物理學史研習會（五）

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

東吳大學第一教學研究大樓 源流講堂

2015 年 10 月 24 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。

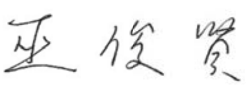
今年本學系再接再厲，於 10 月 24 日及 31 日繼續舉辦兩場「研習會」；「研習會（五）」仍在東吳大學舉行，「研習會（六）」則選在高雄市立高雄中學。因為今年適逢紀念「國際光之年」，特選定「光學」為研習會的主題。兩次研習會因而也被列為「2015 國際光之年」在臺灣的慶祝活動之一。

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逵教授講「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

 謹誌

中華民國 104 年 10 月 24 日

物理學史研習會（五）

手冊

目 錄

物理學史研習會（五）

時間：2015 年 10 月 24 日（星期六）

地點：東吳大學 外雙溪校區 第一教研大樓 源流講堂

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	巫俊賢（東吳大學物理學系主任）	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 中華民國光電學會理事長）	光學與我——兼介紹「2015 國際光之年」
10:25 ~ 10:45 茶敘		
10:45~12:00	劉源俊（東吳大學物理學系名譽教授） 討論	光學的歷史
12:00 ~ 13:00 午餐		
13:00~14:10	邱爾德（陽明大學生醫光電暨分子影像研究中心主任） 討論	顯微術發展史
14:10~15:20	李晁逵（中山大學光電工程學系副教授） 討論	雷射發展史
15:20 ~ 15:40 茶敘		
15:40~16:50	劉容生（清華大學退休榮譽教授） 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 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~）並兼生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」。

李晁逵 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。

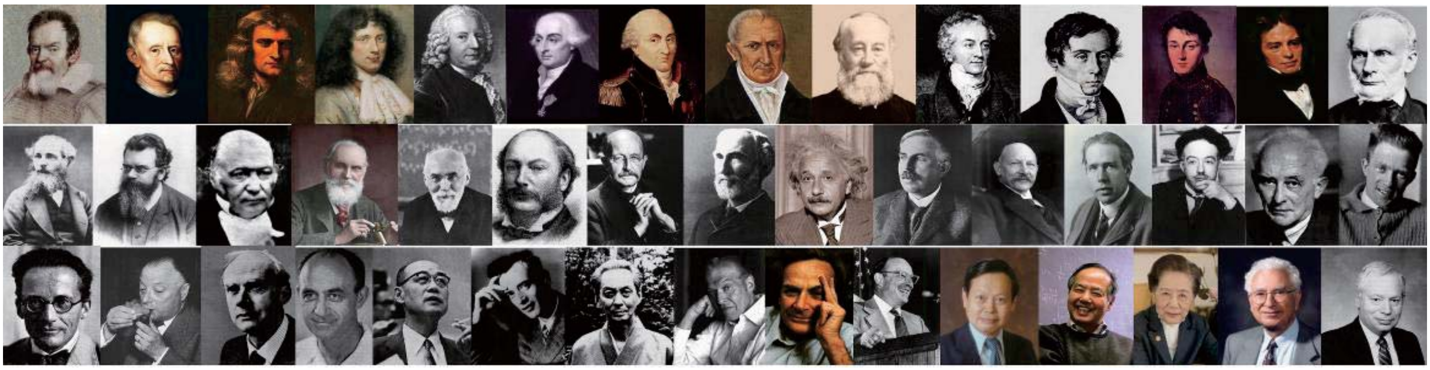
劉容生 現為國立清華大學榮譽退休教授。

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）。



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養天地正氣 法古今完人
SOOCHOW 東吳大學 UNIVERSITY
UNTO A FULL GROWN MAN

till we all attain unto the unity of the faith, and of the knowledge of the Son of God, unto a full grown man, unto the measure of the stature of the fullness of Christ

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

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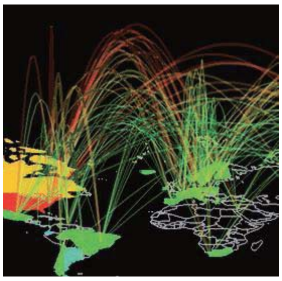
The International Year of Light and Light-based Technologies 2015

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.

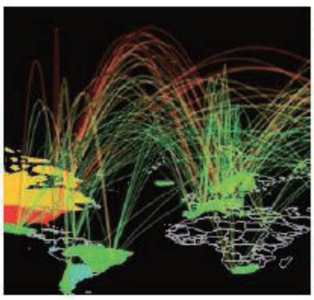
Why Light?

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

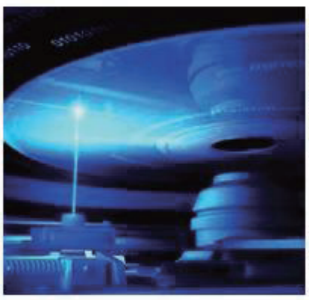
Light-based technology is a major **economic driver** with potential to revolutionize the **21st century** [as electronics did in the **20th century**].

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

INTERNATIONAL
YEAR OF LIGHT
2015

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

- 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准，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，說在摶。
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（一說柂，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

墨子像

《墨經》針孔成像

2015 Celebrates Major Anniversaries

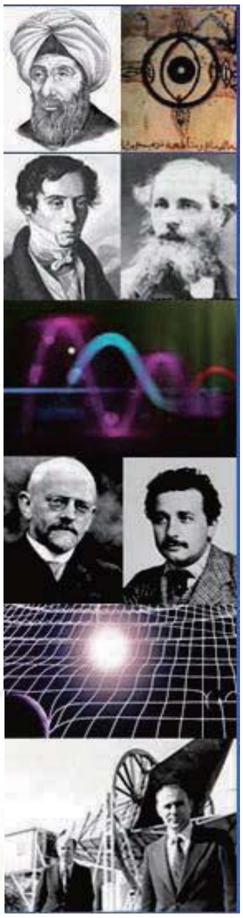
1015 Ibn Al Haythem (伊本・海賽姆) *Book of Optics*

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

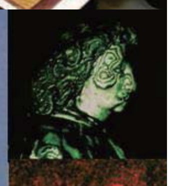
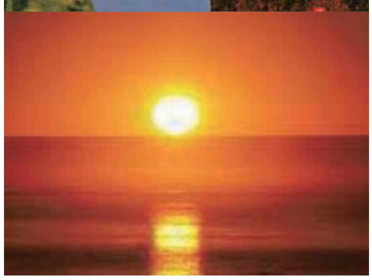

Cultural Heritage

Education for All

Nature

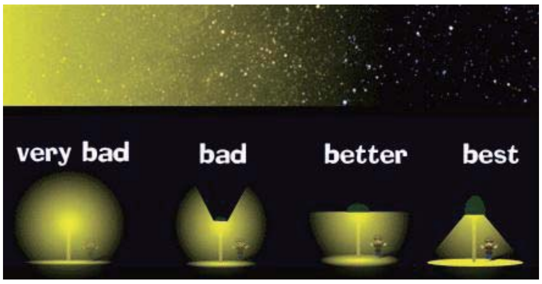
Light and Art



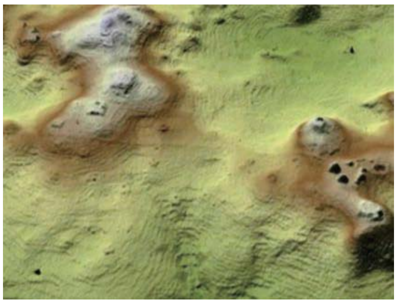



Cultural Heritage

Smart lighting can both highlight culture and reduce light pollution

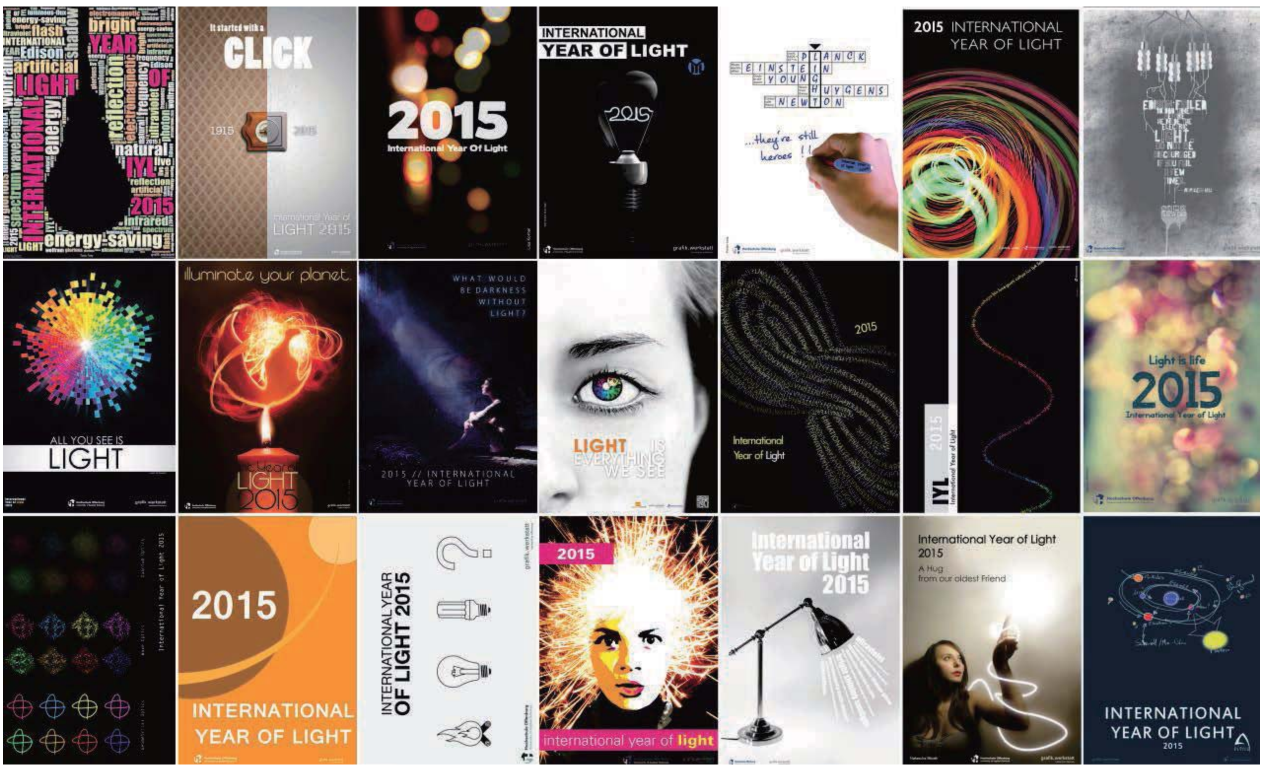


Optical technologies give new impetus - from art to archaeology



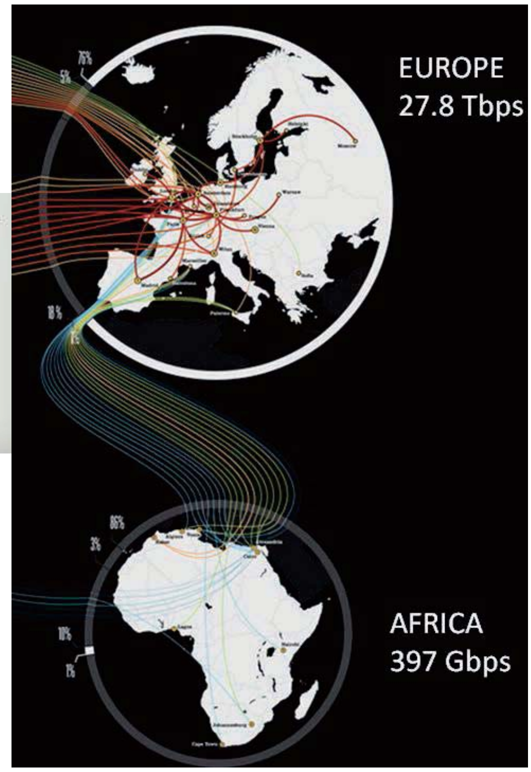
Laser imaging at Caracol, Mexico

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

Photonics Industry

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

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

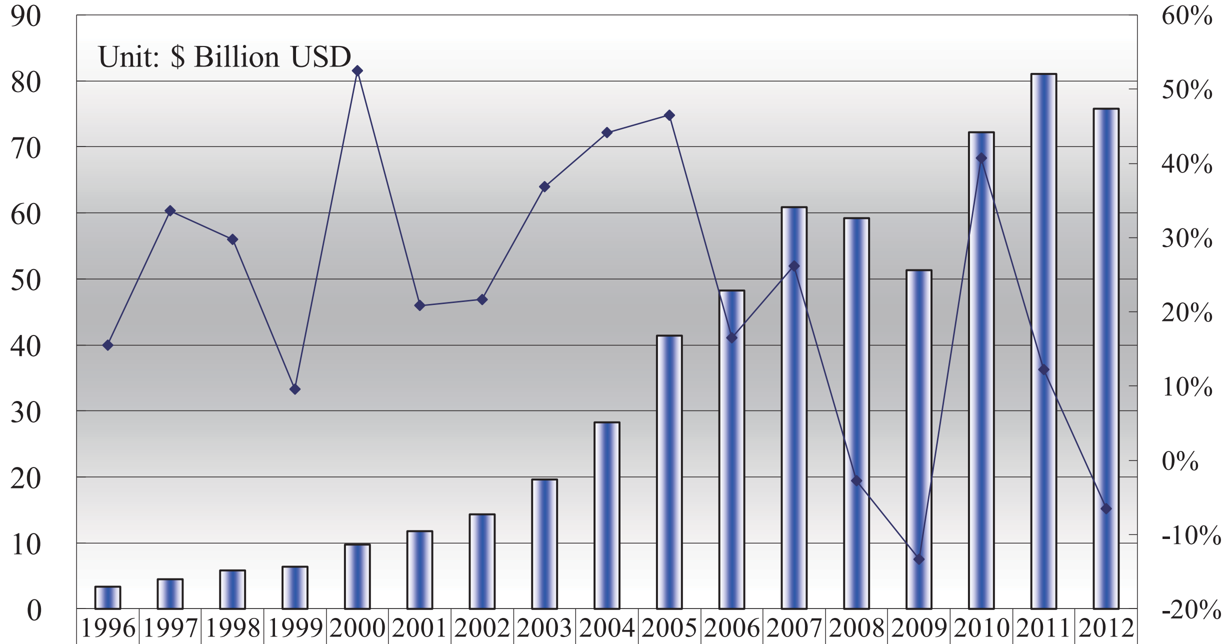
Optical Fiber Communication
- Optical Fiber & Cable
- OFC Components
- OFC Equipments

Precision Optical Components & Lens
- Optical Glass / Plastic Material
- Lens Module

LASER Light Sources & Industry, Biophotonics
- LD, CO_2 / HeNe Lasers
- Material Processing Machine, Medical Device, etc.

Taiwan industry grew with worldwide market

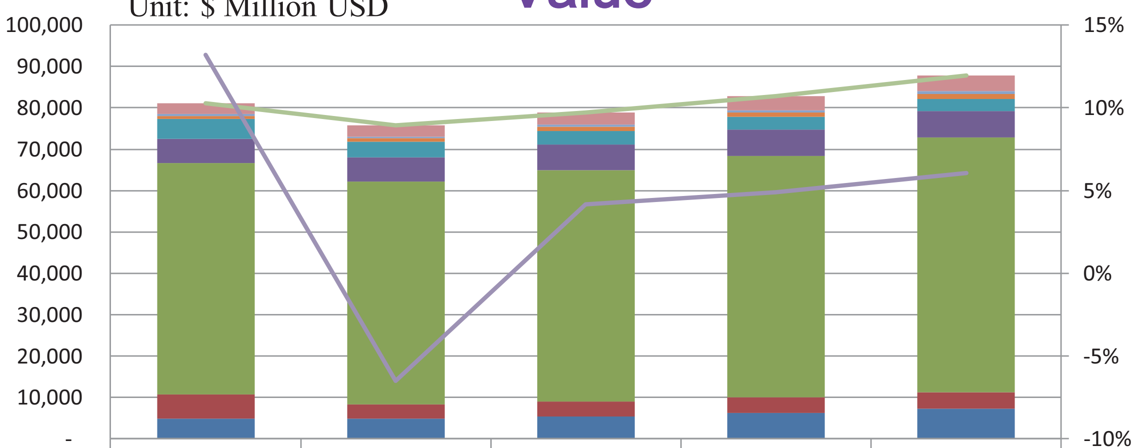
Taiwan Photonics Production Value Trend 1996~2012



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Production Value	3.4	4.5	5.8	6.4	9.7	11.8	14.3	19.6	28.3	41.4	48.2	60.9	59.2	51.3	72.2	81.1	75.8
Growth Rate	16%	34%	30%	10%	52%	21%	22%	37%	44%	46%	17%	26%	-3%	-13%	41%	12%	-7%

June, 2013

The Trend of Taiwan Photonics Production Value



	2011	2012	2013(F)	2014(F)	2015(F)	CAGR
Precision Lens	2,597	2,716	3,023	3,396	3,841	8%
Laser Application	367	424	488	565	655	12%
OFC	811	908	1,014	1,107	1,205	8%
Optical Storage	4,836	3,691	3,339	3,098	2,896	-10%
Sensor & I/O Devices	5,710	5,942	6,111	6,248	6,413	2%
FPD	55,934	53,756	55,999	58,426	61,568	2%
Photovoltaic	5,949	3,542	3,597	3,766	3,955	-8%
LED & SSL	4,845	4,801	5,385	6,229	7,323	9%
Total Value	81,050	75,781	78,955	82,833	87,855	2%
Growth Rate	13%	-7%	4%	5%	6%	

June, 2013

台灣光之年籌備委員會
Taiwan IYL Committee

TIYLC LOGO

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。

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昇成國際盛事。

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”

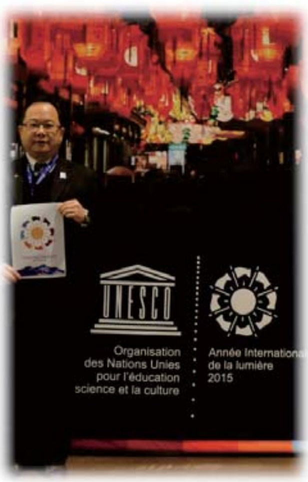
January 9, 2015

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 Arthurs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

臺北市教育局局長
湯志民上台致詞

揭幕典禮

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

李正中老師介紹光之奧妙

於愛因斯坦燈前合影留念

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、二月系列演講 (IYL Talks Series)

台灣IYL 演講活動

- 國際光之年三月系列演講 (IYL Talks Series)

台灣IYL 演講活動

- 國際光之年四月系列演講 (IYL Talks Series)

台灣IYL 演講活動

- 國際光之年五月系列演講 (IYL Talks Series)

台灣IYL 演講活動

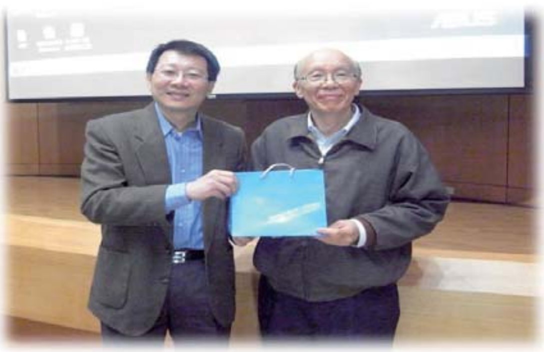
- 國際光之年六月系列演講 (IYL Talks Series)

台灣IYL 演講活動

- 國際光之年九、十月系列演講 (IYL Talks Series)

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

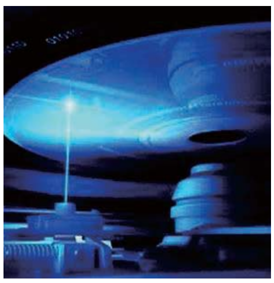
中央大學陳昇暉主任至
台大物理系給予演講

INTERNATIONAL YEAR OF LIGHT 2015

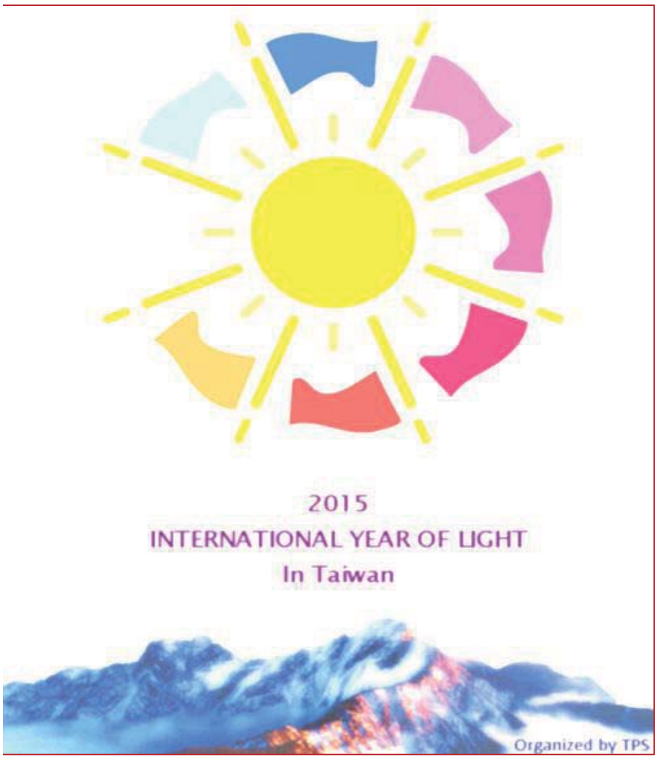
The International Year of Light and Light-based Technologies 2015

UNESCO

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 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 (7th Asia and Oceania Conference on Photobiology , AOCP 2015)	涂世隆	中研院植微所
2015/12/04~12/06	光電年會 OPTIC 2015 (Optics & Photonics Taiwan, International Conference) **The End of IYL 2015**	劉容生 王立康 黃衍介 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

學習光學的故事my story

- 基礎光學, 全相片,光波導 (1979-1983,1983-1985)
  Optics, Hologram, Optical Waveguide
- 拉曼光譜,光學子STM,波導速逝波(1985-1990)
  Raman Spectroscopy, Photon Scanning Tunneling Microscopy, Evanescent Wave
- 近場光學, 奈米光學, 奈米光電, 電漿子光學 (1990-2000)
  Near-field Optics, Nano Optics, Nanophotonics, Plasmonics
- 超穎物質,變換光學,超穎表面,超穎全相片,超穎元件(2000-2015)
  Metamaterial, Transformation Optics, Meta Surface, Meta Hologram, Meta Device and System

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

大綱

光

光源

光速

有關光的重要實驗

光的學說

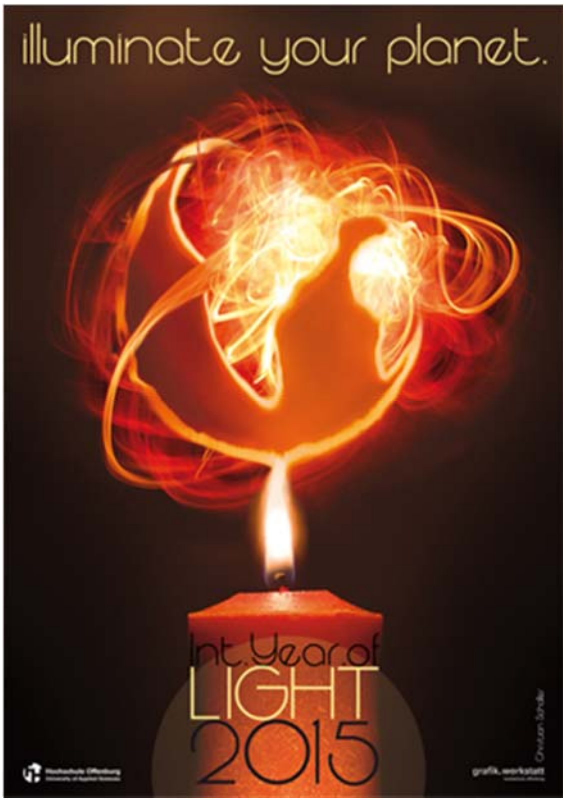
線光學

波光學

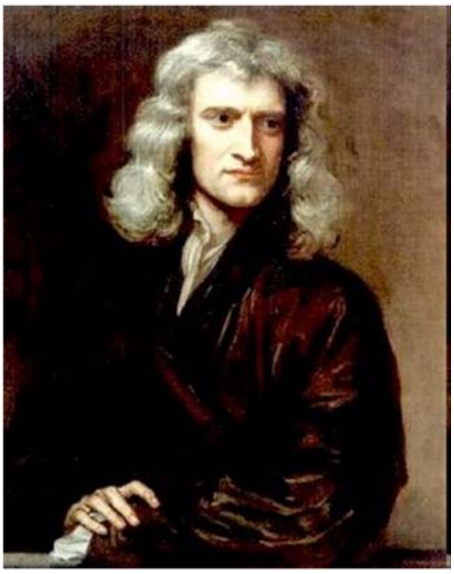
量子光學

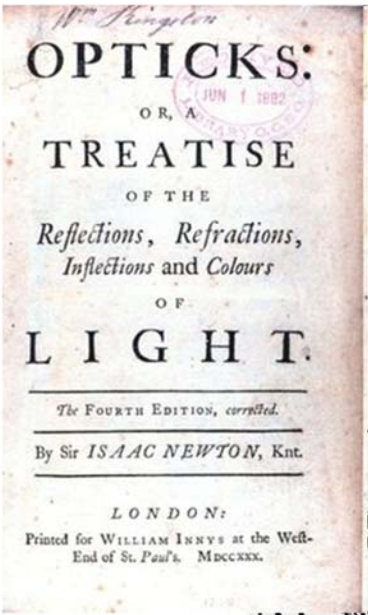
2015 國際光之年 紀念

- 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





OPTICKS:

OR, A

TREATISE

OF THE

Reflections, Refractions, Inflections and *Colours*

OF

LIGHT.

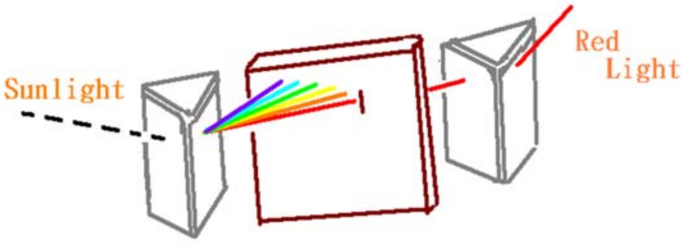
The FOURTH EDITION, *corrected.*

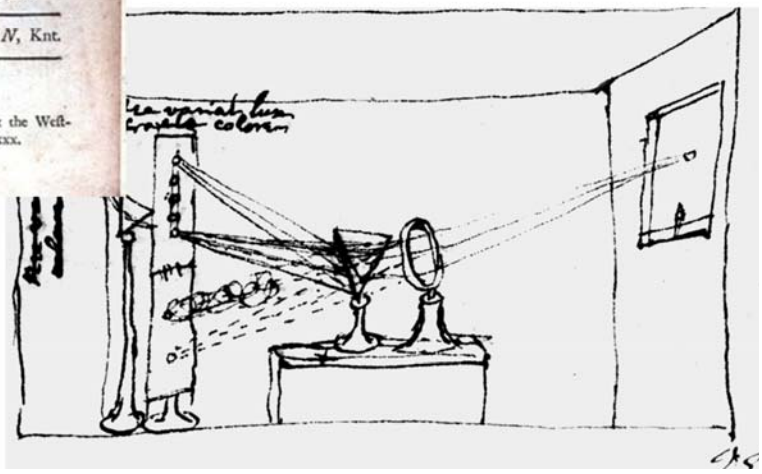
By Sir *ISAAC NEWTON*, Knt.

LONDON:

Printed for WILLIAM INNYS at the West-End of St. *Paul's*. MDCCXXX.

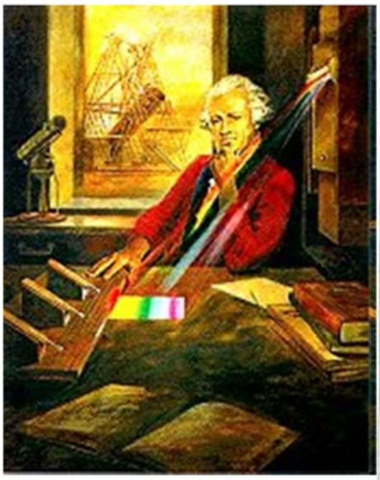
太陽光束經稜鏡生色散。所分出來的單色光再經稜鏡則不生色散。

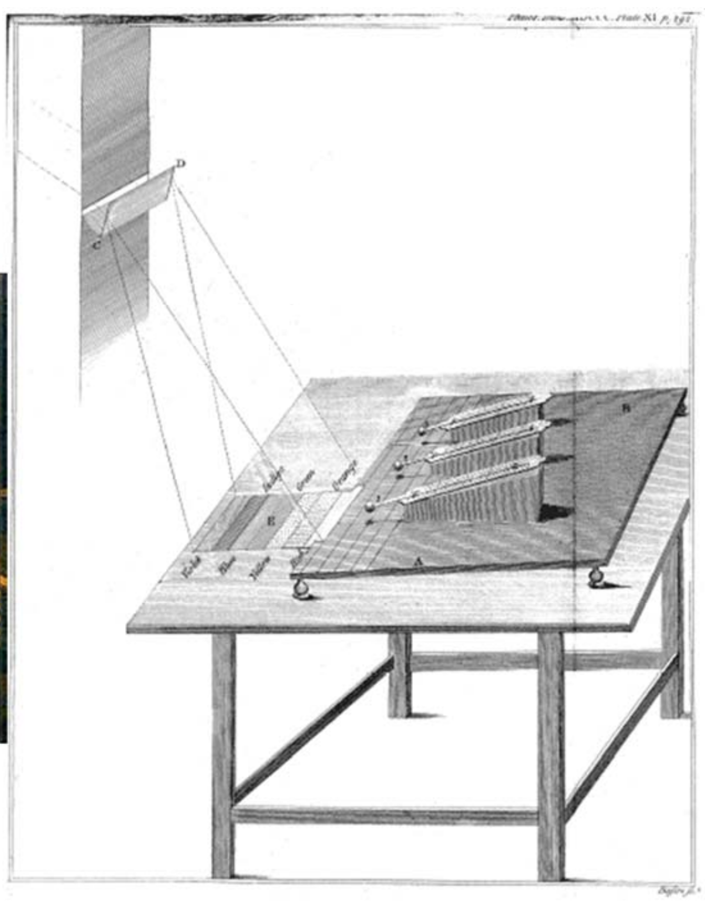




1800 Herschel　發現紅外線

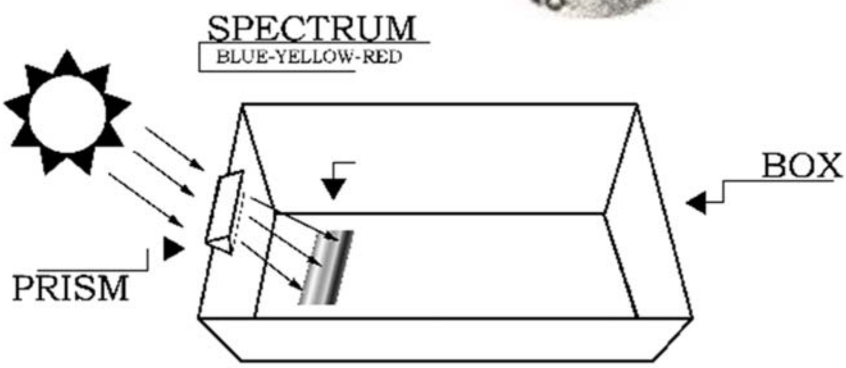
利用稜鏡與溫度計發現紅外線。





1801 Ritter 發現紫外線

紫外線能使氯化銀底片感光。



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


LED
Coffee
OPEN
24/7
BAR

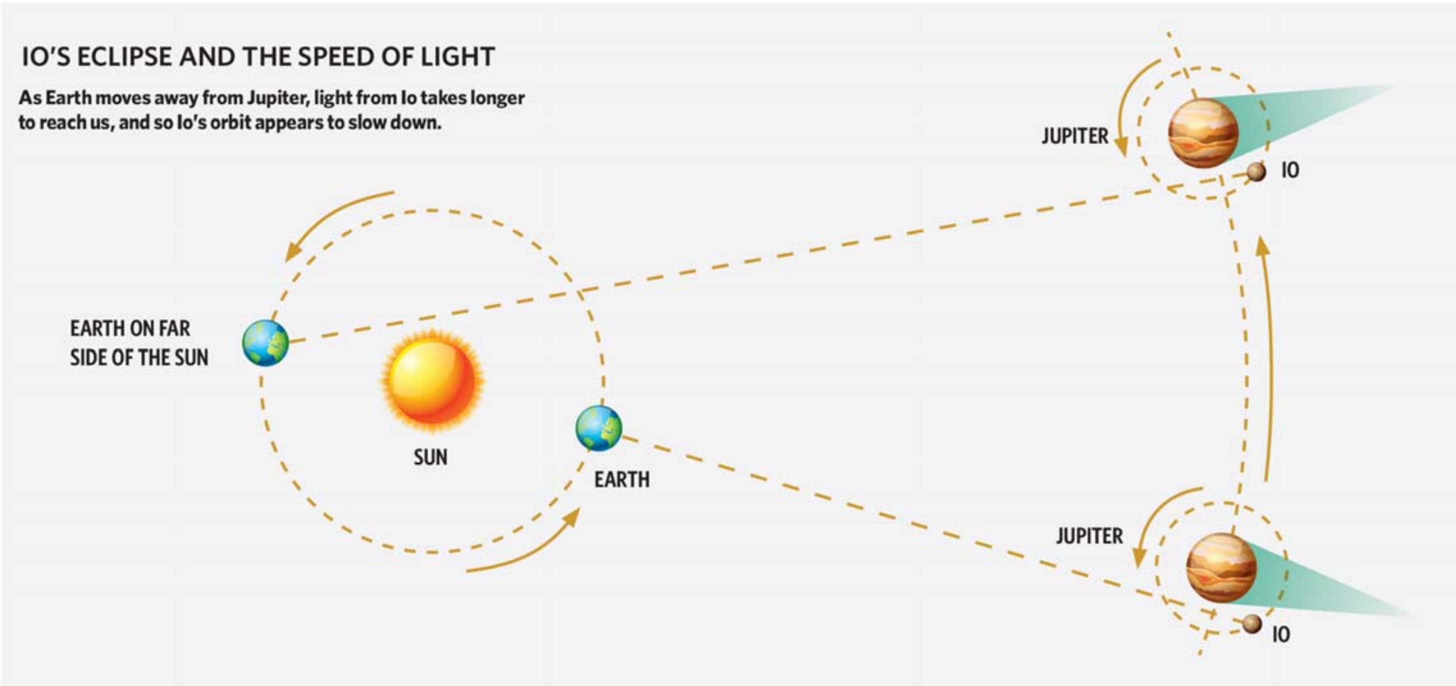
光速的測定（訂定）

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

Galileo

測不出光速

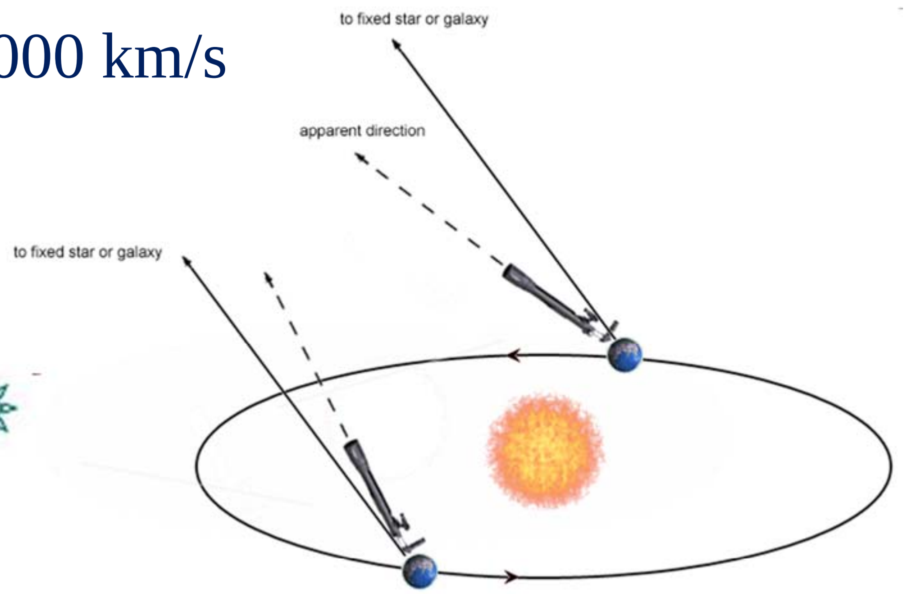
1676 Rømer
從木星衛星蝕的時間延遲推算光速



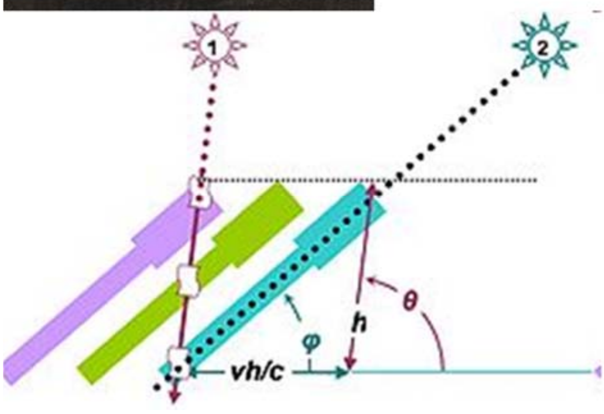
Huygens 估算得光速為110,000,000 toises/s, 1 toise ≈1.949 m 。

1729 Bradley
從星光的光行差測定光速

301,000 km/s

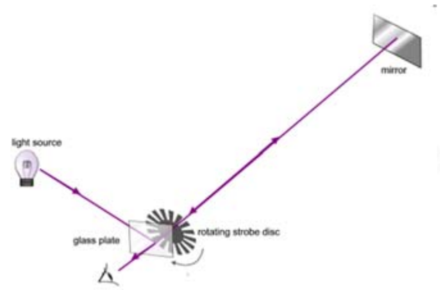


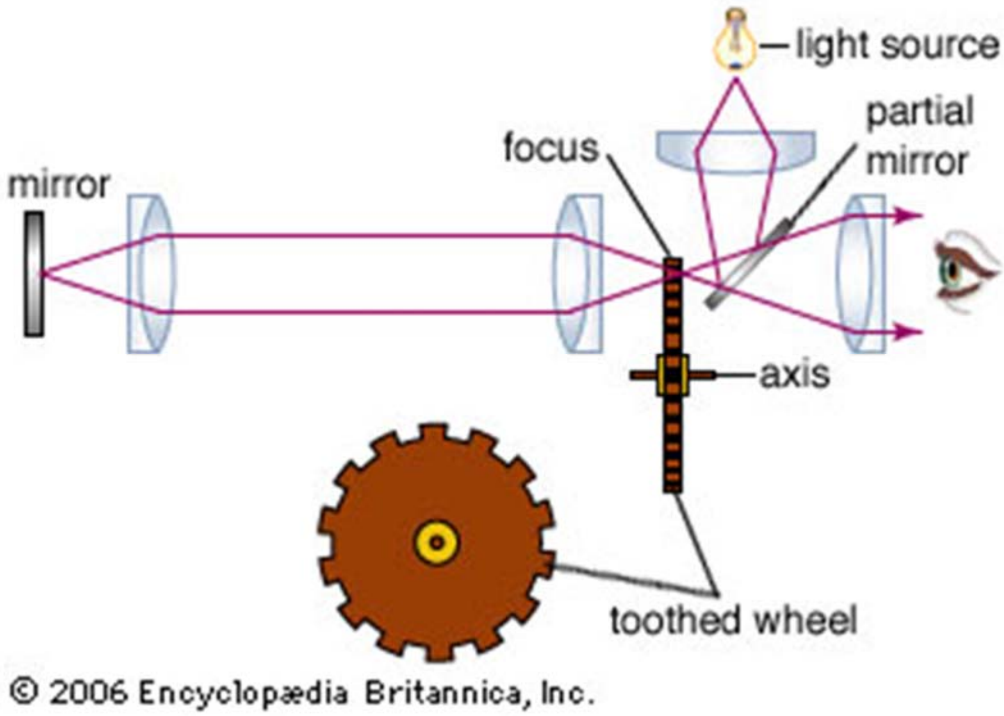
The apparent change in position of a fixed star or galaxy during an earth year is called aberration of starlight and its solution will be by means of derivation of relativistic aberration of starlight which Einstein accomplished in special relativity, 1905.

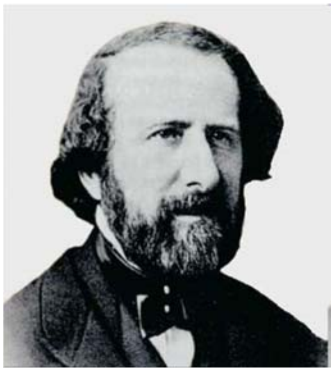


1849 Fizeau 地面上測定光速

- 空氣中光速：313,300 km/s

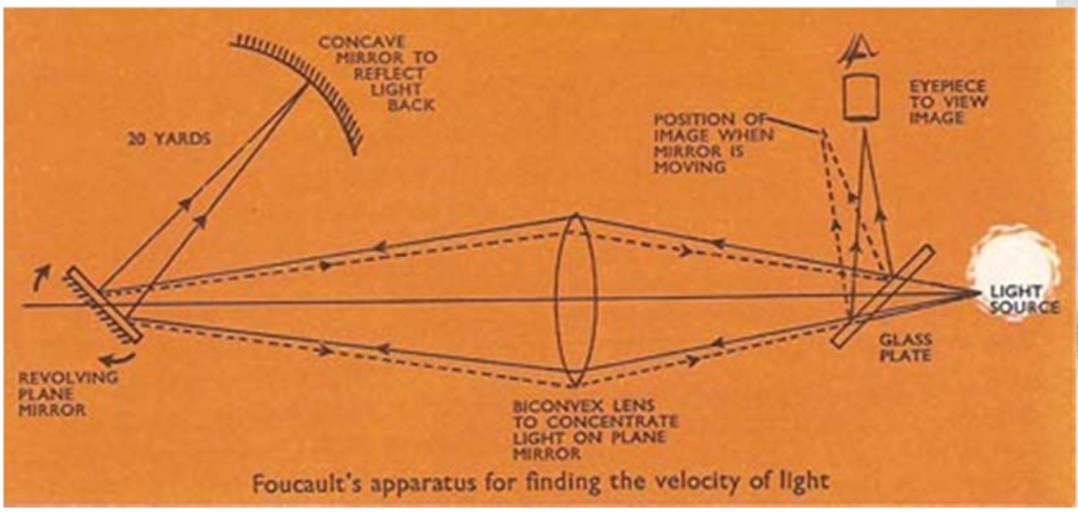






1850 Foucault 測定水中光速

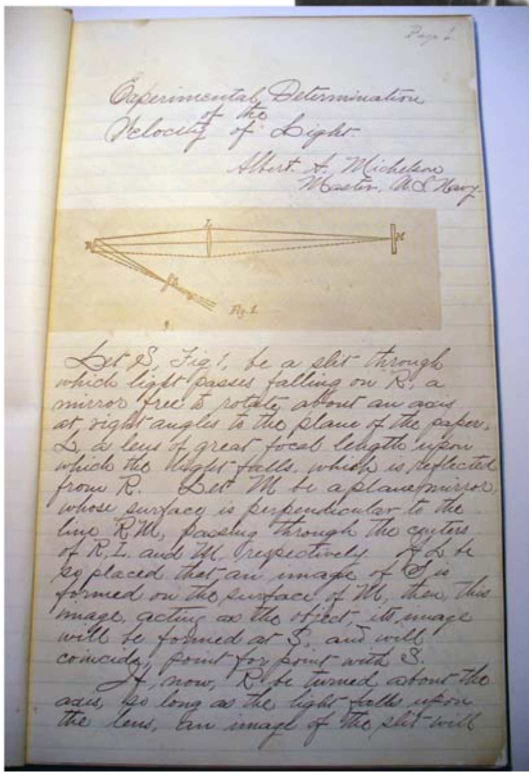
- Foucault 用旋轉鏡方法更準確地測定了光速：298,000 km/s (1862)。
- 發現水中光速較小，支持波動說。



Foucault's apparatus for finding the velocity of light

Michelson 測量光速一生
1877-1931

- 1879 測得 299,910 ± 50 km/s。
- 1883 測得 299,853 ± 60 km/s。
- 1926 測得 299,796 ± 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 ± 11 km/s。



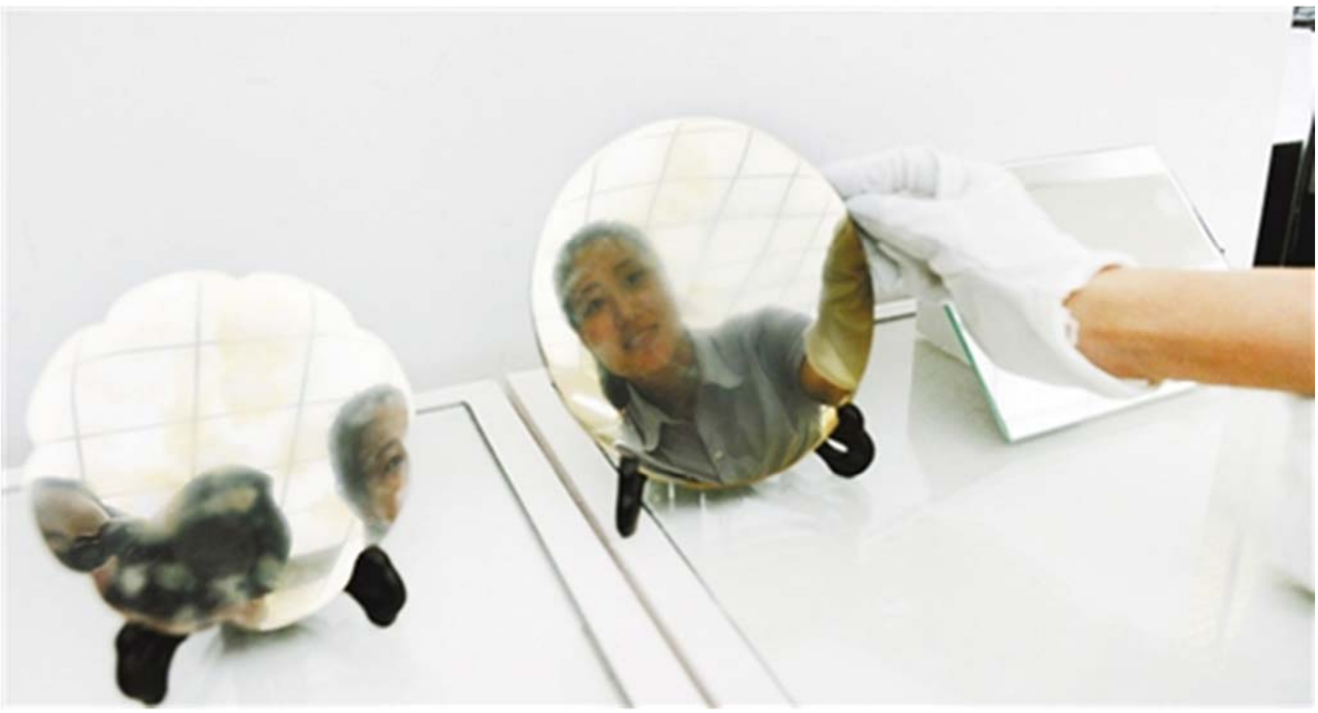
訂定值

- 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4×10^{-9}之內。
- 1983年，國際標準制（SI）訂定光速為確定值 299,792,458 m/s。

有關光的重要實驗

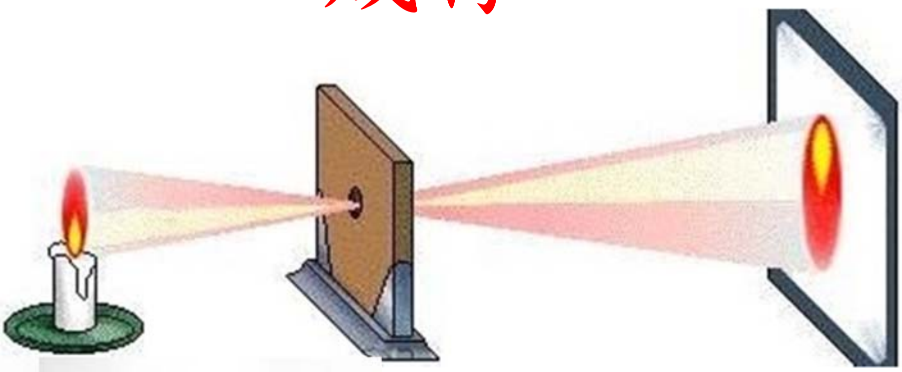
- 照鏡子
- 影
- 折射
- 雙折射
- 針孔成像
- 透鏡成像
- 分光
- 薄膜
- 狹縫干涉與衍射
- 色光三原色
- 偏振
- 光譜儀
- 都普勒效應

