970



- In 1970, Corning scientists Dr. Robert Maurer Dr. Peter Schultz, and Dr. Donald Keck developed a highly pure optical glass that effectively transmitted light signals over long distances. This astounding medium, which is thinner than a human hair, revolutionized global communications. By 2011, the world depended upon the continuous transmission of voice, data, and video along more than 1.6 billion kilometers of optical fiber installed around the globe.

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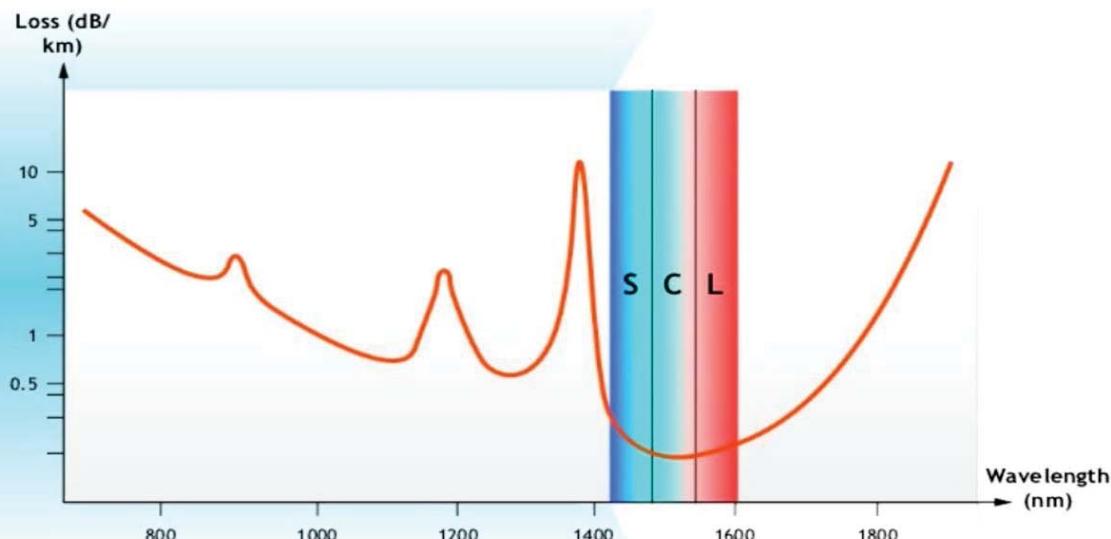


# 上天給人類的禮物 - 低損耗的光纖

## 2.3 DWDM Definition Absorption Spectrum of the Optical Fiber

WDM Technology - Fundamentals - WDM Transmission Basics

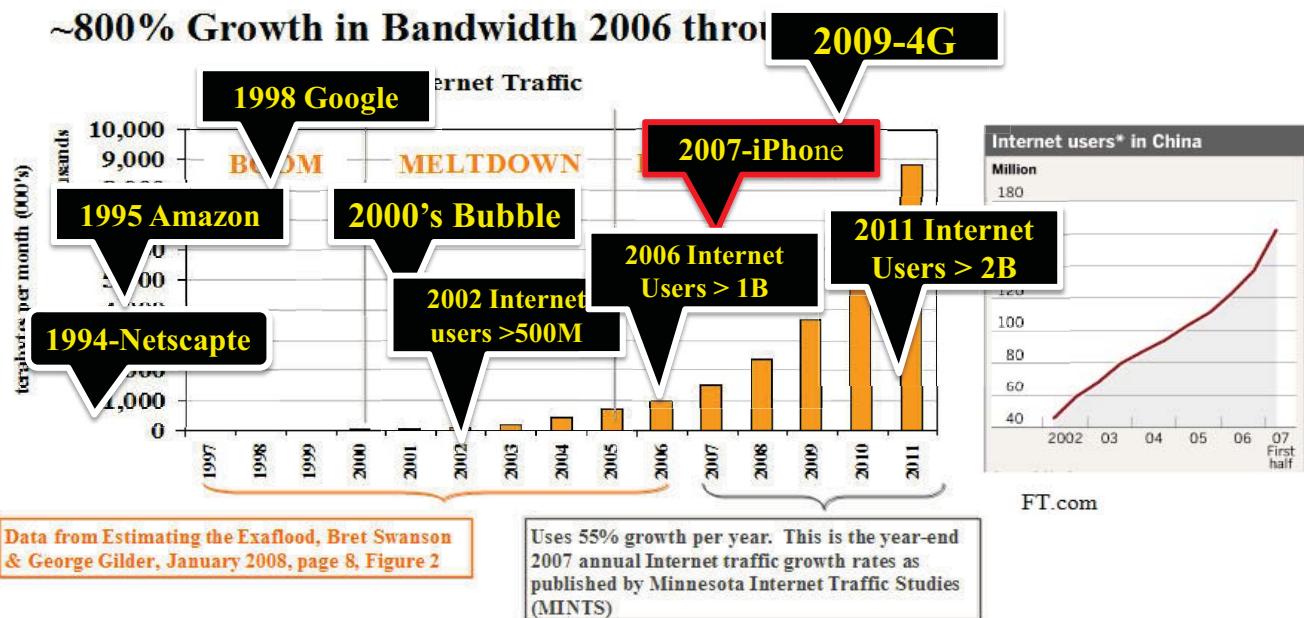
1 - 1 - 2





# 光纖通訊支撐著網際網路、無線通訊的發展

## Bandwidth is Growing Rapidly Since 2005



(Source: Discovery Institute and The Minnesota Internet Traffic Studies showed at the year end of 2007 growth at 50-60% e.q. a growth from 2006 to 2011 of ~800%)