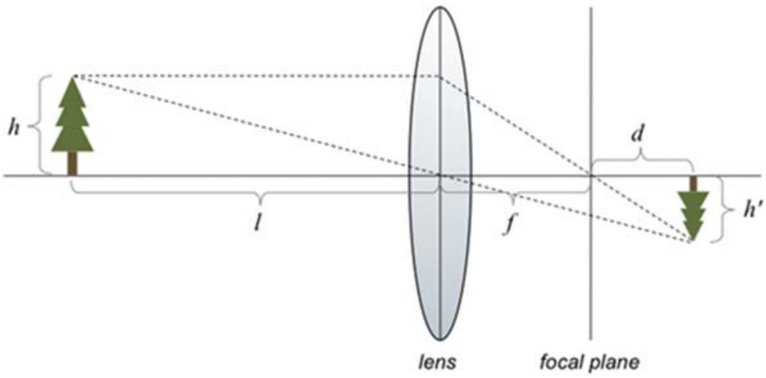
最古老的光學實驗——照鏡子



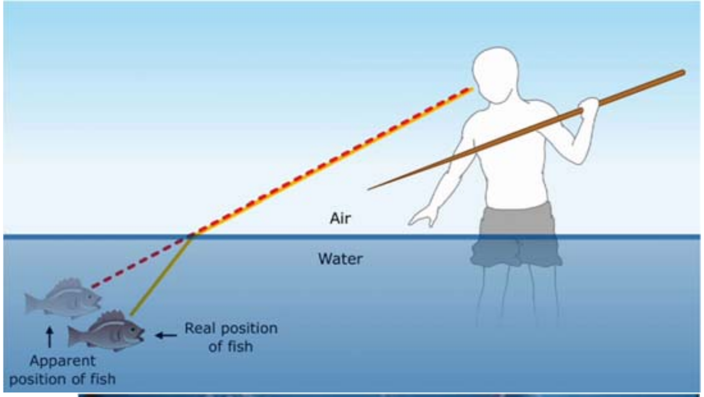
最古老的光學實驗——影

成像

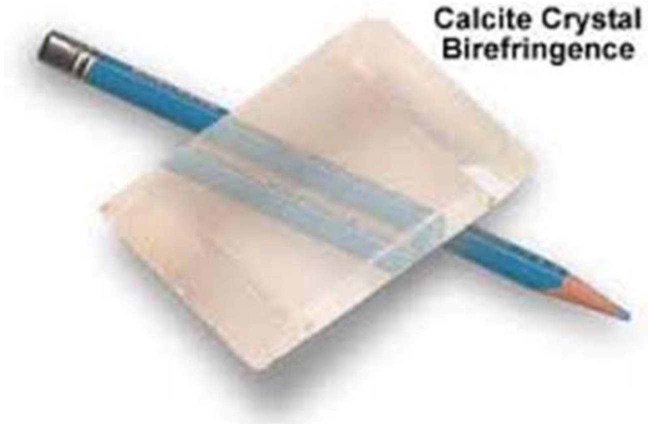




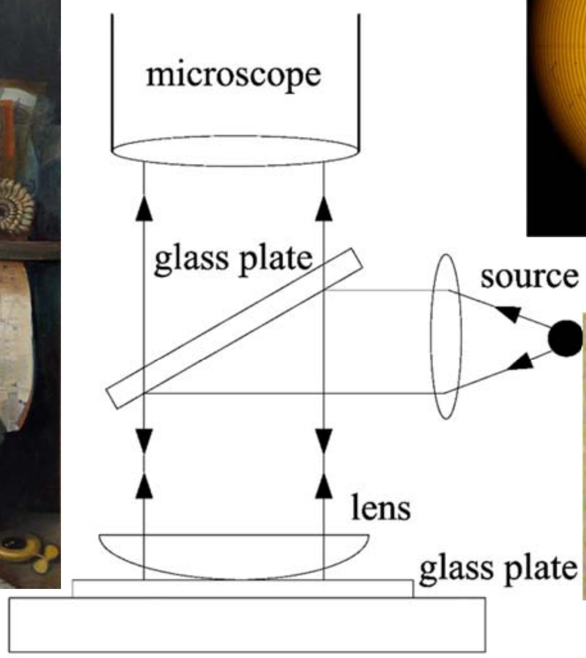
折射



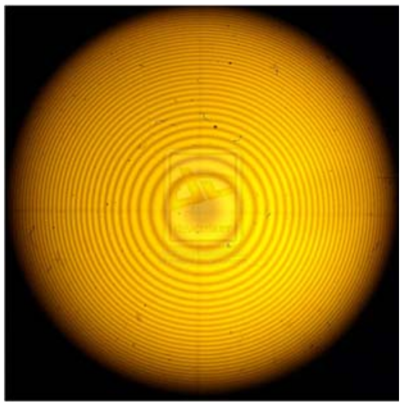
雙折射

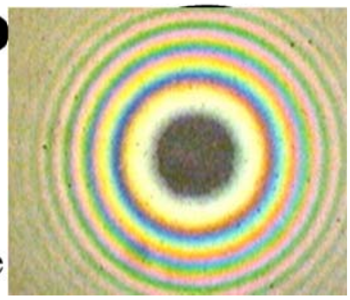


1660s Hooke 牛頓環



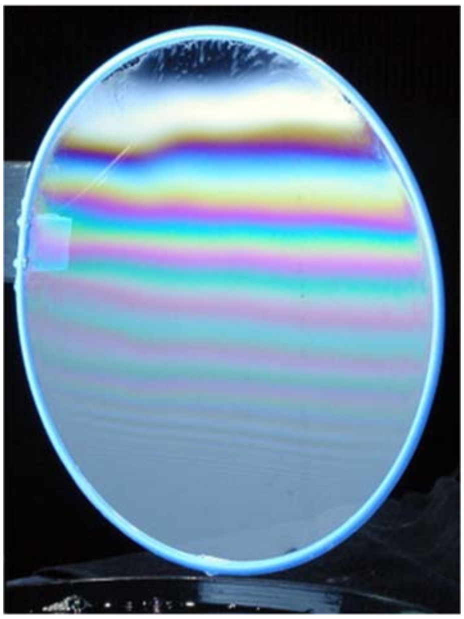
(a)



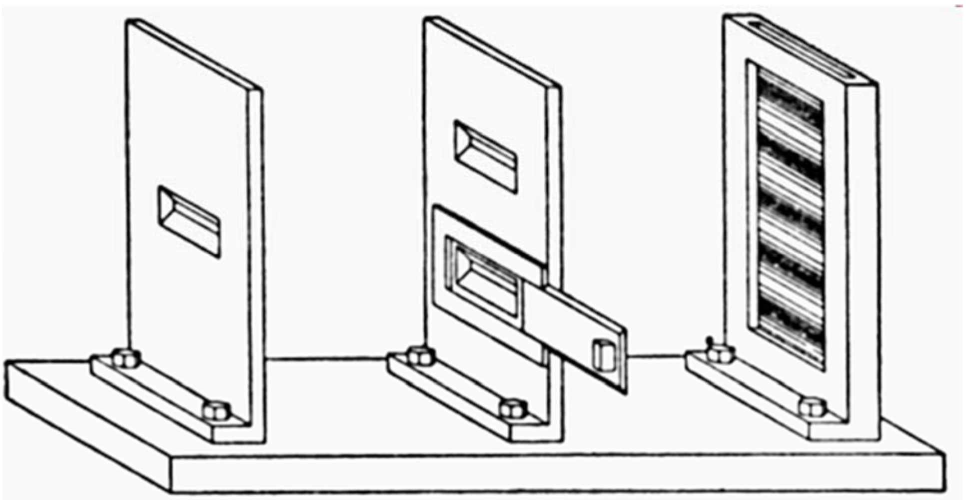


(b)

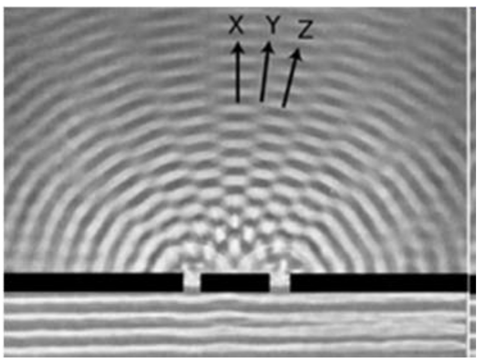
薄膜光彩

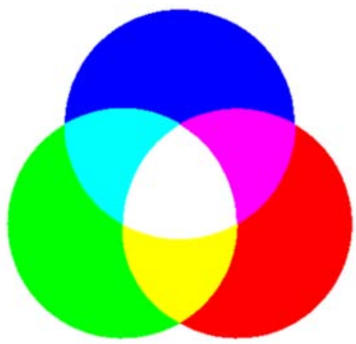


1802 Young　光的雙狹縫干涉

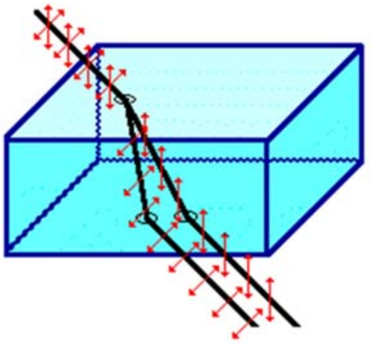


用水波槽譬喻
光的波動說。



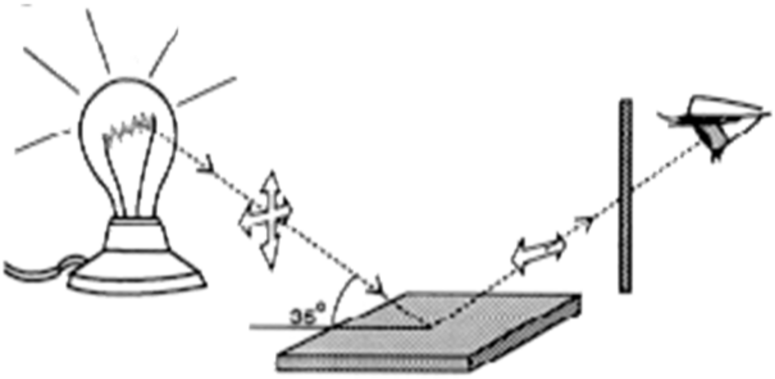


1808 Malus　光反射引致偏振



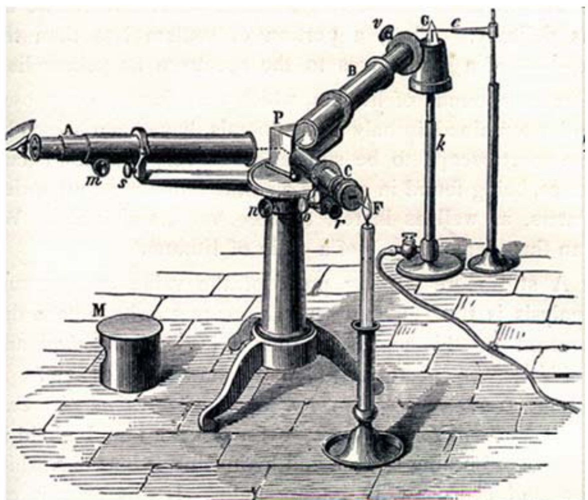
The two refracted rays passing through the Iceland Spar crystal are polarized with perpendicular orientations.

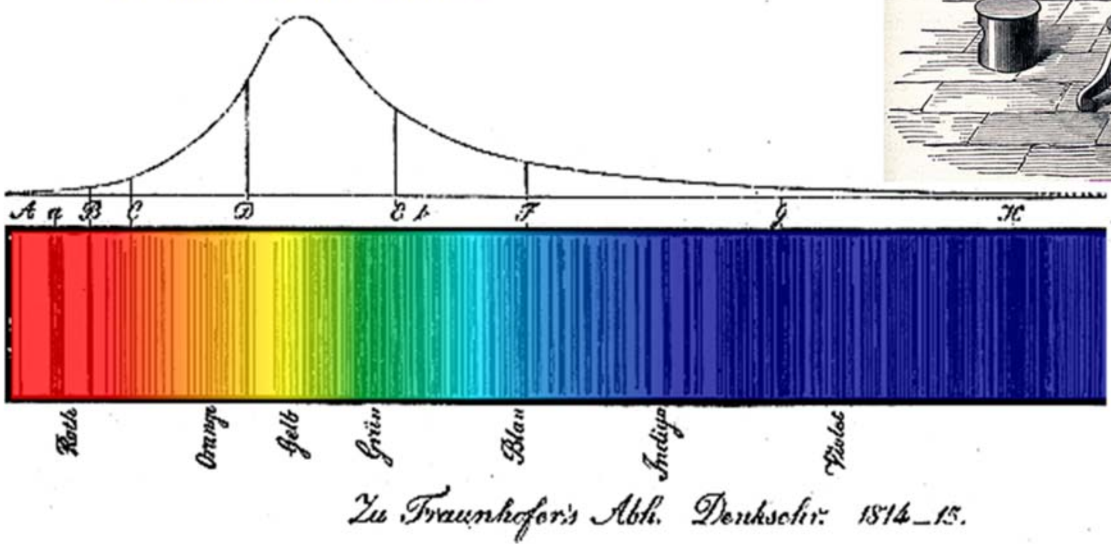
旋轉雙折射晶體（方解石），發現經玻璃反射的光可改變明暗。後經研究，光經反射可偏振化。



1814 von Fraunhofer
光譜儀與太陽暗線光譜

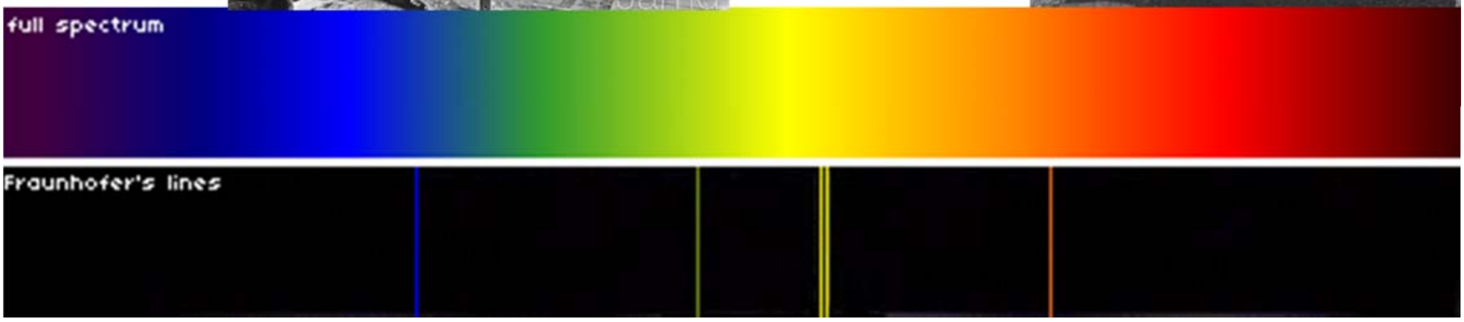
利用光譜儀發現太陽光譜裡的324條暗線，後經Bunsen與Kirchhoff解釋為吸收光譜。



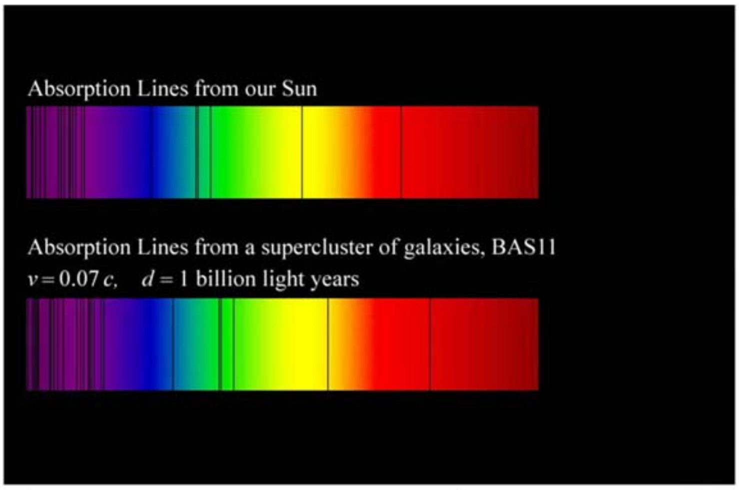


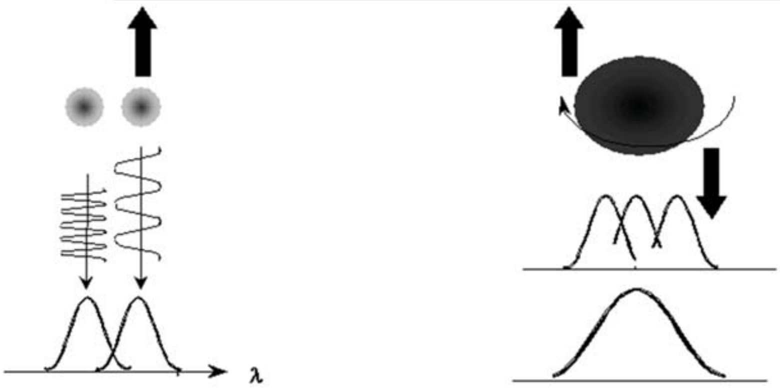
1821 Fraunhofer　絲線光柵

用260條絲線製成最早的光柵，
可分辨出鈉的雙黃線。



1848 Fizeau　光的都普勒效應





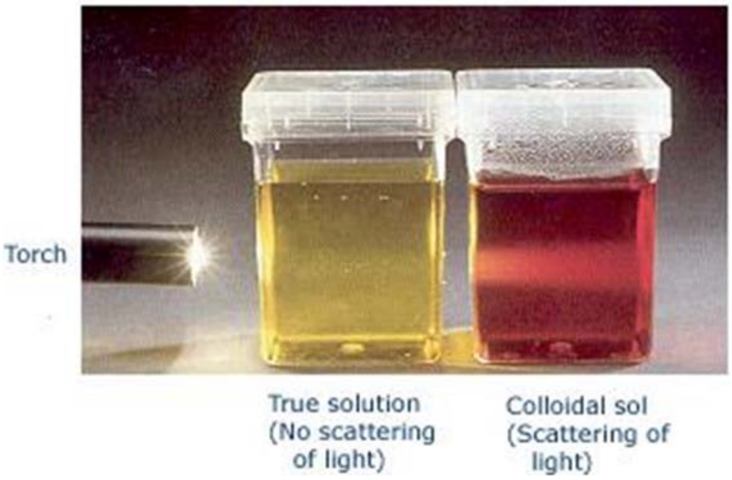
有關光的重要實驗（二）

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

散射

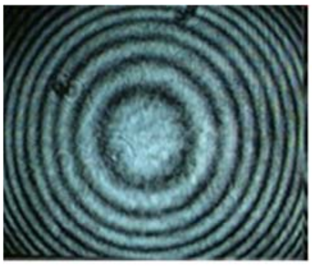
Tyndall 效應



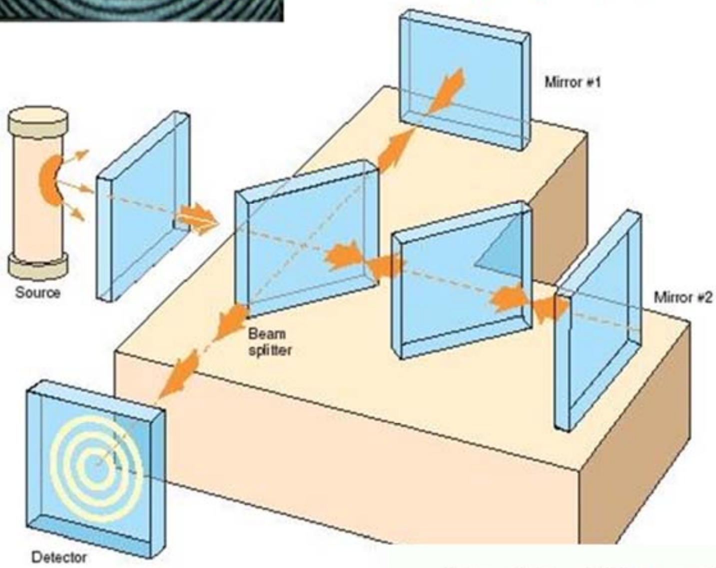


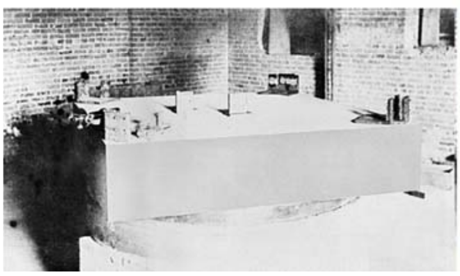
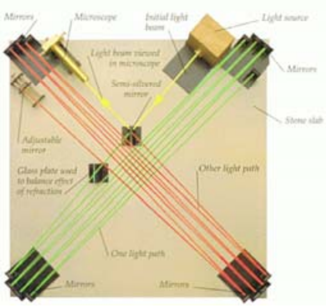
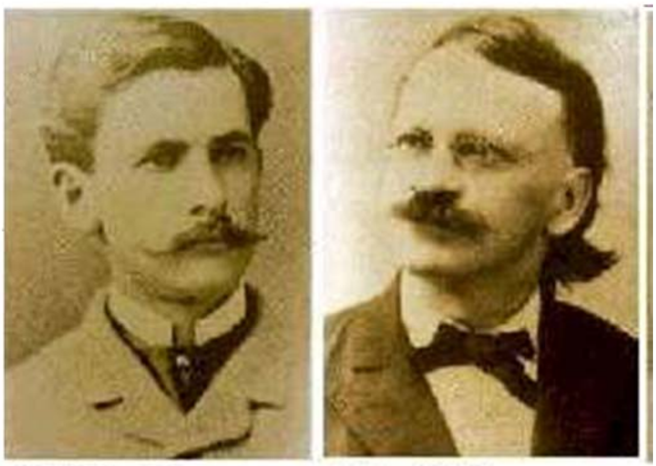
1887 Michelson/Morley

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。

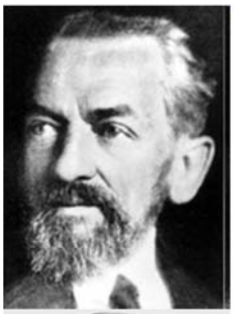


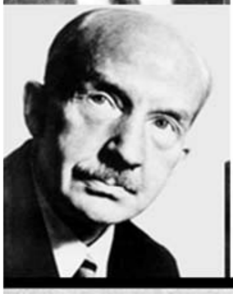




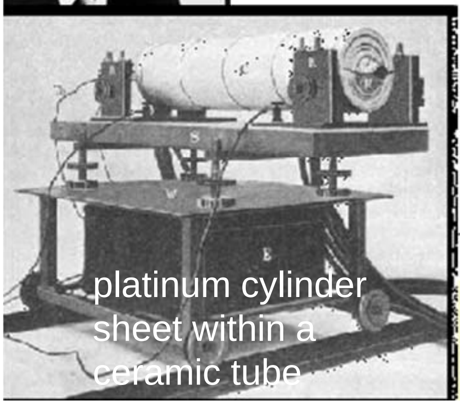
A.A. Michelson 1852 - 1931

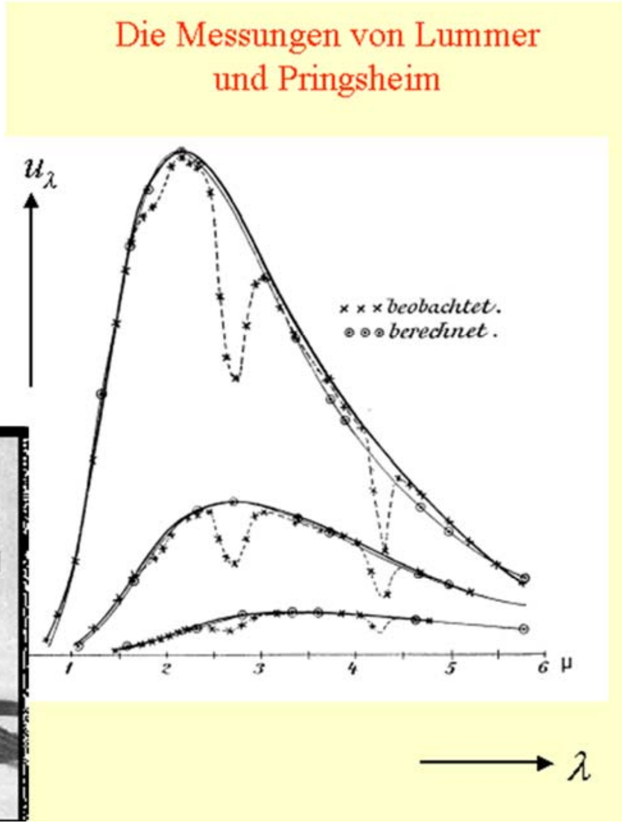
E.W. Morley 1838 - 1923

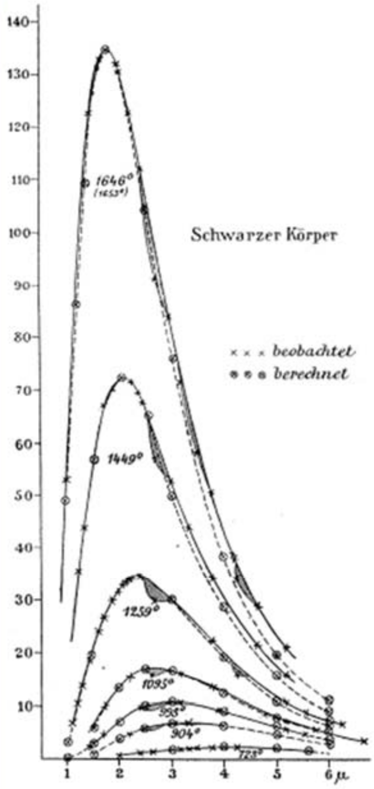
1899 Lummer/Pringsheim 黑體輻射光譜



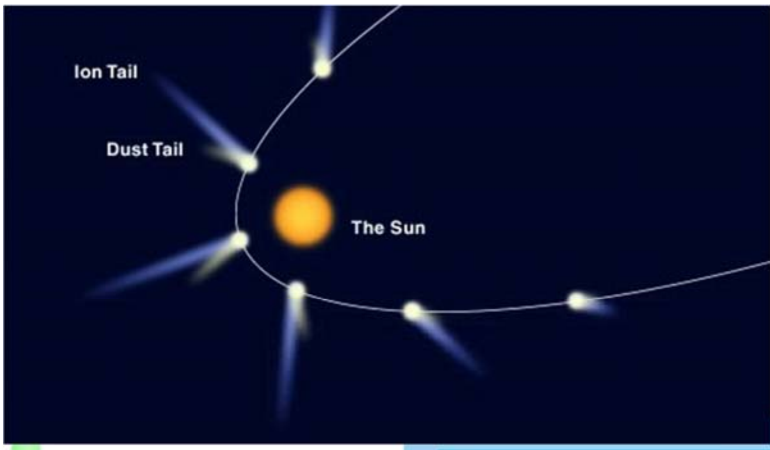




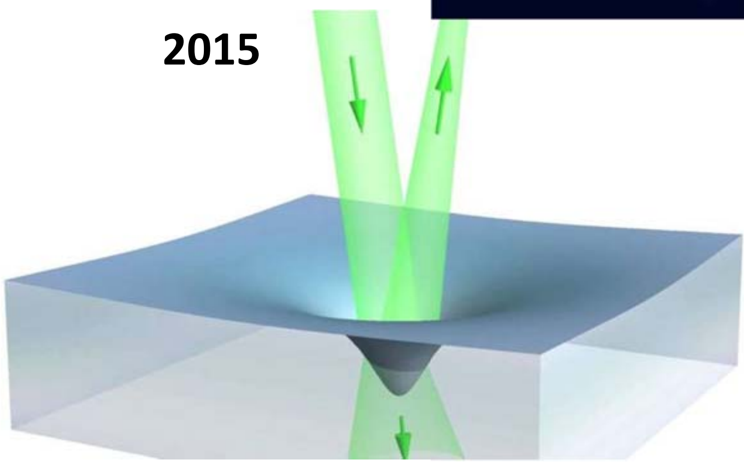


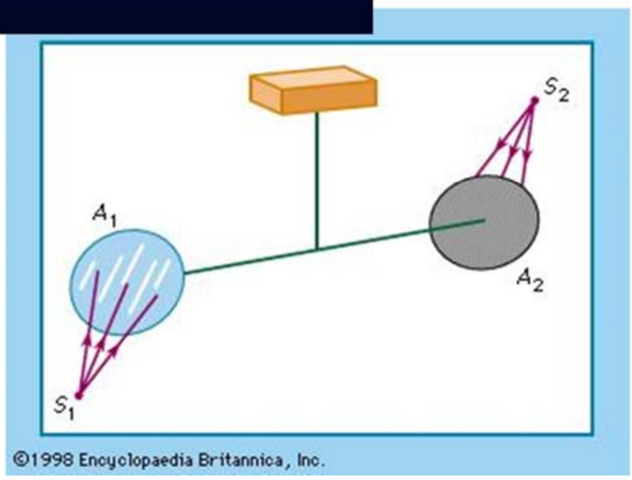


光壓

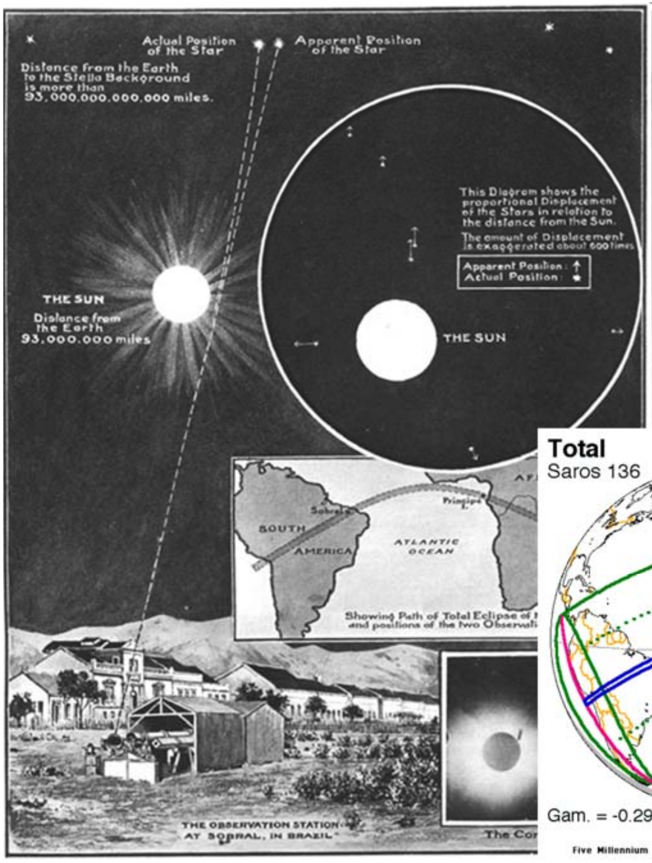


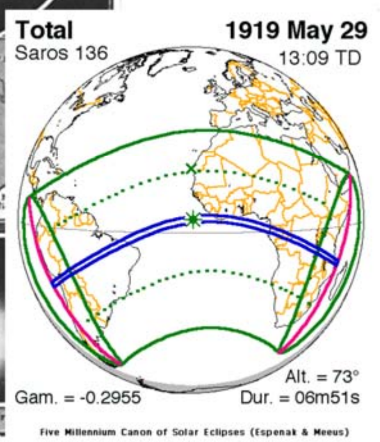
2015





1919 Eddington
星光經太陽附近偏折驗證廣義相對論

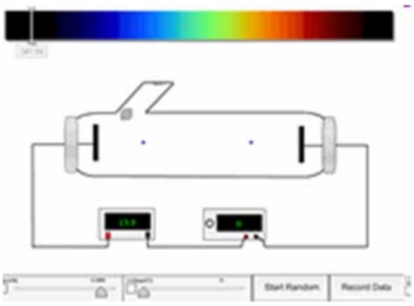


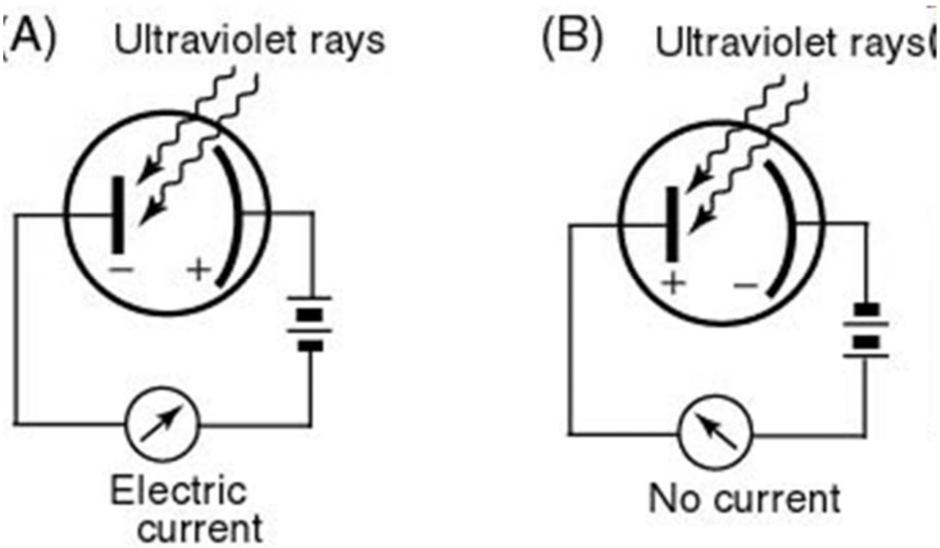


有關光的重要實驗（三）

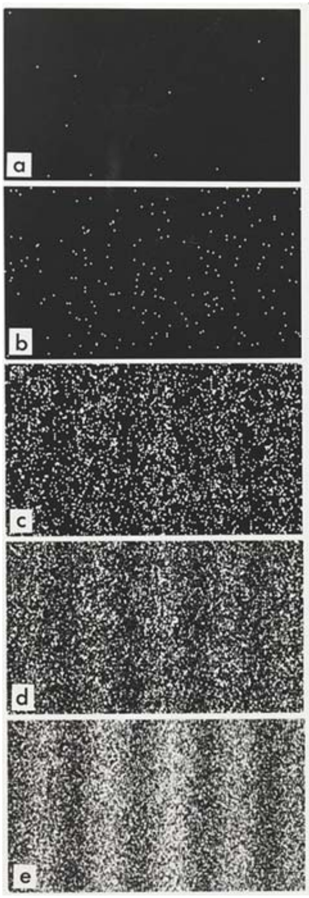
- 光電效應
- 微弱光的干涉
- Raman 效應
- 圓偏振光的角動量
- 光頻激射
- 全像術
- 孿生光子糾纏
- 非線性光學
- 近場光學

1902 Anton von Lenard　光電效應





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.]

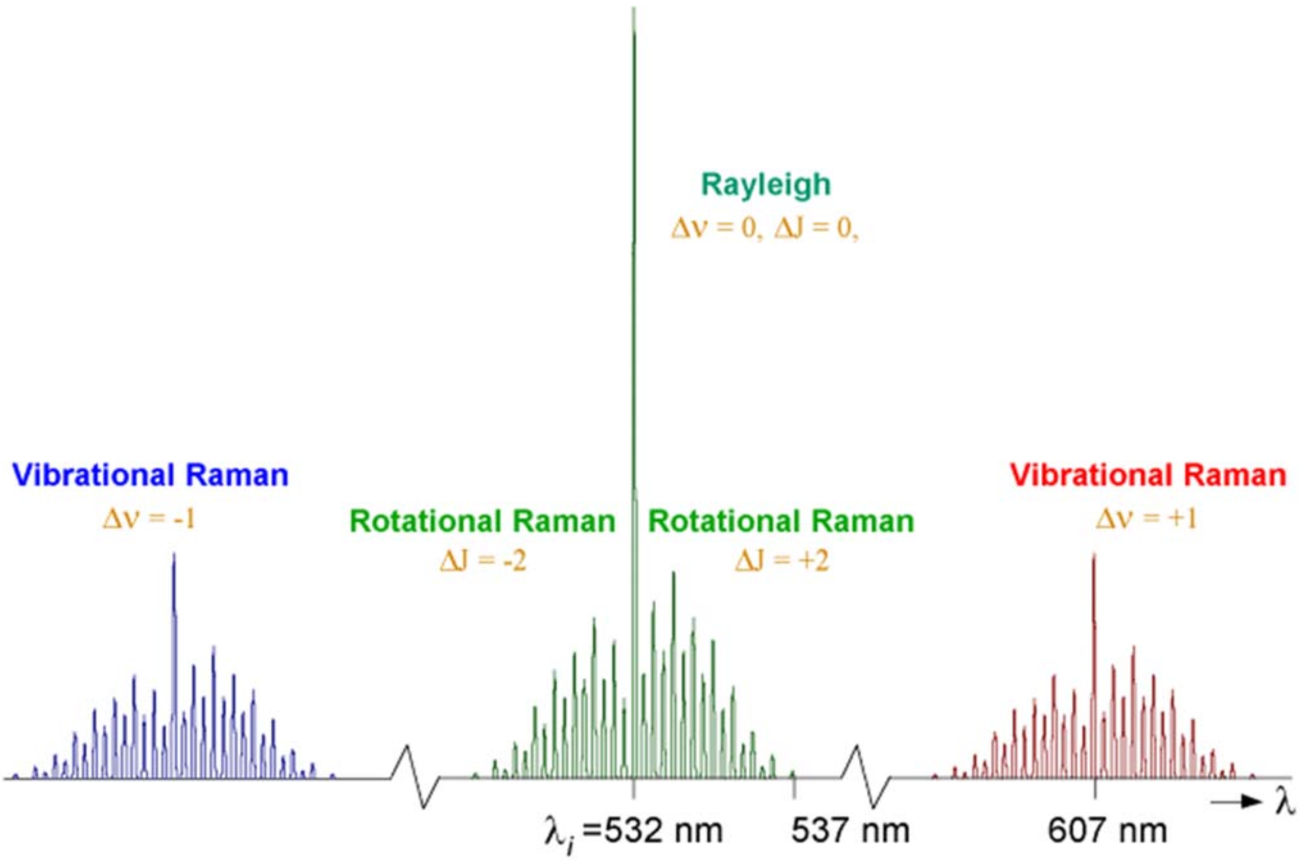
Photographs were taken of the shadow of a needle, the source of light being a narrow slit placed in front of a gas flame. The intensity of the light was reduced by means of smoked glass screens.

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.

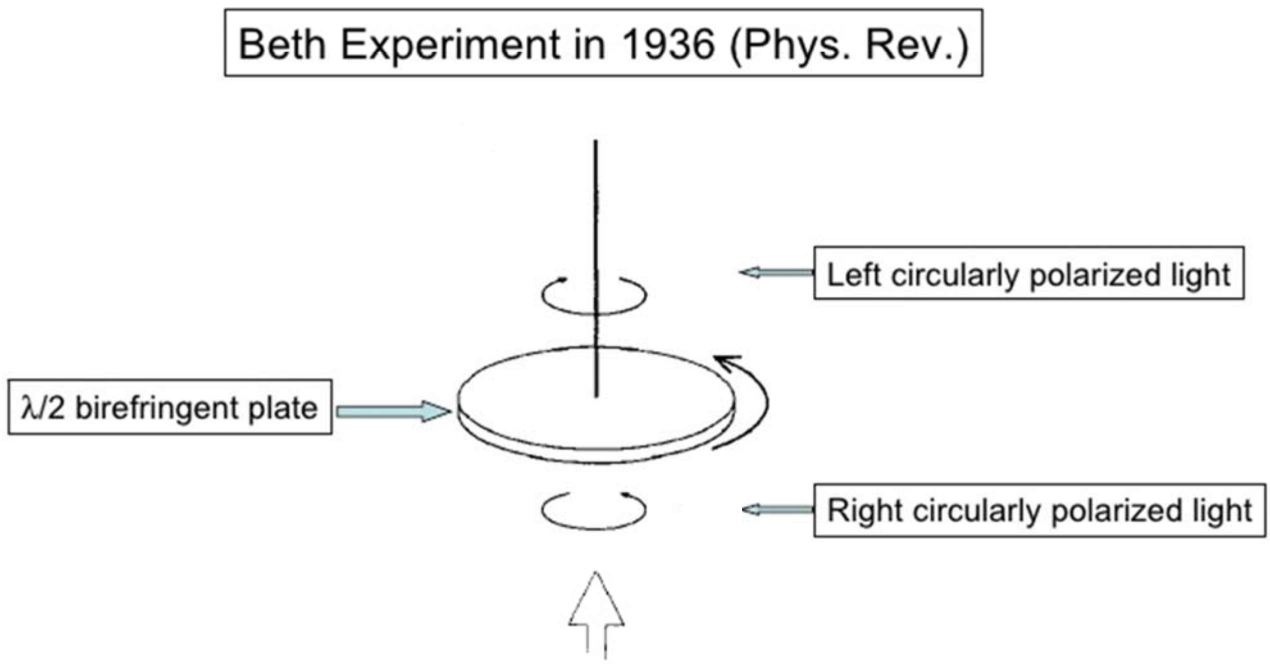
The longest time was 2000 hours or about 3 months. In no case was there any diminution in the sharpness of the pattern although the plates did not all reach the standard blackness of the first photograph.

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

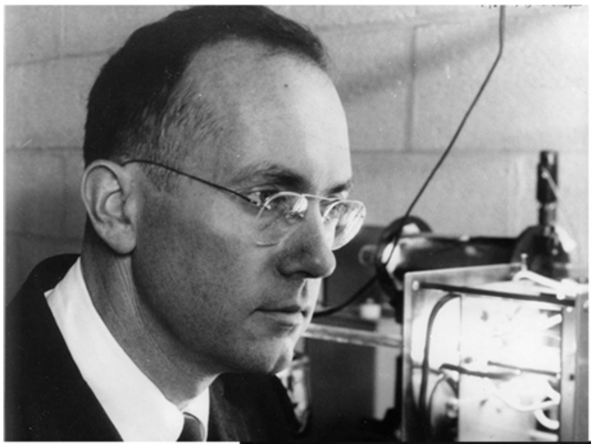
1928 Raman 強光經氣體散射頻率會加減



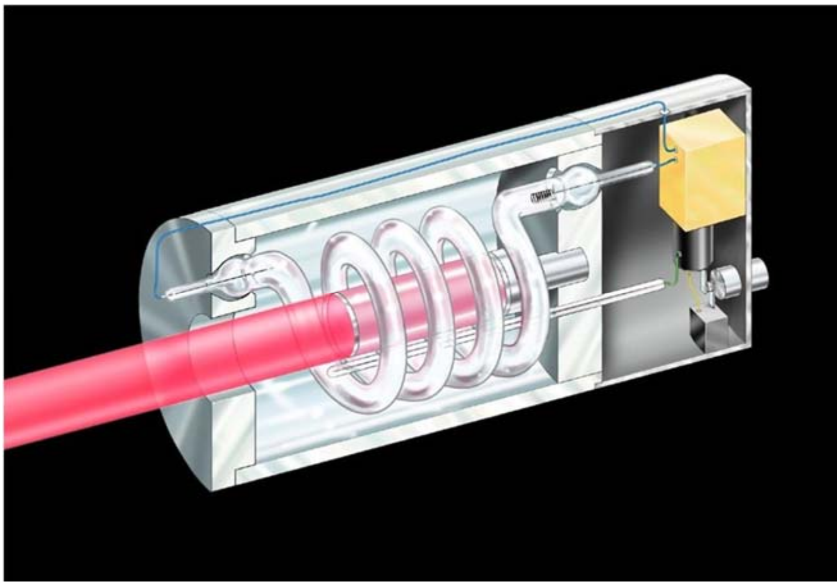
1936 Beth 圓偏振光的角動量



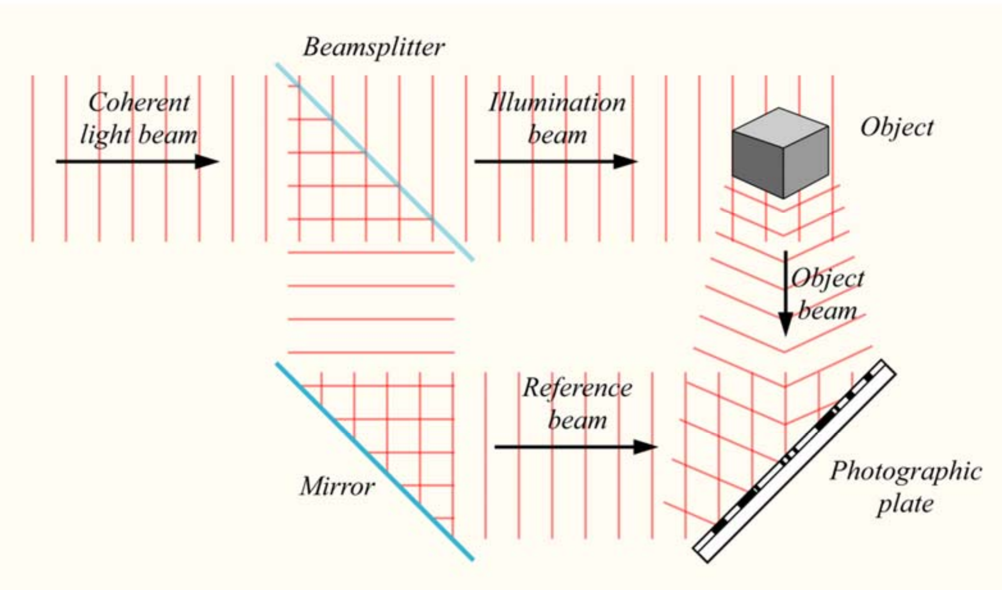
1954 Townes, 1960 Maiman 光頻激射



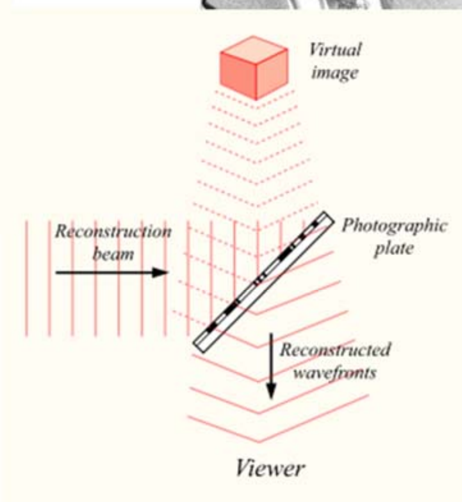
紅寶石雷射



1948 Gabor 全像術



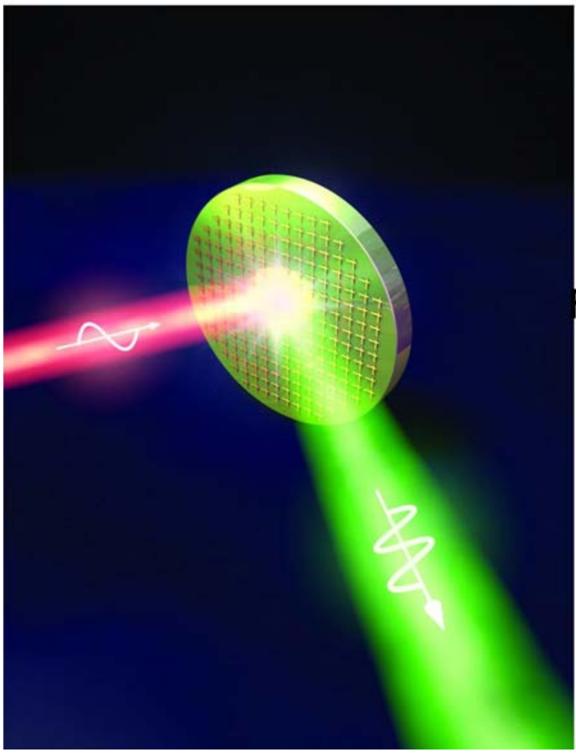
留像

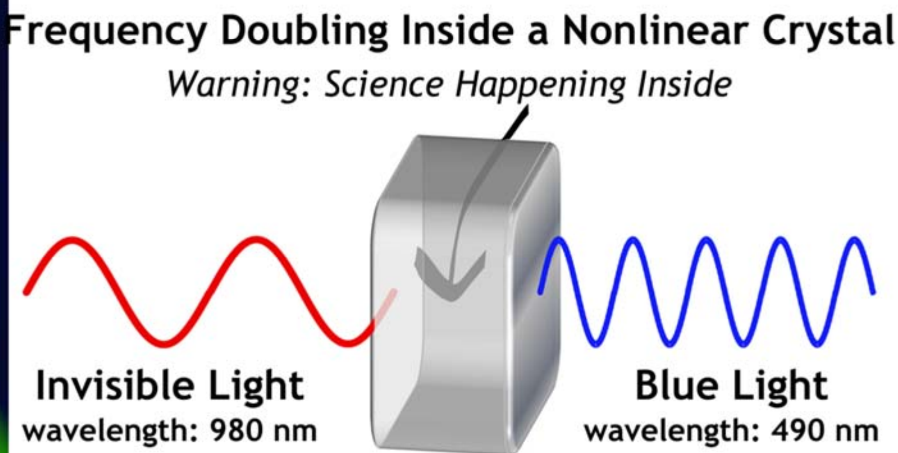


重建

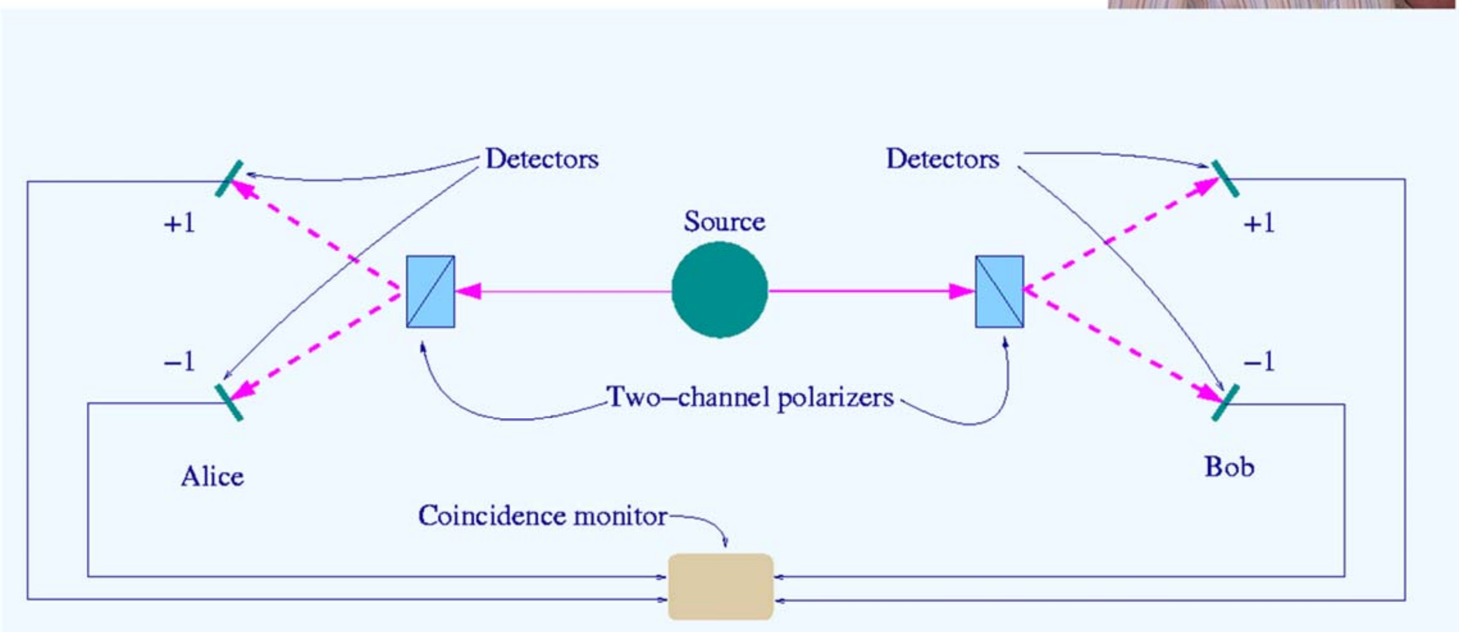
非線性光學

Bloembergen





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,
  von 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 Snell (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

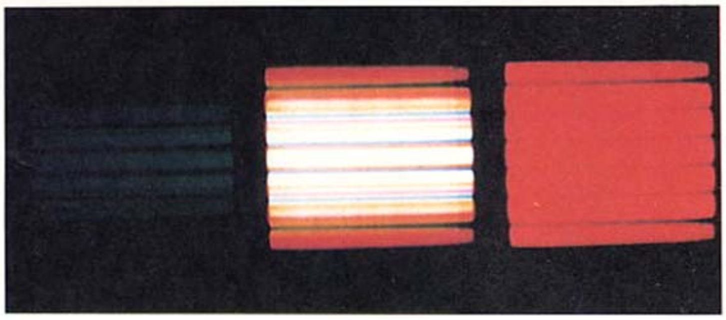
- 19世紀的光學是由英國醫生 Thomas Young 以復興波動說的論文揭開序幕的。
- Young 自小聰穎過人。他起先在愛丁堡大學學醫，後在德國 Göttingen 大學取得了博士學位，1799年開始在倫敦開辦診所。
- Young 的光學研究始自對視覺器官的研究。他第一個發現，眼球在注視距離不同的物體時會改變形狀。

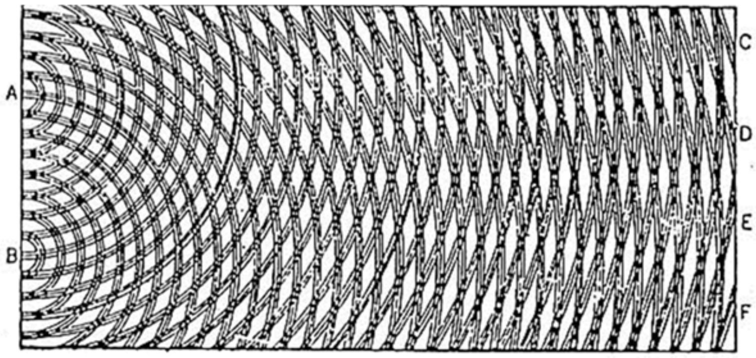
- 1800年，Young 發表了《關於光和聲的實驗和問題》一文，對延續了一個世紀的微粒說提出異議。他說：「儘管我仰慕Newton的大名，但我並不因此非得認為他是萬無一失的。我遺憾地看到他也會弄錯。而他的權威也許有時甚至阻礙了科學的進步。 」
- 在文章的光學部分，Young 提出了否定微粒說的幾個理由：第一，強光和弱光源所發出的光線有同樣的速度，這用微粒說不好解釋；第二，光線由一種介質進入另一種介質時，一部分被反射，而另一部分被折射，用微粒說解釋也很牽強。
- 在文章的聲學部分，Young 依據水波的疊加現象，提出了聲波的疊加理論。他把由疊加造成的聲音的加強和減弱稱為「干涉」。在聲波干涉中，「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。

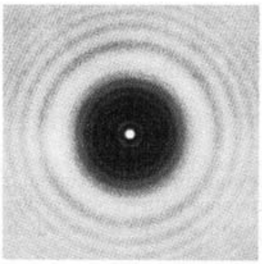
Augustin-Jean Fresnel

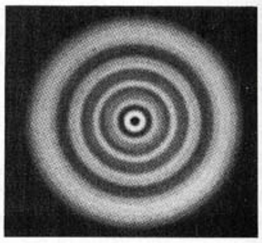
- 幾乎獨立提出光的波動學說的還有法國物理學家 Augustin-Jean Fresnel（1788–1827）。
- 與Young 相反，他從小非常遲鈍，身體也不好，後來由於刻苦努力成了一名工程師。
- 由於反對拿破崙，他曾被關進監獄一段時間。
- 1814年，他對光學開始感興趣，次年便向科學院提交了第一篇光學論文。文中仔細地研究了光的繞射現象，並提出了光的干涉原理。

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



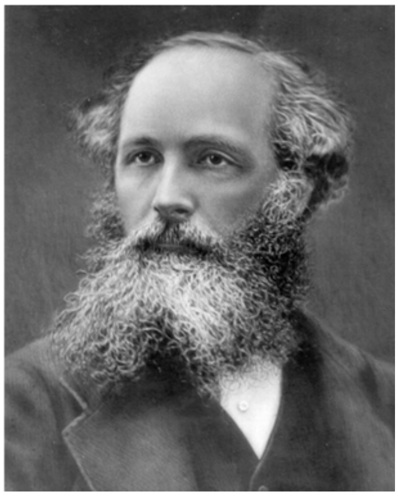


- 1814年，Fresnel開始研究小孔繞射問題。 1817年，法蘭西學術院舉行了一次關於光的本性問題的最佳論文競賽，Fresnel 成功地提出了後人所謂Huygens-Fresnel原理，於1818年提交了論文。
- 科學院成立了一個評委會，儘管不少成員不相信Fresnel的觀點，但是最終授予他優勝獎。
- Poisson想推翻Fresnel的觀點，藉波動理論詳細分析，發現：用一個圓片作為遮擋物時，光屏的中心應出現一個亮點，令人難以相信。
- Fresnel和Arago精心設計了一個實驗，確認了這一亮斑的存在。Poisson當作謬誤提出來的，竟成了支持波動說的強有力的證據！

- 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。
- 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？

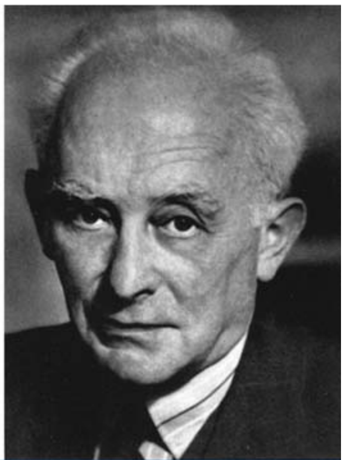


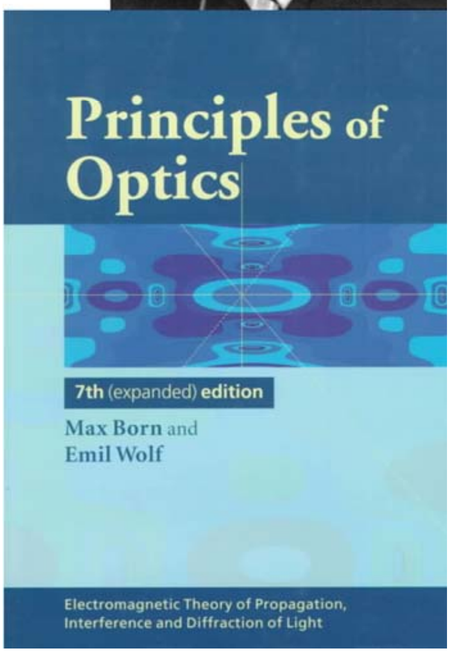
- 物理學家們絞盡腦汁，對光以太的機械特徵進行各種各樣的修正和補充，但總是出現新的問題。這些做法均基於一個前提，即把光看成一種機械波。Maxwell 建立電磁統一理論之後，認為光就是一種波長極短的電磁波，從而在理論上統一了光學與電磁學。
- 光的電磁理論建立之後，光不再被看成機械波，因而光以太的機械特徵問題就不復存在。但是在經典理論中，電磁波的傳播同樣需要被稱為電磁以太（electromagnetic ether）的媒介。
- 光的傳播媒介不再是機械以太（mechanical ether），而是電磁以太。電磁以太又是什麼？這個問題留給了19和20世紀之交的物理學家們。

- 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

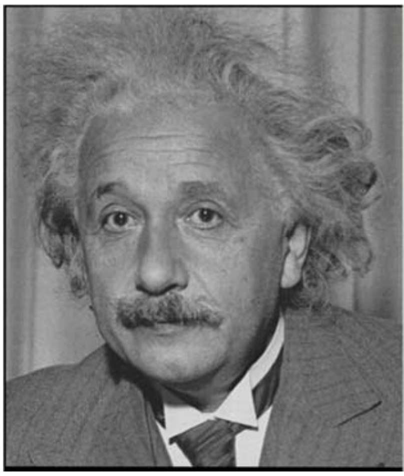
- 電磁波

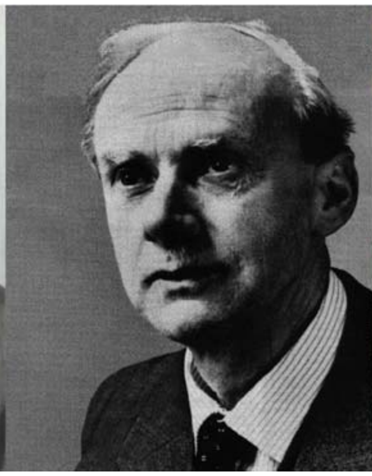
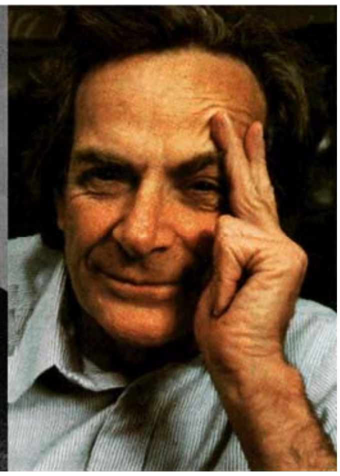
量子光學

- 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ν的光的強度的意義：$I = n \cdot \mathrm{h}\nu$, $\mathrm{h}\nu$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$\mathrm{h}\nu_{nm} = E_n - E_m$。 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 $\boldsymbol{E}$ 與磁場 $\boldsymbol{B}$ 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」

The Story of Microscopy

顯微鏡的故事

Dr. Arthur Chiou
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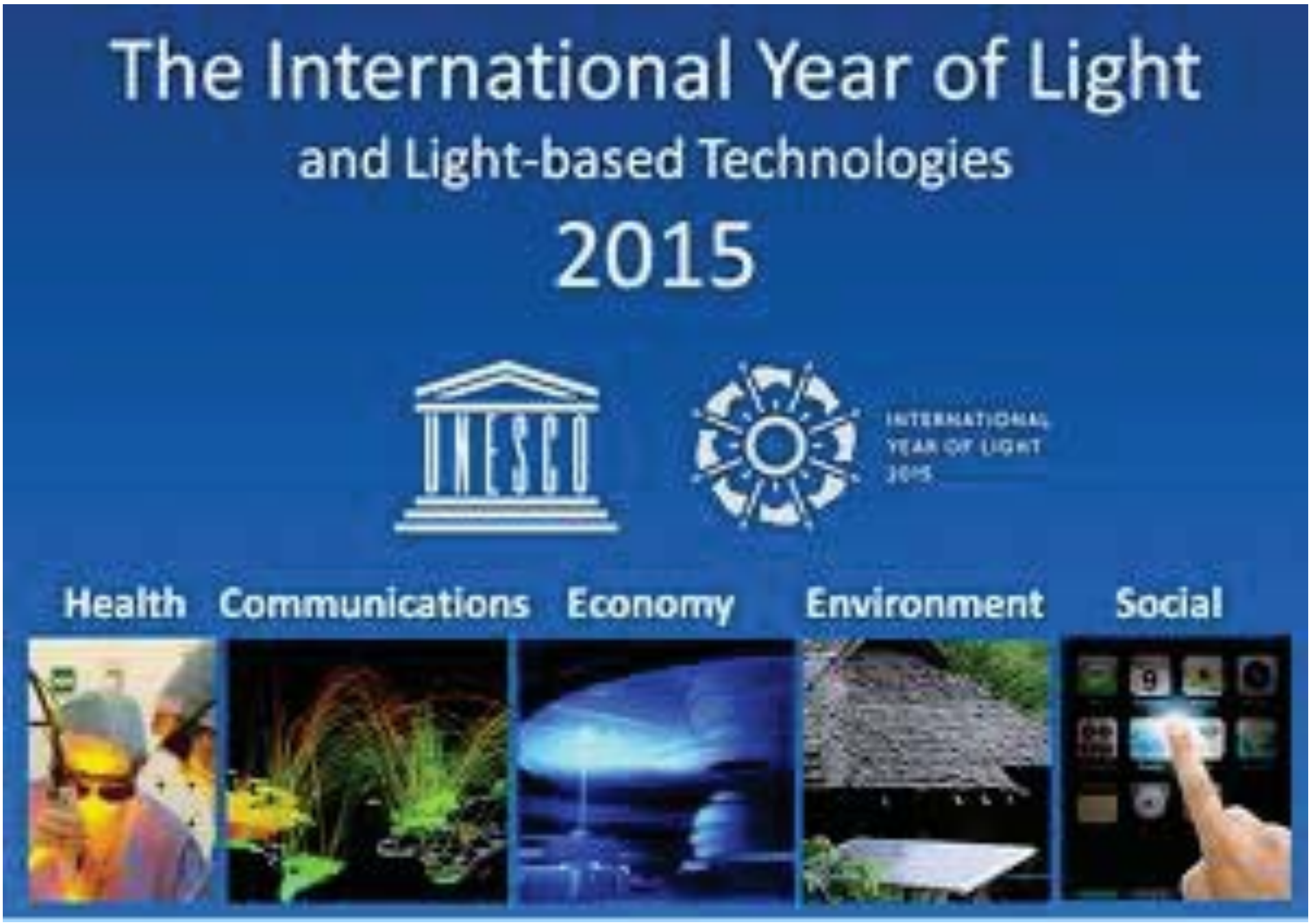
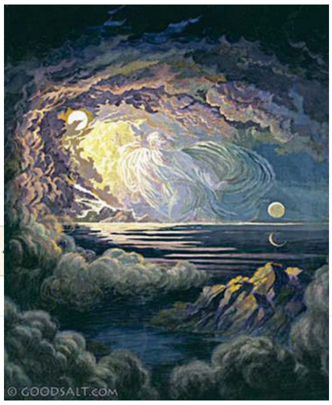


Genesis 1:3

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



King James Version (KJV)

▲ View Chapter

Genesis 1:3 Context

[1]In the beginning God created the heaven and the earth. [2]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. [3]**And
God said, Let there be light: and there was light.** [4]And God saw the light, that [it was] good: and God
divided the light from the darkness. [5]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

The Nobel Prize in Chemistry 2014

Photo: Matt Staley/HHMI

Eric Betzig

Prize share: 1/3

© Bernd Schuller, Max-Planck-Institut

Stefan W. Hell

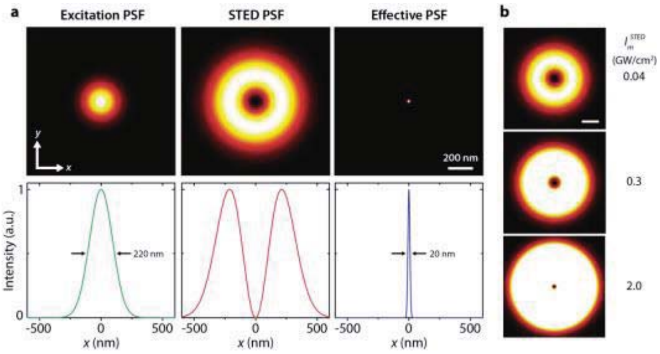
Prize share: 1/3

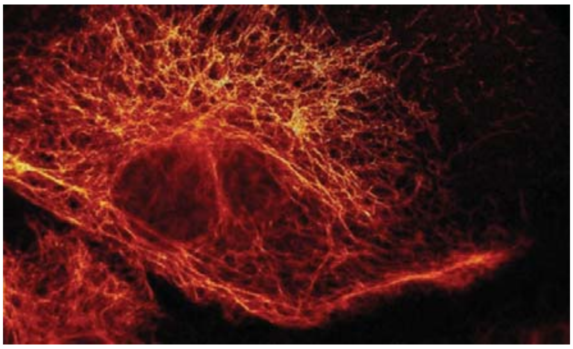
Photo: K. Lowder via Wikimedia Commons, CC-BY-SA-3.0

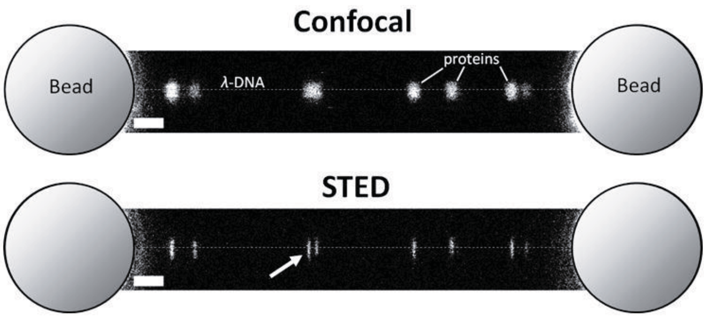
William E. Moerner

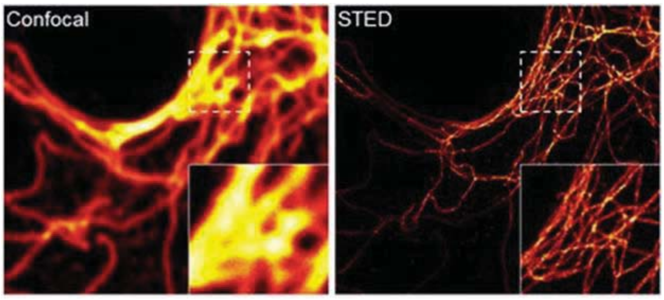
Prize share: 1/3

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

Photo: Yasuo Nakamura/Meijo University

Isamu Akasaki

Prize share: 1/3

Ill. N. Elmehed. © Nobel Media 2014

Hiroshi Amano

Prize share: 1/3

Ill. N. Elmehed. © Nobel Media 2014

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"*.

Arthur L. Schawlow

Charles Townes

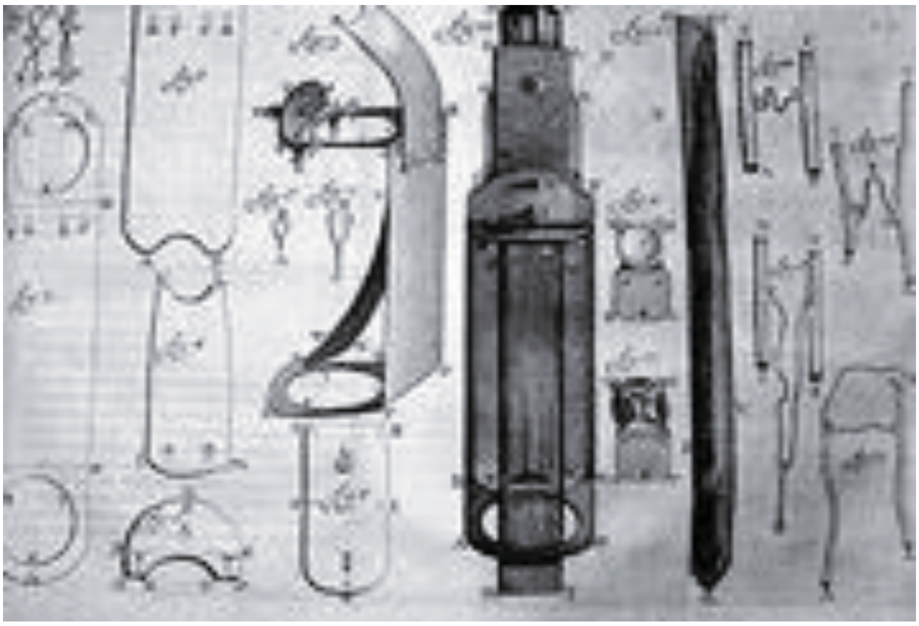
Theodore H. Maiman.

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.

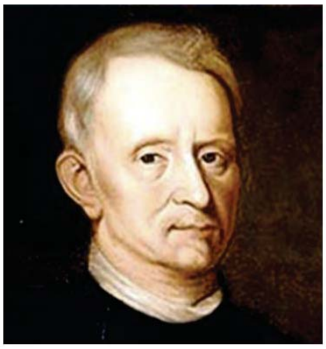
1609 - Galileo Galilei develops a compound microscope with a convex and a concave lens.

Anton van LeeuwenhoeK
(1632 – 1723)



Leeuwenhoek Microscopy

1635 - 1703



Robert-Hooke

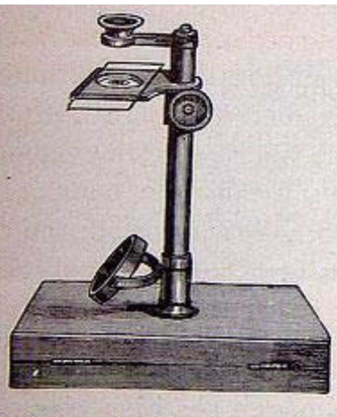


Fig. 227.—Microscopio simple

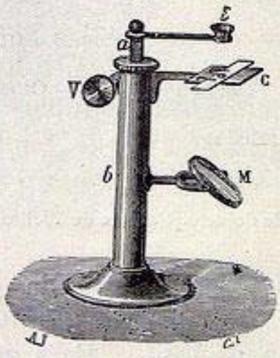
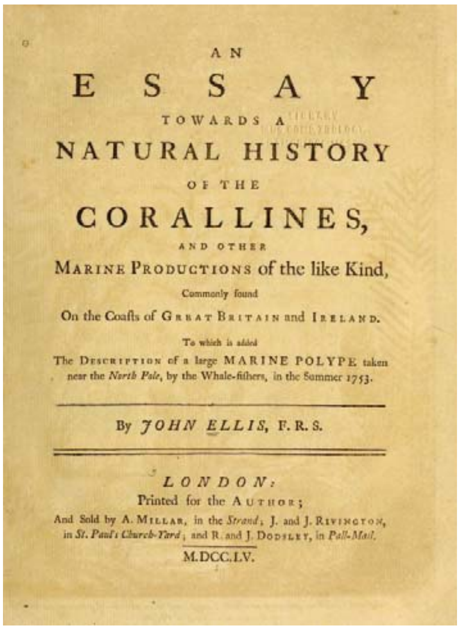


Fig. 228.—Otro microscopio simple

Fig. 229.—Anteojo compuesto



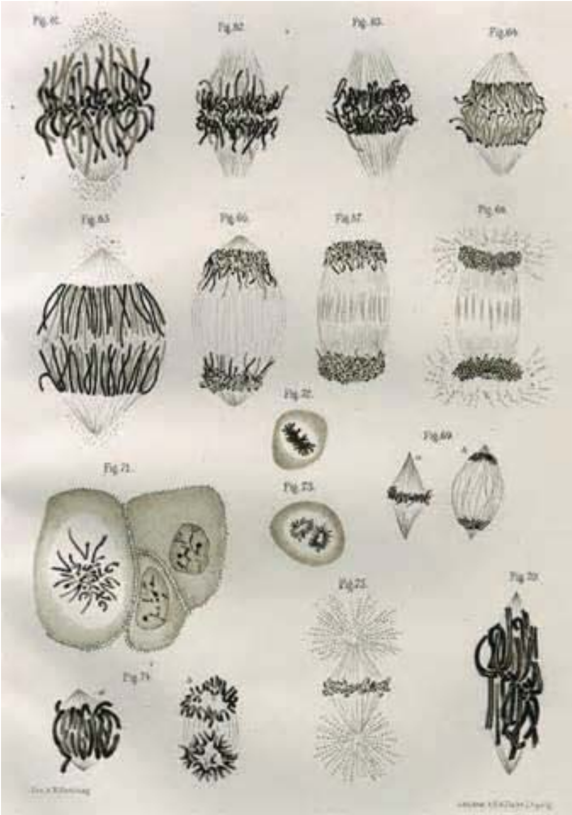
AN
ESSAY
TOWARDS A
NATURAL HISTORY
OF THE
CORALLINES,
AND OTHER
MARINE PRODUCTIONS of the like Kind,
Commonly found
On the Coasts of GREAT BRITAIN and IRELAND.
To which is added
The DESCRIPTION of a large MARINE POLYPE taken near the *North Pole*, by the Whale-fishers, in the Summer 1753.

By *JOHN ELLIS*, F.R.S.

LONDON:
Printed for the AUTHOR;
And Sold by A. MILLAR, in the *Strand*; J. and J. RIVINGTON, in *St. Paul's Church-Yard*; and R. and J. DODSLEY, in *Pall-Mall*.
M.DCC.LV.

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. 30º and 1/50 150º. 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).



Drawing of mitosis by Walther Flemming.

US005238796A

United States Patent [19]

Maruyama et al.

[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**

[30] **Foreign Application Priority Data**

Nov. 14, 1990 [JP] Japan 2-306072

[51] **Int. Cl.**[5] **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

[56] **References Cited**

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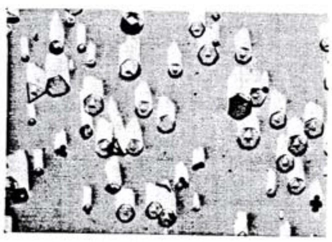
Berry, J. Appl. Phys., 27 (1956), pp. 636-639.
Berry, J. Appl. Phys., 35 (1964), pp. 2165-2169.

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

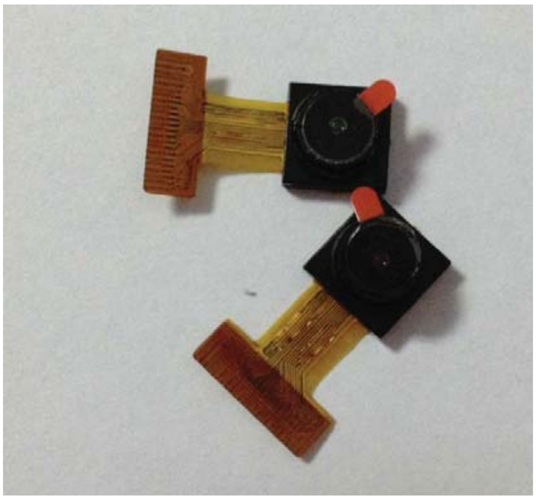
[57] **ABSTRACT**

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 projected 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 and at least one type of a coupler which is coupled with an oxidant of a color developing agent to develop a color are added to at least one of the emulsion layers, thereby obtaining a photographic light-sensitive material having a high sensitivity and good reciprocity characteristics.

20 Claims, 1 Drawing Sheet

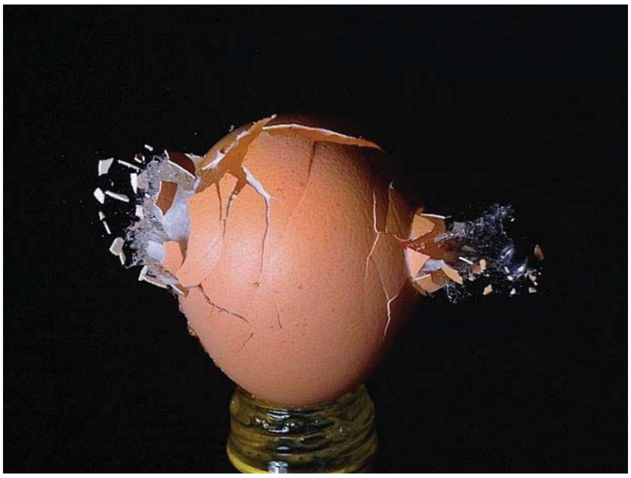


Silver Halide Photographic Emulsion And Photographic Light-sensitive



CMOS 2 Meg.
Pixels

CCD 1600 x 1200



High-Speed Camera

The Nobel Prize in Chemistry 1999
Ahmed Zewail

Share this:

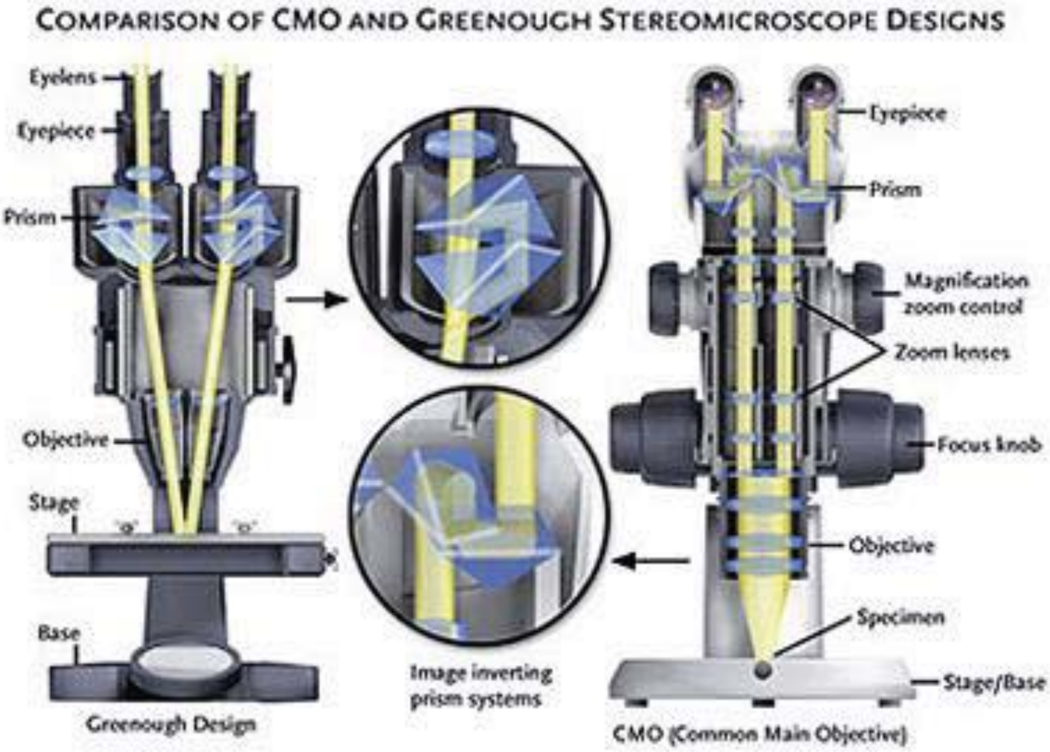
Nobel Lecture

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.





So, what's new!?

細: 空間解析度 (Spatial Resolution)
快:空間解析度 (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-Microscopy?

Spatial: 3-D
Temporal: 1-D
Excitation & Detection Wavelengths: 2- D
Excitation & Detection Polarizations: 2- D

Multi-Functional
Fabrication
Manipulation
Viscoelasticity Mapping
Biochemical/Molecular Functional Mapping

Optics in Jena

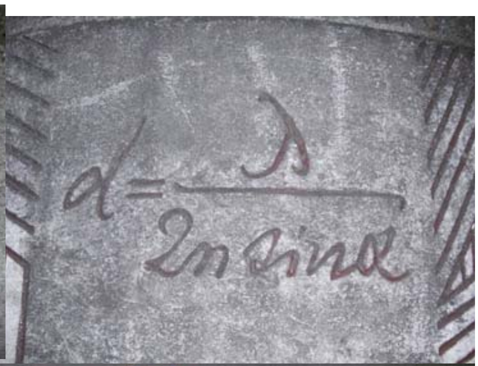
Ernst Abbe

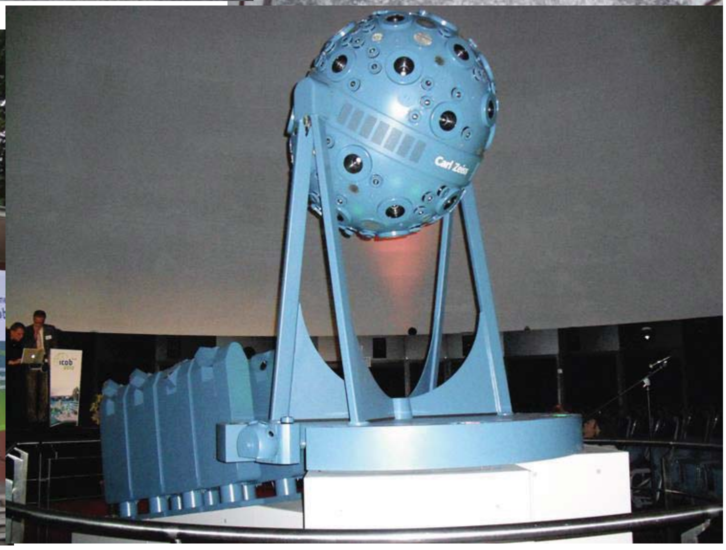
Otto Scholtz

$$d=\frac{\lambda}{2n\sin\alpha}$$

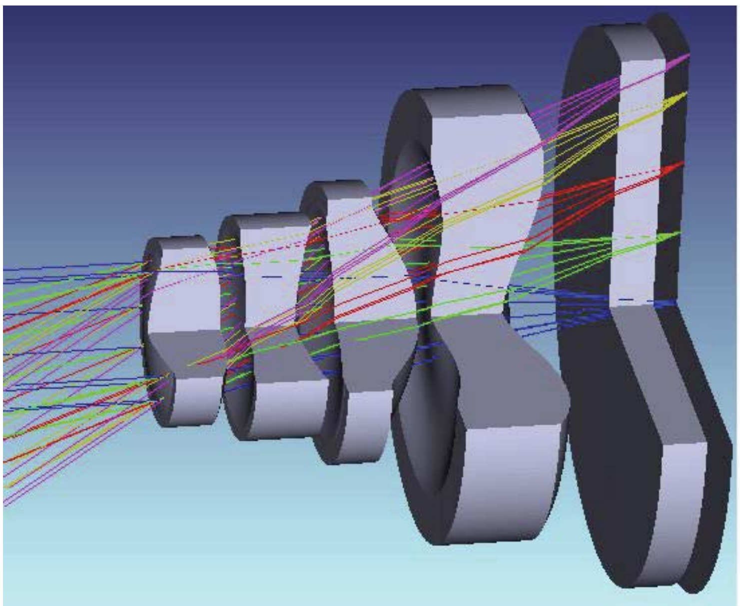
Carl Zeiss

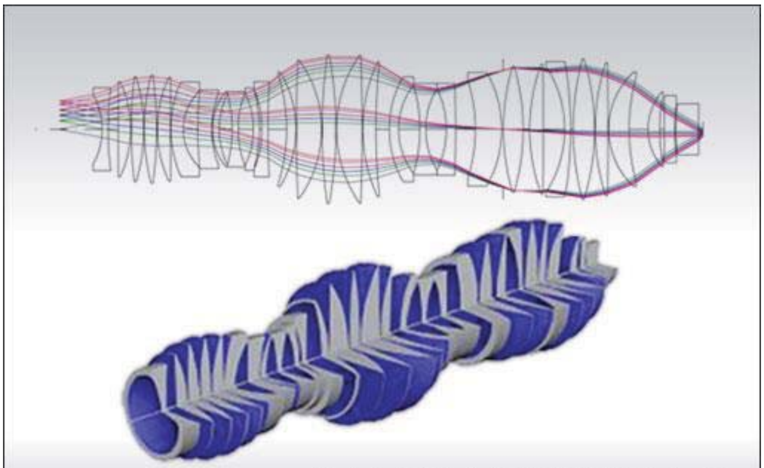
Optics & Photonics in Jena, Germany



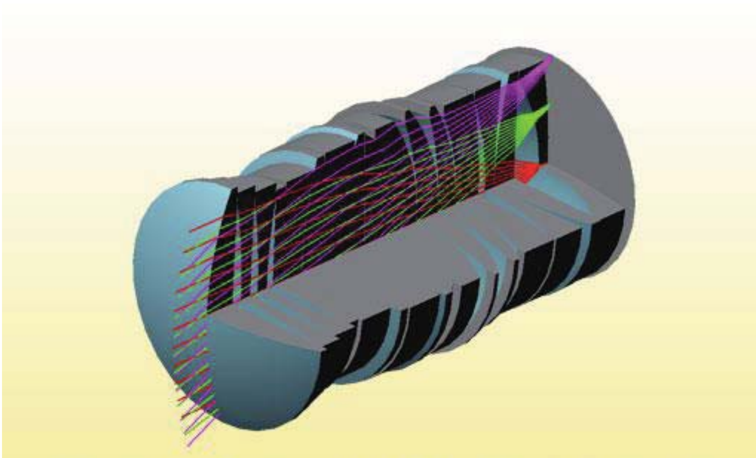


Mobile Phone Camera

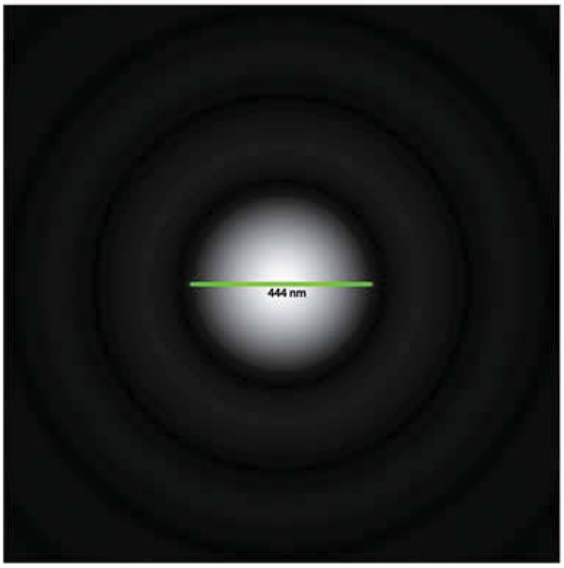


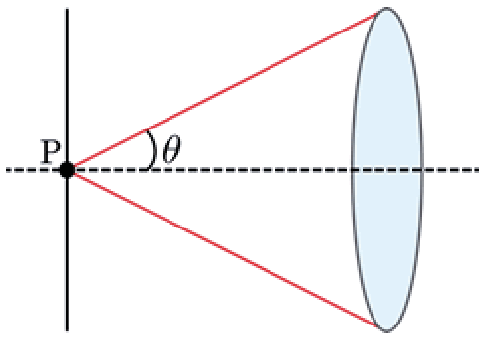


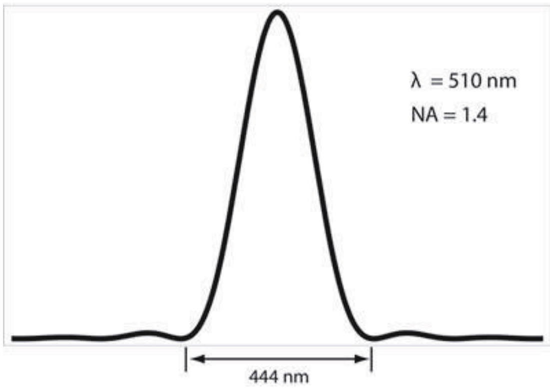
Submitted by Bin Ma for the 2011 Student Optical Design Competition



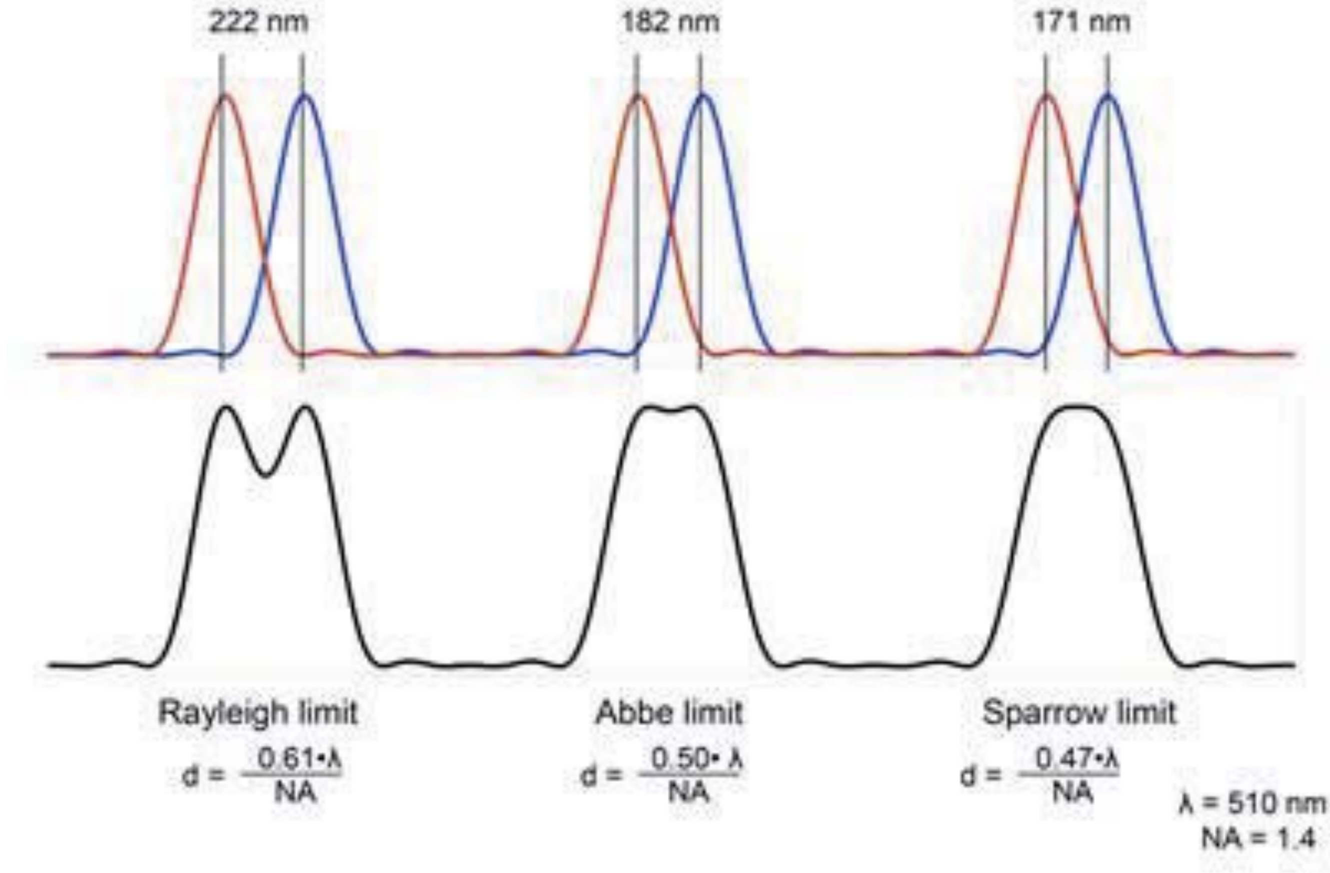
The winning design of the 1994 International Optical Design Conference lens design contest

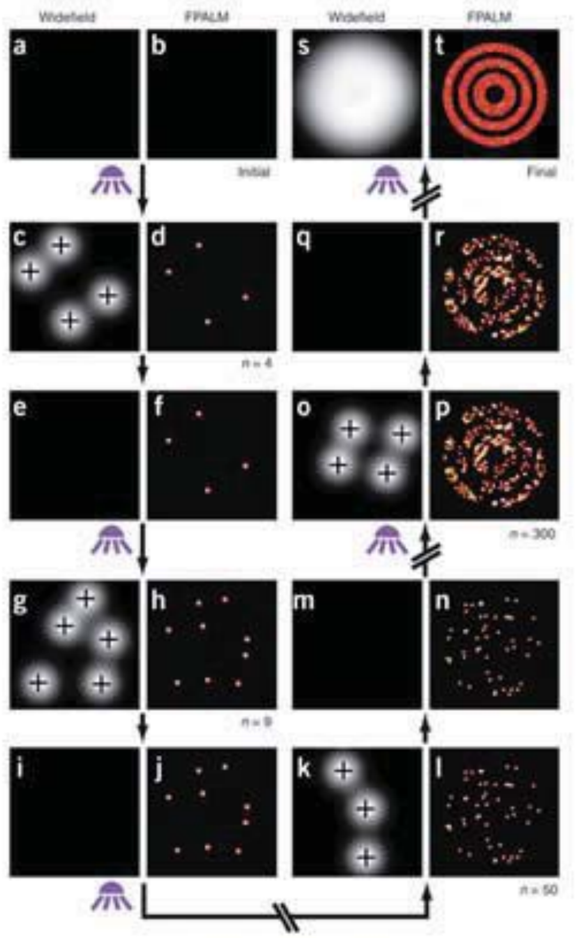




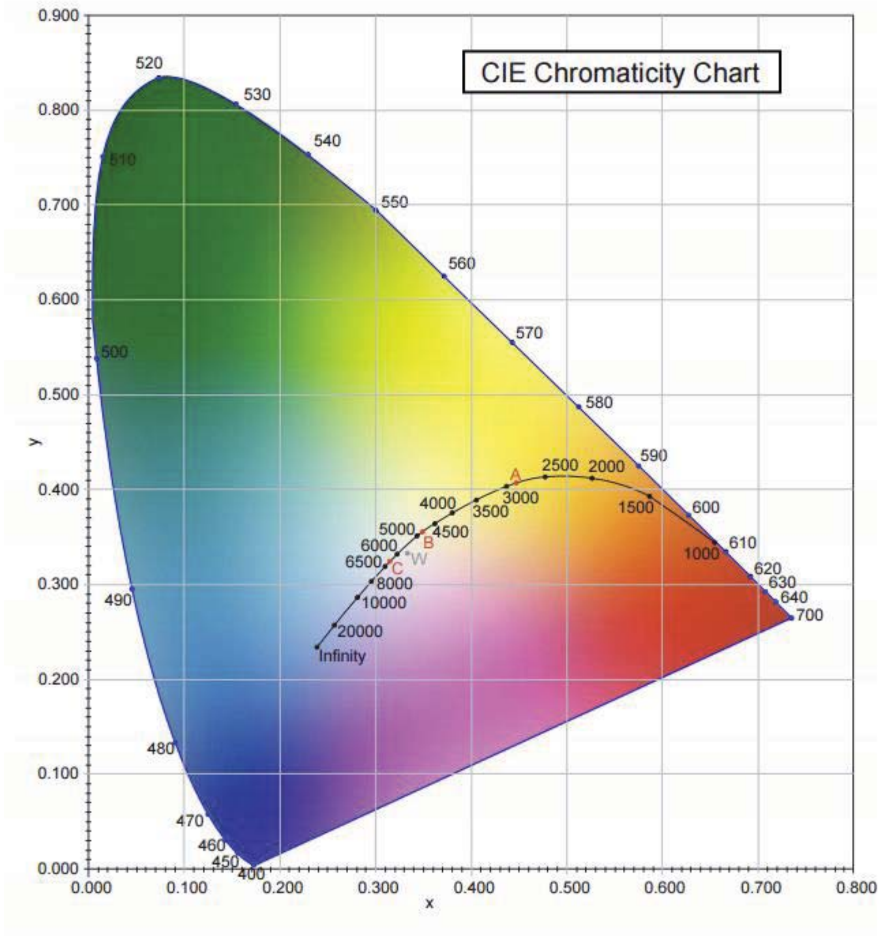


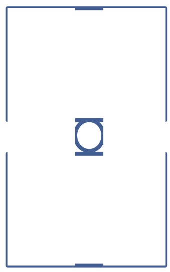
$$r = \frac{0.5\ \lambda}{NA} = \frac{0.5\ \lambda}{n\ sin(\theta)}$$



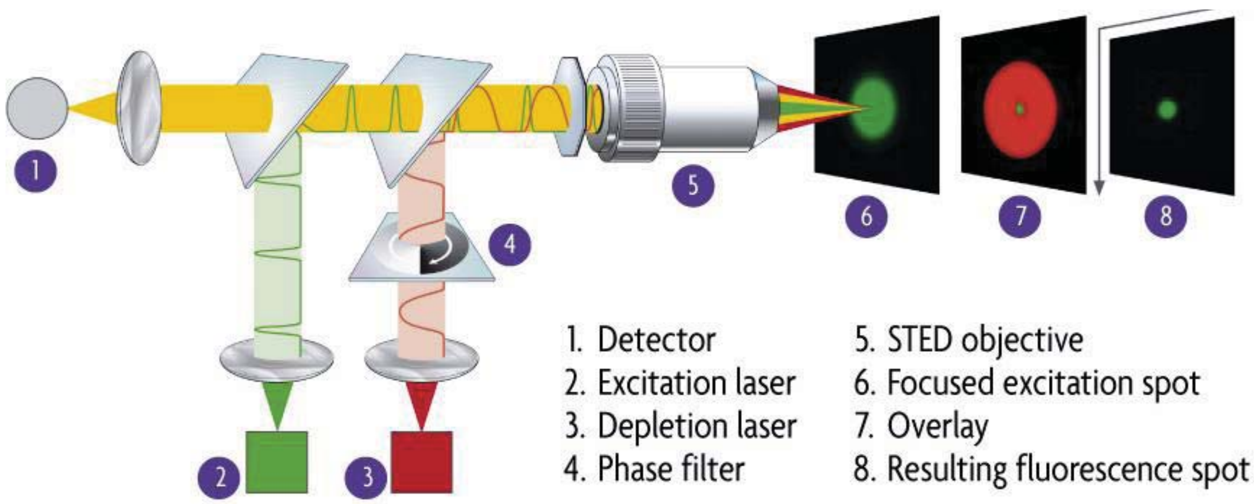


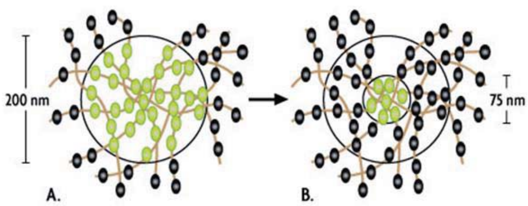
Gould, Verkhusha, Hess, **Nature Protocols**(2009, p291).