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## 光電科技的主要里程碑 Major Milestones in Photonics

1. 愛迪生發明電燈泡  
(Invention of light bulbs ~1880)
2. 愛因斯坦的光電效應  
(Einstein's Photo-electric Effect, ~1890)
3. 相干光輻射的發明  
(Invention of Coherent Radiation, LASER ~1960)
4. 光纖通訊的發明  
(Invention of fiber optics communication, ~1970)
5. 高亮度藍光/白光LED的發明  
(Invention of High Brightness White LED, ~1990)

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## 光電科技的主要里程碑 Major Milestones in Photonics

### 5. 高亮度藍光/白光LED的發明

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### 世界第一個紅光發光二極體 World's first LED at GE

- 1962, Holonyak built the world's first LED which emitted only red light but it lit a research boom whose multi-colored offspring now illuminate homes and cities, the latest iPad "retina" screens, and flat-screen TVs. "Boy, those were the golden years," says Holonyak, now 83 years old. "When I went in, I didn't realize all that we were going to do. As far as I am concerned, the modern LED starts at GE." - See more at:

<http://www.gelighting.com/LightingWeb/emea/news-and-media/news/First-LED-by-the-GE-engineer-Nick-Holonyak.jsp#sthash.aUjKU4L1.dpuf>

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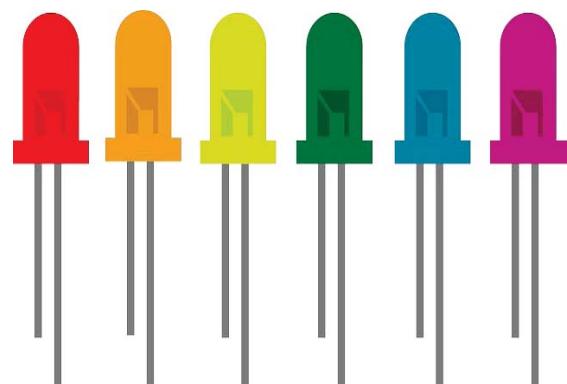
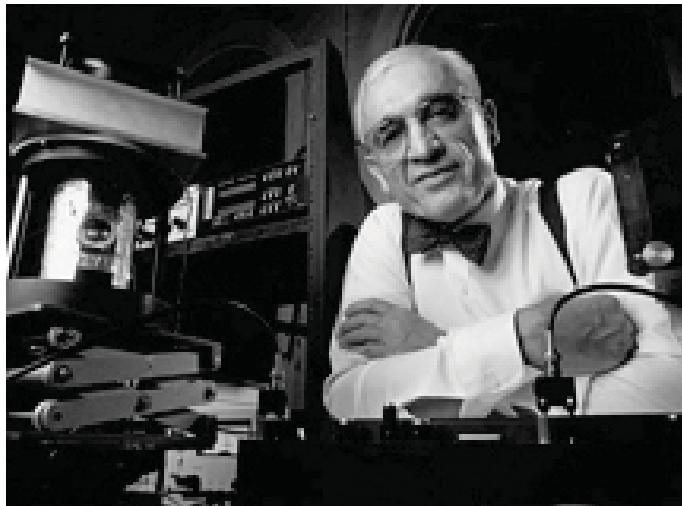