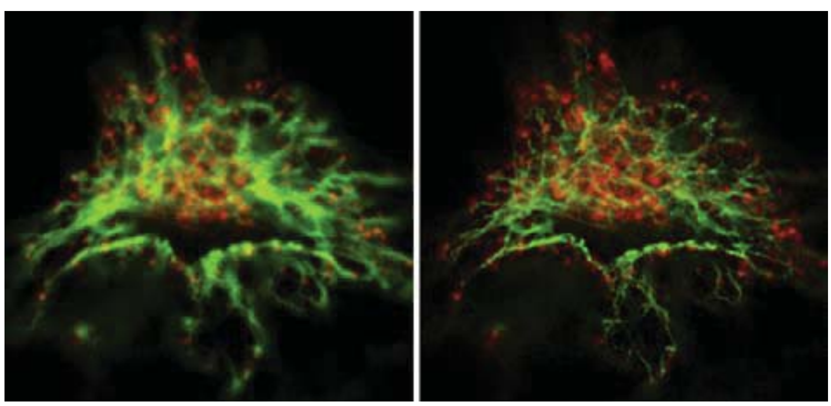




Principle of STED Microscopy/Nanoscopy







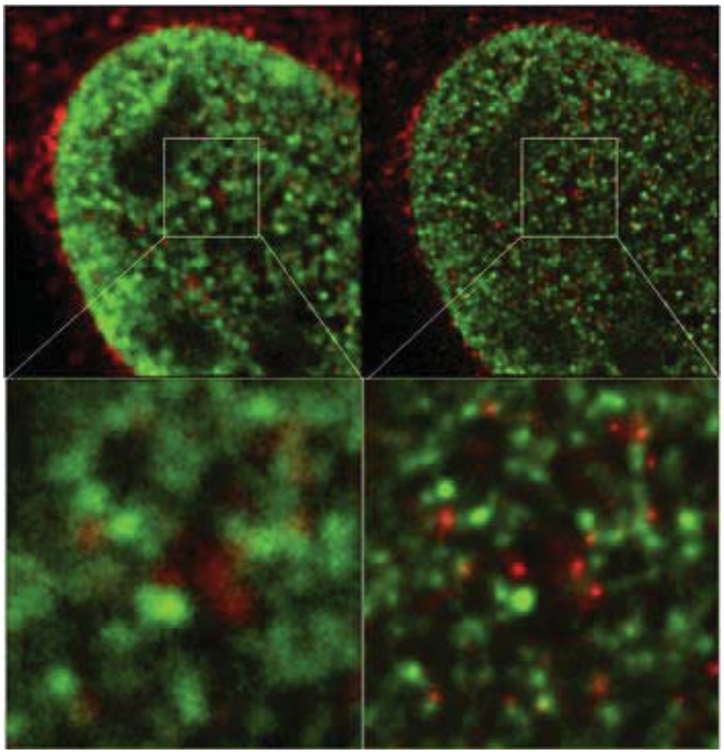
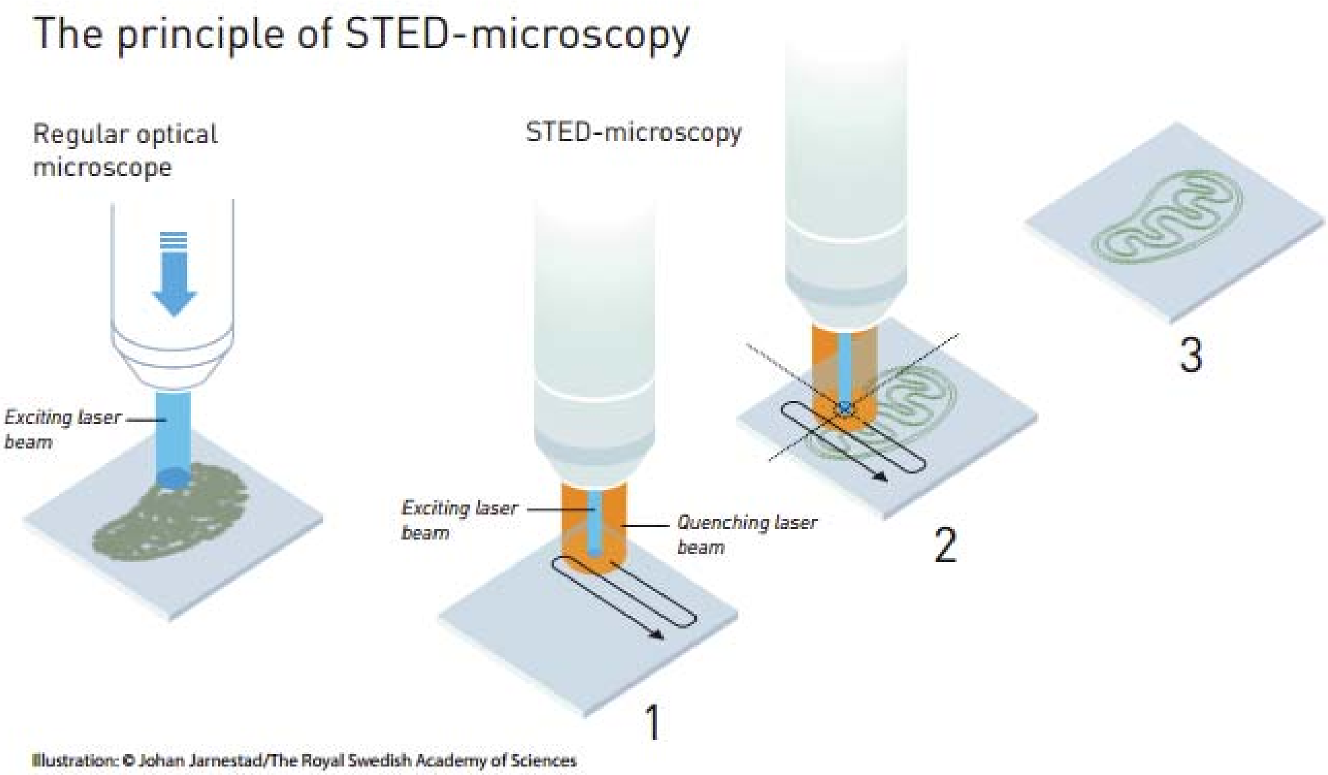
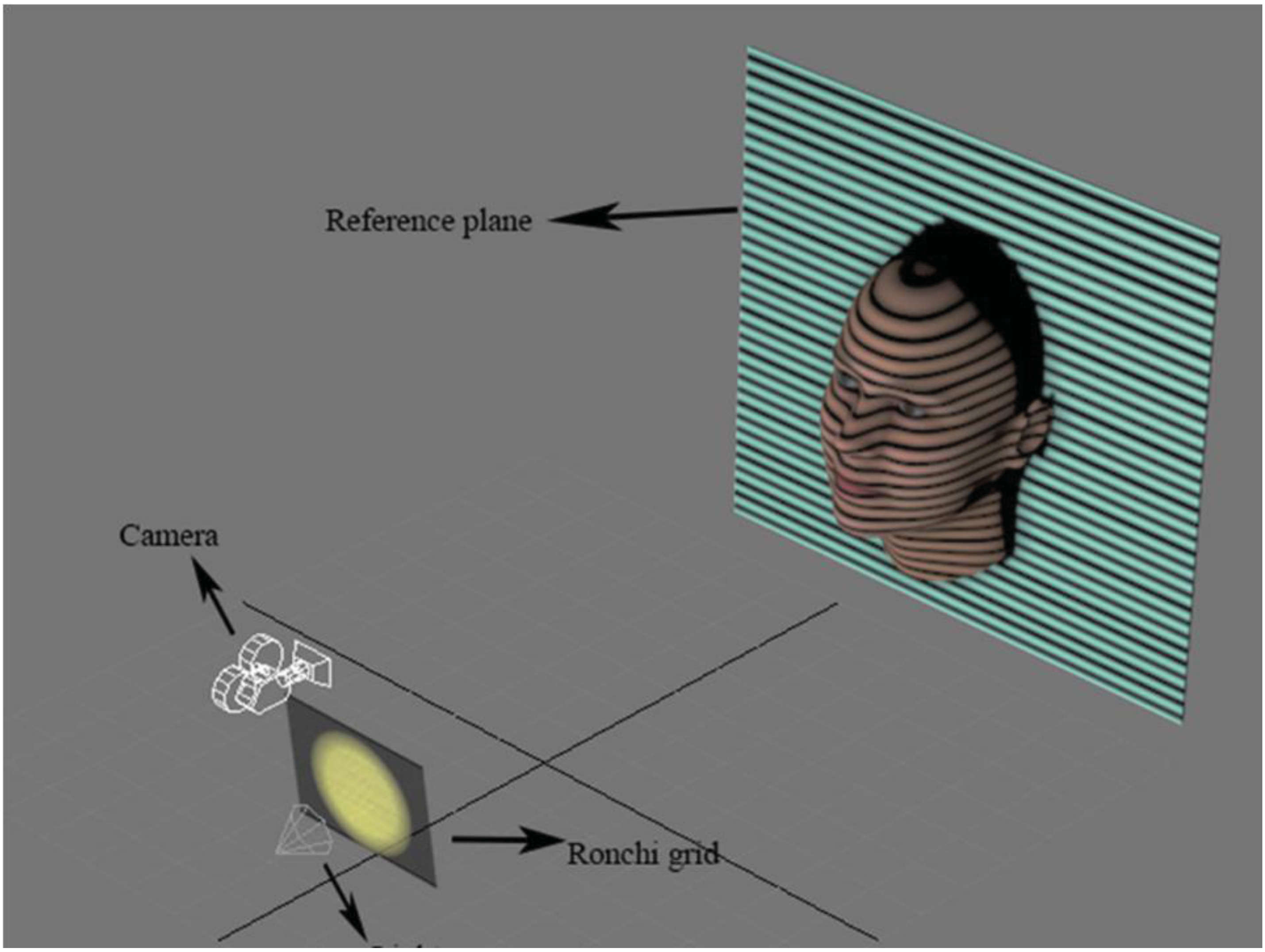
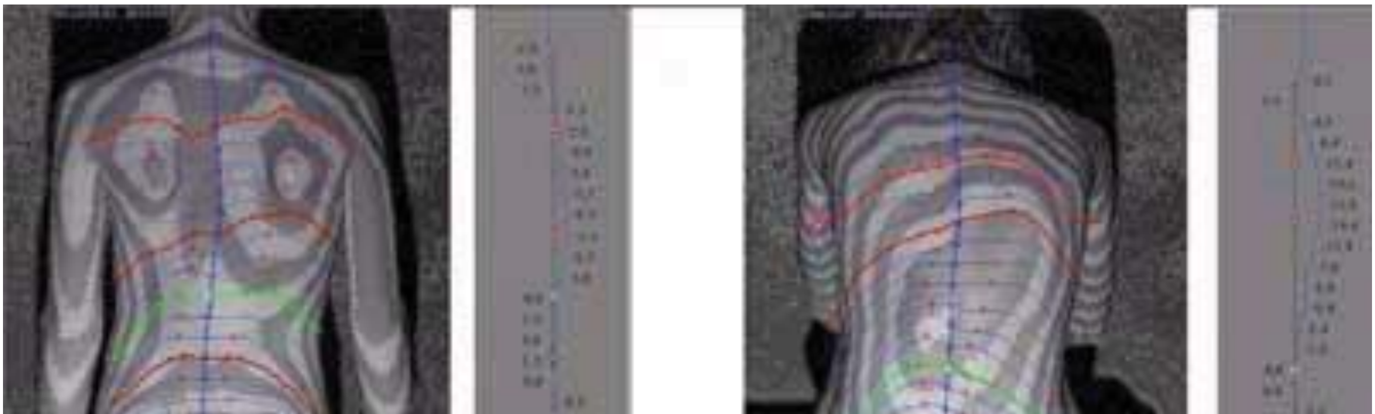


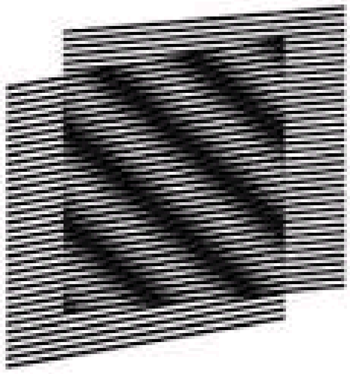
Figure 6: Nuclear structures visualized by dual color STED experiments.
The image on the left was prepared using a confocal microscope, while that on the right was produced using a STED microscope. The nuclear structures have been visualized with Chromeo 494 (green) and ATTO 647N (red). Images courtesy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

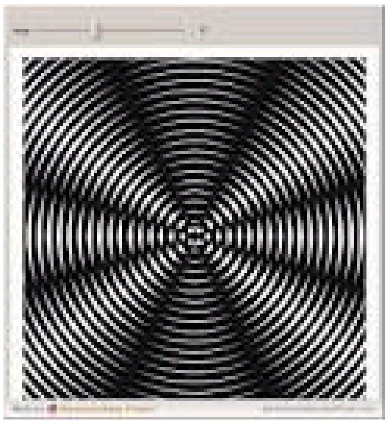


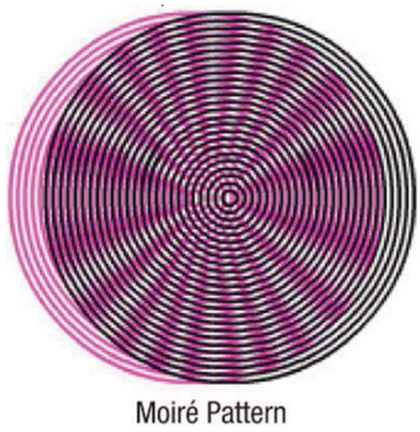

Reference plane
Camera
Ronchi grid

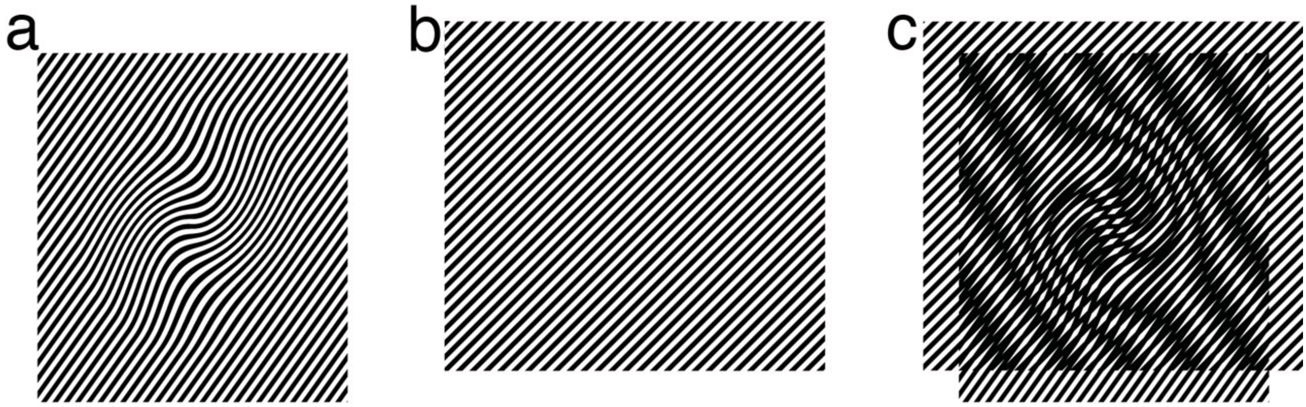

A
B
C
D

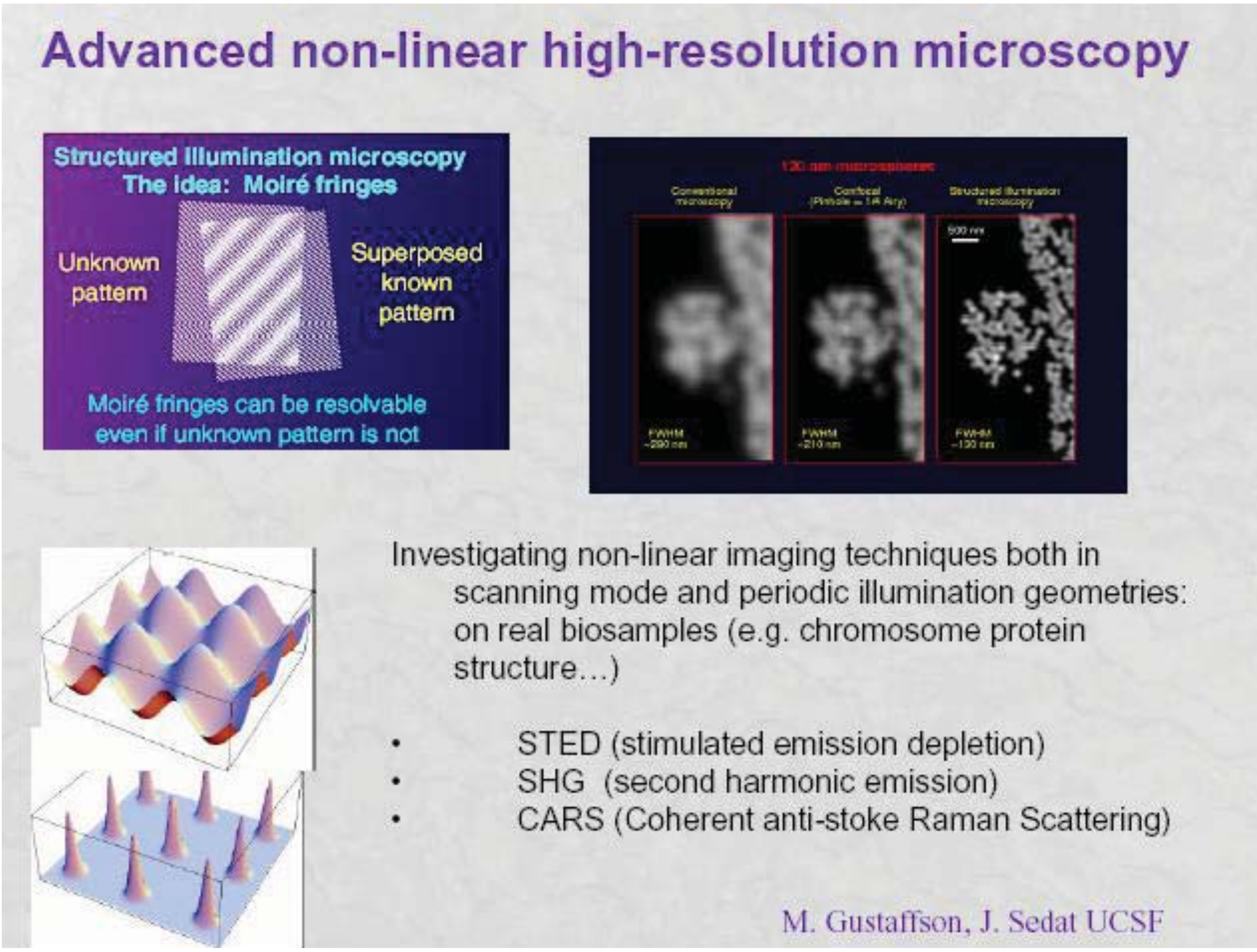
Moire Patterns

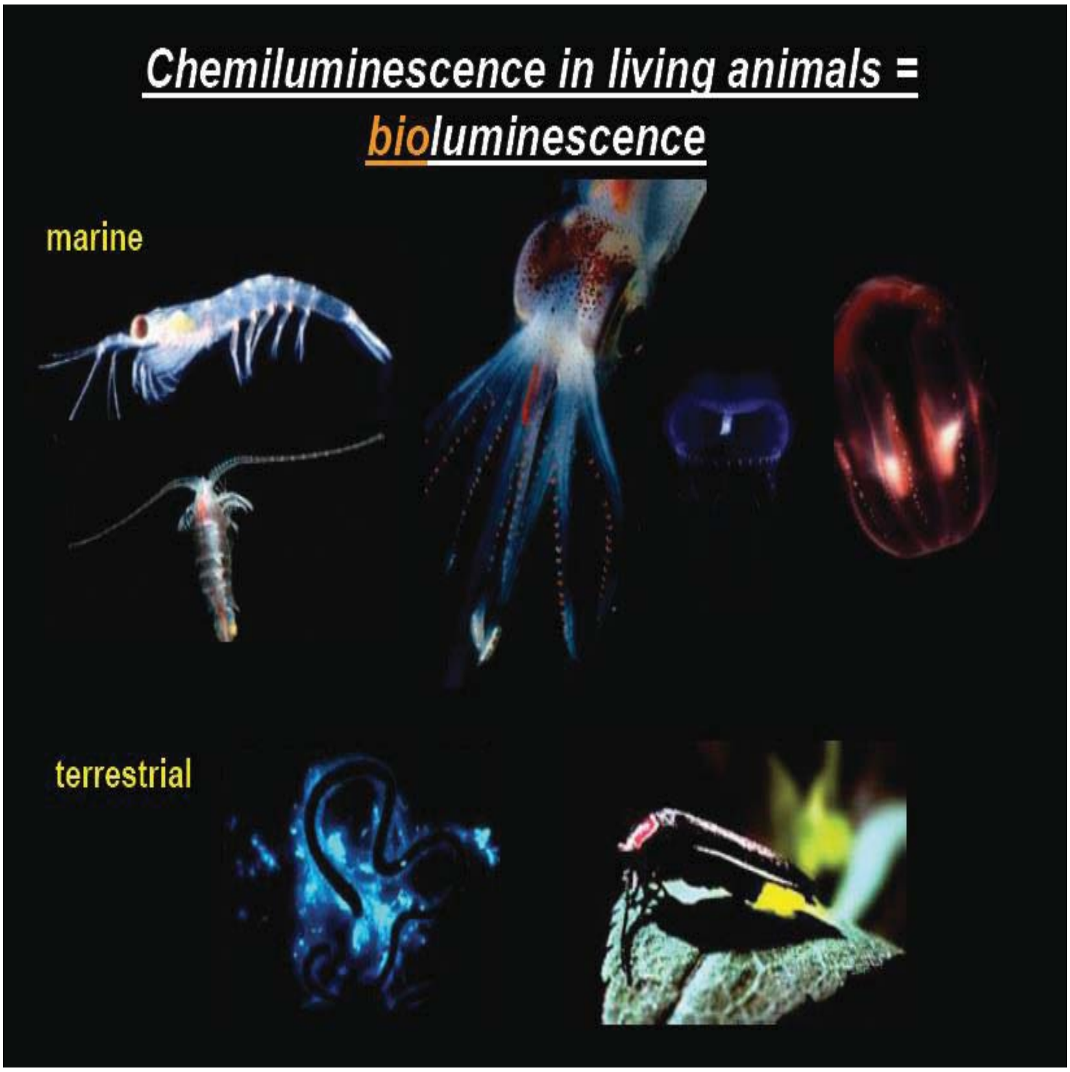


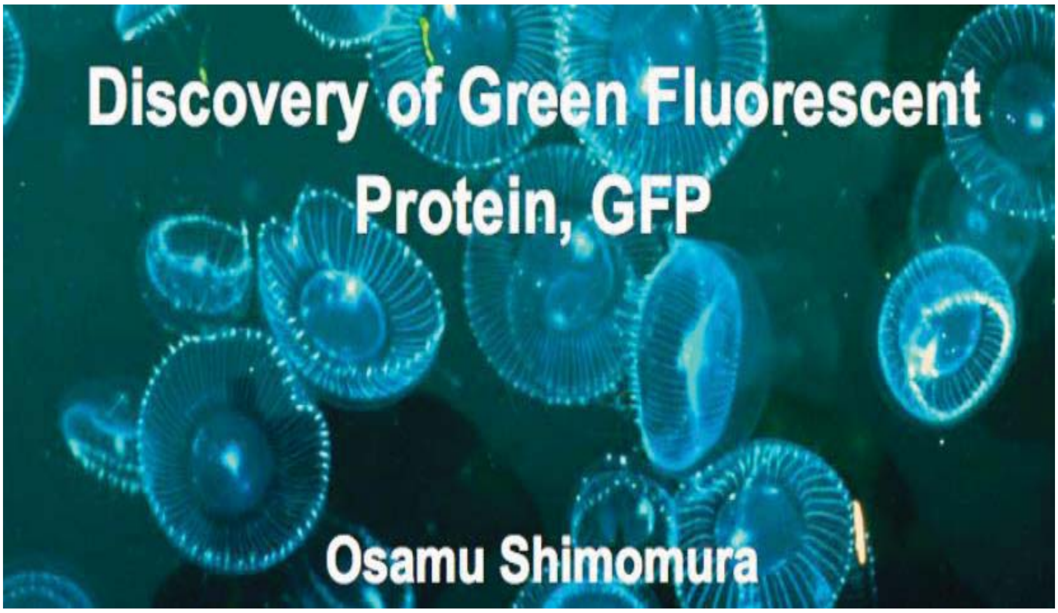




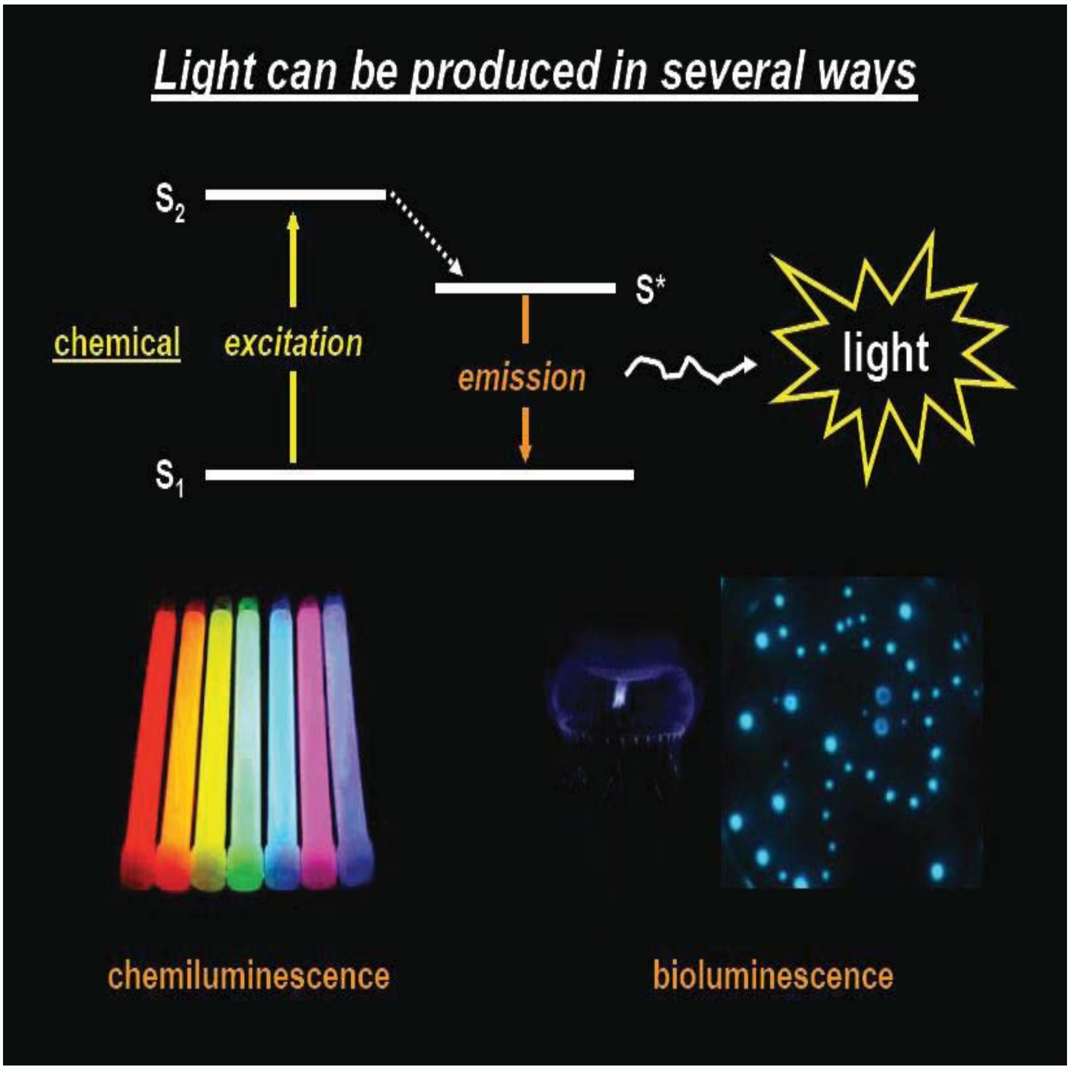




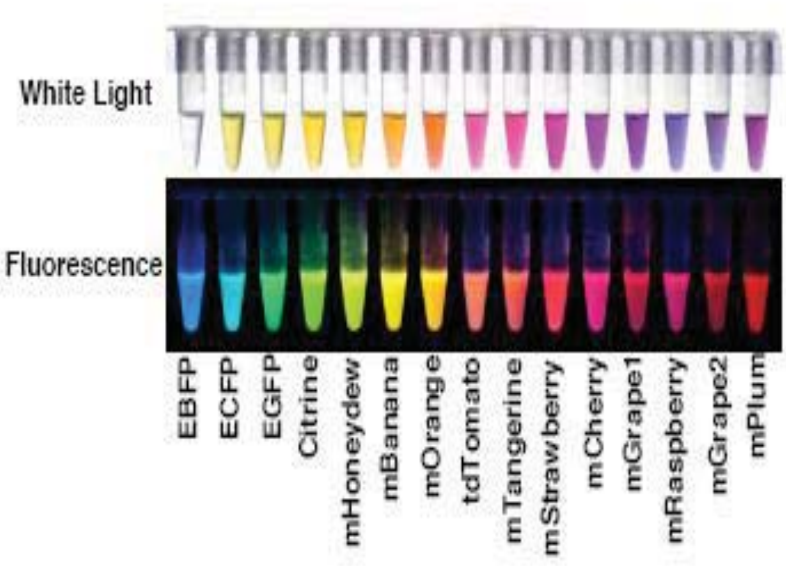

Chemiluminescence in living animals =
bioluminescence
marine
terrestrial

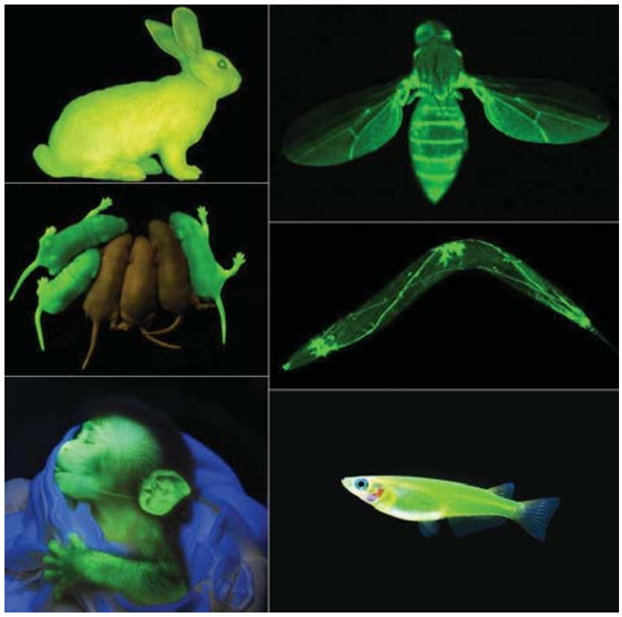

Discovery of Green Fluorescent Protein, GFP
Osamu Shimomura


GFP
509 nm
395 nm



Fluorescence Proteins (FPs)





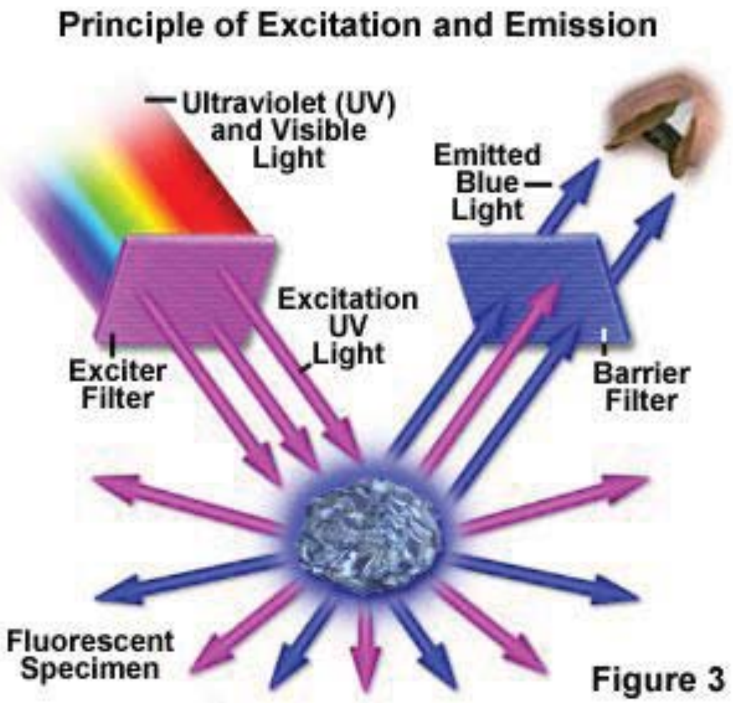
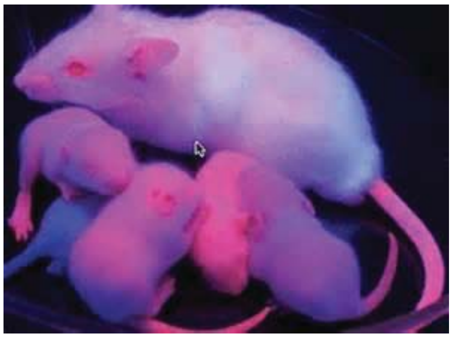
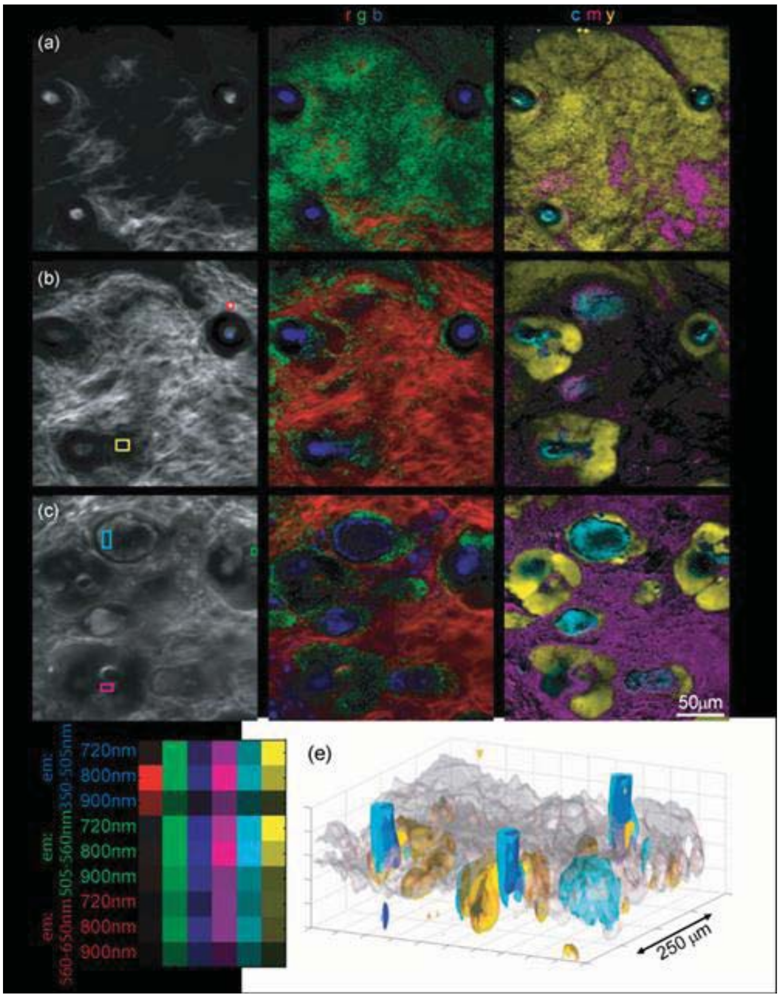

Principle of Excitation and Emission
Ultraviolet (UV) and Visible Light
Emitted Blue Light
Excitation UV Light
Exciter Filter
Barrier Filter
Fluorescent Specimen

Figure 3





Hyper-Spectral Imaging
or
Spectro-Microscopy

3D Spectral Unmixing of 6 Components in Lving 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

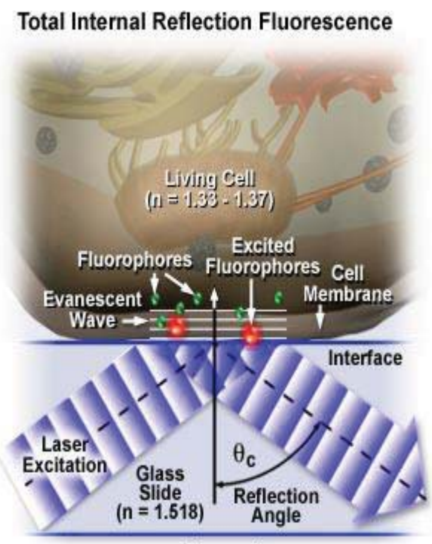
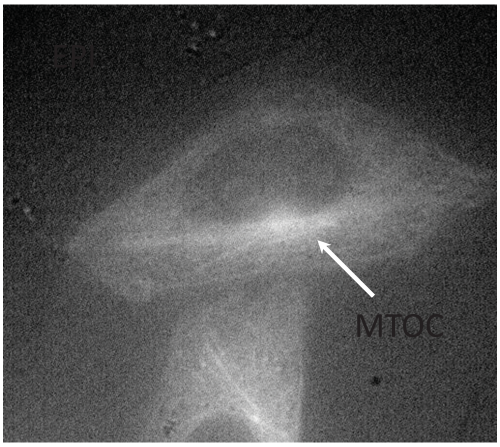
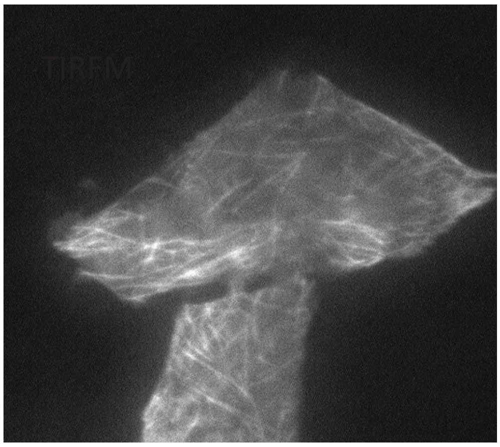


Figure 1

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

Comparison between Epi-fluorescence and TIRFM image





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

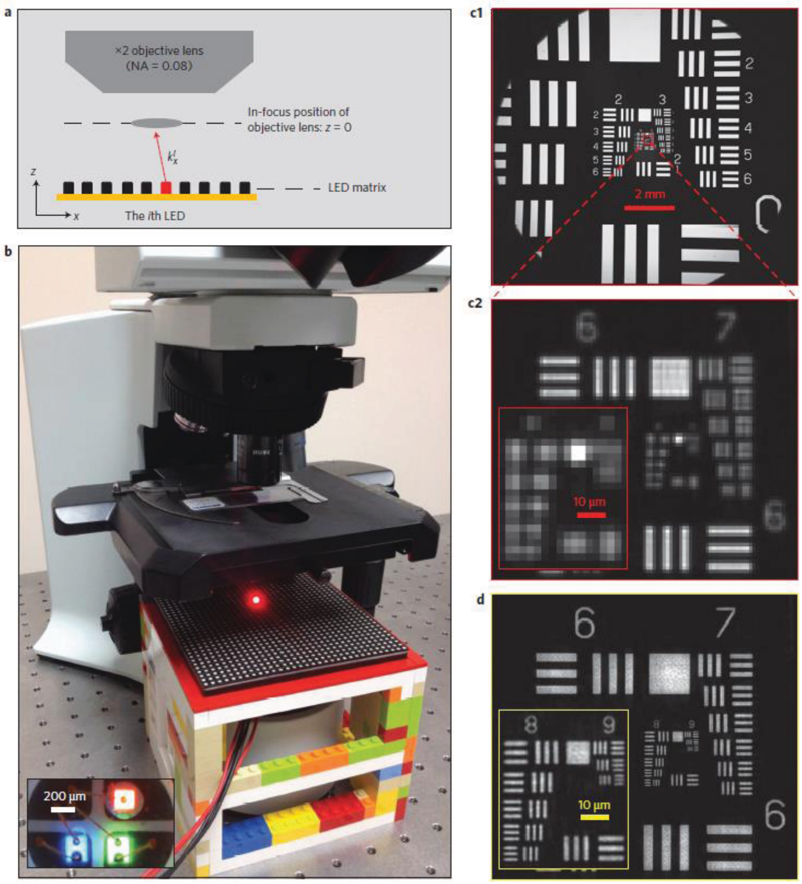
The same cell under TIRFM exhibited a much clearer picture where individual microtubules near the growth substrate could be resolved

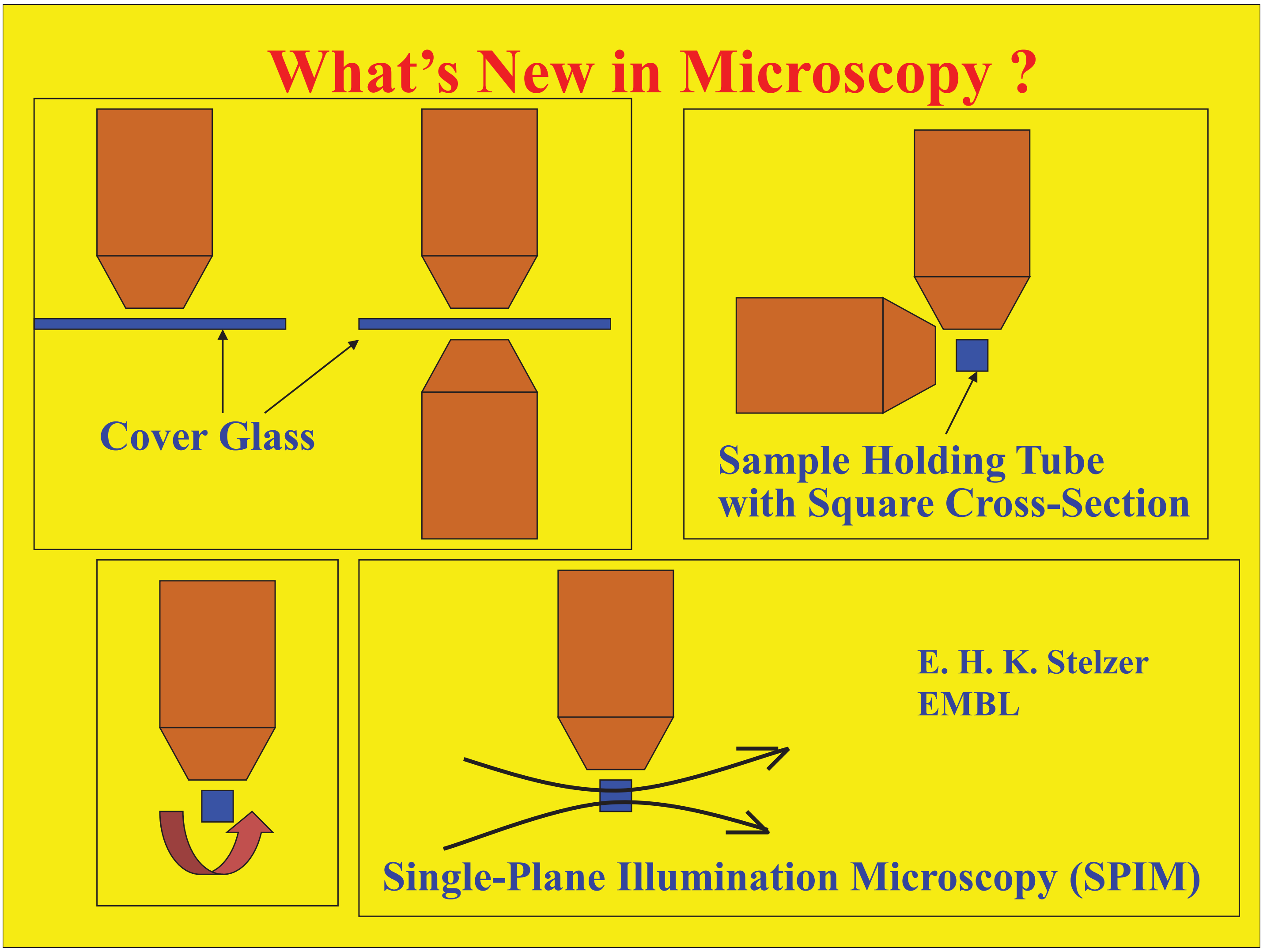
P/NSTL@NTU

nature photonics | ARTICLES
PUBLISHED ONLINE: 28 JULY 2013 | DOI: 10.1038/NPHOTON.2013.187

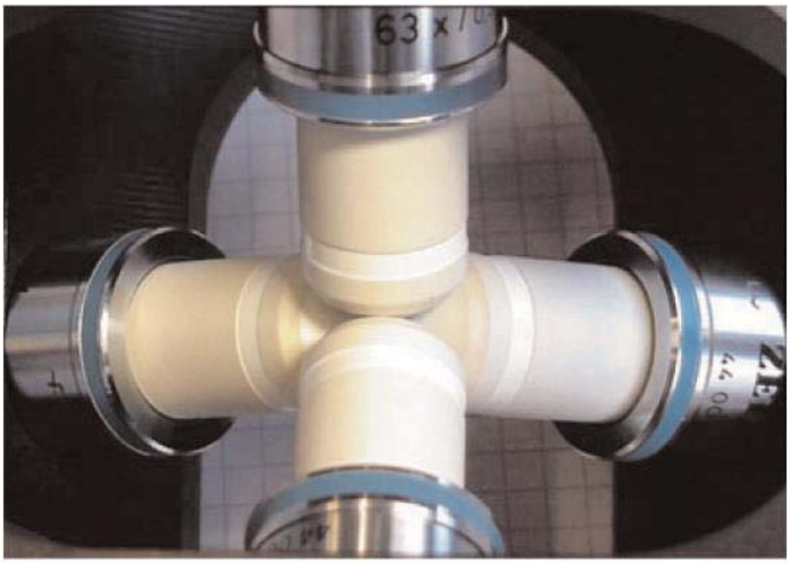
Wide-field, high-resolution Fourier ptychographic microscopy

Guoan Zheng†*, Roarke Horstmeyer and Changhuei Yang





What's New in Microscopy ?



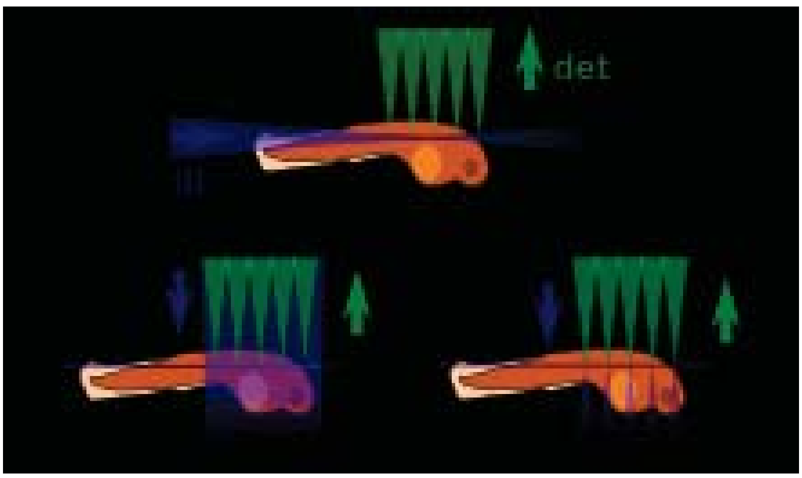
- Multi-Axis Imaging Microscopy (MAIM)
- Differential Active Optical Manipulator

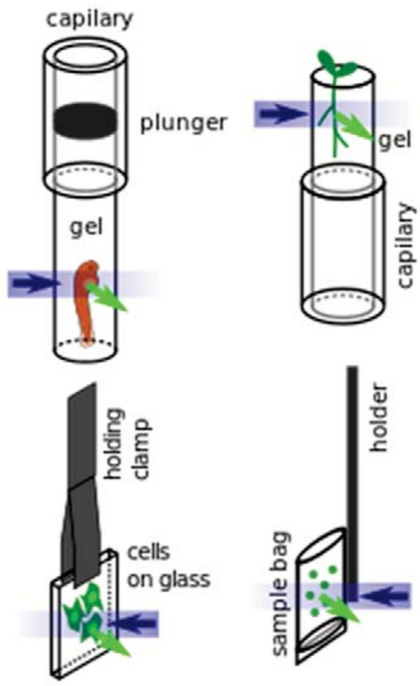
E. H. K. Stelzer, EMBL.

What's New in Microscopy ?

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

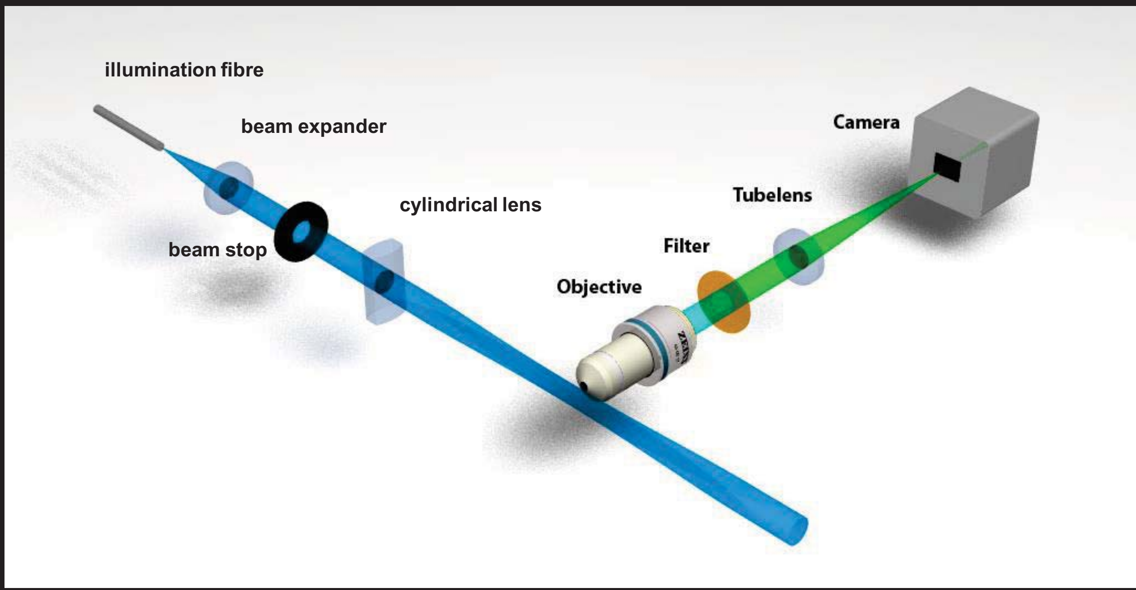
E. H. K. Stelzer, EMBL.