# 世界第一個紅光發光二極體

World's first LED at GE

國立清華大學  
National Tsing Hua University

1962年，通用電氣公司(GE)的尼克·何倫亞克開發出第一種可實際應用的可見光發光二極體。



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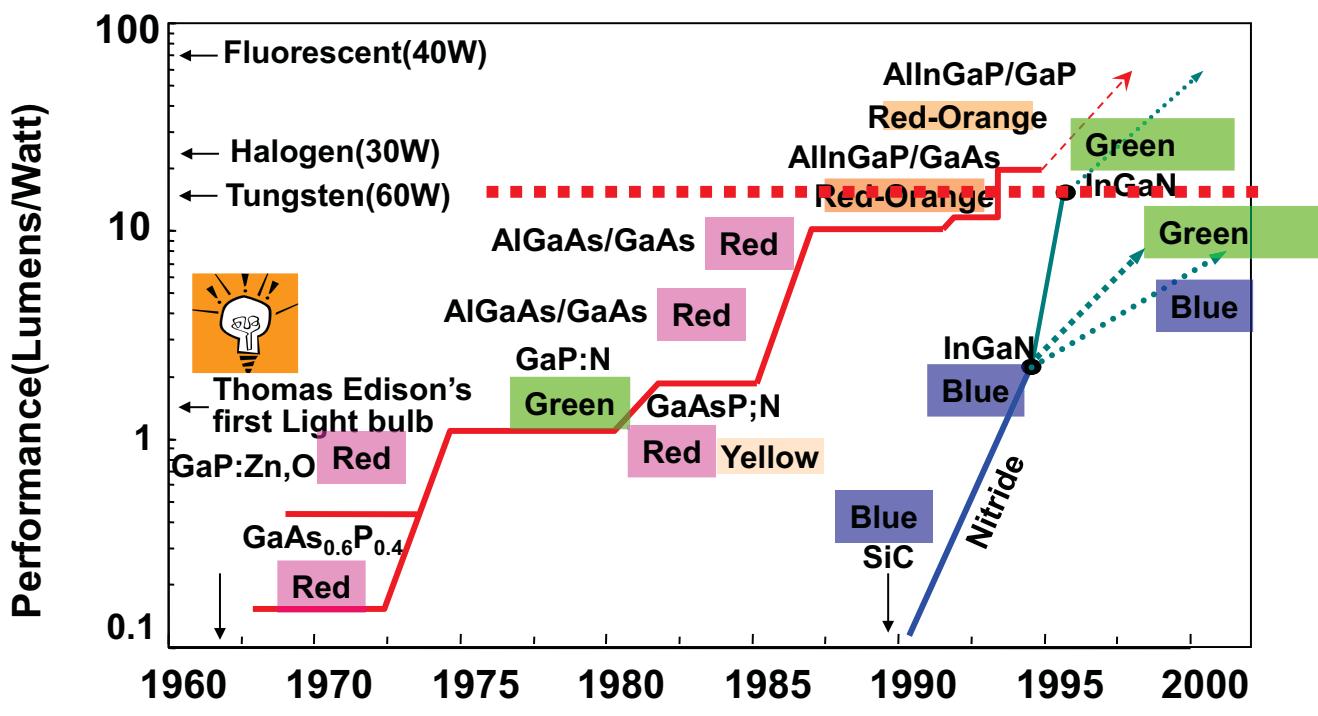
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## LED 的發展里程圖

Major Advances in LED Devices  
- Materials and devices breakthroughs

國立清華大學  
National Tsing Hua University

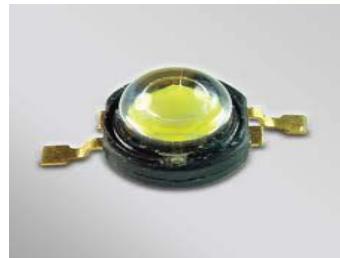
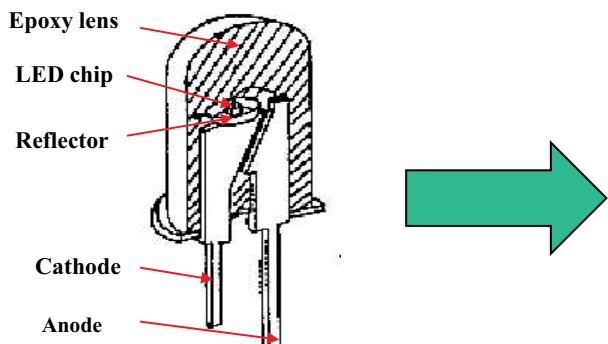


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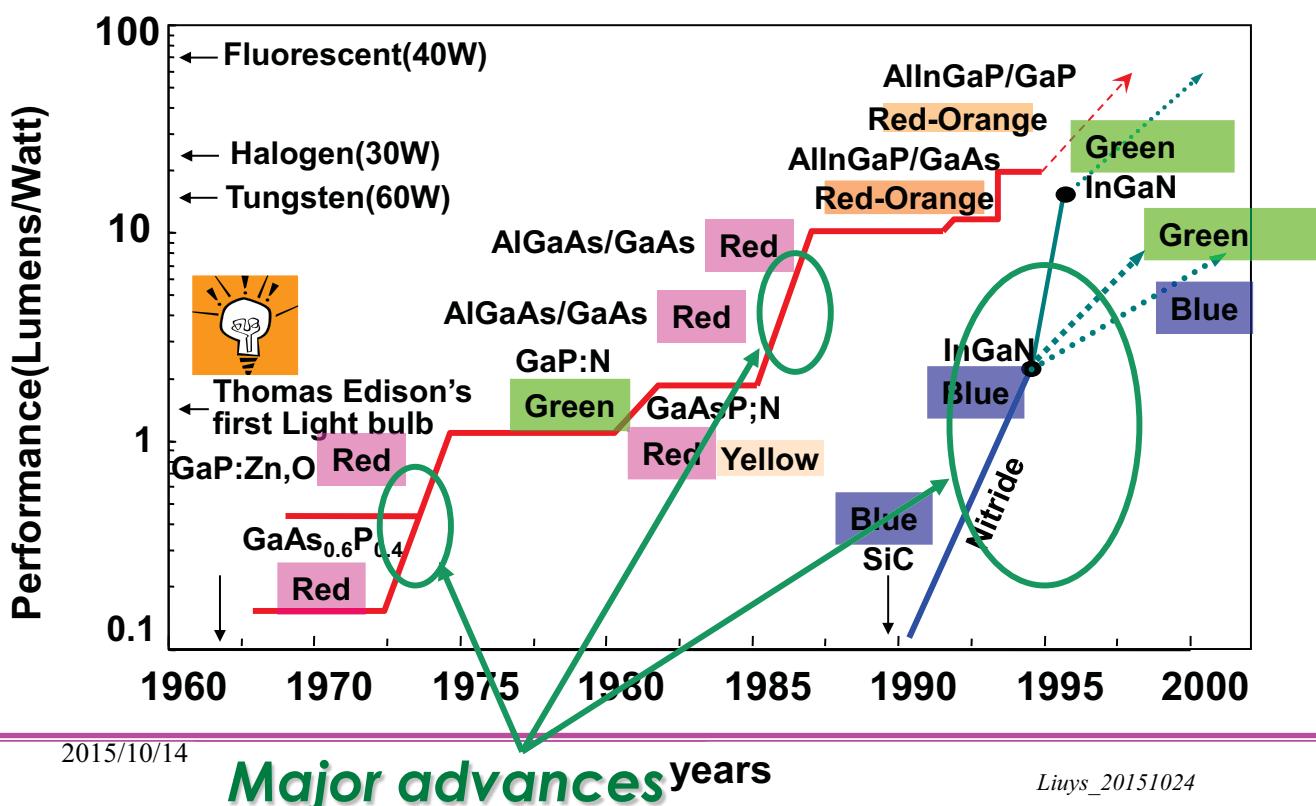
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## LED 的發展過程

### Major Advances in LED Devices



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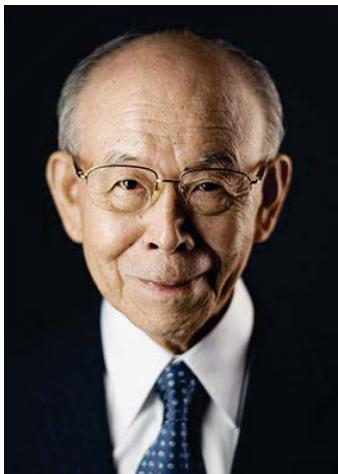
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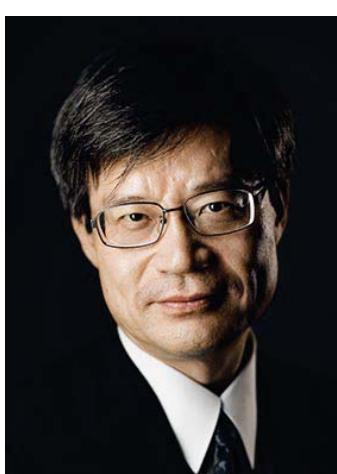
# 2014年諾貝爾物理獎得主

國立清華大學  
National Tsing Hua University

"for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources"



Isamu Akasaki



Hiroshi Amano



Shuji Nakamura

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國立清華大學  
National Tsing Hua University

## 1997代表奇異公司拜訪中村修二



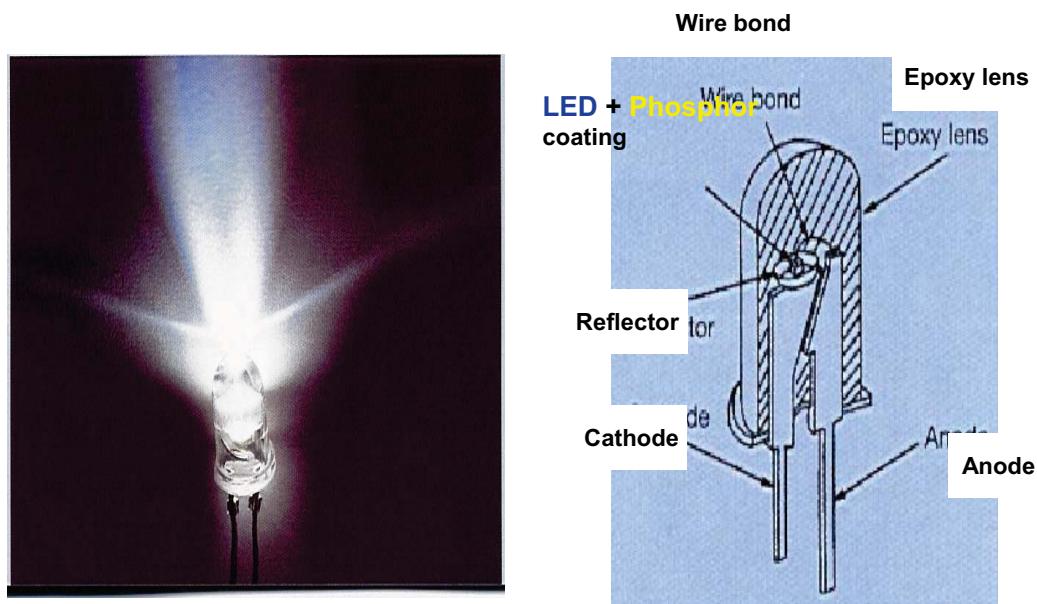
Dr. Shuji Nakamura drank Sake and discussed the future of white LED technology in Akita, Japan, 4 Oct 1997