Selective Plane Illumination Microscopy (SPIM)

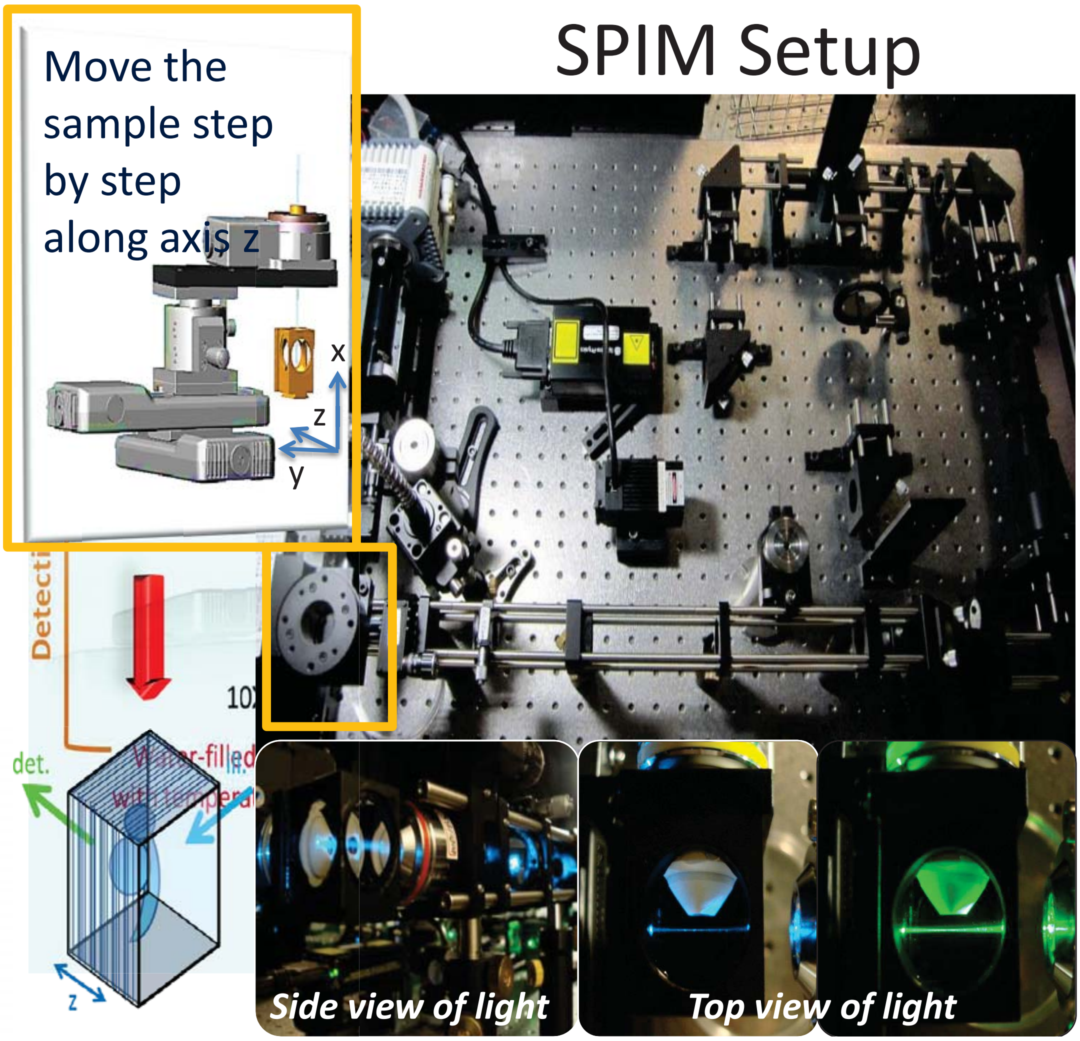
components & benefits



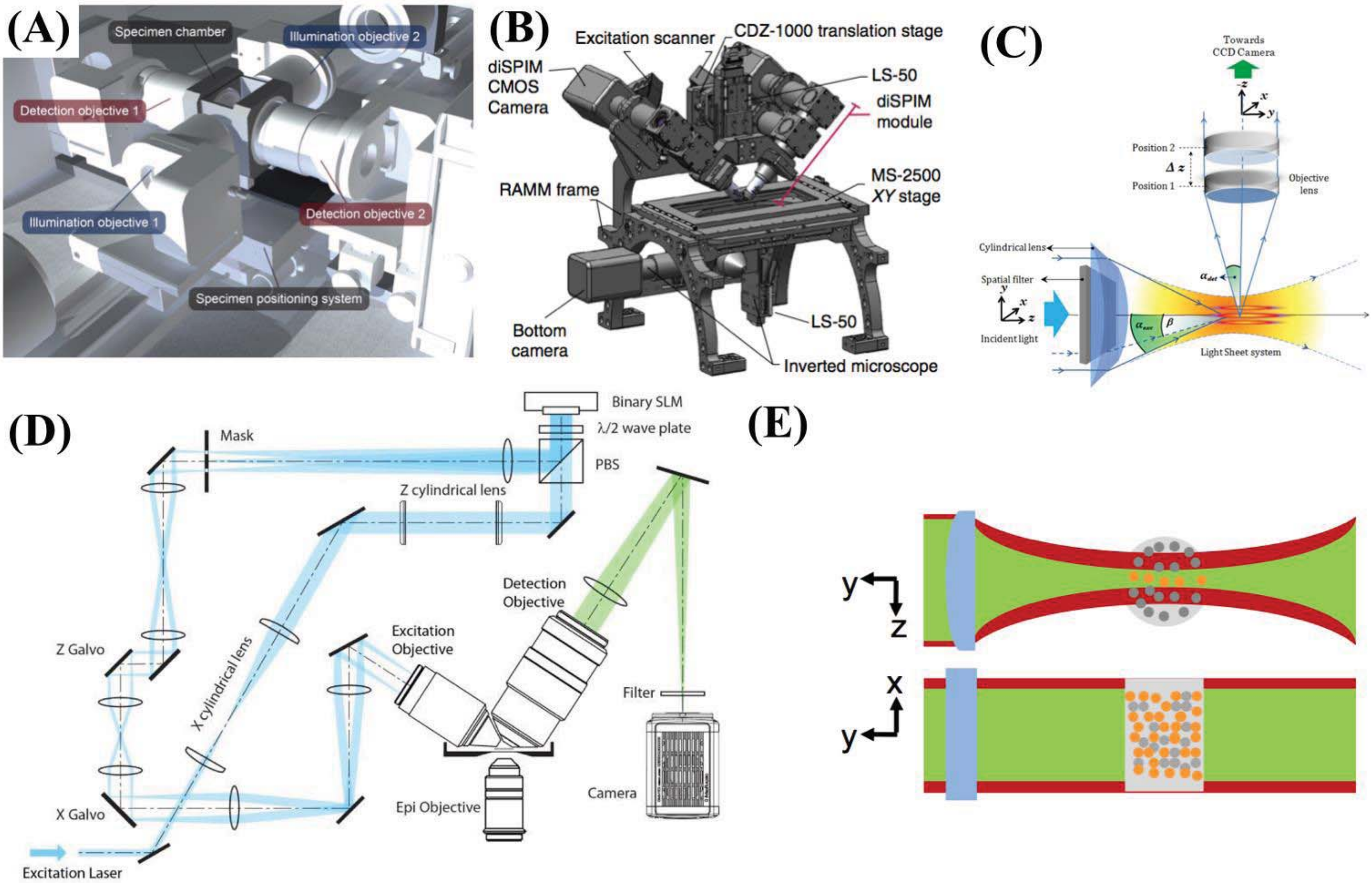
- Only focal plane is illuminated ➔ Optical sectioning; reduced bleaching
- Translation stage ➔ 3D stacks
- Water bath ➔ Aberration reduction; “bio-friendly”

Huisken et al., Science **305**, 1007 (2004)

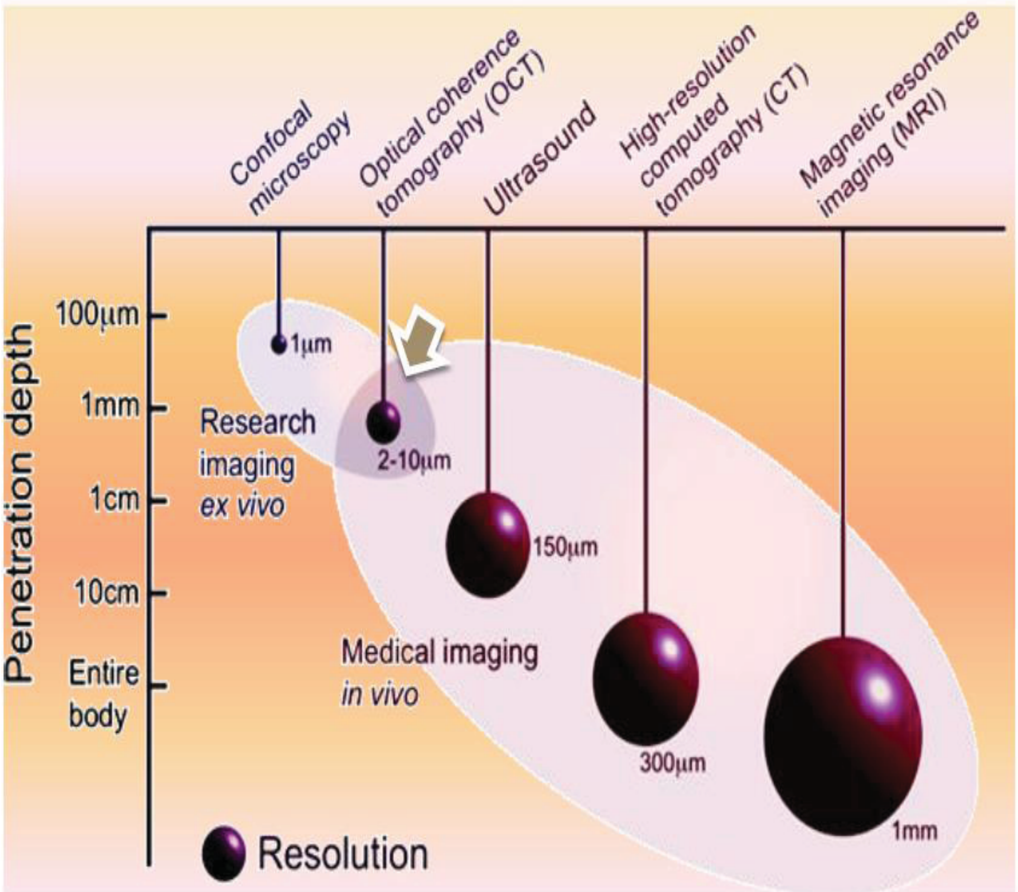
SPIM Setup

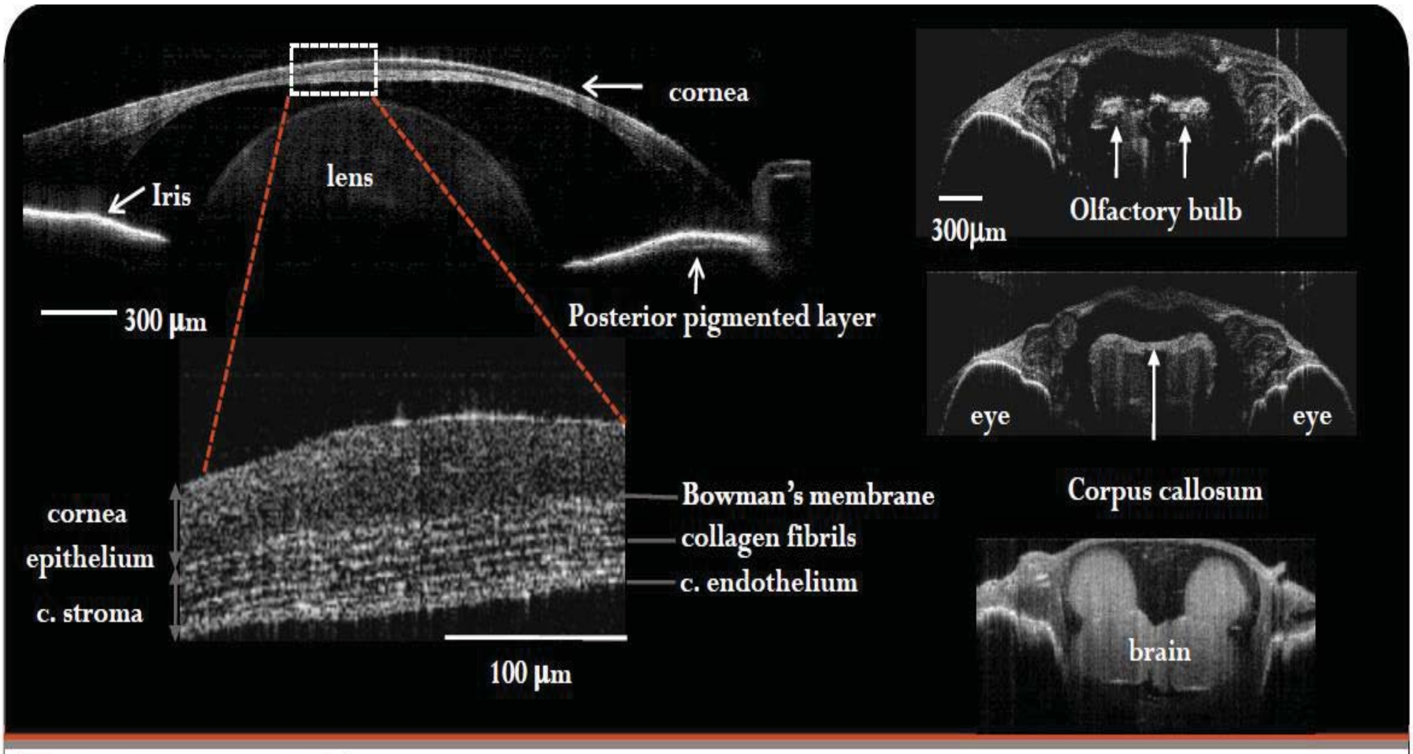


Light-Sheet Microscopy



Attractive features

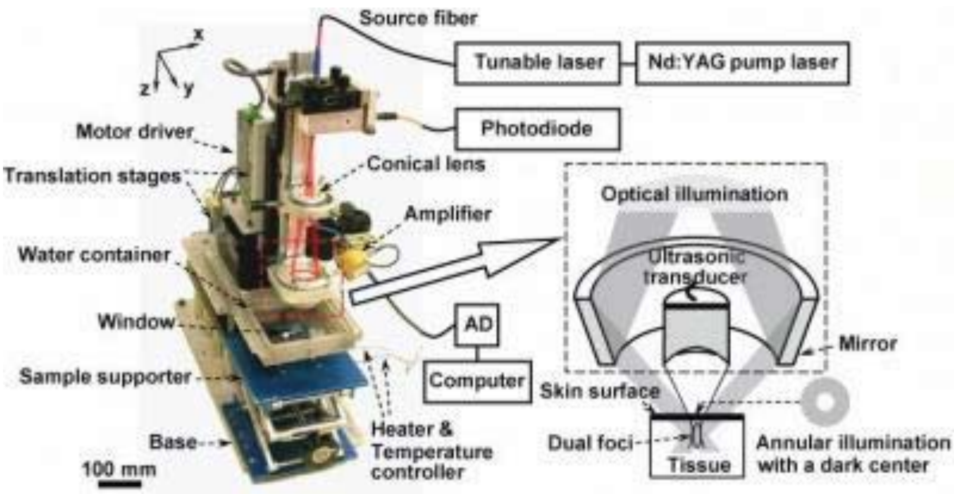


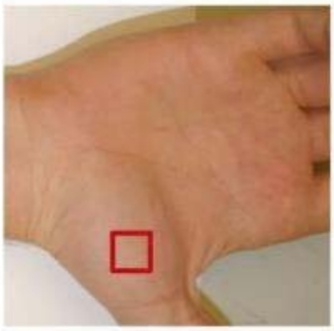


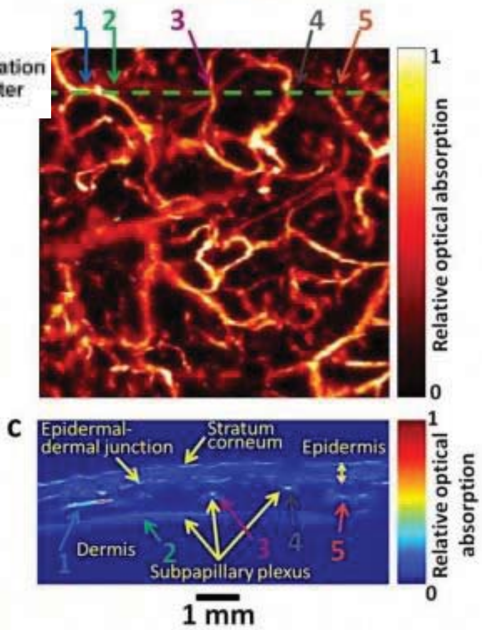
Ultrahigh resolution OCT (2.6 X 6 µm)

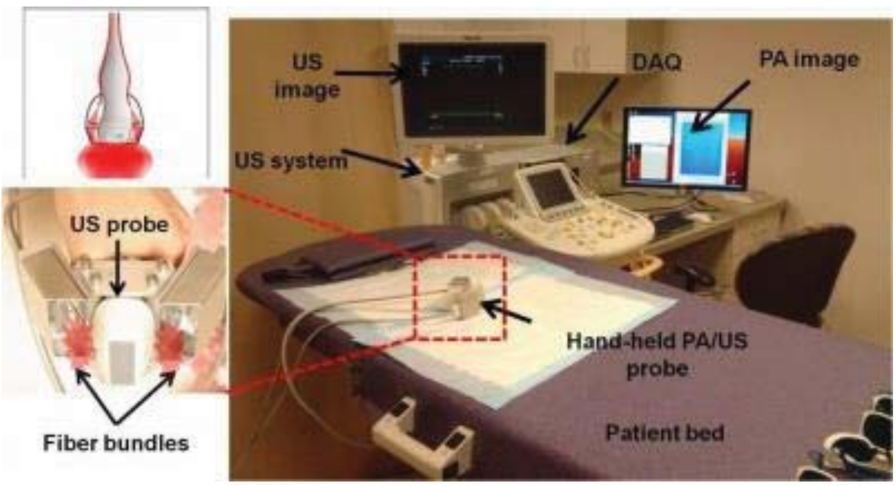
High speed (45 fps, 1000×4096 pixels) *in vivo* eye and brain tomograms of a living fish.

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

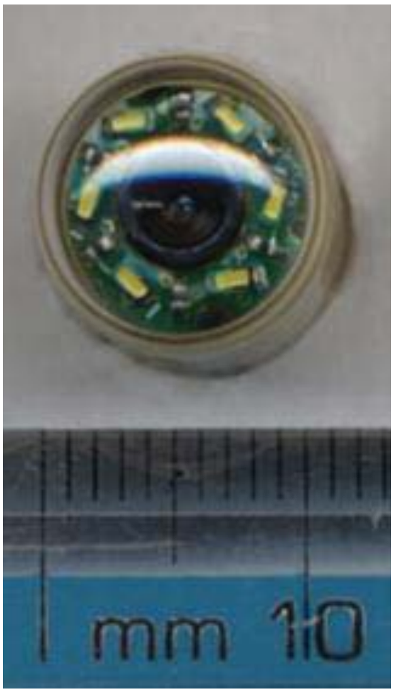


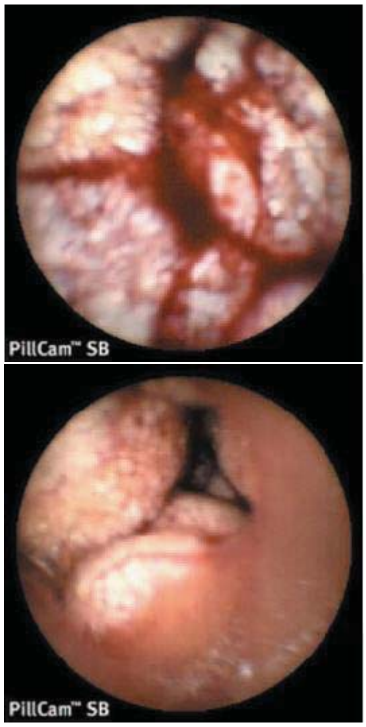




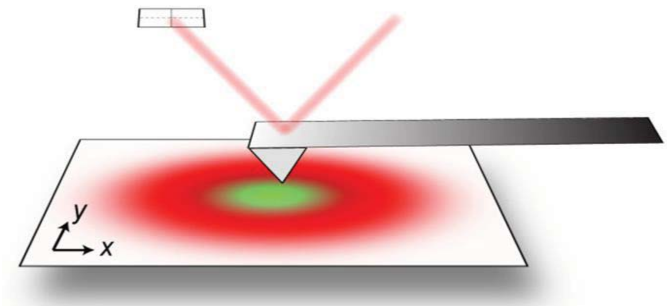


Capsule Endoscopy

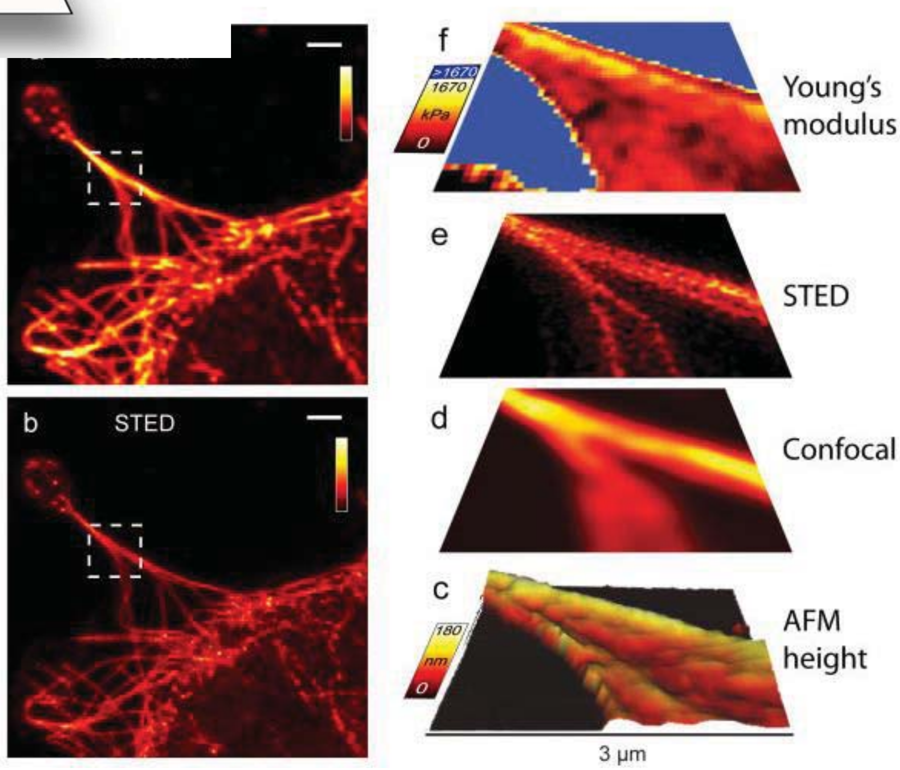




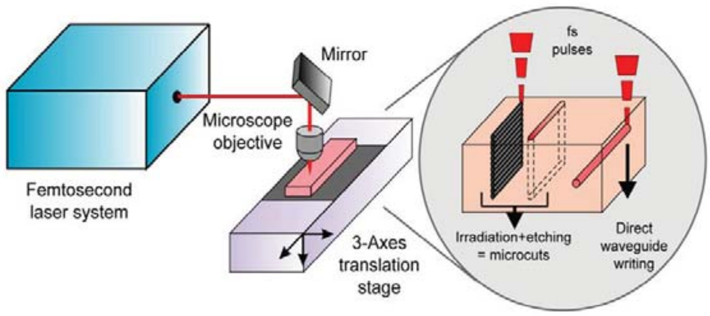
Endoscopic capsule end-on, showing six LEDs and camera lens.

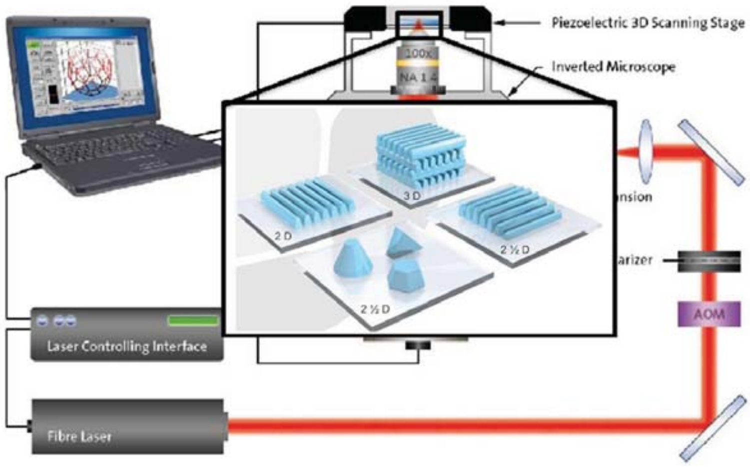


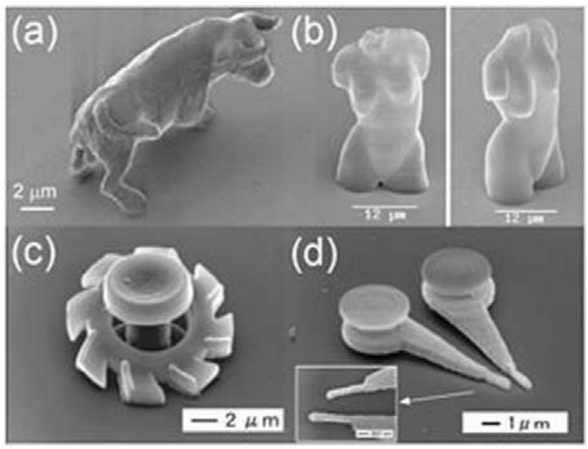
Integration of AFM with STED

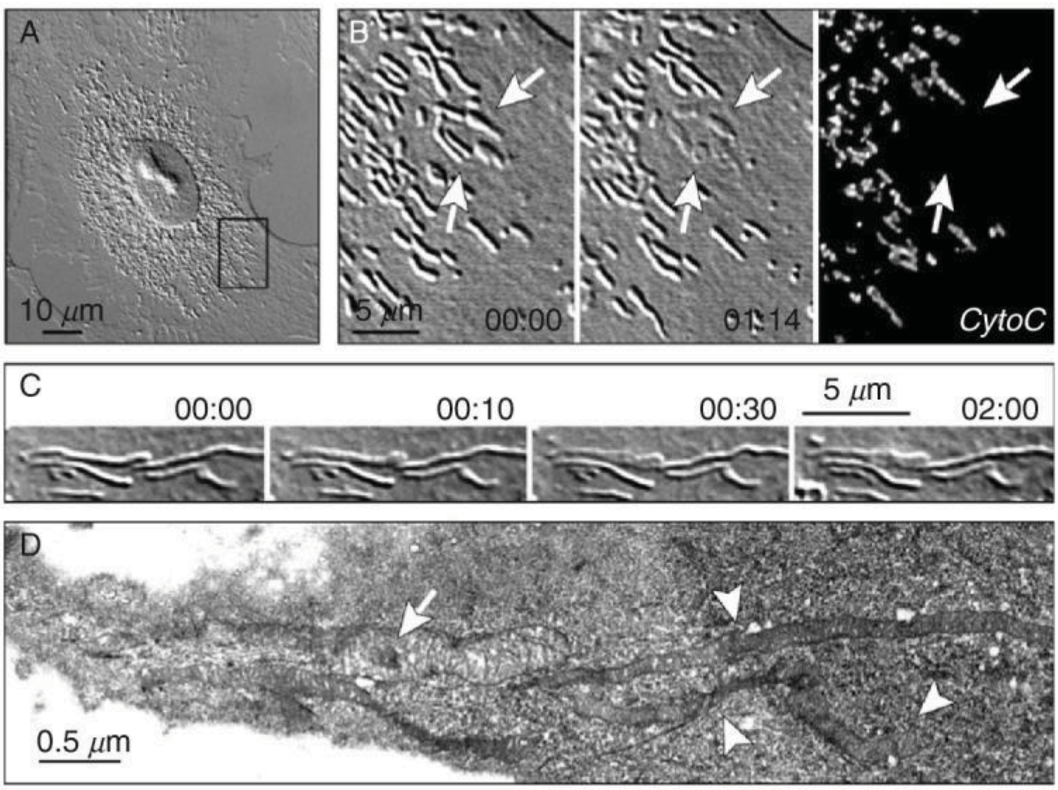


Laser 3-d Micro- and Nano- Fabrications









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

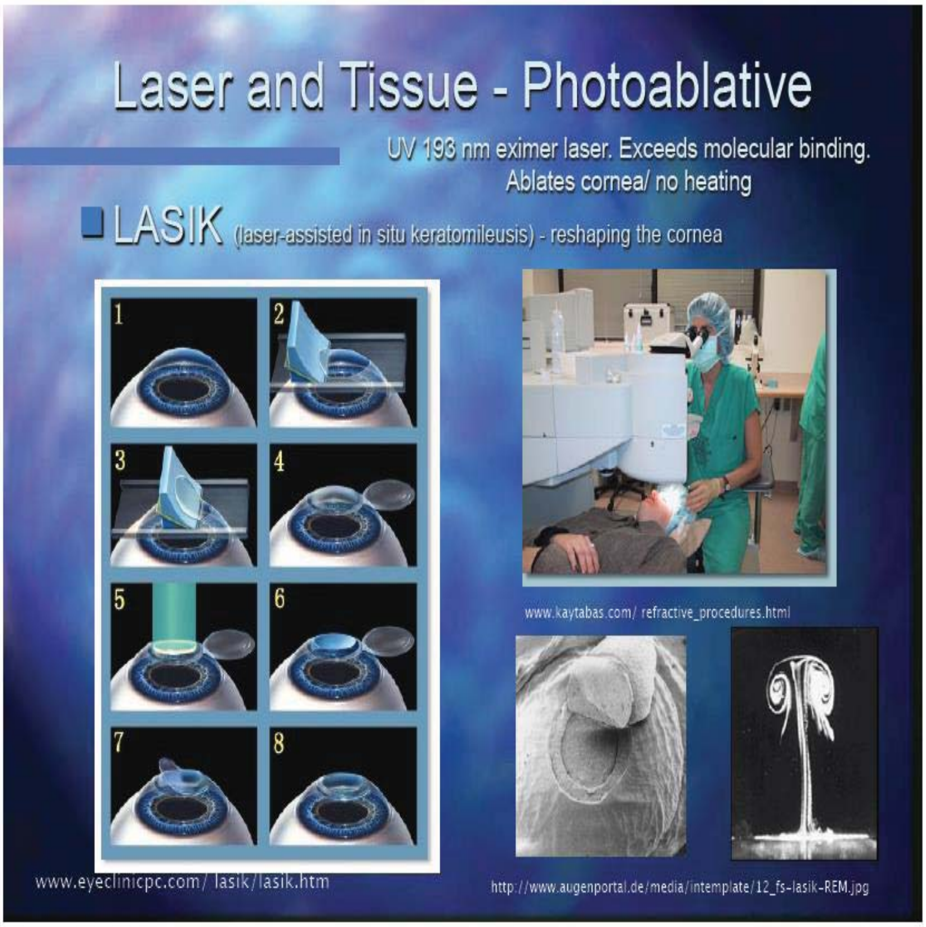
Laser Microsurgery in the GFP Era: A Cell Biologist's Perspective

Valentin Magidson, Jadranka Lončarek, Polla Hergert,* Conly L. Rieder, and Alexey Khodjakov

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



Optical Manipulation
(光學微操控)

Optics & Photonics News (March 2010)

Forty Years of Optical Manipulation

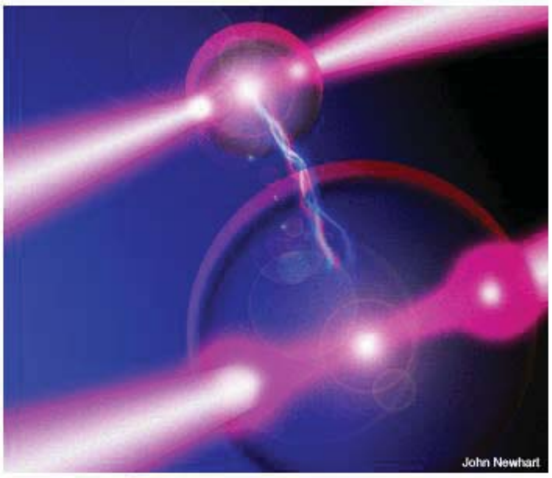
David McGloin and Jonathan P. Reid

This year, as the laser celebrates its 50th anniversary, a field that was made possible through laser technology reaches an important milestone as well. Over the past 40 years, optical manipulation research has deepened our understanding of physics and biology, and it has yielded the optical-tweezer technique that is used across all the sciences.

OPEN ACCESS

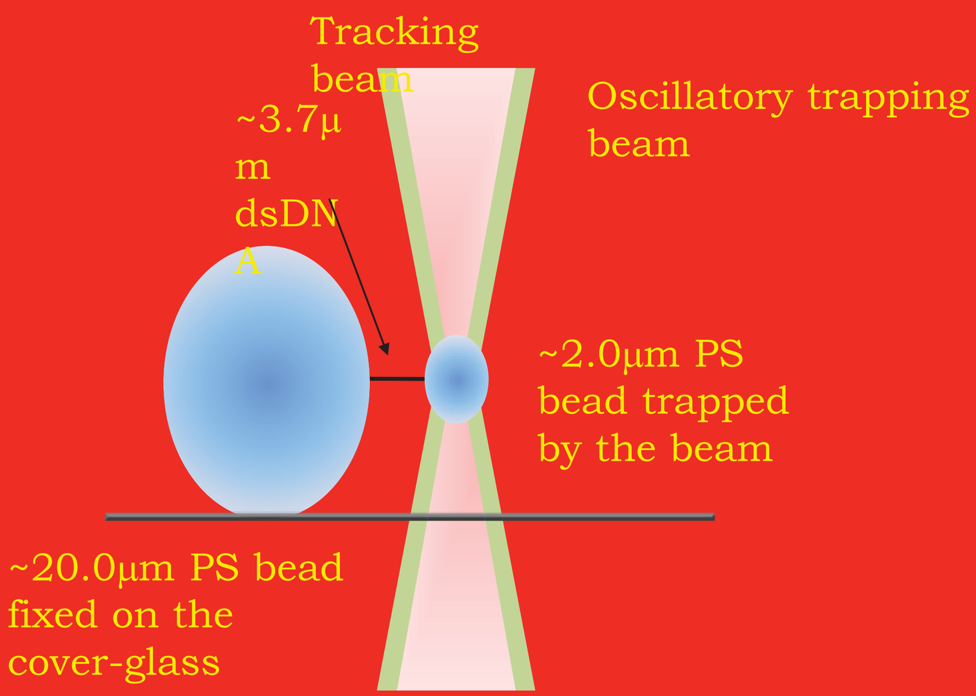
It is strange to think that light—that most ephemeral of things—can have any *mechanical* effect. But it has long been known that the universal palette can, in fact, push and pull on physical objects. The idea was put on sound mathematical footing with the development of the theory of electromagnetism by James Clerk Maxwell, who described what we now call radiation pressure.

Radiation pressure is the most intuitive form of optical force: Light incident on a surface produces a force on that surface. As P.N. Lebedev notes in his experimental verification of this hypothesis, "The value of this beam pressure is rather small." This is something of an understatement. The maximum pressure exerted by the sun on a reflecting object is on the order of 1 $\mu N/m^2$. Measuring such a tiny force at the turn of the century, as Lebedev somehow managed to do, was an impressive feat.



Artist's interpretation of a DNA strand held under tension by two beads trapped in optical tweezers.

DNA Spring Constant Measured by Oscillatory Optical Tweezers

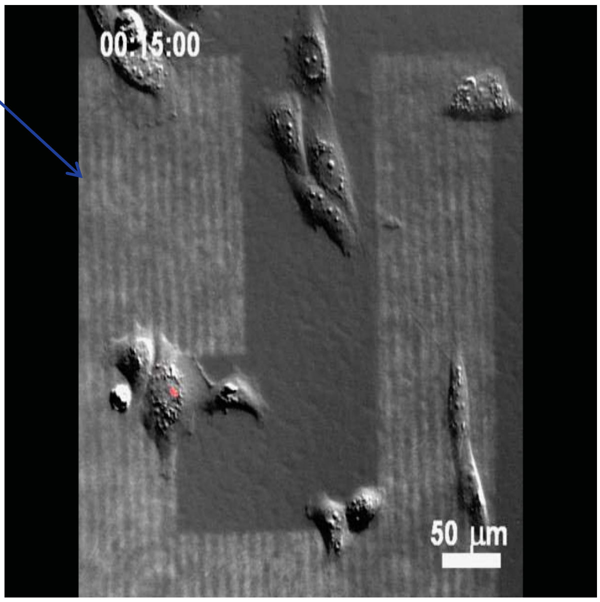


33

Using a blue light pattern to guide cell migration

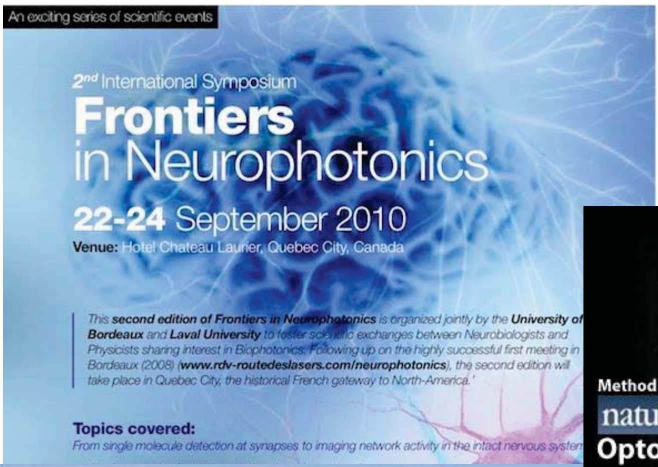
The motion direction of the cell centroid was turned by ~90 degree.

0.2 W/cm^2

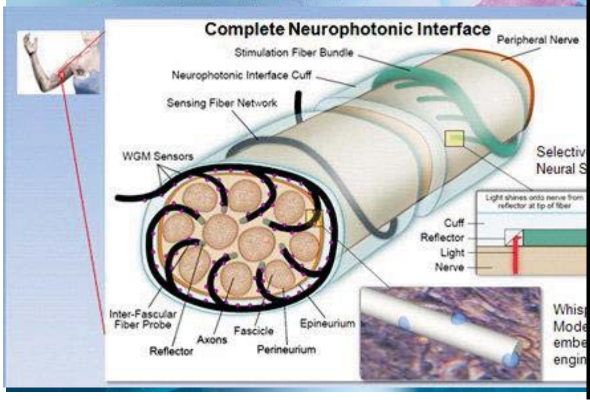


J.-L. Xiao, D.-H. Lu, and C.-H. Lee, *Appl. Phys. Lett.* **102,** 123703 (2013).

Frontiers in Multi-displinary Research & Development



Optogenetics:
Controlling the Brain with Light
(An illuminating journey into the brain



DARPA funds Neurophotonics Center

Thank You

Lasers:
History, Basics, and Applications

李晁逵
中山大學光電所

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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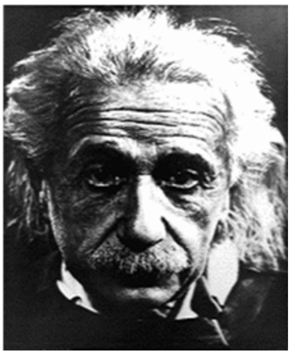
Noble Prizes Related to Lasers

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 heterstructures for optoelctronics
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

http://nobelprize.org/nobel/

Laser Pioneers



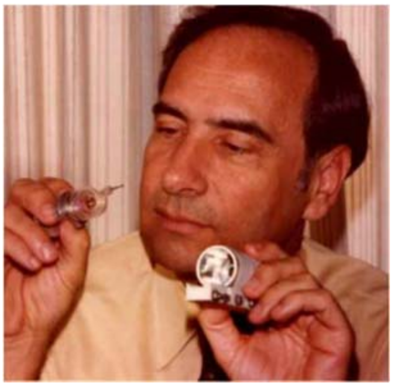
Einstein
1917

Stimulated
Emission

Gould
1957

Laser
Patent

Townes and Schawlow 1958
Optical Maser



Maiman 1960

The 1st 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)

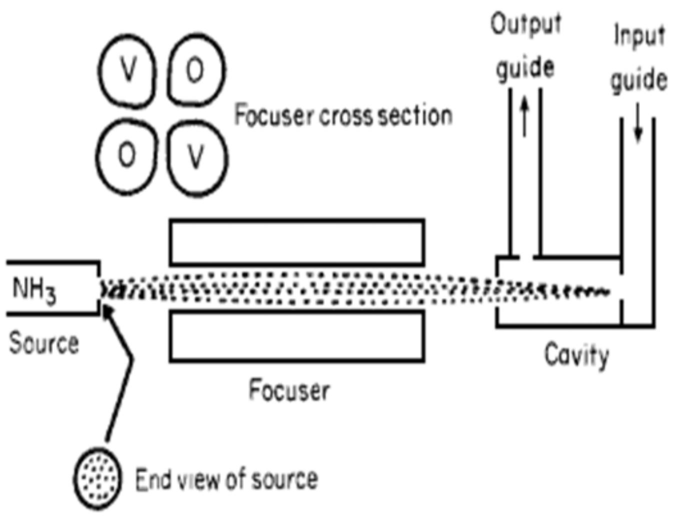
The MASER(I)

- 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.

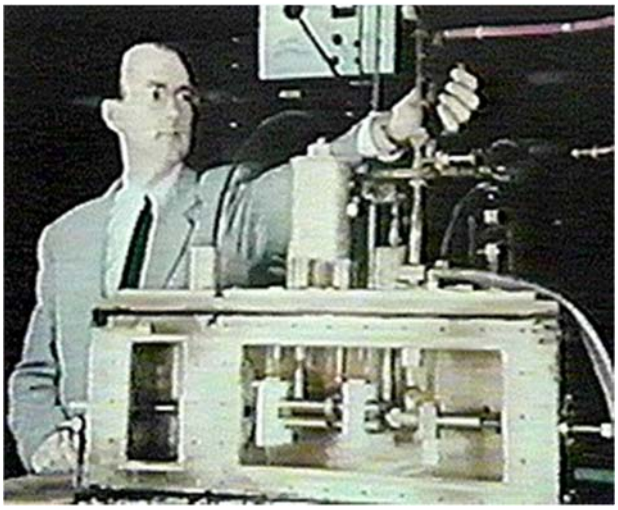
The MASER(II)-Townes

- 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.

Maser: Microwave Amplification by Stimulated Emission of Radiation



1st Maser: NH_3 (λ= 1.25 cm)



Townes and the 1st Maser 1954

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

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 enrrgy levels lead to enhance the sensitivity, 1950.
- Basov's doctoral thesis.

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

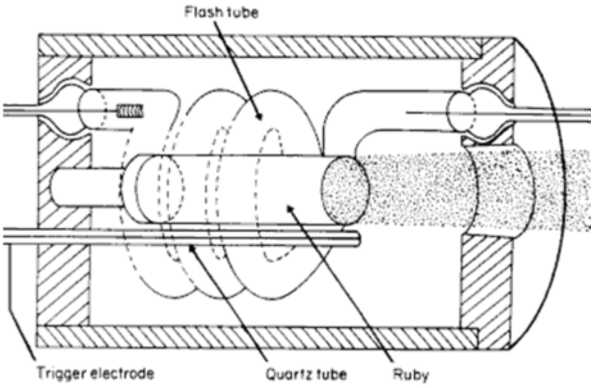
Before the LASER

- 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.

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 inteferometer.
- 1959, Schawlow and T. Maiman @ Hughes.
- 1960 May 16: silvered coated end inside a spring-shaped flashlamp.
- Rejected by PRL.

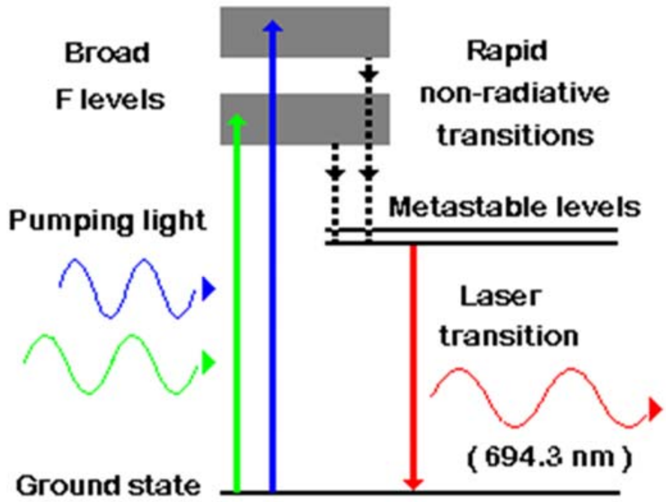
Ruby : The 1st Laser



$Cr^{3+}:Al_2O_3$

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

http://www.invent.org/hall_of_fame/96.html



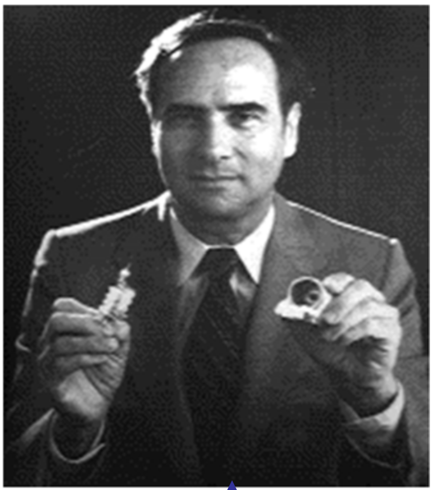
Energy levels of chromium ions in ruby

Ruby Laser: Mechanical Parts

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 1st Ruby Laser:

Lasing observed on May 16, 1960

Outline

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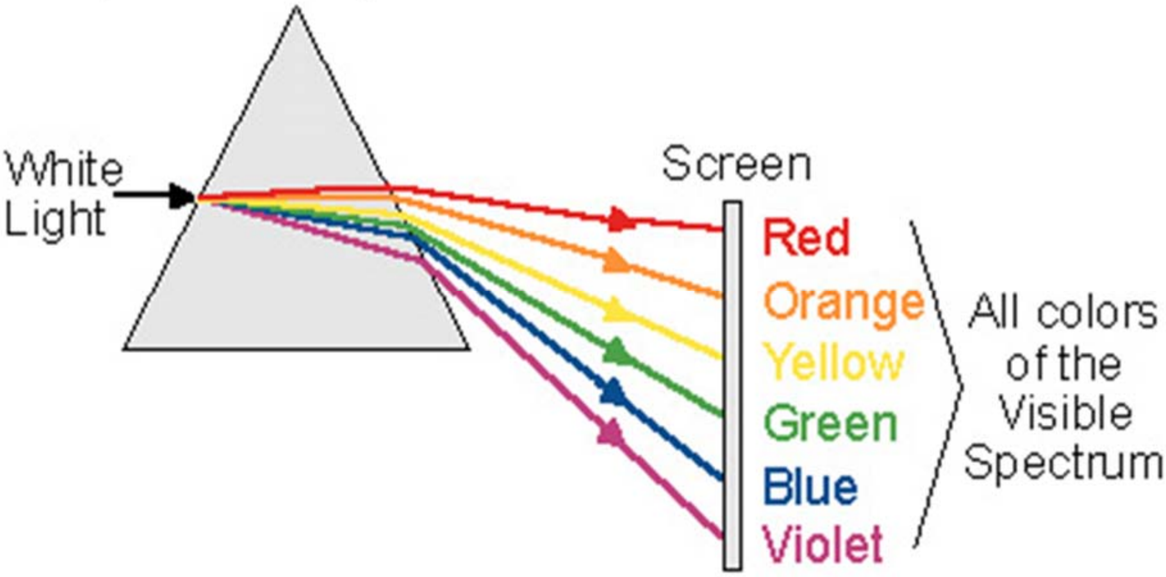
Solar Spectrum

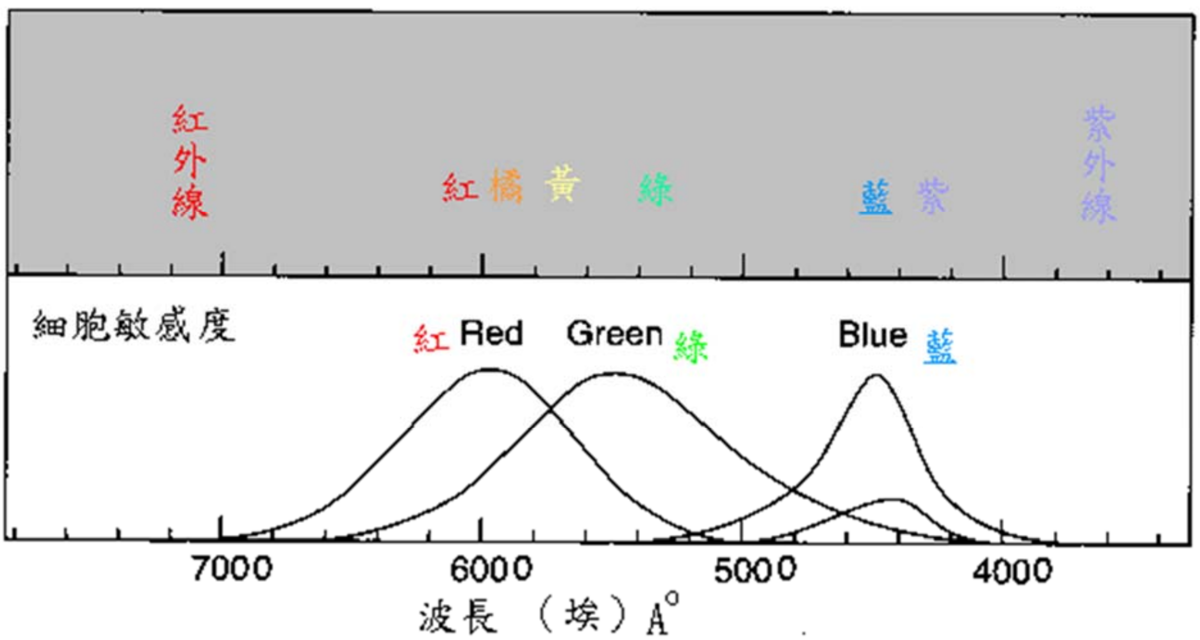
Newton showed that sunlight is made up of many different "colors."