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# 1996 白光 LED 的突破



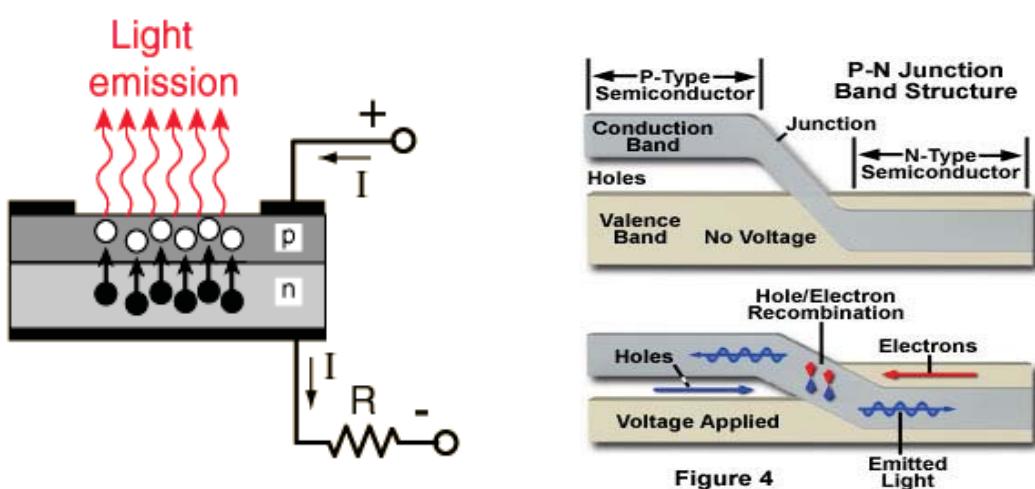
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## 發光二極體的基本結構 Light Emitting Diode Structure



LEDs are p-n junction devices constructed of GaAs, GaAsP, or GaP. The device is forward biased and when electrons and holes cross the junction and recombined, photons are produced. The process is called electroluminescence.

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- 1962- LED first demonstrated at GE Research Laboratory
- 1968- First products in electronic display introduced by HP. about **0.001 lumens at 20 mA in red till 1985,**
- 1985- LED reached **>10 lumens.**
- 1990- **>10 lm/W in GaAlAs**, but color limited to **> 640 nm.**
- 1990's AlGaNp developed and color ranging **from red to yellow-green; > 20 lm/W in 620 nm**
- 1995- HP worked toward 50 lm/W
- In 1995, Nichia reported a breakthrough in GaN blue-green LED and completed the full color spectrum. A new era of solid state lighting began.

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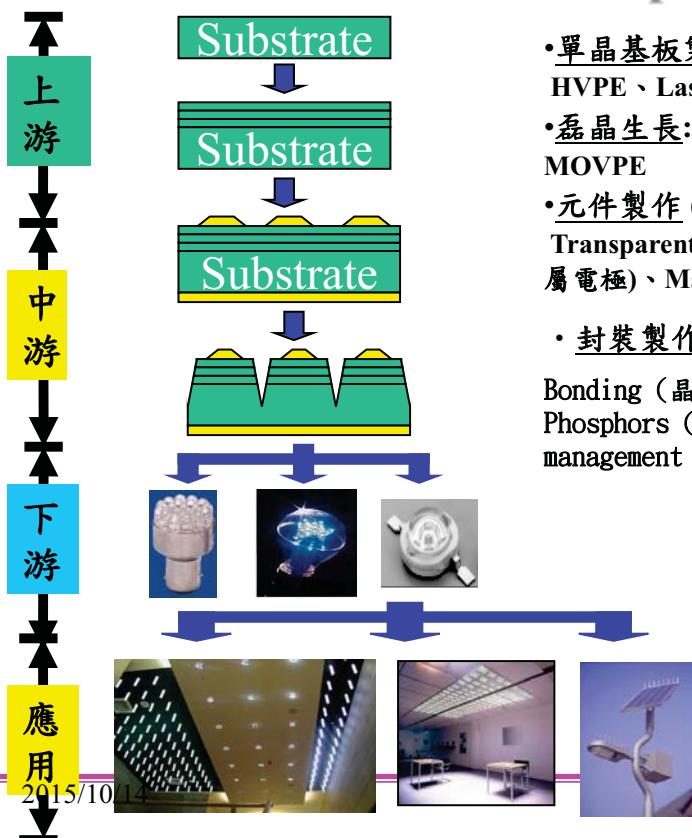
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## 白光 LED的製程

### White LED processes



• 單晶基板製作: (Substrate)

HVPE、Laser lift-off

• 磊晶生長: (Epitaxy)

MOVPE

• 元件製作 (Processing and Fabrication)

Transparent electrodes (透明導電膜)、Metal contacts (金屬電極)、Masks (光罩)、Etching (蝕刻)、Polishing (磨薄)

• 封裝製作 (Packaging)

Bonding (晶粒黏著打線)、Flip-chip (覆晶黏著)、Phosphors (螢光粉塗佈)、Epoxy (樹脂選用)、Heat management (高散熱設計)、Optical Design (光學設計)

• 測試及應用 (Testing):

Optical lumens (光強度)、efficiency (效率)、Color temperature (色溫)、CRI (演色性)、Lamp design、SMD

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## MOCVD System

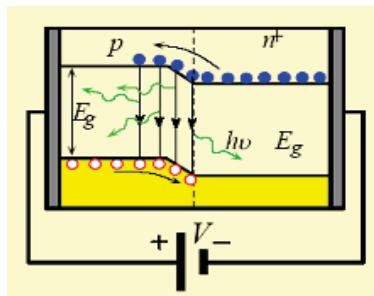
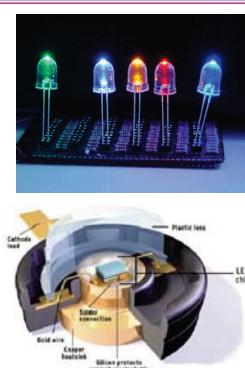
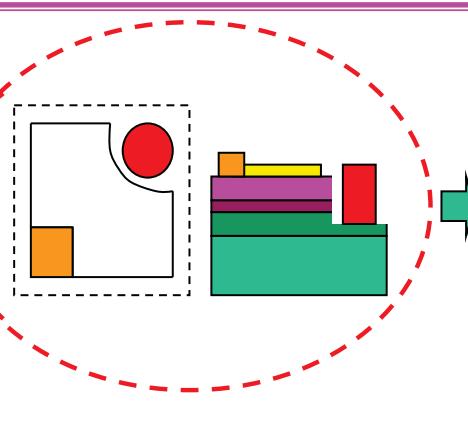
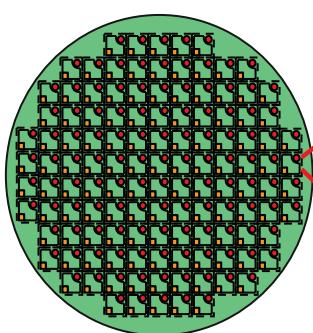
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## Light Emitting Diode (發光二極體)

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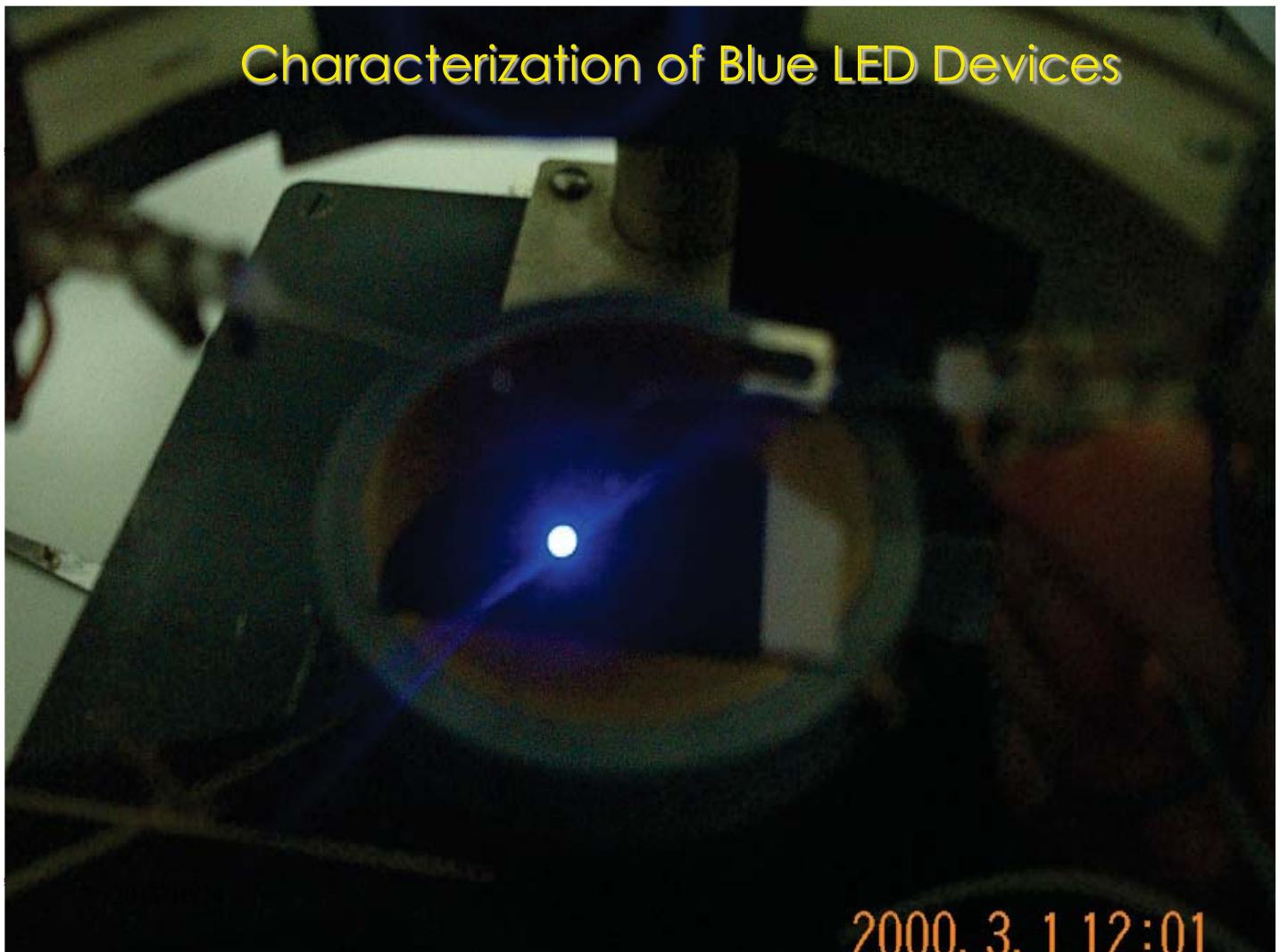