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

Solar Spectrum

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



Blackbody Radiation

Every object absorbs radiation and emits radiation.

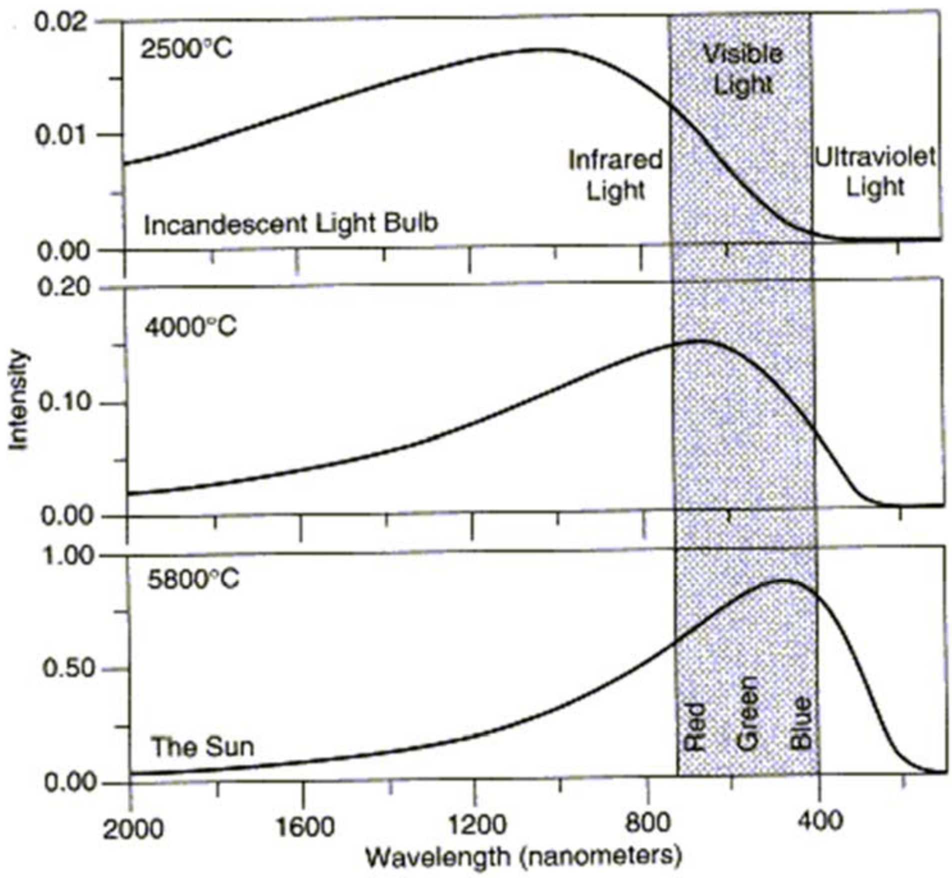
For an "ideal" object, these amounts are equal.

Sun: T = 10,000º F → λ_{peak} = 500 nm

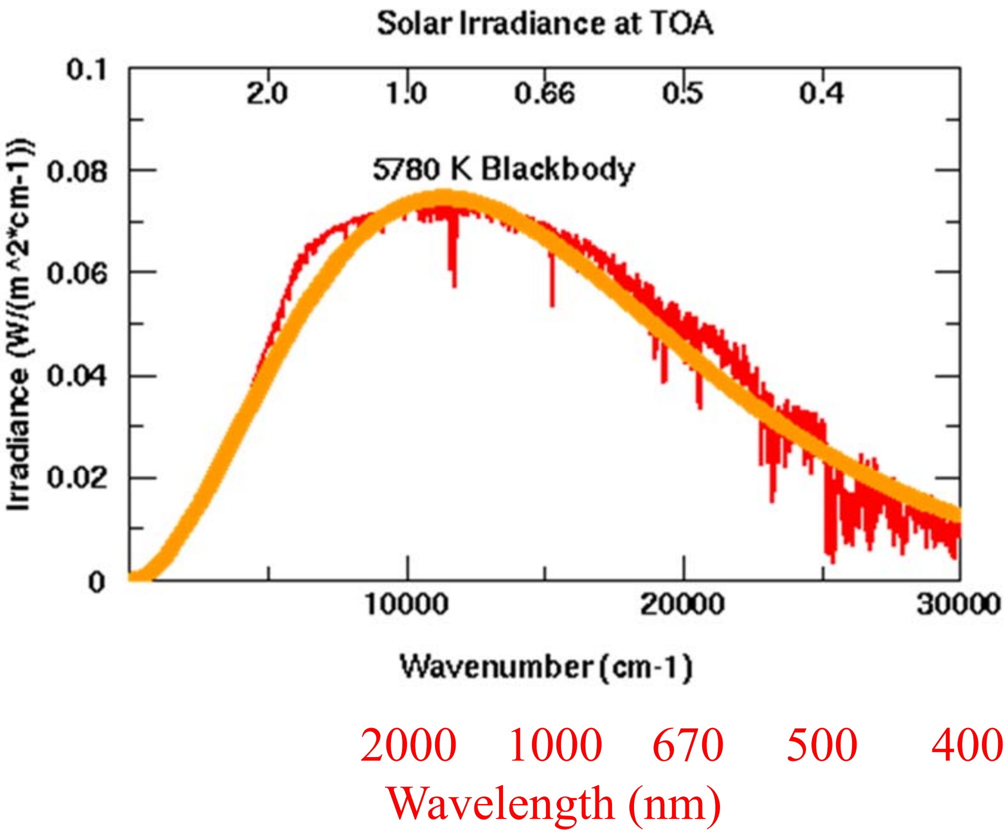
Photo Flood Lamp: T = 5000º F → λ_{peak} = 1000 nm

You: T = 100º F → λ_{peak} = 10,000 nm

Blackbody Radiation Spectra



Solar Spectrum



Common Light Sources

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

Common Light Sources

Fluorescent lights
- glowing gas
- tube coated with phosphor

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

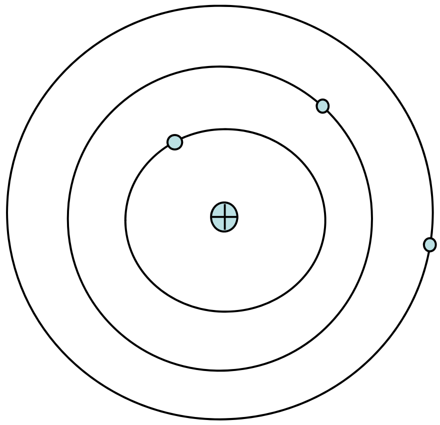
Spectral Lamps and Atoms

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.html

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.*

What does the word "Laser" come from?

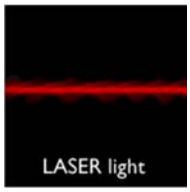
Laser: Light Amplification by Stimulated Emission of Radiation

or

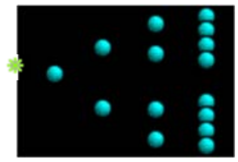
Lots of Applied Scientists Eating Regularly

"1957 by Gould"

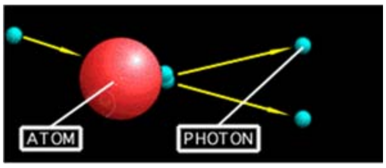
The "L" in LASER stands for **Light**



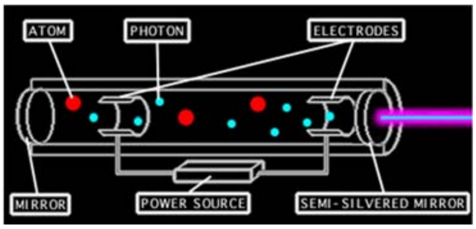
The "A" in LASER stands for **Amplification**



The "S" in LASER stands for **Stimulated**

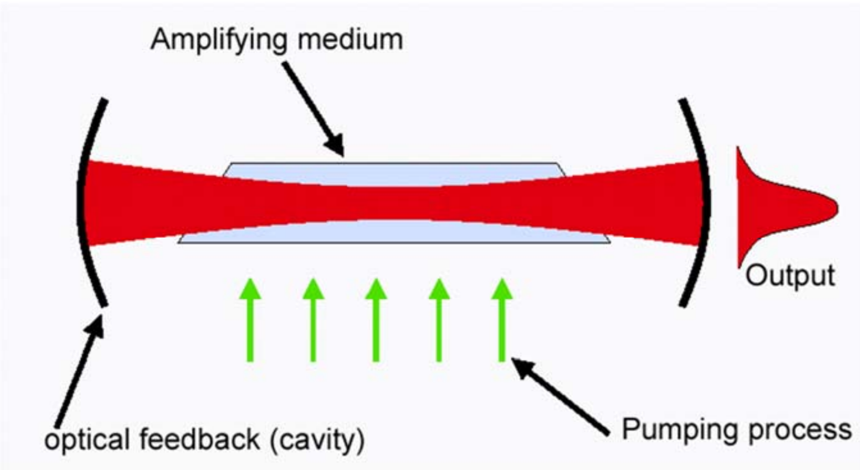


The "E" in LASER stands for **Emission**



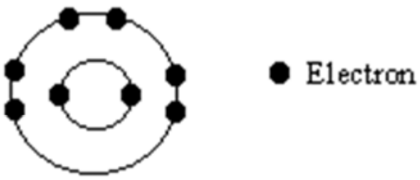
The R in laser stands for **radiation**.

Key Elements of a Laser

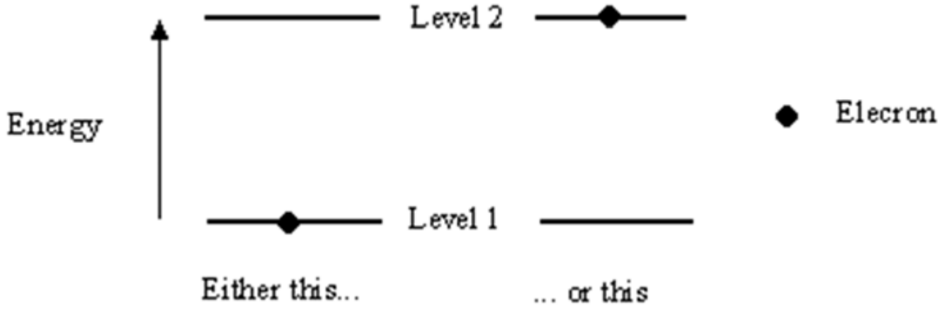


- Pumping process prepares amplifying medium in suitable state
- Optical power increases on each pass through an amplifying (gain) medium consisting of atoms, molecules in the form of gases, liquid or solids
- If gain exceeds loss, device will oscillate, generating a *coherent* output

Atoms and Energy Levels



“Shell Model” of the Atom



An “idealized” 2-level system

Photons are also “quantized”

$$E = \frac{h\,c}{\lambda}$$

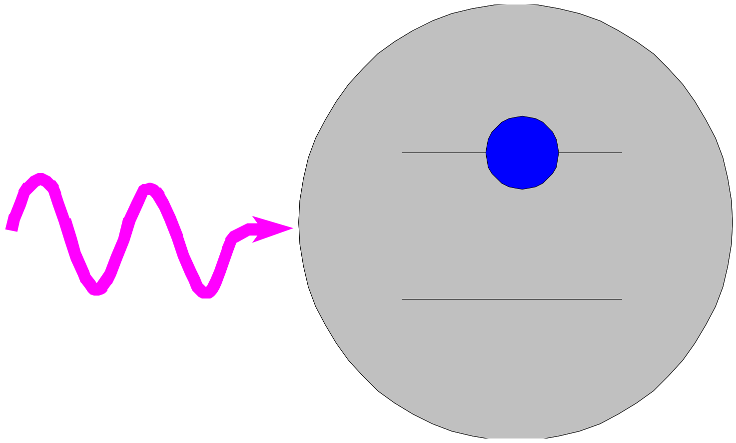
E is the Energy
λ is the Wavelength
h and c are fundamental constants which just get the units correct

Ground and Excited States

“Ground State”

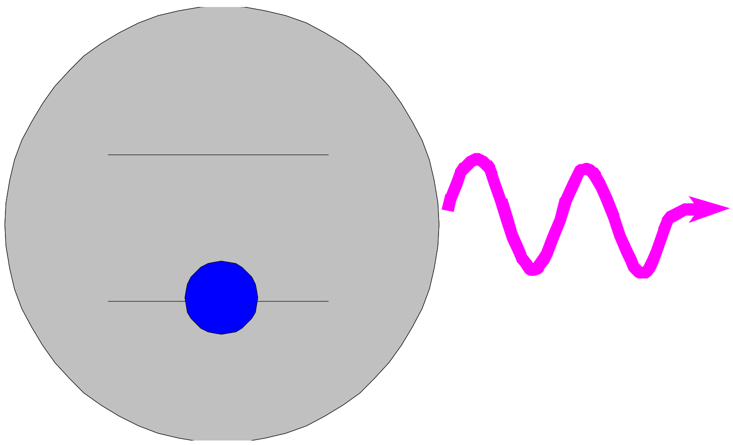
“Excited State”

Three Atomic Processes



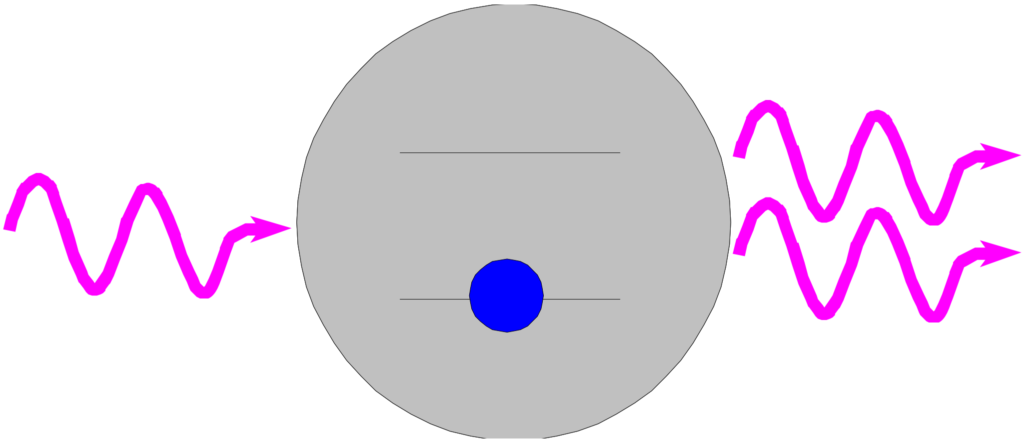
Stimulated absorption

Three Atomic Processes



Spontaneous emission

Three Atomic Processes



Stimulated emission

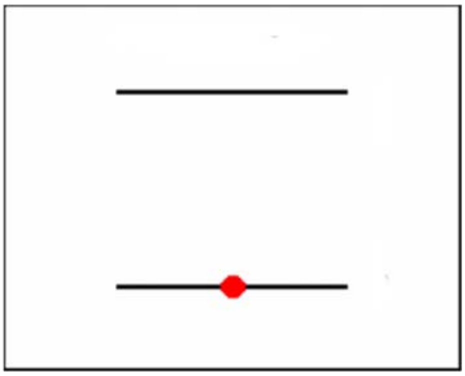
Physics 2000

Two types of emission processes

Absorption

&

Spontaneous Emission

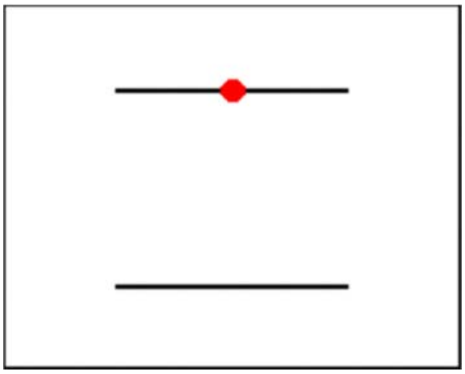


Two-level System

Absorption

&

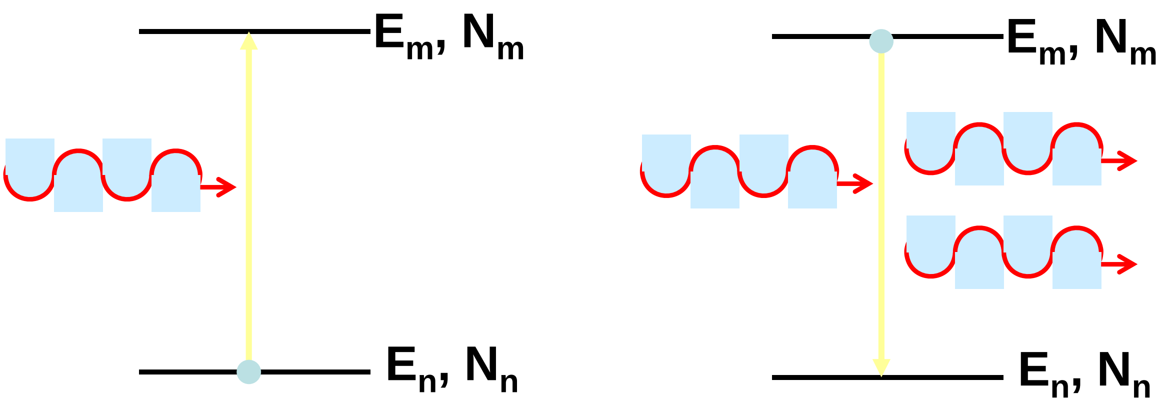
Stimulated Emission



Laser light results from stimulated emission

A "Photon Slide"
Photons in the Laser Environment

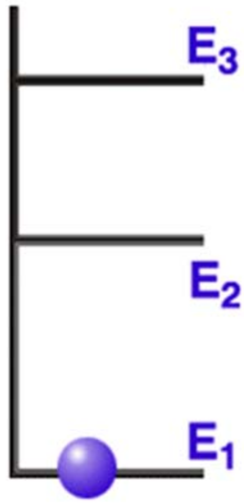
Two Level System



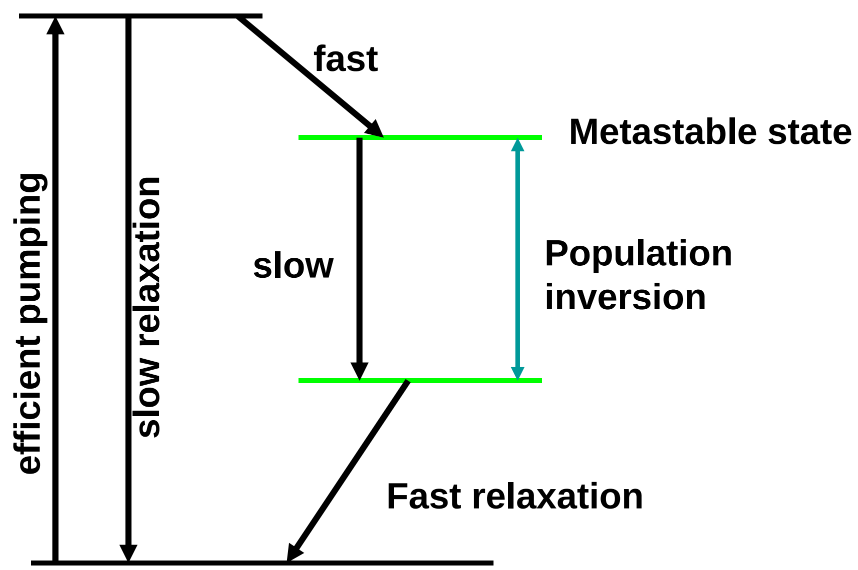
Even with very a intense pump source, the best one can achieve with a two-level system is

excited state population = ground state population

Lasing in a 3-Level System

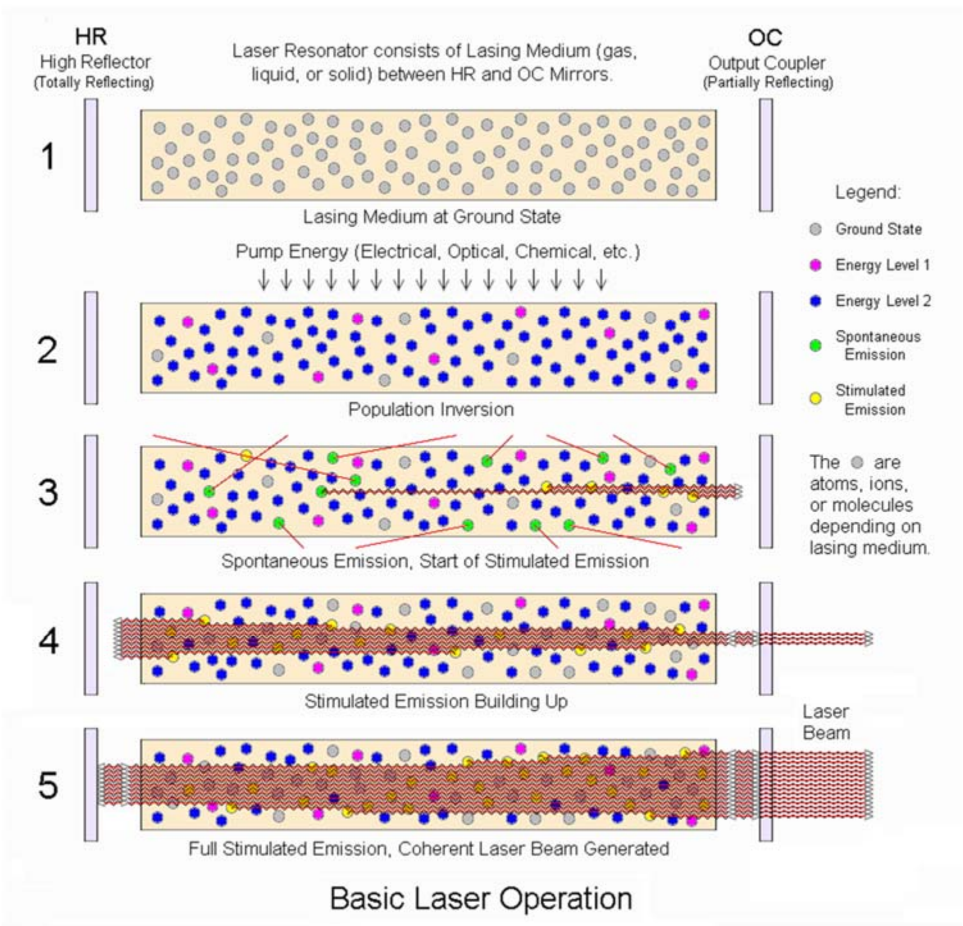


Lasing in a 4-level system



The MASER(IV)-levels

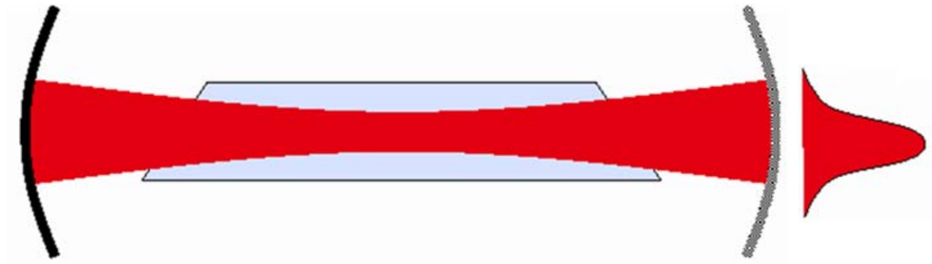
- Two-level first.
- 1956, Basov and Prokhorov proposed in 3-level gas material
- 1956, Nicolas Bloembergen @ Harvard proposed 1st 3-level solid-state maser.
- Ali Jven also work in 3-level maser.

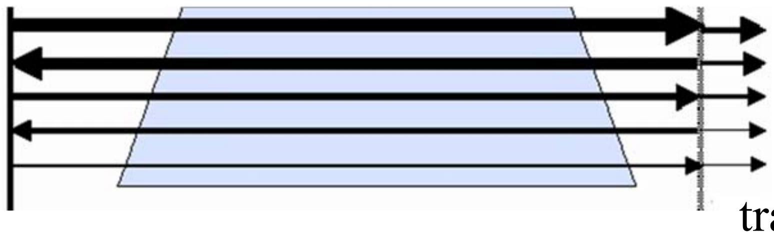


Basic Laser Operation

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

Feedback in an Optical Cavity



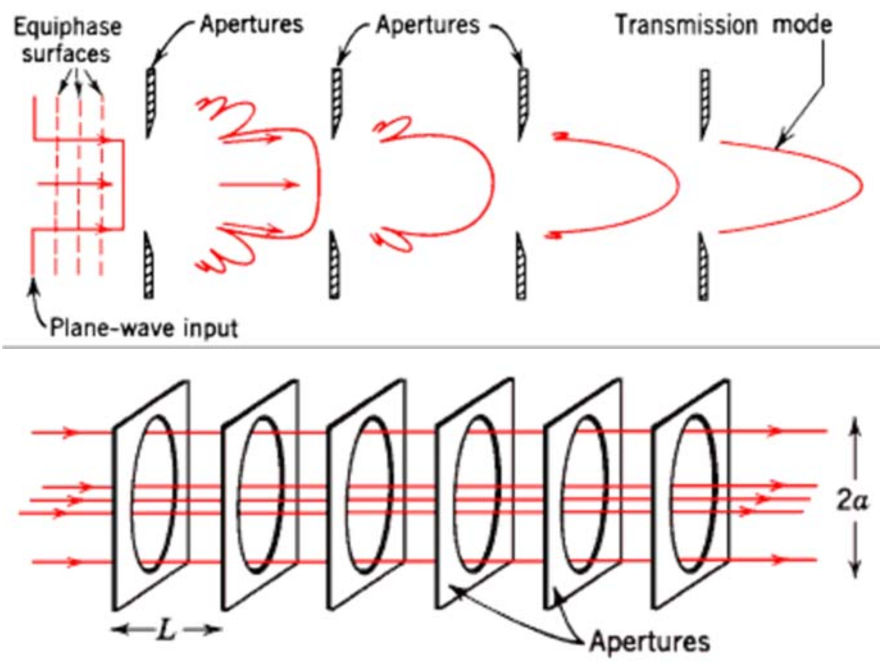


- Each successive pass grows or shrinks depending on g > or < T

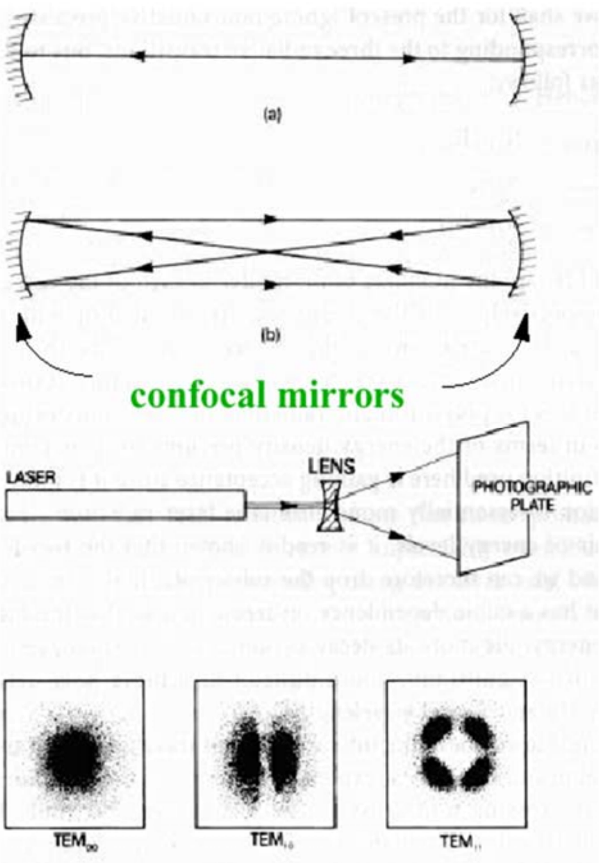
– can picture as Fabry- Perot interferometer

- Curved mirrors lead to Gaussian transverse intensity profile

Optical Cavity and Directionality of the laser beam



Diffraction-limited optical beam: $\theta \approx \lambda/2a$

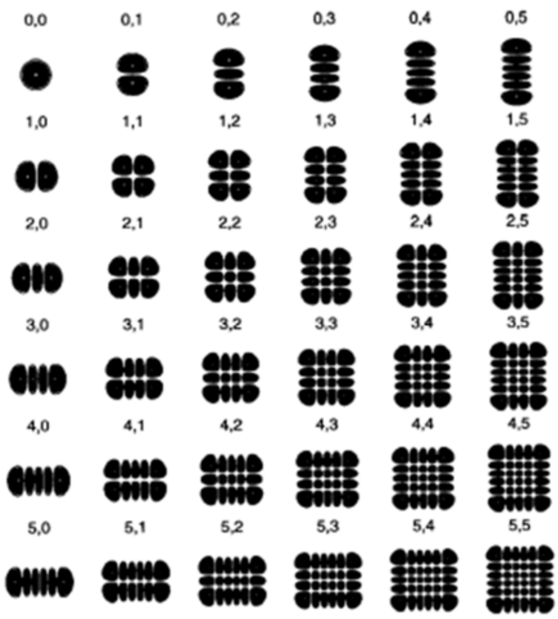


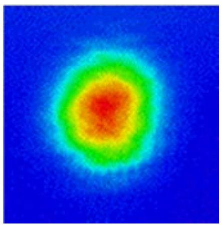
TEM modes *

- a) on axis TEM00
- b) off axis TEM10
  - (TEMpq) confocal
  - p, q, # intensity min.
- multimode – less coherence
- narrow cavity TEM00

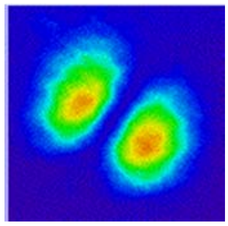
*transverse electromagnetic mode

Mode-Selection by the FP: Transverse Modes

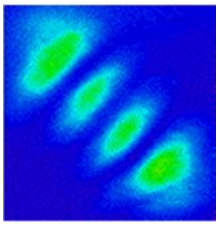




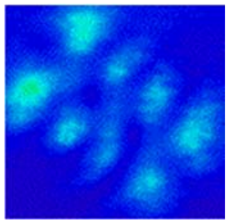
TEM00



TEM01



TEM03



TEM13

http://www.iap.uni-bonn.de/lehre/ss01_laserphysics/optres.html

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

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 (~ one optical cycle) in the near IR, sub-fs (EUV)
- Extremely high power possible (beyond terawatt, 10^{12} W)

Properties Of Laser Beams (I)

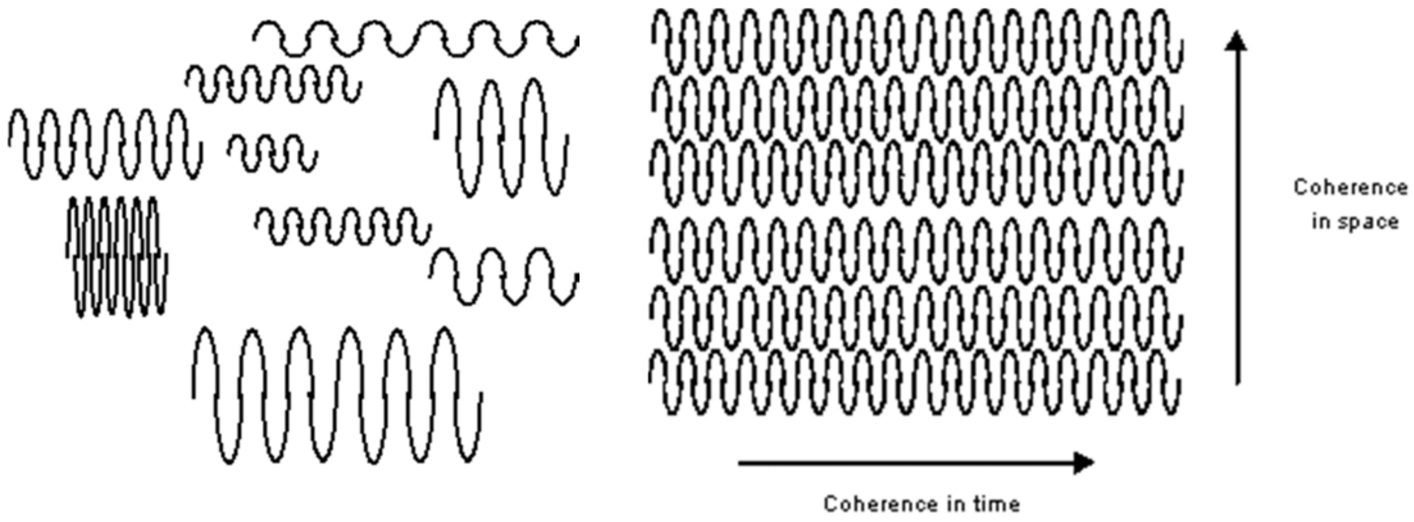
Highly Monochromatic

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

Temporally coherent!

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

Coherence



A TRAIN OF INCOHERENT PHOTONS

A TRAIN OF COHERENT PHOTONS

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

Properties Of Laser Beams (III)

Extremely Bright

- Brightness is defined as

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

- For an optical beam of power P, diameter D, divergence, θ_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

Outline

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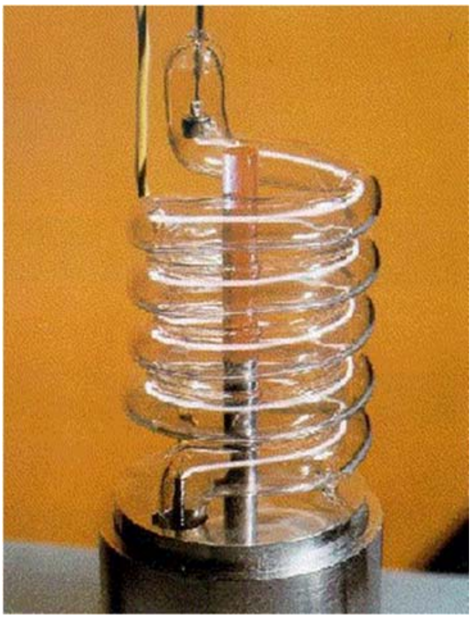
Lasers: Big and Small Ones

5 mW laser for CD player
< $0.50

All operate on same general principles

Lasers: Big and Small Ones (II)



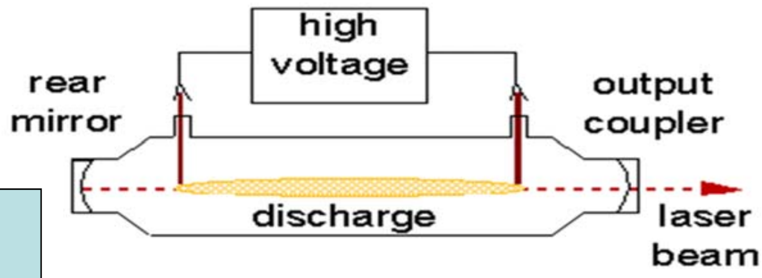
The 1st (Ruby) Laser

The Nova Laser for Fusion Research

Types of Lasers : Classified by Gain Medium

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

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)**
- **CO2 : 10.6 μm (1964) (cw or pulsed)**

– electron impact excites atomic or molecular species

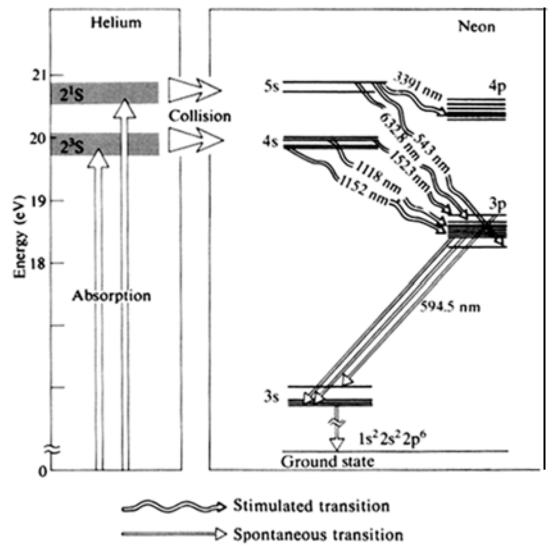
– low efficiency (10^{-4} typical), discrete wavelengths (UV – FIR)

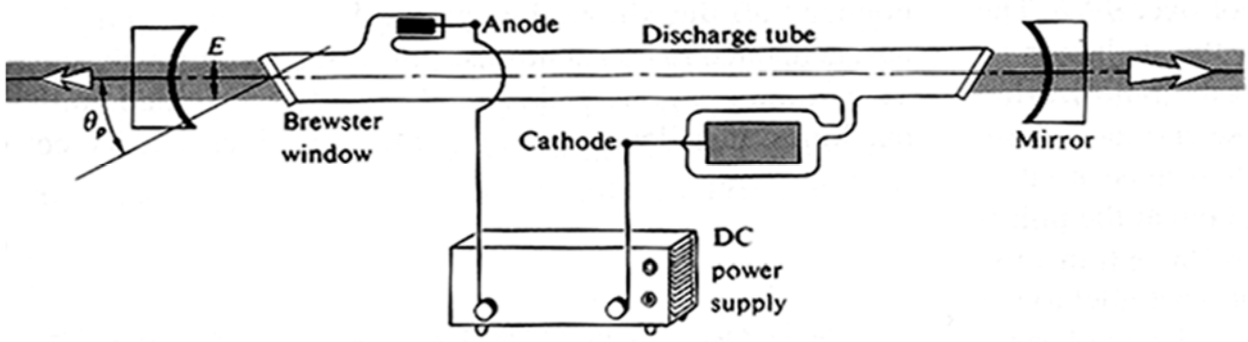
The Helium-Neon Laser

"1st gas laser"

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

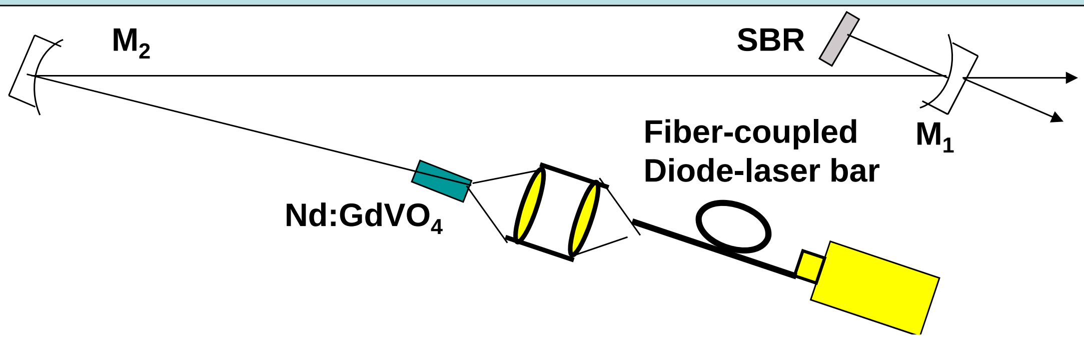
Energetic electrons in a glow discharge collide with and excite He atoms, which then collide with and transfer the excitation to Ne atoms, an ideal 4-level system.



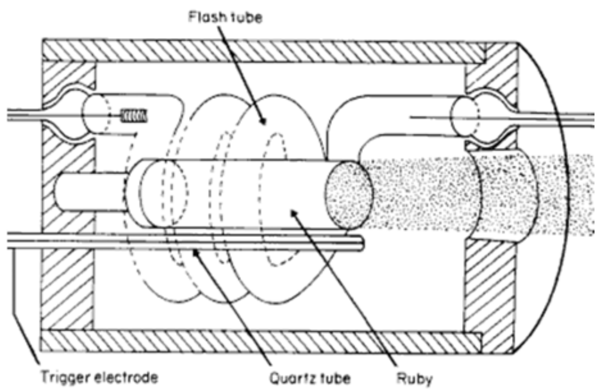


Types of Lasers (II):Solid State Lasers

- 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 (Cr^{3+} in Al_2O_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 Nd^{3+} in a $Y_3Al_5O_8$ (YAG) or $YLiF_4$(YLF) crystal or in a glass.

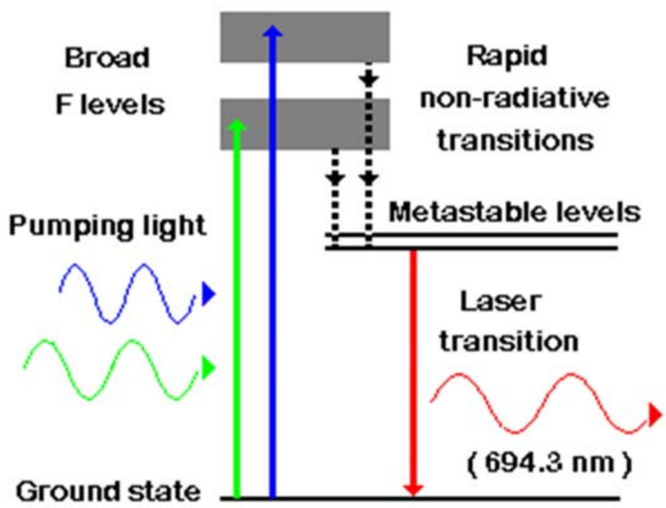


Ruby : The 1st Laser



$Cr^{3+}:Al_2O_3$

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



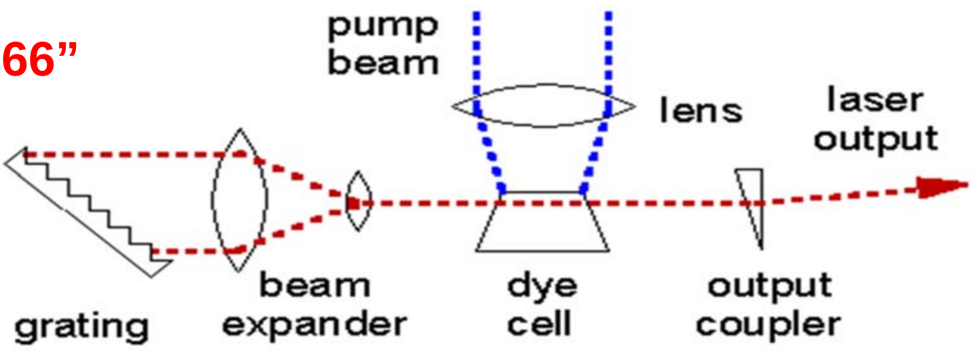
Energy levels of chromium ions in ruby

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

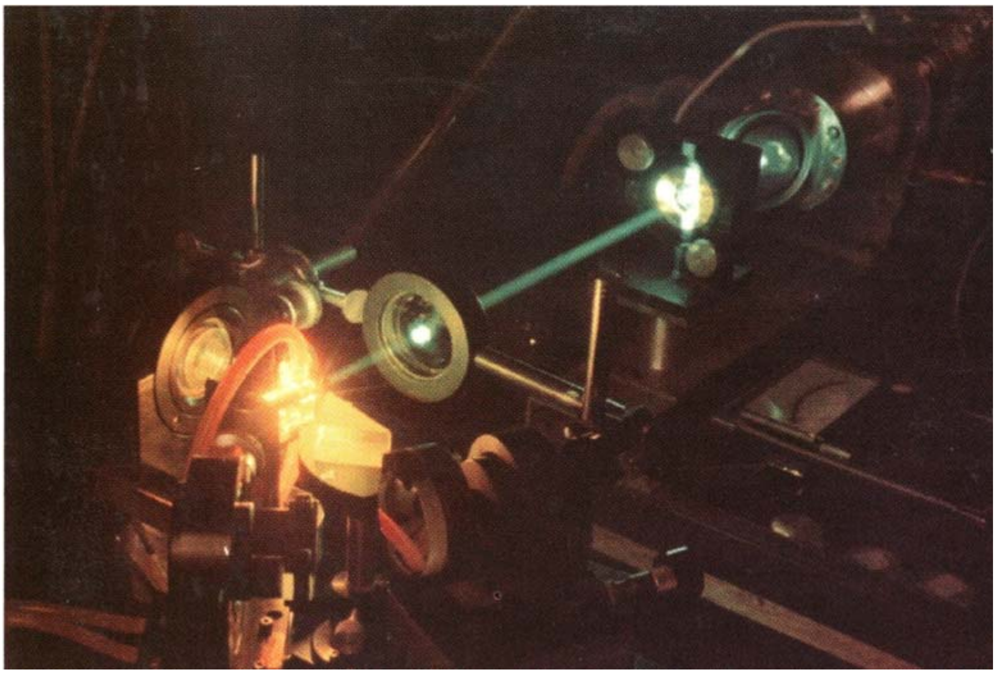
Types of Lasers (II): Dye Lasers

- 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

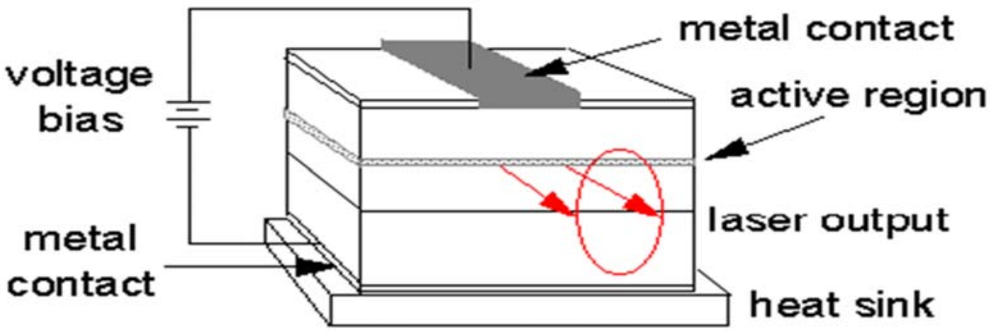


Dye lasers are an ideal four-level system, and a given dye will lase over a range of ~100 nm.

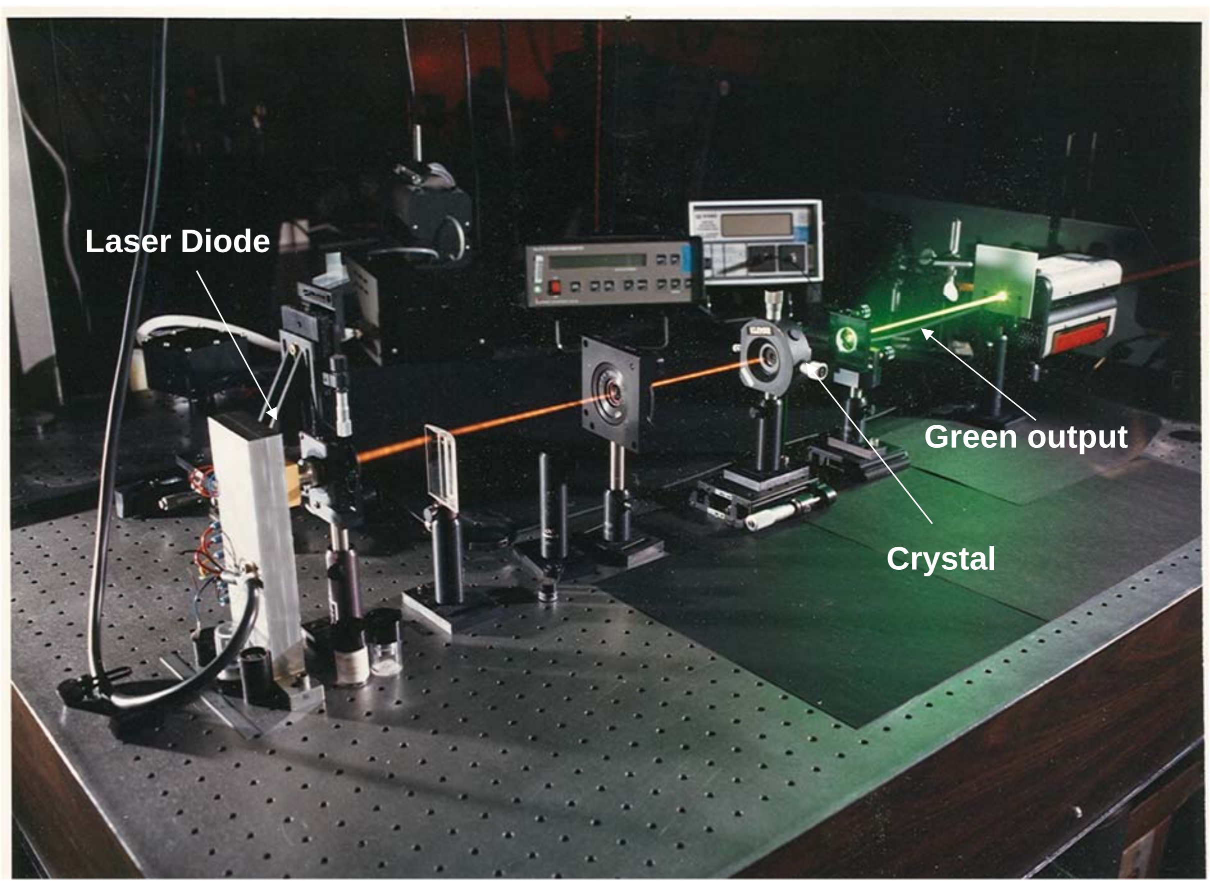
Types of Lasers (III):Semicon. Lasers

- 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"



DIODE PUMPED GREEN LASER



Lasers:
Light Extraordinary!

Laser machining

Barcode Scanner

Laser Surgery

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

Laser Applications

Medical applications	Welding and Cutting	Surveying
Garment industry	Laser nuclear fusion	Communicati on
Laser printing	CDs and optical discs	Spectroscopy
Heat treatment	Barcode scanners	Laser cooling

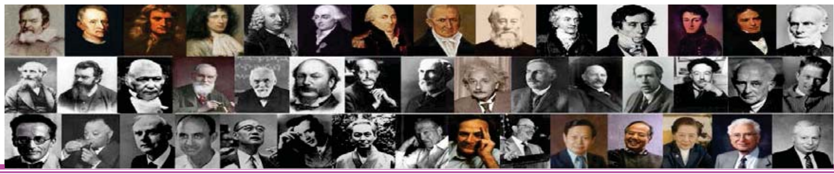
http://hyperphysics.phy-astr.gsu.edu/hbase/optmod/lasapp.html#c0

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

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.