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# Characterization of Blue LED Devices

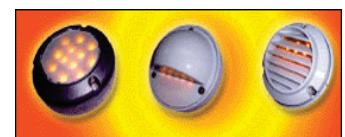


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National Tsing Hua University

## LED 燈的應用



## 2015 LED 投影機

### 1686 投影機



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# 2008 北京奧運

- 奧運會開幕式開創了奧運歷史上大規模使用LED照明技術的先例
- 水立方世界上最大規模的全彩色可變場景LED景觀照明，節電70%



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## 照明的一百多年發展史 - History of Lighting

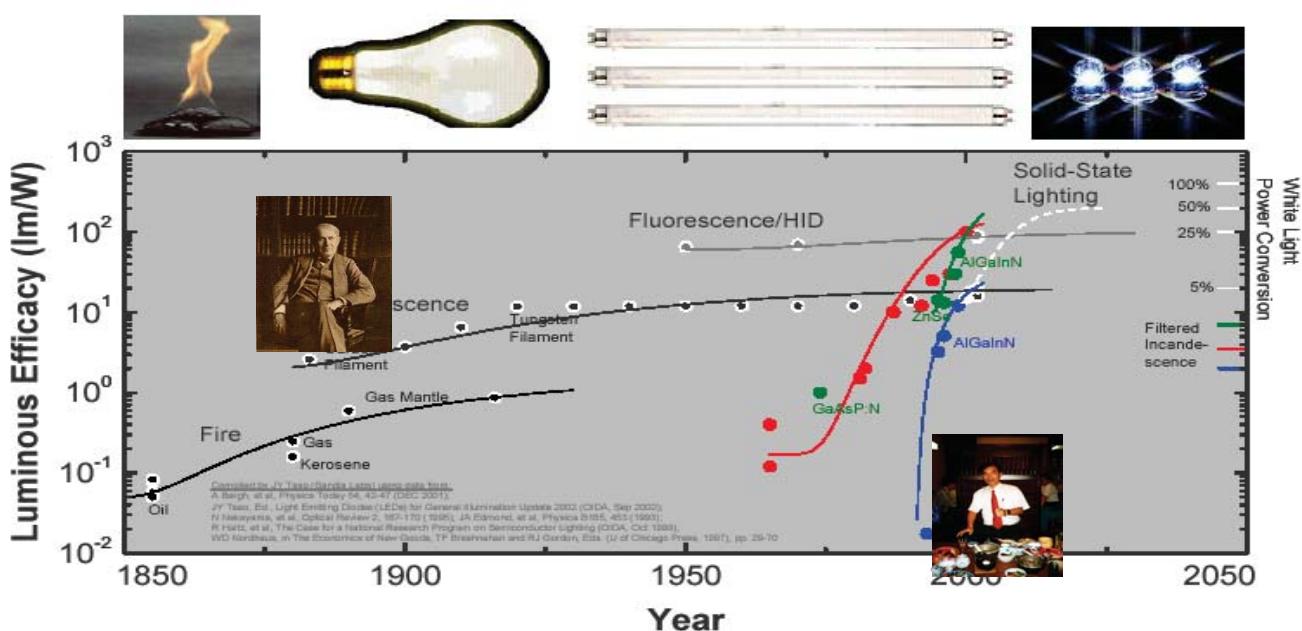


Figure 1: 200-year evolution of luminous efficacy for various lighting technologies.



# LED 燈泡可持續亮19年

楊士範,Tim Hornyak 2009/09/14 17:52:02

- Panasonic 新的家用LED燈泡比之前的白熱燈泡壽命長40倍。這款燈泡屬於EverLed產品線下，在2009/10/21於日本上市，月產量為5萬顆。使用者不需要更換本來家中的白熱燈泡的設備。
- 根據Panasonic，如果每天使用5.5小時，這顆新的LED電球可以持續使用19年，比之前的白熱燈泡長了40倍。
- 這個燈泡僅用到白熱燈泡1/8的電力，60瓦的LED燈泡一年僅需耗新台幣107元，而非本來的一年約新台幣854元。
- Panasonic EverLed產品的售價大約是4000日圓。(約新台幣1438元)



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## LED發展里程表

Table 1: Lamp targets and derived costs for SSL-LED and traditional lighting technologies