光電科技發展史
History of Photonics

劉容生

國立清華大學

Yung-sheng Liu (Professor Emeritus)
Naitonal Tsing Hua University
Hsinchu, Taiwan

Oct 24, 2015

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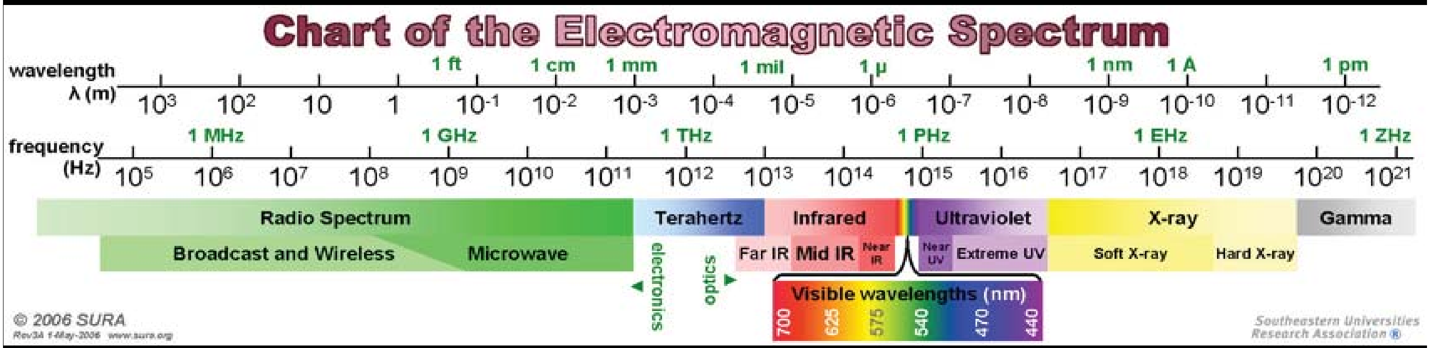
Light 光
Optics 光學
Photonics 光電

創世的第一天就有了光!

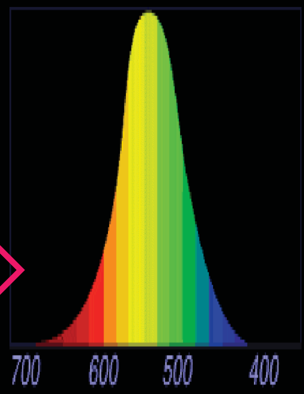
“ 起初神創造天地 。地是空虛混沌．淵面黑暗．神的靈運行在水面上。神說、要有光、就有了光。神看光是好的、就把光暗分開了。神稱光為晝 、 稱暗為夜．有晚上、有早晨、這是頭一日。”

… 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.



人眼的可見光譜範圍



光學的歷史

History of optics - From Wikipedia encyclopedia

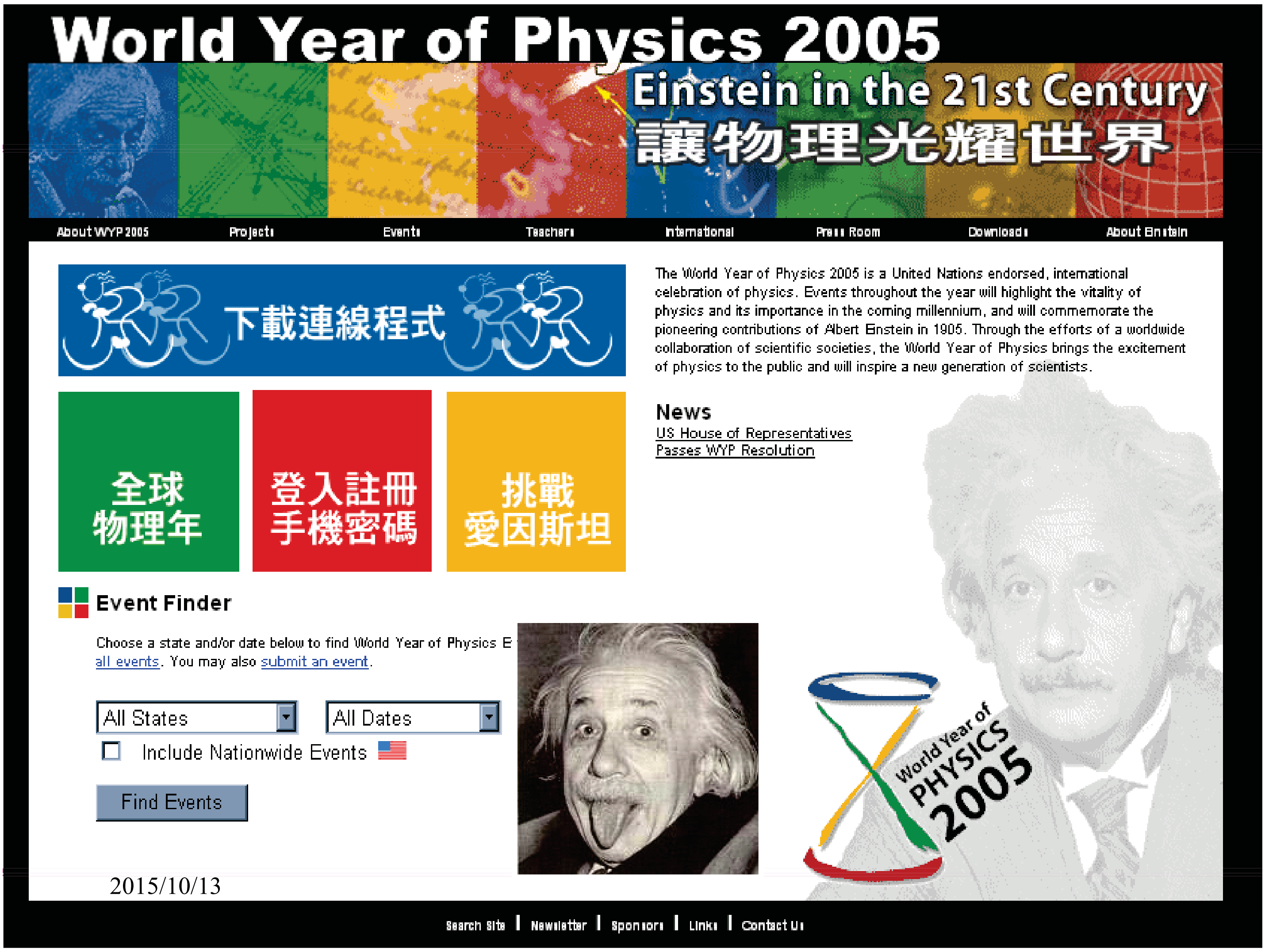
- 光學和視覺 (~BC)
- 古典光學 (~1600)
- 近代光學 (~1900)

- The word *optics* is derived from the Greek "*τα ὀπτικά*" 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.



"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澎湃發展，徹底的改變了人類的生活 … "

\- 劉容生- 科學人 "讓物理光耀世界"

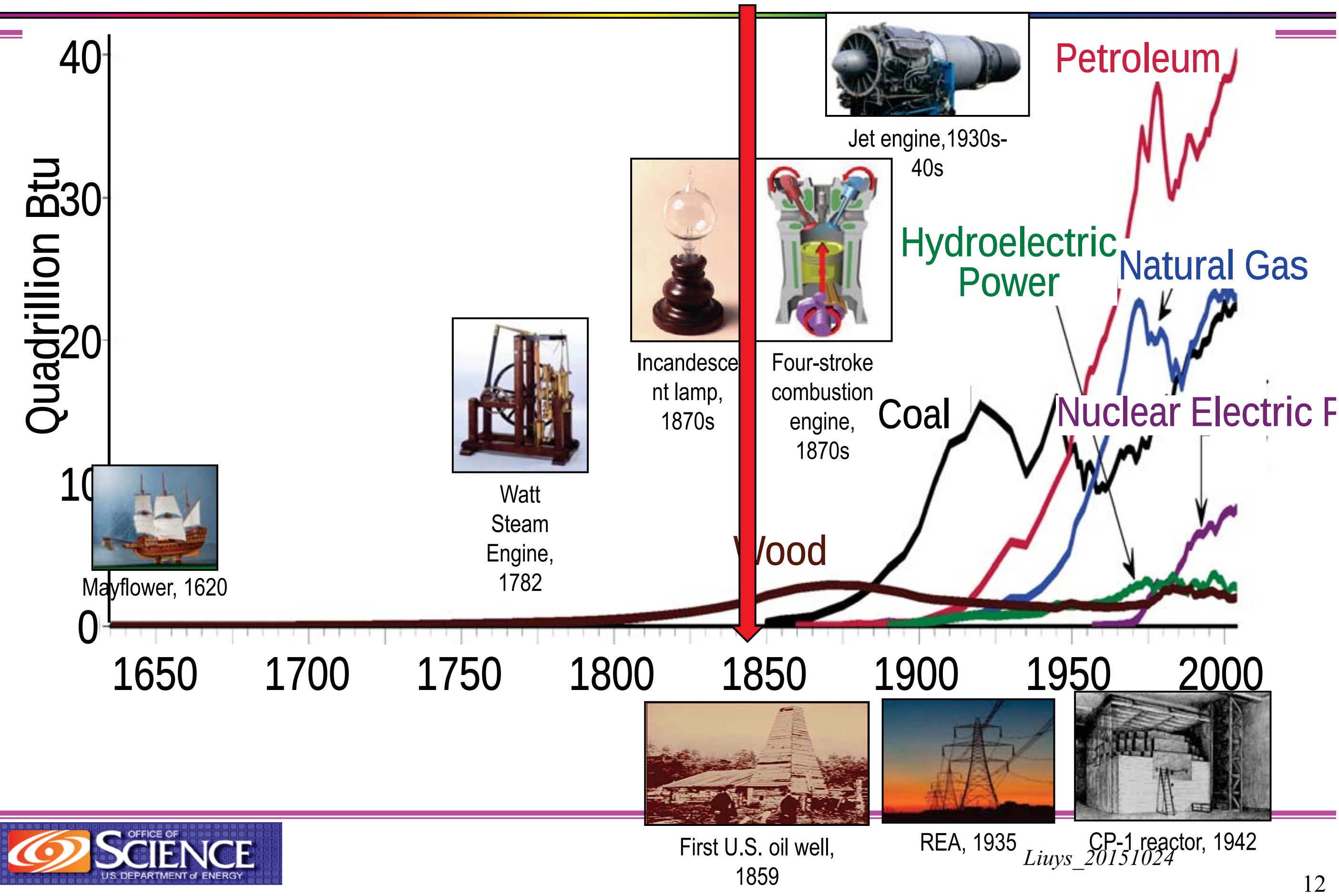
"100 Years ago, Einstein developed the theory for the photo-electric effect which uncovered the modern quantum physics. The theory also lay the foundation of modern optics (coherent optics) and introduced the 20th century opto-electronics (photonics), that brought forth the huge optoelectronics industry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

國立清華大學
National Tsing Hua University

光電科技發展史
History of Photonics

17世紀以來人類 能源消耗的成長

國立清華大學



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)

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. 高亮度籃光/ 白光**LED**的發明
   (Invention of High Brightness White LED, ~1990)

發明 vs 發現
Discovery vs Invention

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-ˈhir-ənt, -ˈher-\

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>

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)
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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

照明的一百多年發展史
- History of Lighting

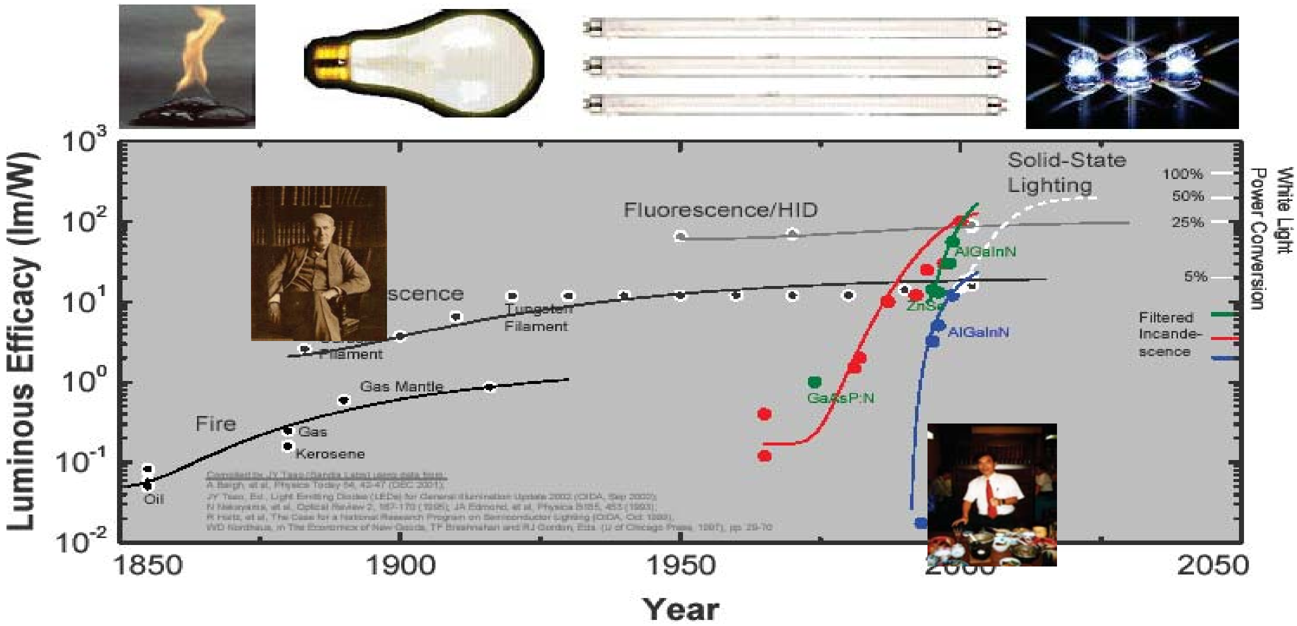
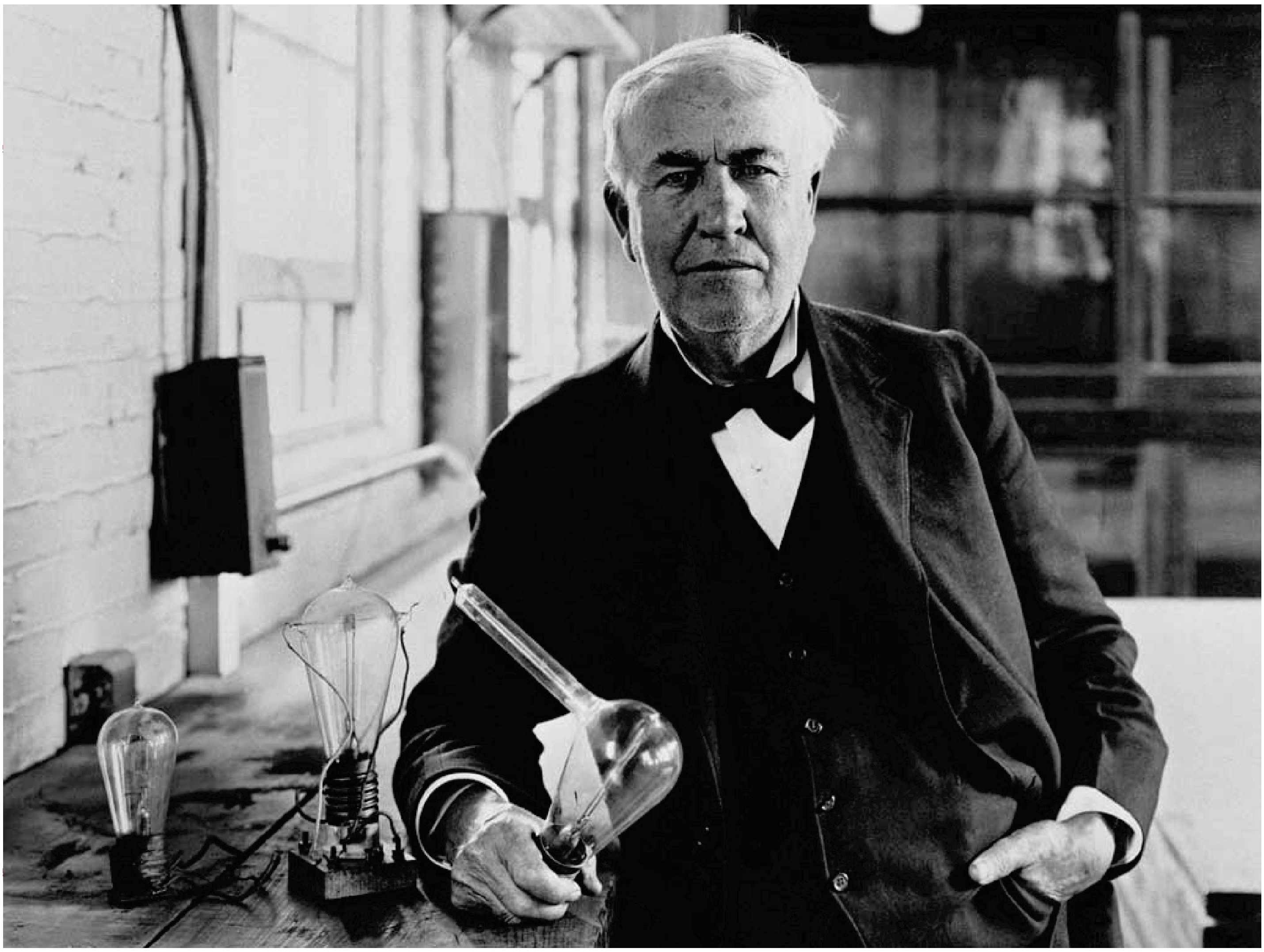
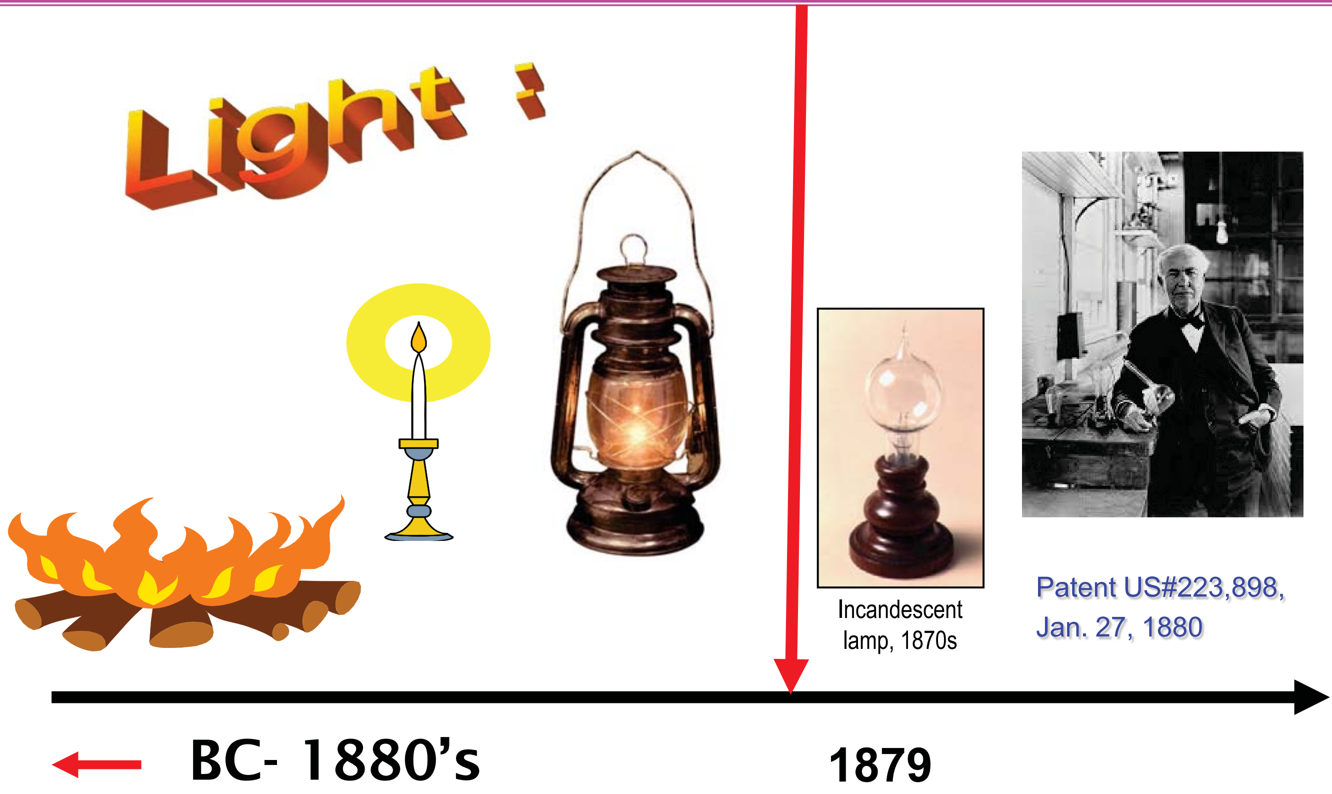


Figure 1: 200-year evolution of luminous efficacy for various lighting technologies.

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



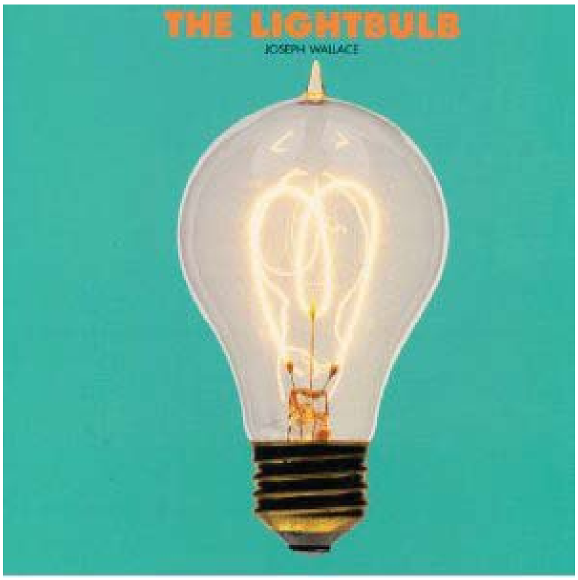
白熾燈的誕生
Incandescence Light – Birth of Lighting

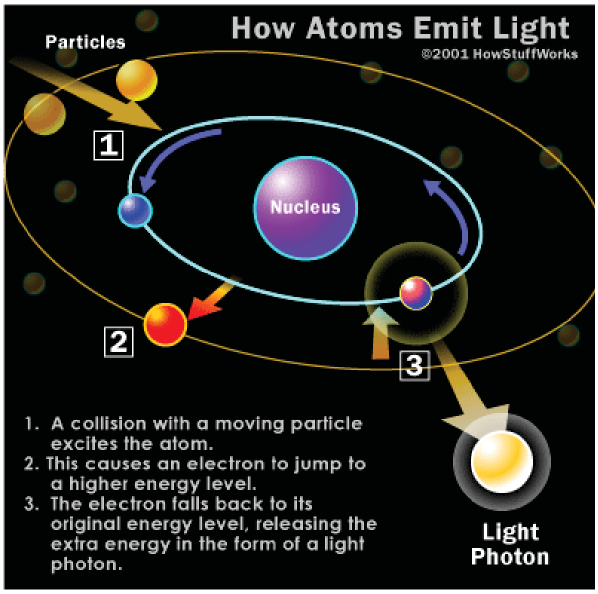


沒有電燈以前的光源




白熾燈的原理





白熾燈發光的原理-黑体幅射

PLANCK DISTRIBUTION- BLACKBODY RADIATION

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

- P_λ = Power per m² area per wavelength
- h = Planck's constant (6.626 x 10-34 J-s)
- c = Speed of Light (3 x 10⁸ m/s)
- λ = Wavelength (m)
- k = Boltzmann Constant (1.38 x 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.

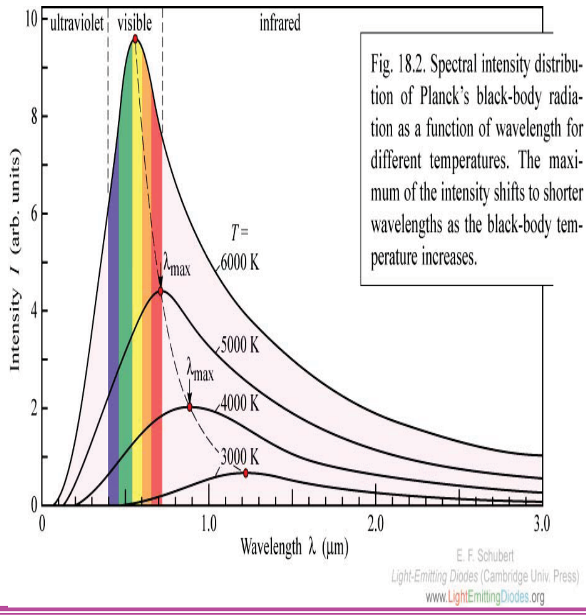


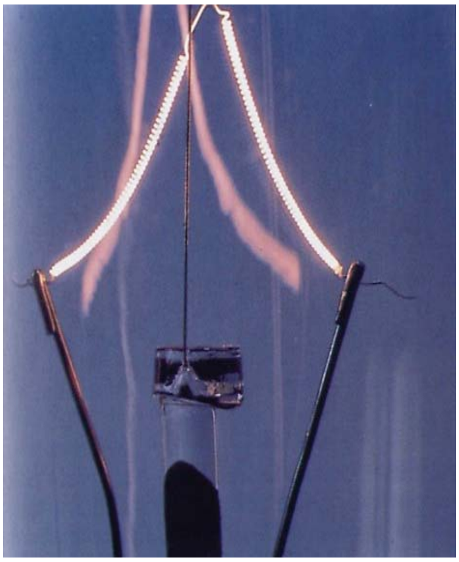
Fig. 18.2. Spectral intensity distribution of Planck's black-body radiation as a function of wavelength for different temperatures. The maximum of the intensity shifts to shorter wavelengths as the black-body temperature increases.

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.



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?

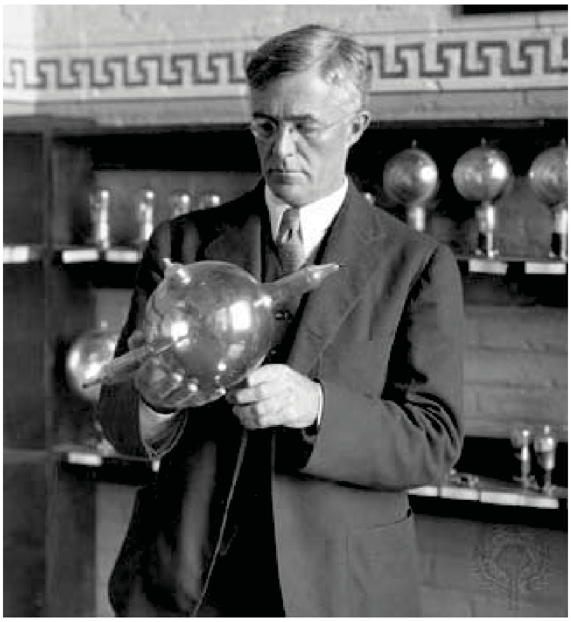
1932 諾貝爾化學獎

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，發明了氫氣焊接、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



朗繆爾化學期刊

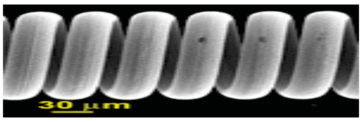
國立清華大學
National Tsing Hua University

- 《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。

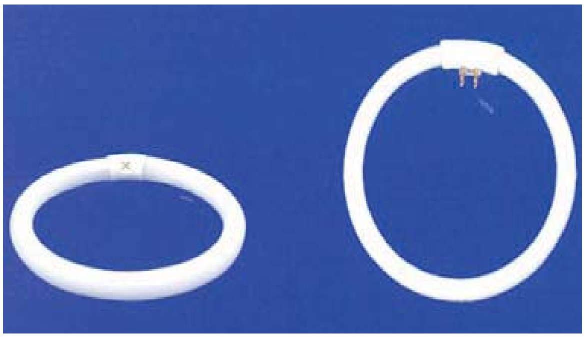
1909鎢絲燈的發明

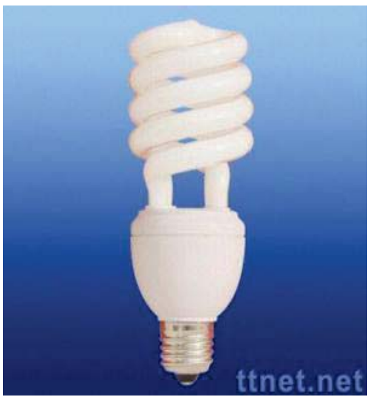
Coolidge's Tungsten Lamp at 10 LPW

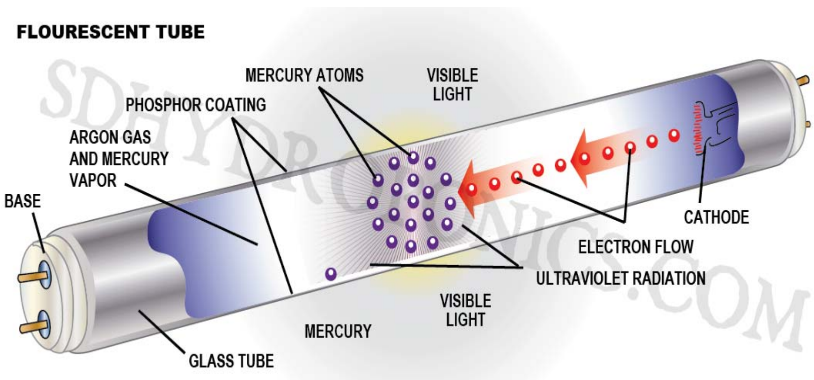
- 威廉·大衛·柯立芝 （1873-1975) 物理學家作出重大貢獻的X光機。 他是通用電氣(GE)研究實驗室和公司的副總裁。 也是著名的“韌性的發展鎢 ” (Ductile tungsten)發明人，對於白熾燈有重要貢獻。



螢光燈 - 利用放電和螢光粉轉換







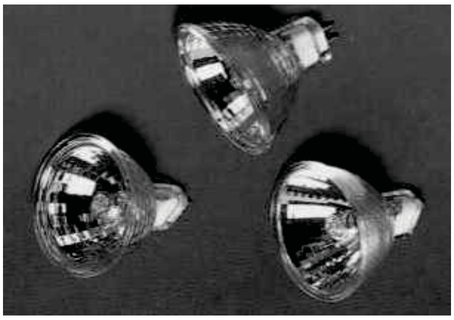
對人類的影響: 百年的照明技術

Artificial Light Sources in the past century

國立清華大學 National Tsing Hua University

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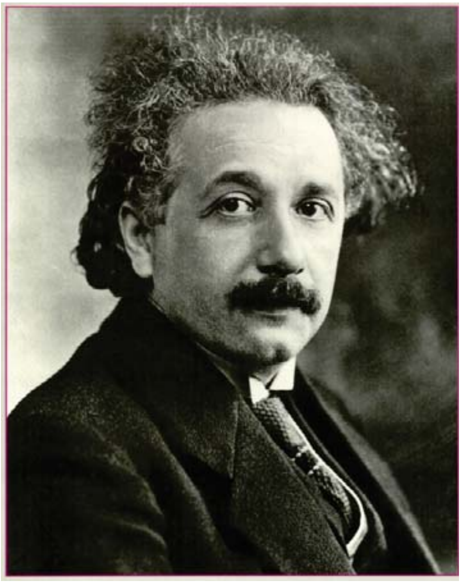
光電科技的主要里程碑
Major Milestones in Photonics

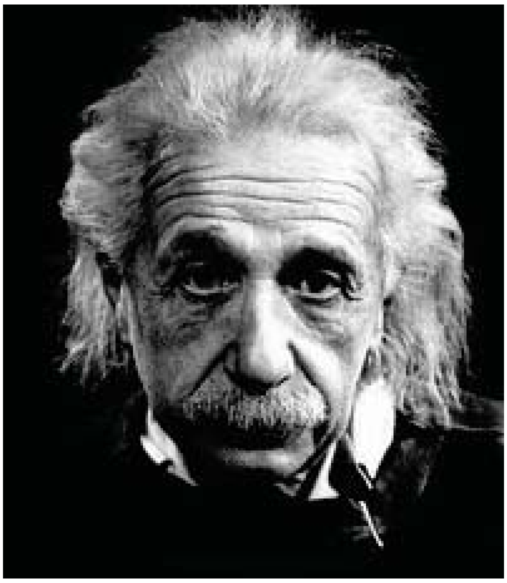
1. 愛迪生發明電燈炮
   (Invention of light bulbs ~1880)
2. 愛因斯坦的光電效應
   (Einstein's Photo-electric Effect, 1890-1916)
3. 相干光幅射的發明
   (Invention of Coherent Radiation, LASER ~1960)
4. 光纖通訊的發明
   (Invention of fiber optics communication, ~1970)
4. 高亮度籃光/ 白光LED的發明
   (Invention of High Brightness White LED, ~1990)

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)

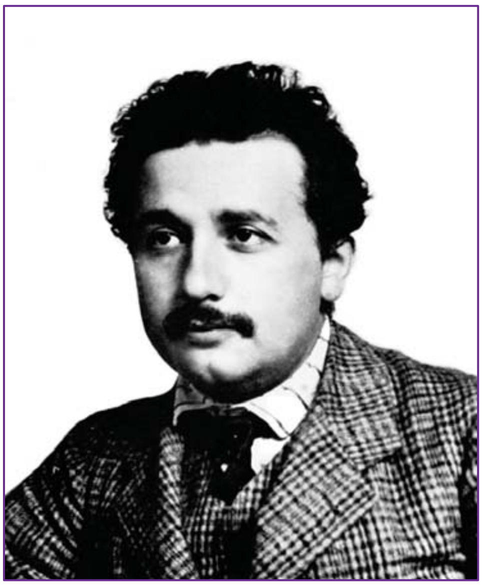
愛因斯坦
(Albert Einstein - 1879-1955)





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 = mc²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)



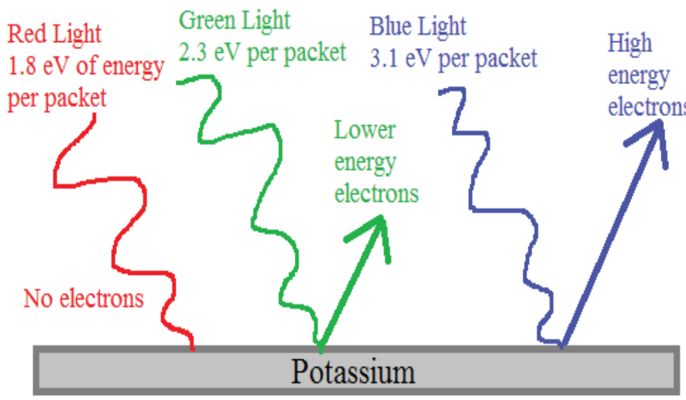
1905年，愛因斯坦在26歲發表的幾篇論文裏，提出了對人類有巨大影響的四個重大基本觀念：

- **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)
  - 闡述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 = mc2

- 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

Philipp 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

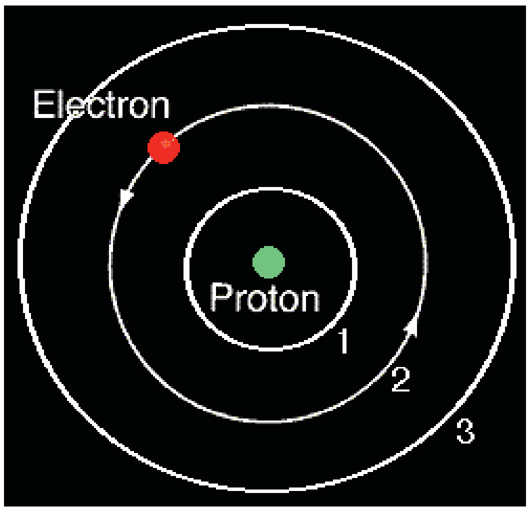
(1885-1962) 維基百科

- 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)

尼爾斯·玻爾的原子模型

- 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, *h*, 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/2π, 2h/2π, 3h/2π, … 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 hν, where ν 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)

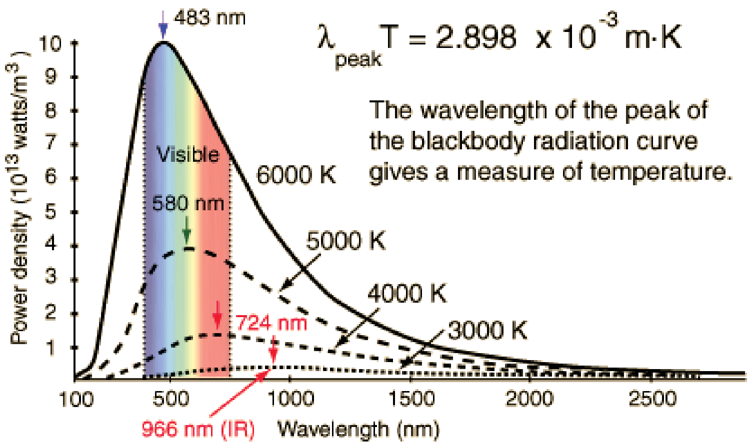
- 德國國籍德國
- 研究領域: 物理學家
- 任職於基爾大學, 柏林洪堡大學, 哥廷根大學
- 母校慕尼黑大學
- 著名成就普朗克常數、普朗克黑體輻射定律、舊量子 諾貝爾物理學獎（1918年）

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]

PLANCK ENERGY DISTRIBUTION FORMULA



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

Max Planck (1858-1947)

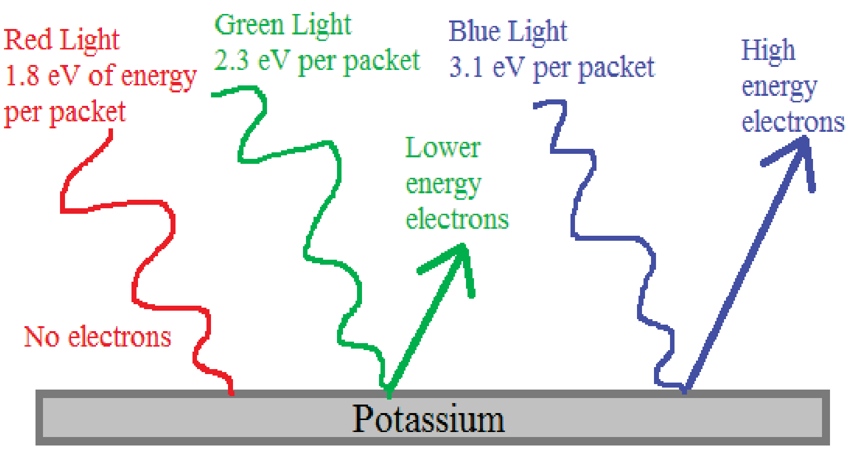
Where, P_λ =Power per m^2 area per m wavelength; **h = Planck's constant (6.626×10^{-34} J.s);** c = Speed of Light (3 x 108 m/s); λ= Wavelength (m); k = Boltzmann Constant (1.38×10^{-23} J/K); T = Temperature (K)

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."**[2]

菲利普·萊納德 光電效應
Philipp Lenard (1862-1947)



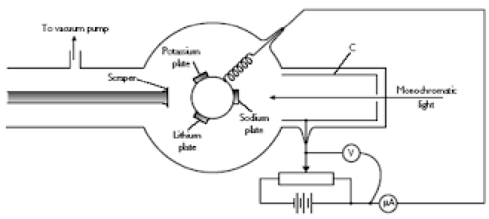
Potassium electrons need 2 units of energy to escape (2 eV).

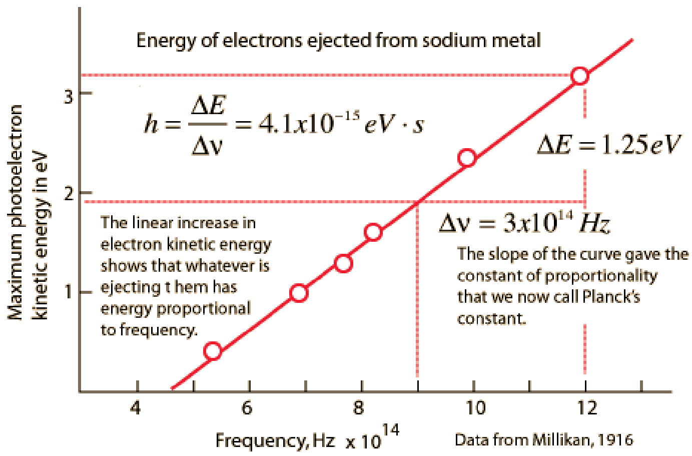
- 愛因斯坦在〈一個關於光的產生與轉換的啟發性看法〉這篇論文裡，解釋為什麼當光束照射到金屬的表面會產生電子，同時說明光電效應中電子飛離金屬表面的速度與光波長的關係。更重要的是，他提出的一個革命性基本光子(photon)的觀念：
  - 光子是一個帶有能量的粒子，每個光子所帶的能量等於光的頻率乘上一個普朗克常數 ..

$$\varepsilon = h\,v$$

- 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。

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]

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.

路易·德布羅意
(1892-1987)

- 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

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 λ to momentum *p*, de Broglie proposed that this relationship would determine the wavelength of any matter, in the relationship, called the "*de Broglie wavelength*".

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

光電效應的產品

IMPACTS:

- 感光器件、太陽電池、數位相機、CCD …

光電科技的主要里程碑

Major Milestones in Photonics

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   (Invention of light bulbs ~1880)
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   (Invention of High Brightness White LED, ~1990)

1958 –
相干光幅射的發明的故事
- 雷射的發明

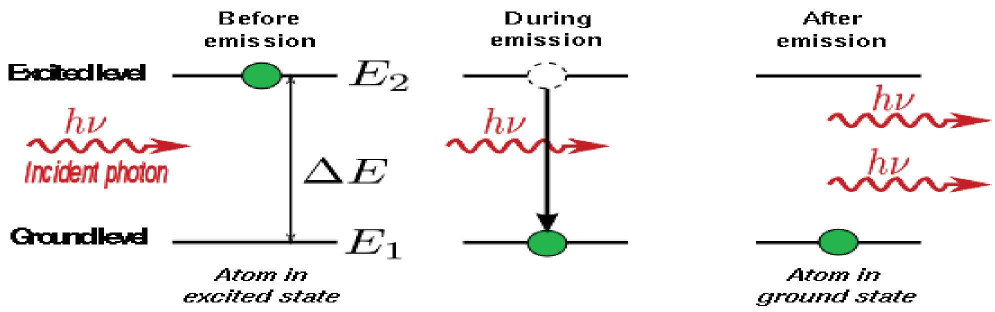
第一個相干光幅射的光源
The First Maser and the First Laser

- 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)

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。

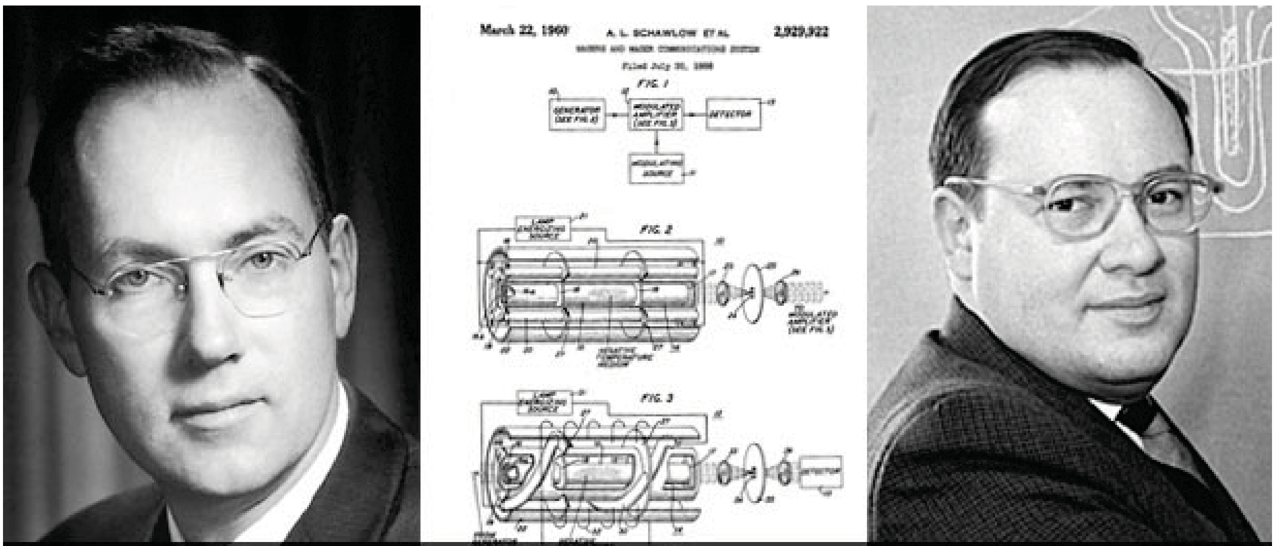


$$E_2 - E_1 = \Delta E = h\nu$$

(Ref: 維基百科)

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

Infrared and Optical Masers

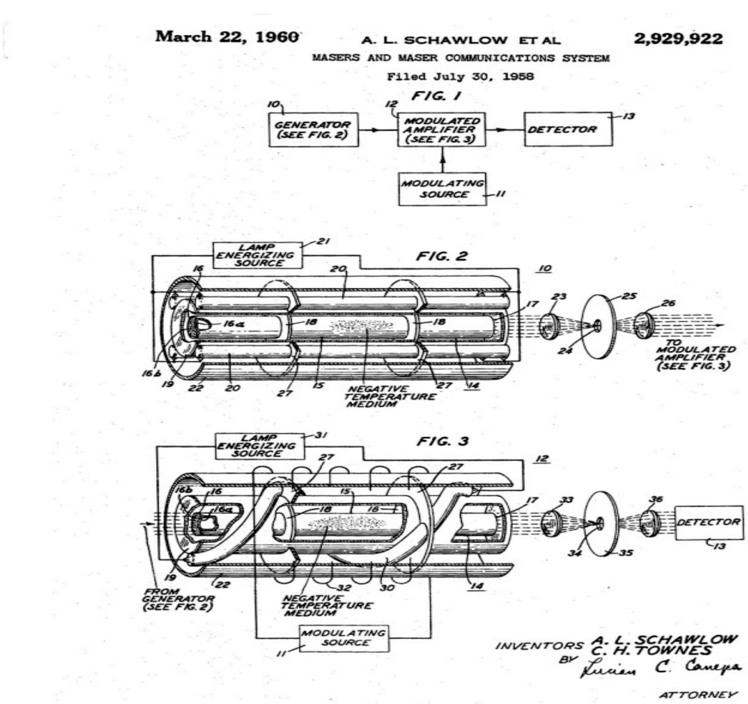
A. L. Schawlow and C. H. Townes

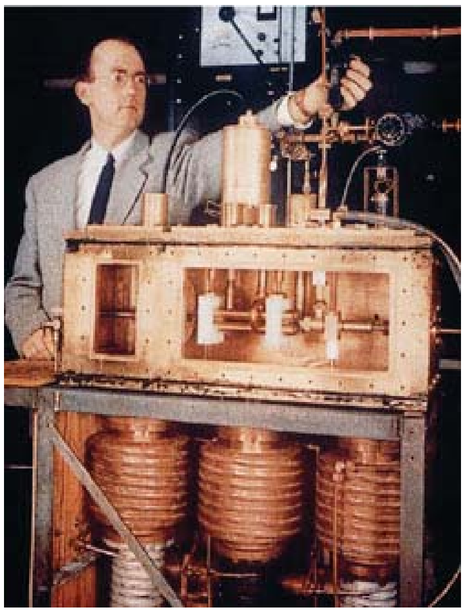
Phys. Rev. 112, 1940 – Published 15 December 1958

- 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.

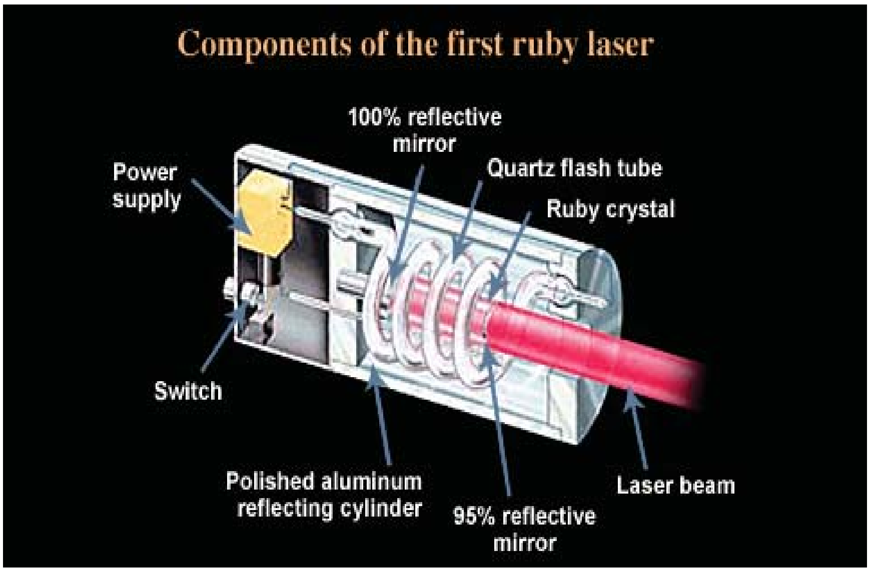
- A. L. Schawlow and C. H. Townes,* , Bell Telephone Laboratories, Murray Hill, New Jersey; *Permanent address: Columbia University, New York, New York.; Received 26 August 1958

1958, 相干光的發明
Invention of Coherent Light



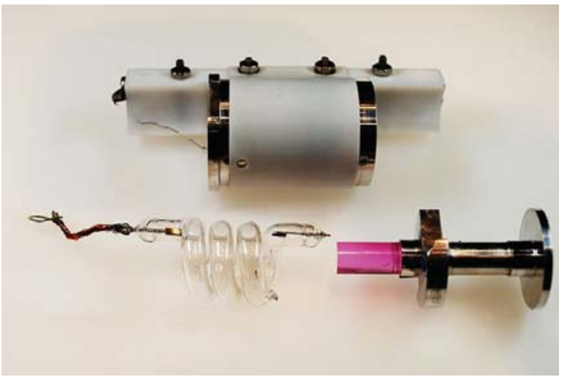


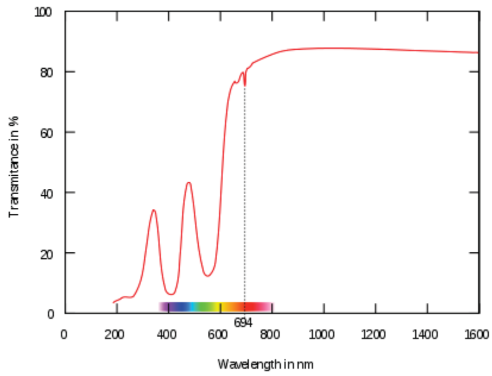
西奥多·梅曼的第一個紅寶石雷射

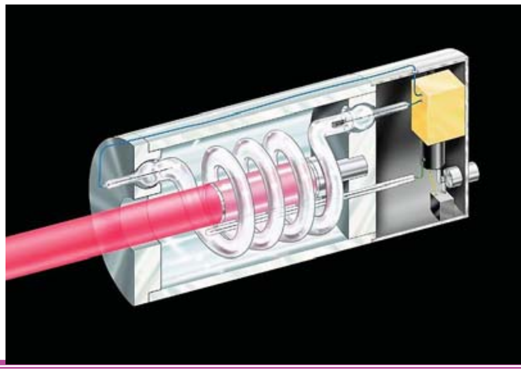


Theodore Maiman developed the first working laser at Hughes Research Lab in 1960, and his paper describing the operation of the first laser was published in Nature three months later

梅曼的第一個紅寶石雷射







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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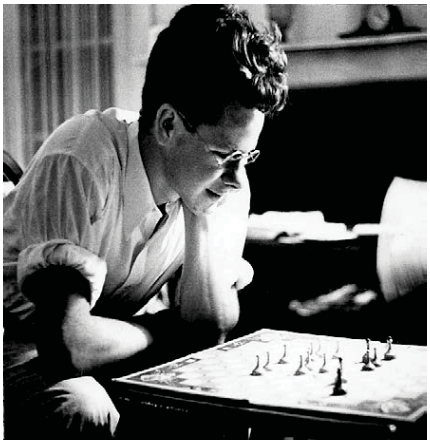
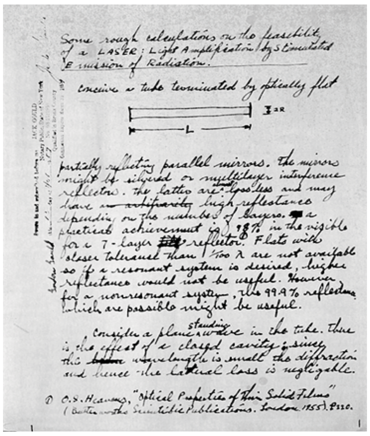
雷射發明專利的戰爭

Gould's Patent and Patent War!

Laser Inventor: Gorden Gould (1920-2005)





Some rough calculations on the feasibility of a LASER: Light Amplification by Stimulated Emission of Radiation.

Conceive a tube terminated by optically flat

L

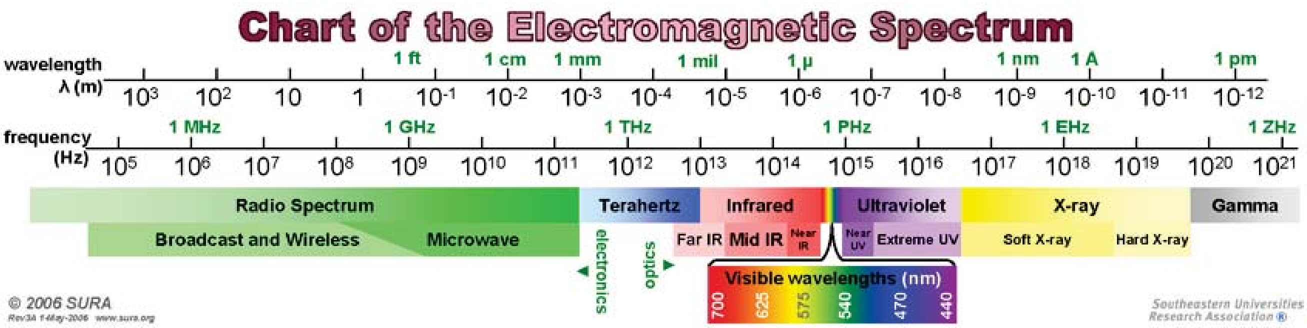
partially reflecting parallel mirrors. The mirrors might be silvered or multilayer interference reflectors. The latter are almost lossless and may have a high reflectance depending on the number of layers. A practical achievement is 98% in the visible for a 7-layer reflector. Flats with closer tolerance than 1/100 λ are not available so if a resonant system is desired, higher reflectance would not be useful. However for a nonresonant system, the 99.9% reflectance which are possible might be useful.

Consider a plane standing wave in the tube. There is the effect of a closed cavity & since the wavelength is small the diffraction and hence the lateral loss is negligable.

① O.S. Heavens, "Optical Properties of Thin Solid Films" (Butterworths Scientific Publications. London 1955). P220.

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.

雷射光的特殊性質
Properties of Laser Radiation



- 同相 (Coherent)
- 集束 (Collimated)
- 高亮度 (High Brightness, Watt/cm2/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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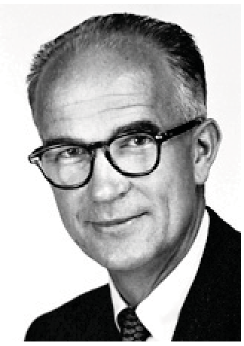
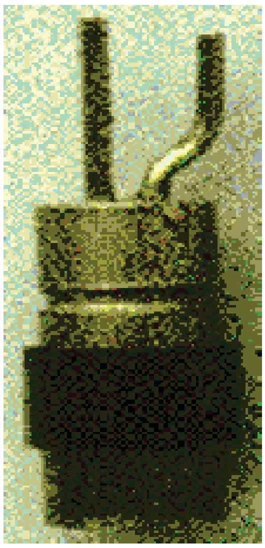
   (Invention of High Brightness White LED, ~1990)

4. 光纖通訊的發明
- 半導体雷射 (1962~)
- 低損耗的光纖 (1970~)

電晶体的發明 – 革命性改變了電子科技和產業
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"*.

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.

奇異公司發明第一個半導体雷射 (1962)

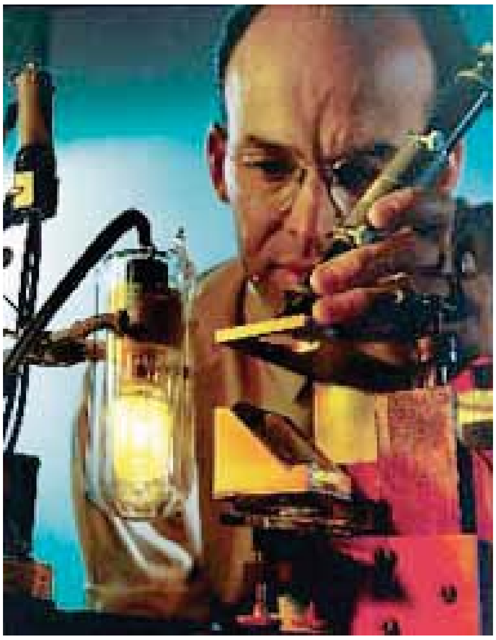
Dr. R. N. Hall : inventor of the semiconductor injection laser.

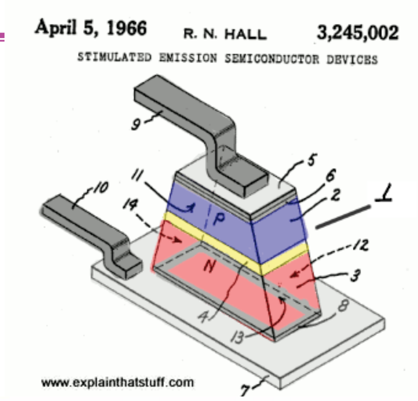
"For the first realization of the semiconductor injection laser:
A basic element of optical fiber communications."

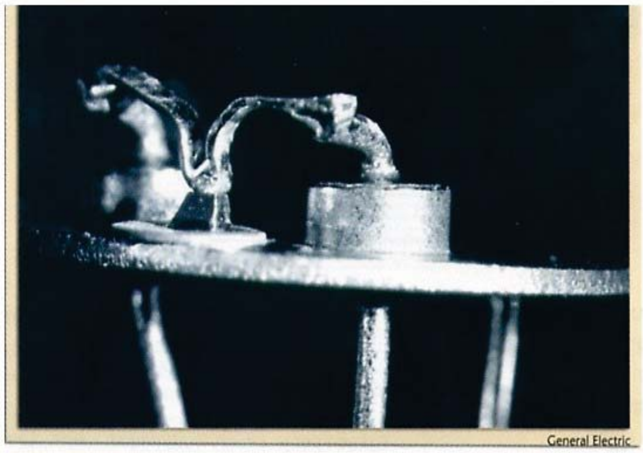
- 1962 GE's Research Center.

- 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.**







發明半導体雷射的競賽

- 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 . i
- 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).

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）

阿爾費羅夫 的奇妙設計使得半導体雷射實用

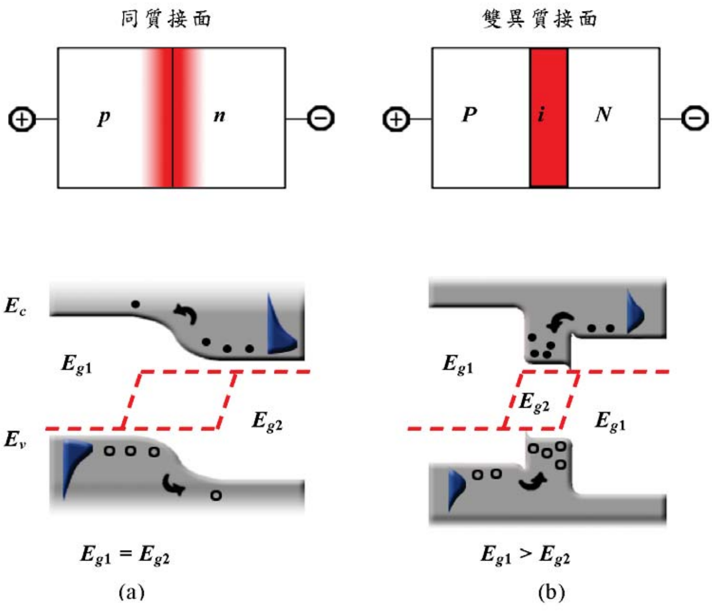
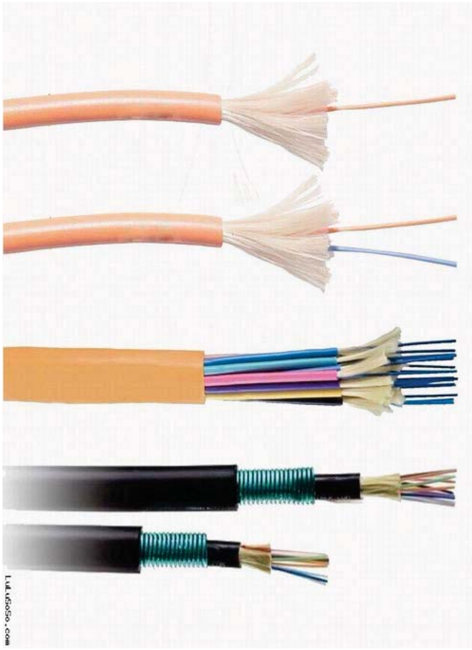
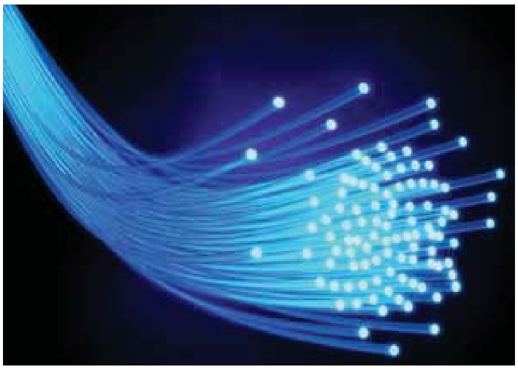
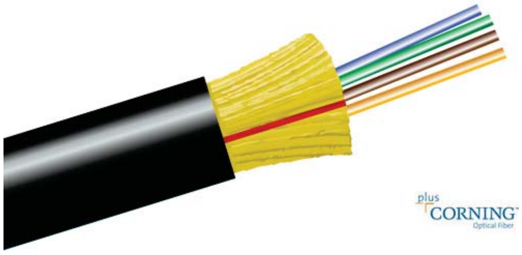


圖 3-1 (a)同質接面結構圖；(b)雙異質接面結構圖

現代通訊的傳輸介質 - 光纖

國立清華大學
National Tsing Hua University

光纖之父- 偉大的先知

高錕

Charles Kao (1933-)

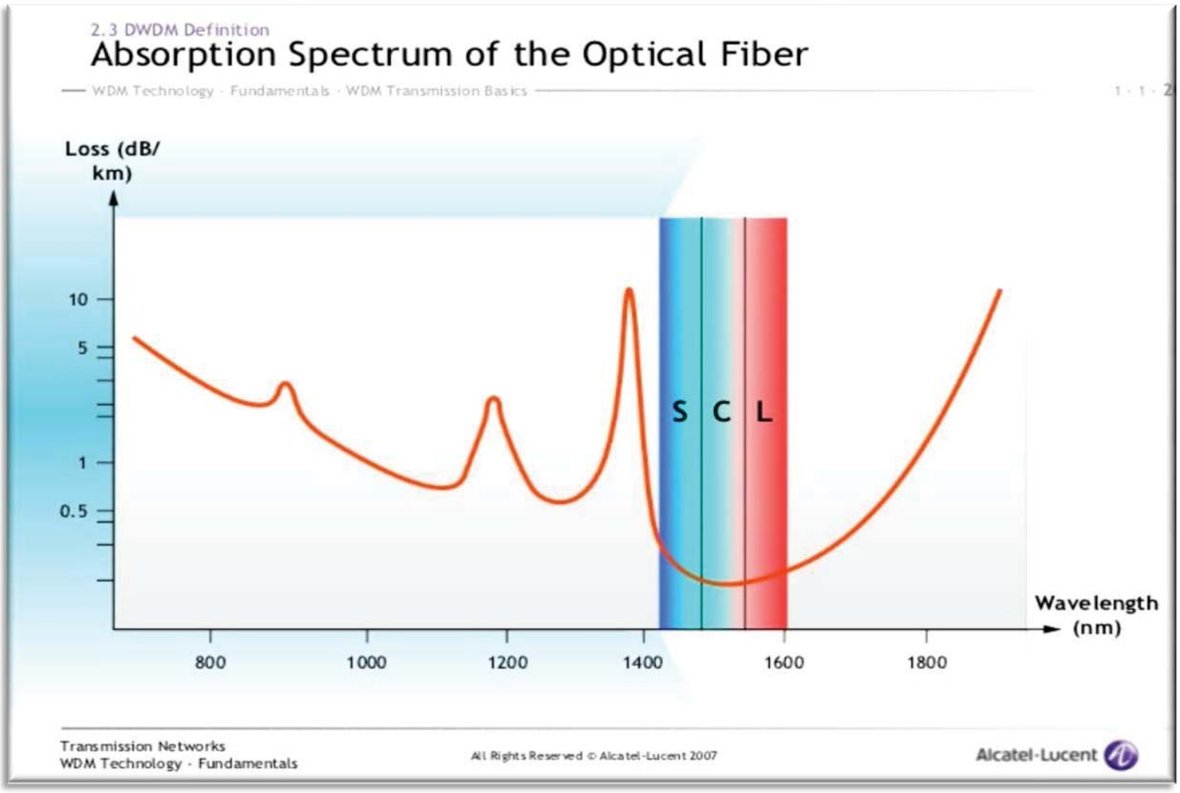
- 高錕爵士，華裔電機工程師及物理學家，生於中國上海。1949年移居香港，赴英留學。

1970 康寧公司宣佈光纖的突破

World's First Low-Loss Optical Fiber for Telecommunications announced by Corning - 1970

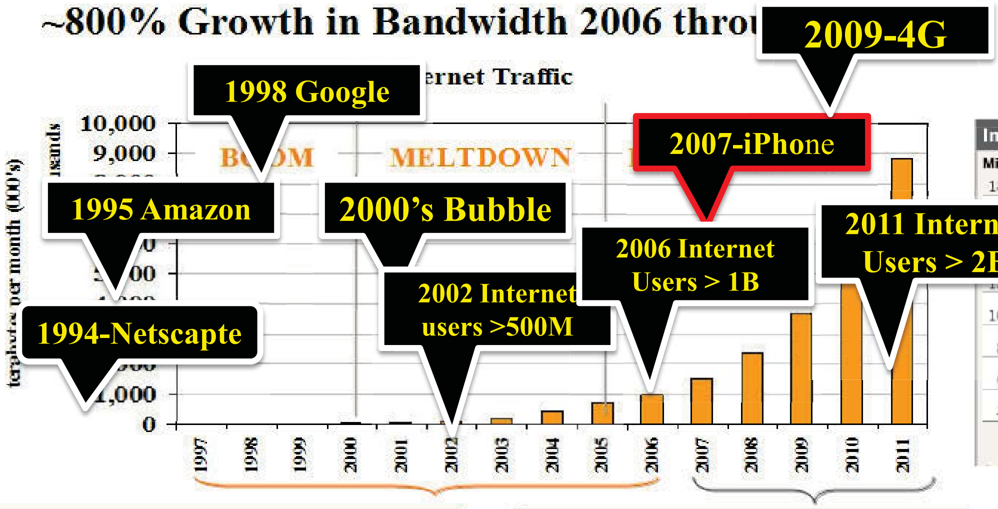
- *In 1970, Corning scientists Dr. Robert Maurer Dr. Peter Schultz, and Dr. Donald Keck developed a highly pure optical glass that effectively transmitted light signals over long distances. This astounding medium, which is thinner than a human hair, revolutionized global communications. By 2011, the 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.*

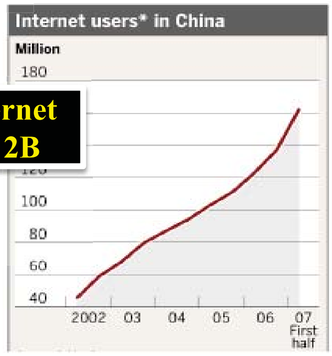
上天給人類的禮物 - 低損耗的光纖



光纖通訊支撐著網際網路、無線通訊的發展

Bandwidth is Growing Rapidly Since 2005





FT.com

Data from Estimating the Exaflood, Bret Swanson & George Gilder, January 2008, page 8, Figure 2

Uses 55% growth per year. This is the year-end 2007 annual Internet traffic growth rates as published by Minnesota Internet Traffic Studies (MINTS)

(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%)

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)
5. 高亮度籃光/ 白光LED的發明

   (Invention of High Brightness White LED, ~1990)

5. 高亮度籃光/ 白光LED的發明

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世界第一個紅光發光二極体
World's first LED at GE

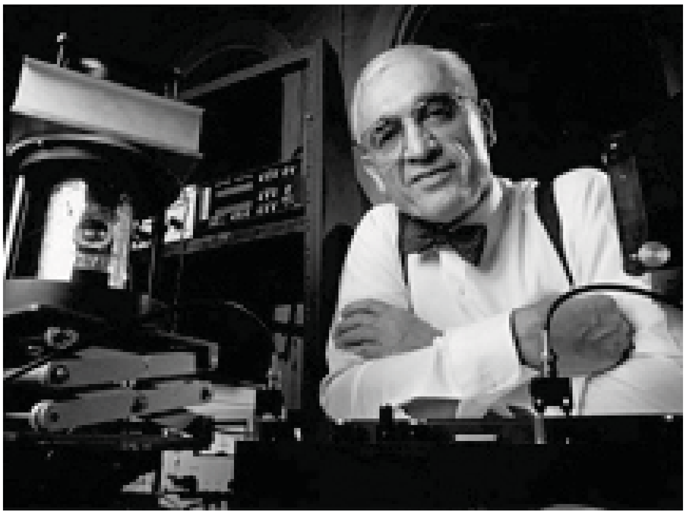
- 1962, Holonyak built the world's first LED which emitted only red light but it lit a research boom whose multi-colored offspring now illuminate homes and cities, the latest iPad “retina” screens, and flat-screen TVs. “Boy, those were the golden years,” says Holonyak, now 83 years old. “When I went 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:

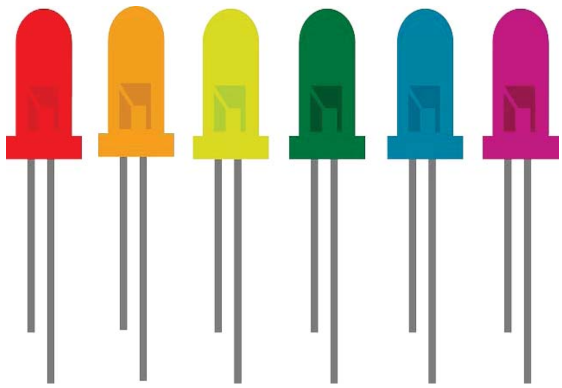
  http://www.gelighting.com/LightingWeb/emea/news-and-media/news/First-LED-by-the-GE-engineer-Nick-Holonyak.jsp#sthash.aUjKU4L1.dpuf

世界第一個紅光發光二極体
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。

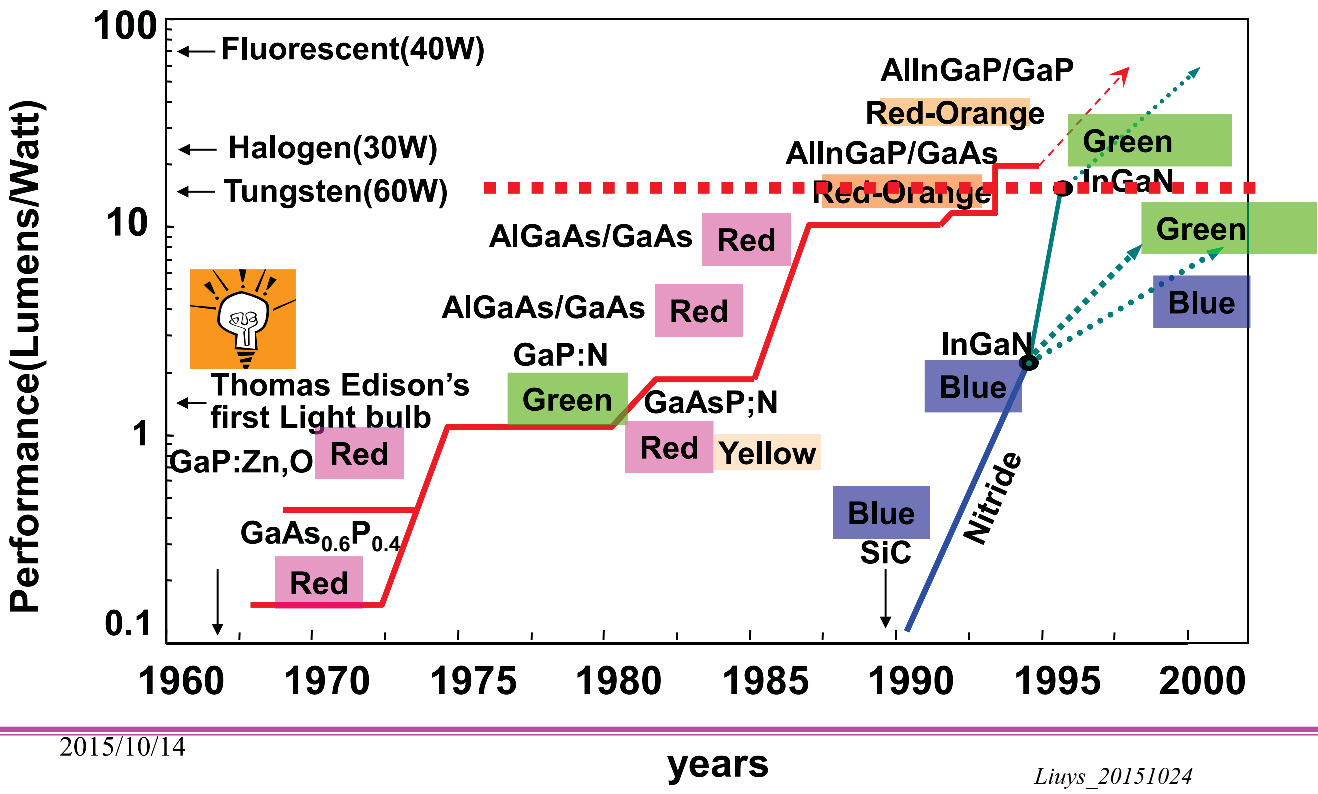




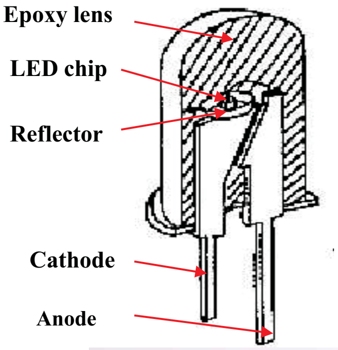
LED 的發展里程圖

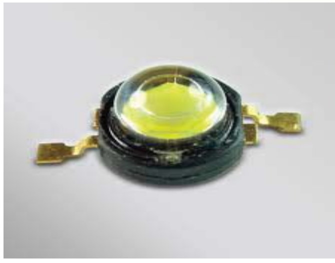
國立清華大學 National Tsing Hua University

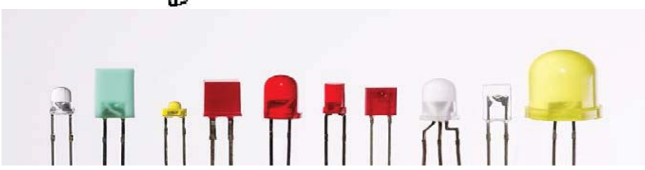
Major Advances in LED Devices
- Materials and devices breakthroughs



LED (發光二極體)

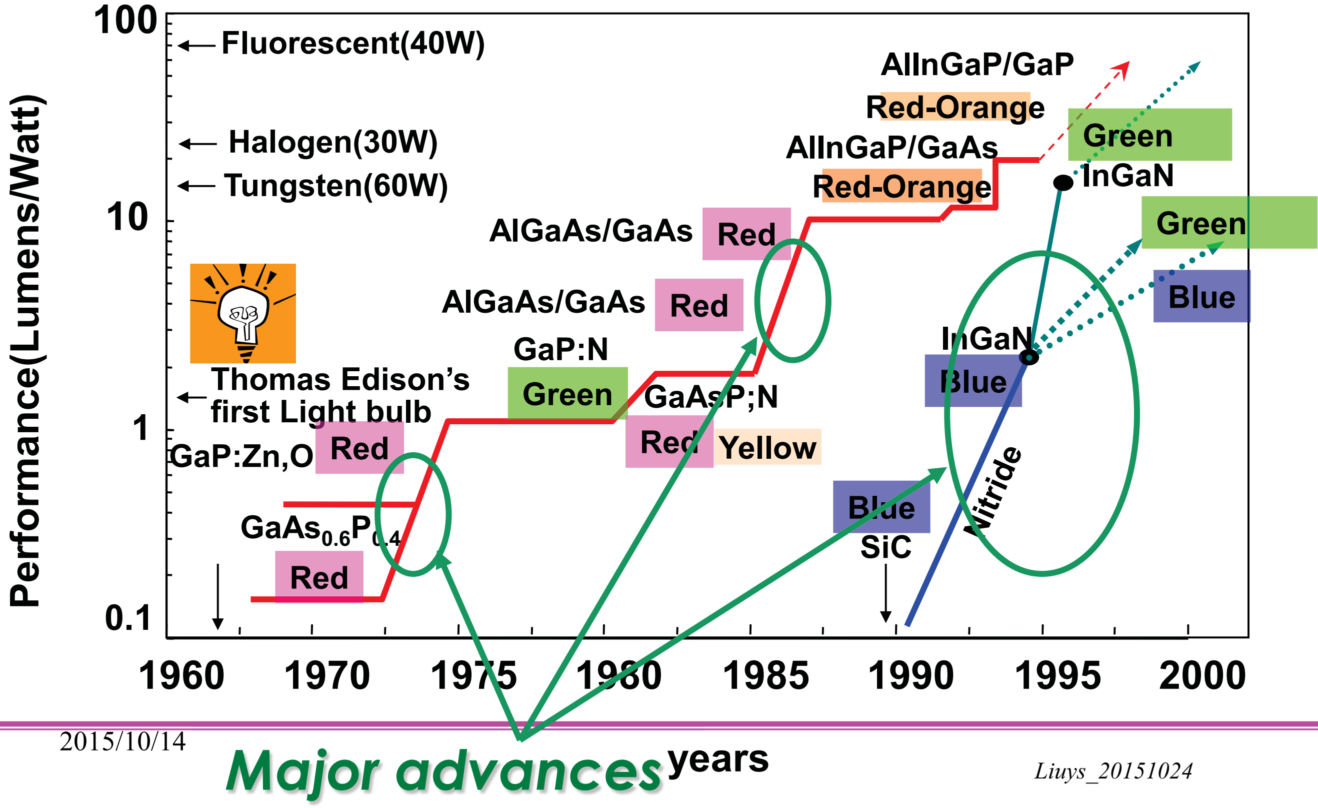






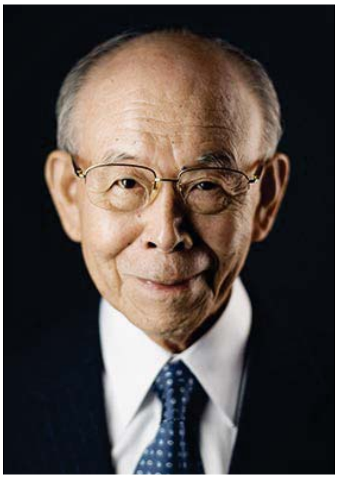
LED 的發展過程

Major Advances in LED Devices



2014年諾貝爾物理獎得主

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



Isamu Akasaki

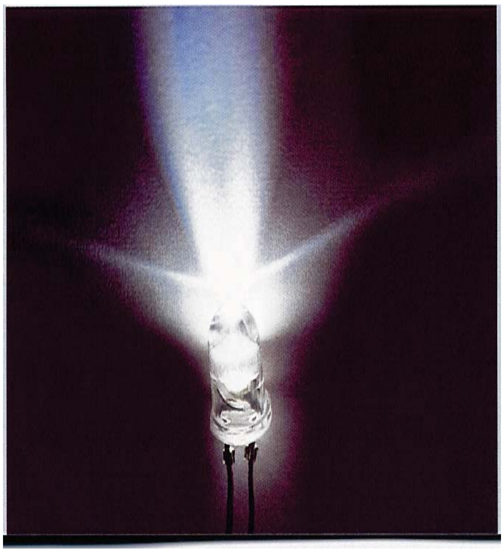
Hiroshi Amano

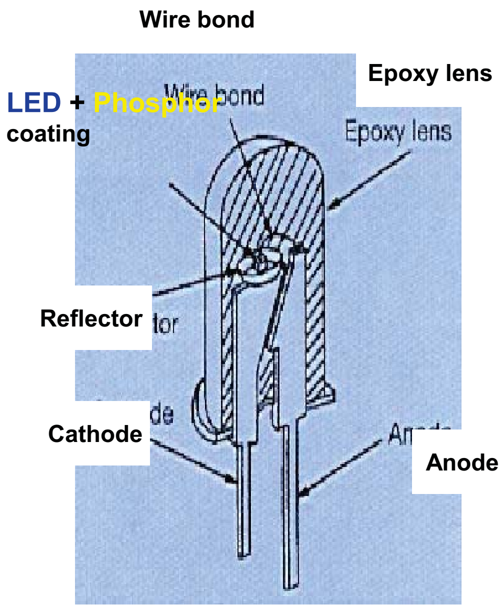
Shuji Nakamura

1997代表奇異公司拜訪中村修二

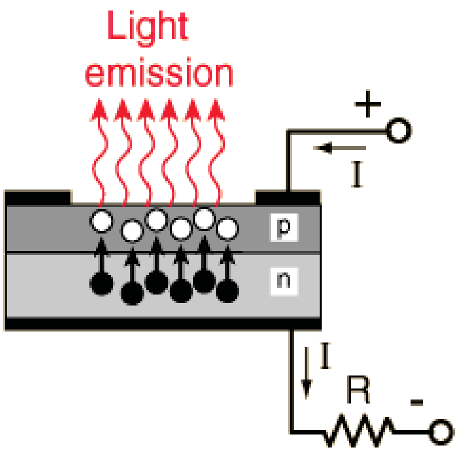
Dr. Shuji Nakamura drank Sake and discussed the future of white LED technology in Akita, Japan, 4 Oct 1997

1996 白光 LED 的突破





發光二極体的基本結構
Light Emitting Diode Structure



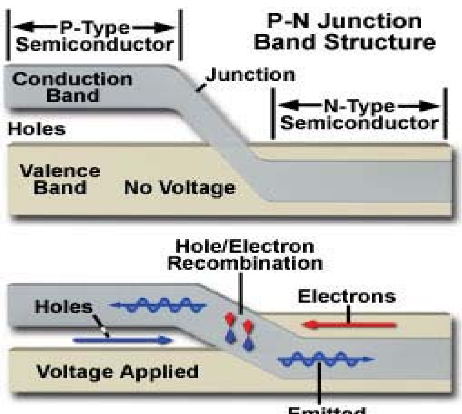


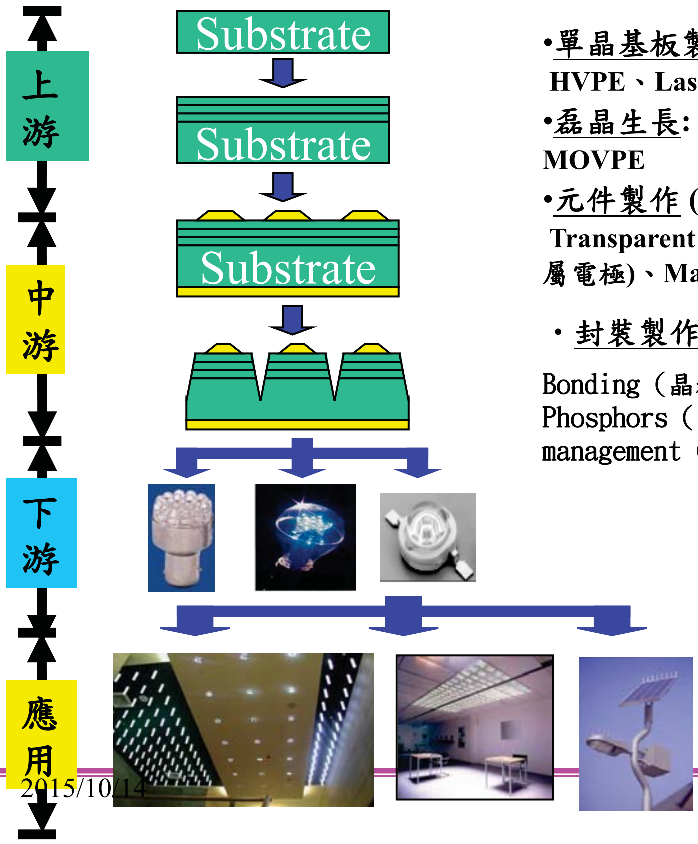
Figure 4

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.

LED 的發展史

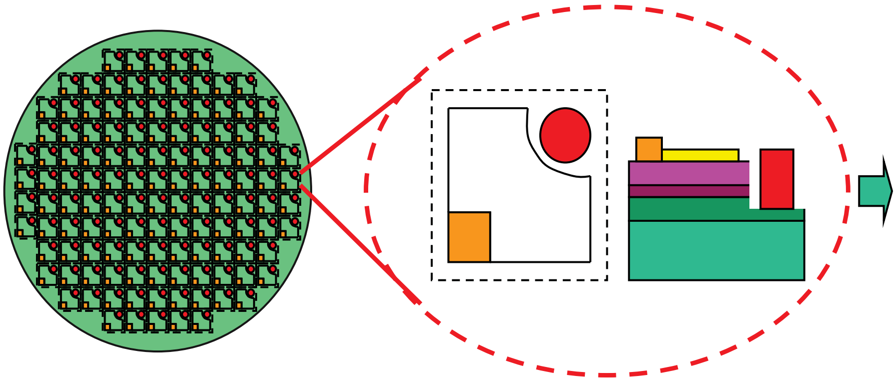
- 1962- LED first demonstrated at GE Research Laboratory
- 1968- First products in electronic display introduced by HP. about **0.001 lumens at 20 mA in red till 1985,**
- 1985- LED reached **>10 lumens**.
- 1990- **>10 lm/W in GaAlAs,** but color limited **to > 640 nm.**
- 1990's AlGaInP developed and 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.**

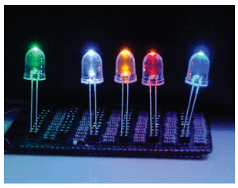
白光 LED的製程
White LED processes

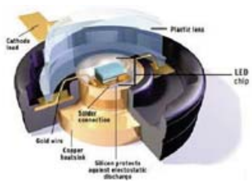


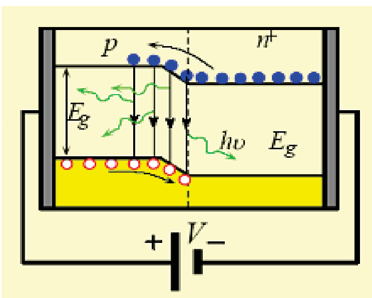
- **單晶基板製作: (Substrate)**
  HVPE、Laser lift-off
- **磊晶生長: (Epitaxy)**
  MOVPE
- **元件製作 (Processing and Fabrication)**
  Transparent electrodes (透明導電膜)、Metal contacts (金屬電極)、Masks (光罩)、Etching (蝕刻)、Polishing (磨薄)
- 封裝製作 (Packaging)
  Bonding (晶粒黏著打線)、Flip-chip (覆晶黏著)、Phosphors (螢光粉塗佈)、Epoxy (樹脂選用)、Heat 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

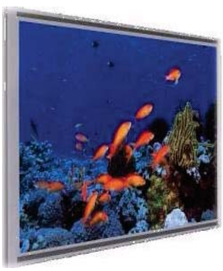
Light Emitting Diode (發光二極體)

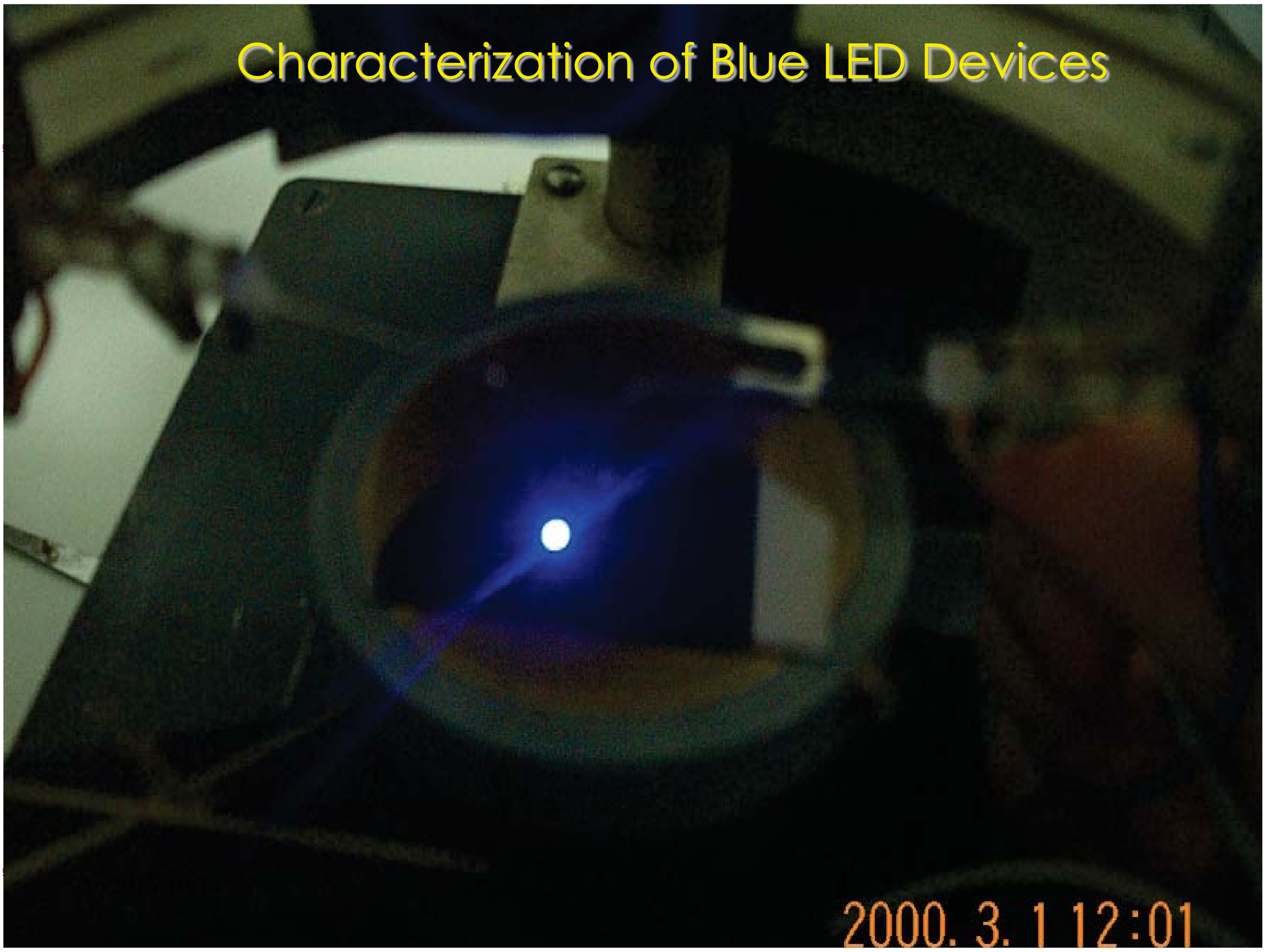




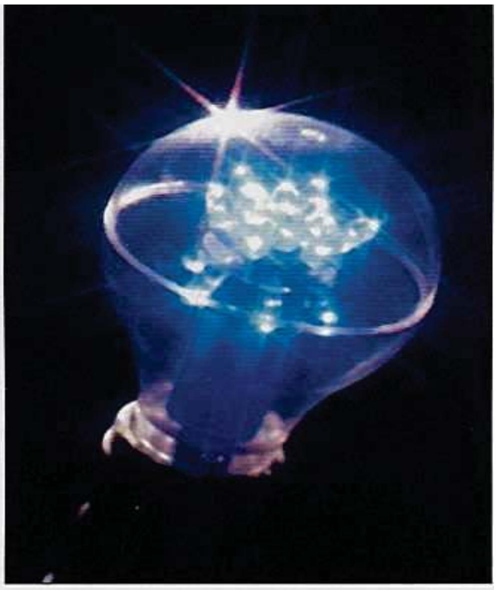


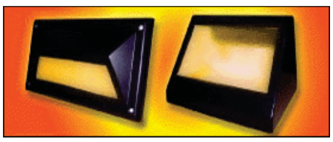


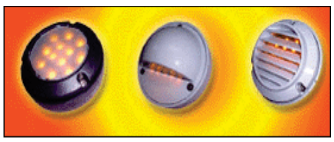




LED 燈的應用

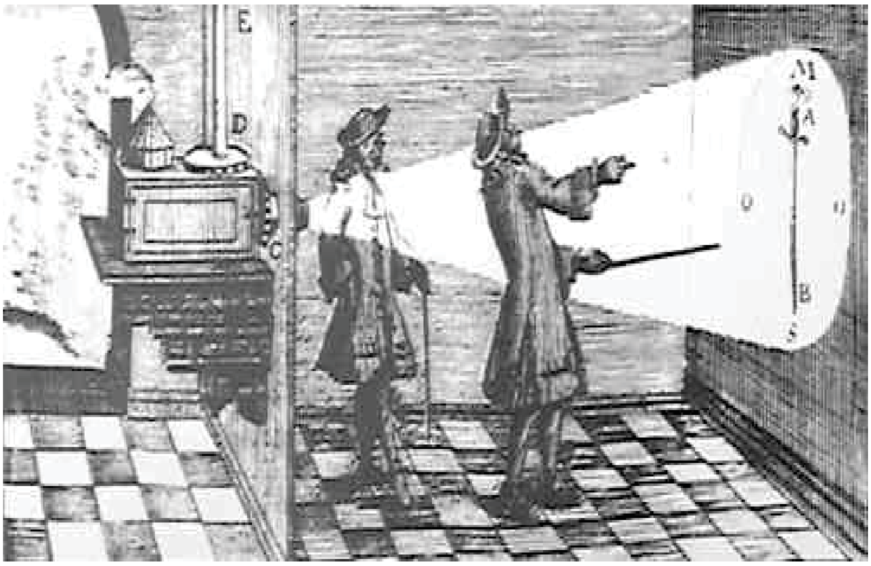






2015 LED 投影機

1686 投影機



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，节電70%

Liuys_20151024

國立清華大學
National Tsing Hua University

照明的一百多年發展史

- History of Lighting

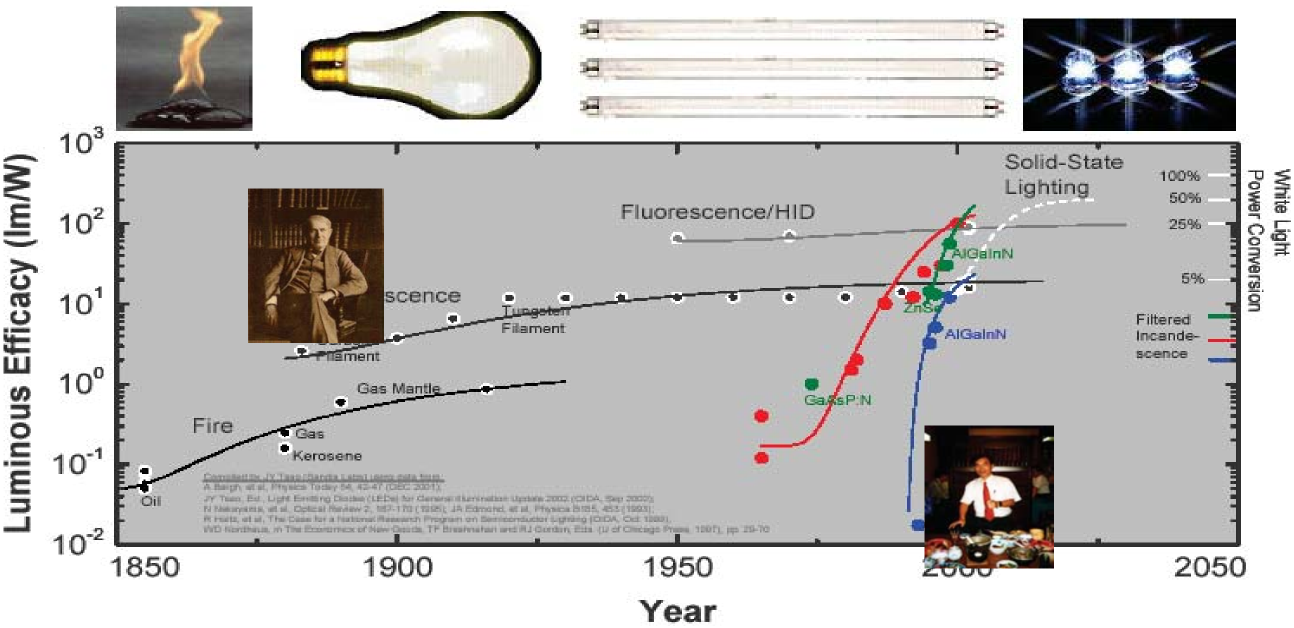


Figure 1: 200-year evolution of luminous efficacy for various lighting technologies.

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

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）

LED發展里程表

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

	SSL-LED 2002	SSL-LED 2007	SSL-LED 2012	SSL-LED 2020	INCAN-DESCENT	FLUOR-ESCENT	HID
LAMP TARGETS[1]							
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 $/lamp)	5.0	4.0	5.0	3.0	0.5	5.0	35.0
Color rendering index (CRI)	70	80	80	80	100	75	80
DERIVED LAMP COSTS[2]							
Capital cost [$/(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).

LED給人類及地球帶來的重大影響

Save Earth, Energy and Environment

Goal (2015): 開發高效率半導体光源
- ➪ 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_2 廢氣產生 (USA)

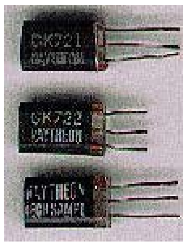
In China:
- ➪ 每年減少 1,000億度電力 (= 長江三峽大壩發電量)

In the World:
- ➪ 給世界無電無光的20億人口帶來一線曙光

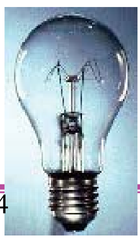
廿世紀最重要的科技

The most important technologies in 20-21 Century

Vacuum Tubes → 1940-1980 → Transistors



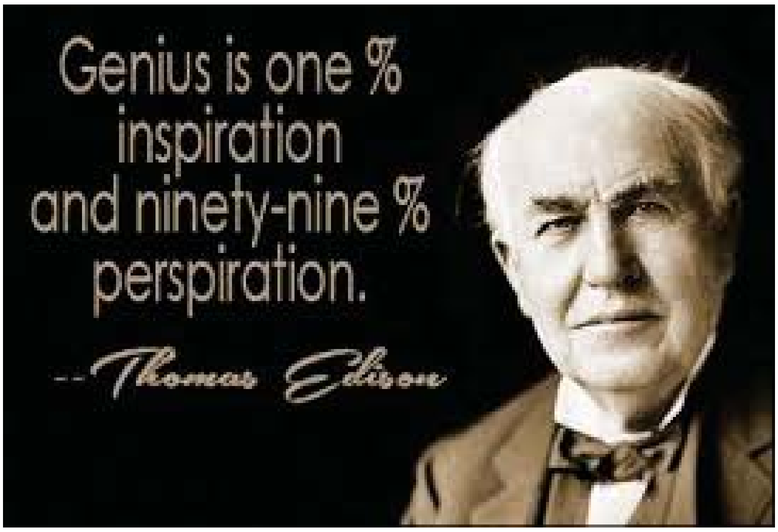
CRT TV → 1980-2010 → Flat Panel TV and Displays



Light Bulbs → 1996-2020 → White Light Semiconductor Sources ?

"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



" 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*

講演完畢

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.**