|                                 | SSL-LED<br>2002 | SSL-LED<br>2007 | SSL-LED<br>2012 | SSL-LED<br>2020 | INCAN-<br>DESCENT | FLUOR-<br>ESCENT | HID    |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-------------------|------------------|--------|
| LAMP TARGETS <sup>1</sup>       |                 |                 |                 |                 |                   |                  |        |
| Luminous efficacy (lm/W)        | 20              | 75              | 150             | 200             | 16                | 85               | 90     |
| Lifetime (h)                    | 20,000          | 20,000          | 100,000         | 100,000         | 1,000             | 10,000           | 20,000 |
| Flux (lm/lamp)                  | 25              | 200             | 1,000           | 1,500           | 1,200             | 3,400            | 36,000 |
| Input power (W/lamp)            | 1.3             | 2.7             | 6.7             | 7.5             | 75.0              | 40.0             | 400.0  |
| Lamp cost (in \$/klm)           | 200.0           | 20.0            | 5.0             | 2.0             | 0.4               | 1.5              | 1.0    |
| Lamp cost (in \$/lamp)          | 5.0             | 4.0             | 5.0             | 3.0             | 0.5               | 5.0              | 35.0   |
| Color rendering index (CRI)     | 70              | 80              | 80              | 80              | 100               | 75               | 80     |
| DERIVED LAMP COSTS <sup>2</sup> |                 |                 |                 |                 |                   |                  |        |
| Capital cost [\$/(Mlm-h)]       | 12.00           | 1.25            | 0.30            | 0.13            | 1.25              | 0.18             | 0.05   |
| Operating cost [\$/(Mlm-h)]     | 3.50            | 0.93            | 0.47            | 0.35            | 4.38              | 0.82             | 0.78   |
| Ownership cost [\$/(Mlm-h)]     | 15.50           | 2.18            | 0.77            | 0.48            | 5.63              | 1.00             | 0.83   |

1. SSL-LED lamp targets taken from the U.S. SSL-LED Roadmap Update 2002. The targets were developed under the assumption of significant national investment directed towards the key science and technology challenges outlined in that roadmap.

2. Derived lamp costs, assuming that the targets are met. The capital cost is the cost (per Mlm) to buy a light bulb or lamp, amortized over its lifetime (up to 20,000 hours). The operating cost is the cost (per Mlm-h) to run a light bulb or lamp. The life-ownership or ownership cost is the sum of the capital and operating costs. The units for all three are \$/(Mlm-h).

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## Save Earth, Energy and Environment

Goal (2015): 開發高效率半導體光源

⇒ 10x 白熾燈效率

⇒ 2x 螢光燈效率

In USA:

⇒ 每年可減少 25 GW 電力、節約US\$350億電費

⇒ 每年減少 7.5 億噸 CO<sub>2</sub>廢氣產生 (USA)

In China:

⇒ 每年減少 1,000 億度電力 (= 長江三峽大壩發電量)

In the World:

⇒ 紿世界無電無光的20億人口帶來一線曙光

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## 廿世紀最重要的科技

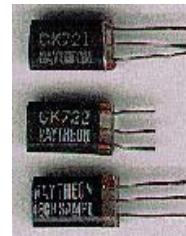
The most important technologies in 20-21 Century



Vacuum  
Tubes

1940-1980

Transistors



CRT  
TV

1980-2010

Flat Panel  
TV and  
Displays



Light  
Bulbs

1996-2020

White Light  
Semiconductor  
Sources



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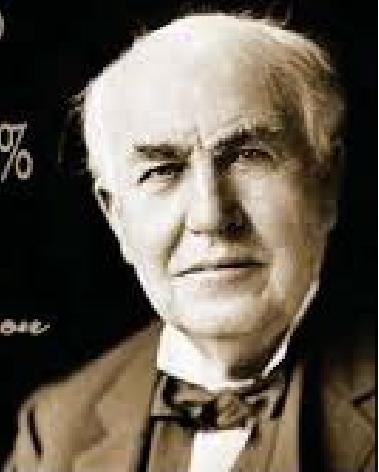


“發明電燈相當了不起、要比我原來想像還要好！但未來如何發展、到何為止、只有上帝才知道！...”

-- 愛迪生, Oct 1879

Genius is one %  
inspiration  
and ninety-nine %  
perspiration.

-- Thomas Edison



" We are striking it big in the electric light, better than my vivid imagination first conceived. Where this thing is going to stop Lord only knows. "

- Thomas Edison, October 1879

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## 封面圖案說明

封面圖案由四十四位重要物理學家的圖片或相片依成就的大致先後順序組圖而成，他們是：

第一列：Galileo **Galilei**, Robert **Hooke**, Isaac **Newton**, Christiaan **Huygens**, Daniel **Bernoulli**, Joseph-Louis **Lagrange**, Charles-Augustin **de Coulomb**, Alessandro **Volta**, James Prescott **Joule**, Thomas **Young**, Augustin-Jean **Fresnel**, Nicolas Léonard Sadi **Carnot**, Michael **Faraday**, Rudolf Julius Emanuel **Clausius**.

第二列：James Clerk **Maxwell**, Ludwig Eduard **Boltzmann**, William Rowan **Hamilton**, William Thomson (Lord **Kelvin**), Hendrik Antoon **Lorentz**, John William Strutt (Lord **Rayleigh**), Max **Planck**, Josiah Willard **Gibbs**, Albert **Einstein**, Ernest **Rutherford**, Heike Kamerlingh **Onnes**, Niels **Bohr**, Louis **de Broglie**, Max **Born**, Werner **Heisenberg**.

第三列：Erwin Schrödinger, Wolfgang **Pauli**, Paul **Dirac**, Enrico **Fermi**, 湯川秀樹 (Hideki **Yukawa**), Lev **Landau**, 朝永振一郎 (Sin-Itiro **Tomonaga**), Julian **Schwinger**, Richard **Feynman**, John **Bardeen**, 楊振寧 (Chen Ning **Yang**), 李政道 (Tsung Dao **Lee**), 吳健雄 (Chien Shiung **Wu**), Murray **Gell-Mann**, Steven **Weinberg**.