求是之光
浙江大学光电信息工程学系
Department of Optical Engineering, Zhejiang University

Optoelectronics

光电子学

http://opt.zju.edu.cn/optelec/index.php

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Zhejiang University

What is Optoelectronics?

- **A field of technology that combines the physics of light with electricity. Optoelectronics encompasses the study, design and manufacture of hardware devices that convert electrical signals into photon signals and vice versa.**
- **Any device that operates as an electrical-to-optical or optical-to-electrical transducer is considered an optoelectronic device.**
- **Optoelectronic technologies include fiber optic communications, laser systems, electric eyes, and are widely used in the daily household appliances, office electronics, lighting, remote sensing systems, medical diagnostic systems and optical information systems.**

Different point of views

- **Optoelectronics is a branch of electronics that overlaps with physics. The field concerns the theory, design, manufacture, and operation of hardware that converts electrical signals to visible or infrared radiation (infrared) energy, or vice-versa.**

- **Optoelectronics is the branch of physics that studies the mutual conversion of electricity and light energy.**

Optoelectronics (contents)

- Laser theory and techniques
- Semiconductor light device
- Photodetectors
- Modulation (electro-optics effect, Photoacoustic effect, Magnetoptics effect)
- Display
- Nonlinear optics

Including

- Optoelectronic components for example: photocells, solar cells, detector arrays,opto-isolators (also called optical couplers or optocouplers), modulator, LEDs (light-emitting diodes), laser, and laser diodes.

- Applications include light sources, electric eyes, photovoltaic power supplies, various monitoring and control circuits, and optical fiber communications systems, display, information storage.

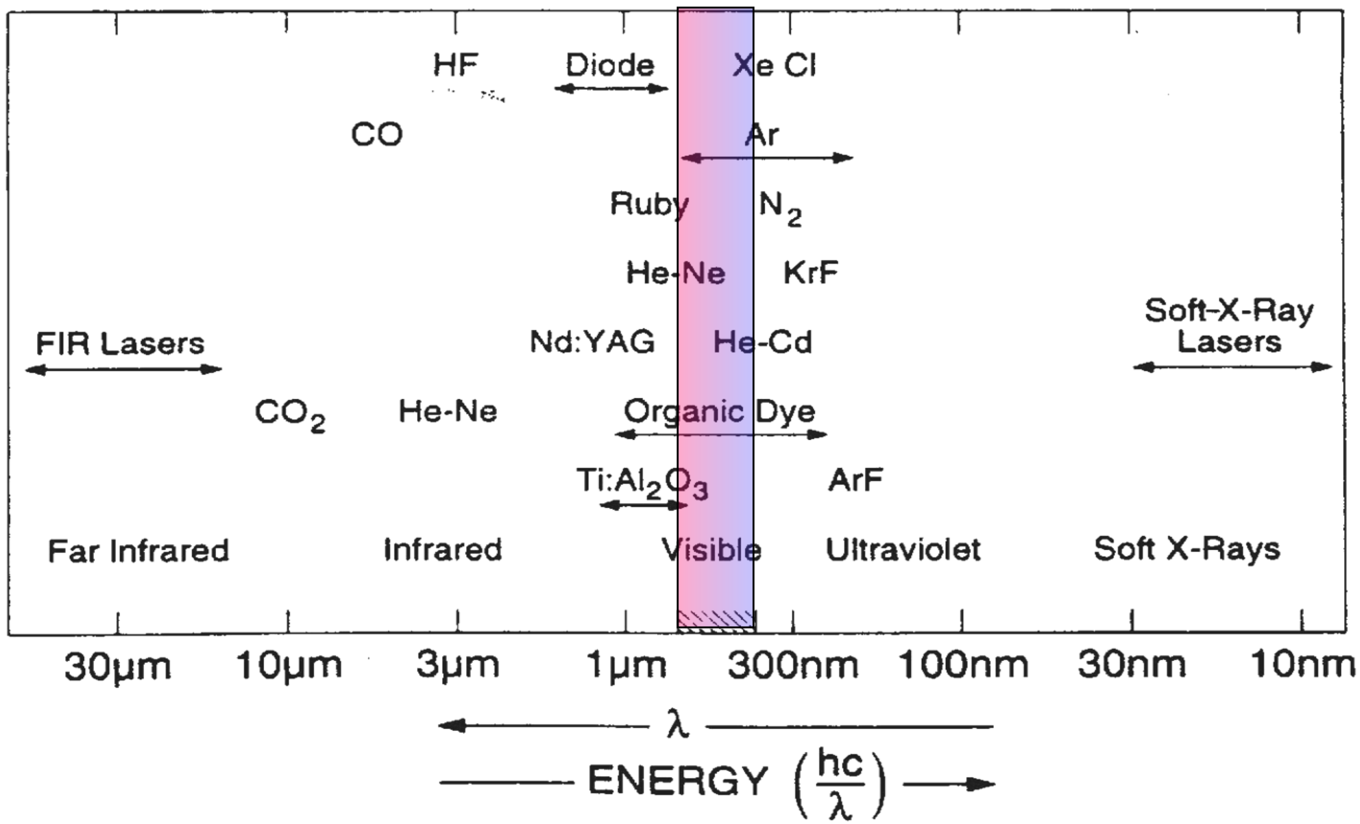
Optoelectronics

Electrics $\longleftrightarrow$ **Photons**

Different relations between photon and other physical parameters：

laser sources	E~Photon
semiconductor	E_{Photon}~Eg
Photodetector	E_{Photon}>Eg
Electro-optical effect	N~ E
Acoustic optics,	N~Phonon,
magnetic optics	N~B
non-linear effect	N~I^3, I^2

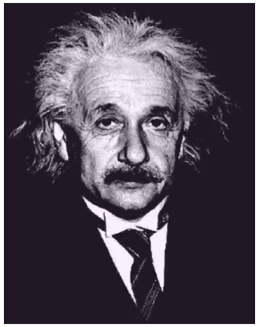
Luminescent spectrum of different materials



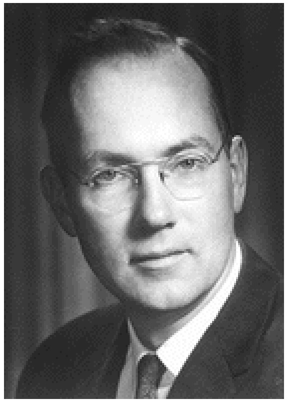
Laser theory is the basic part of Optoelectronics

History of Laser

- LASER – Light Amplification by Stimulated Emission of Radiation
- 1917
  - Albert Einstein first theorized about the process which makes lasers possible called "Stimulated Emission"
- 1951
  - Charles H. Townes conceived the concept of MASER (Microwave Amplification by Stimulated Emission of Radiation)
- 1954
  - First MASER device by Townes, Gould and Zerger
- 1958
  - Schawlow and Townes showed theoretically that masers could be made to operate in the optical and infrared region
  - "Infrared and Optical Masers," published in the December 1958 *Physical Review*.
  - Received a patent for the invention of the laser in 1960

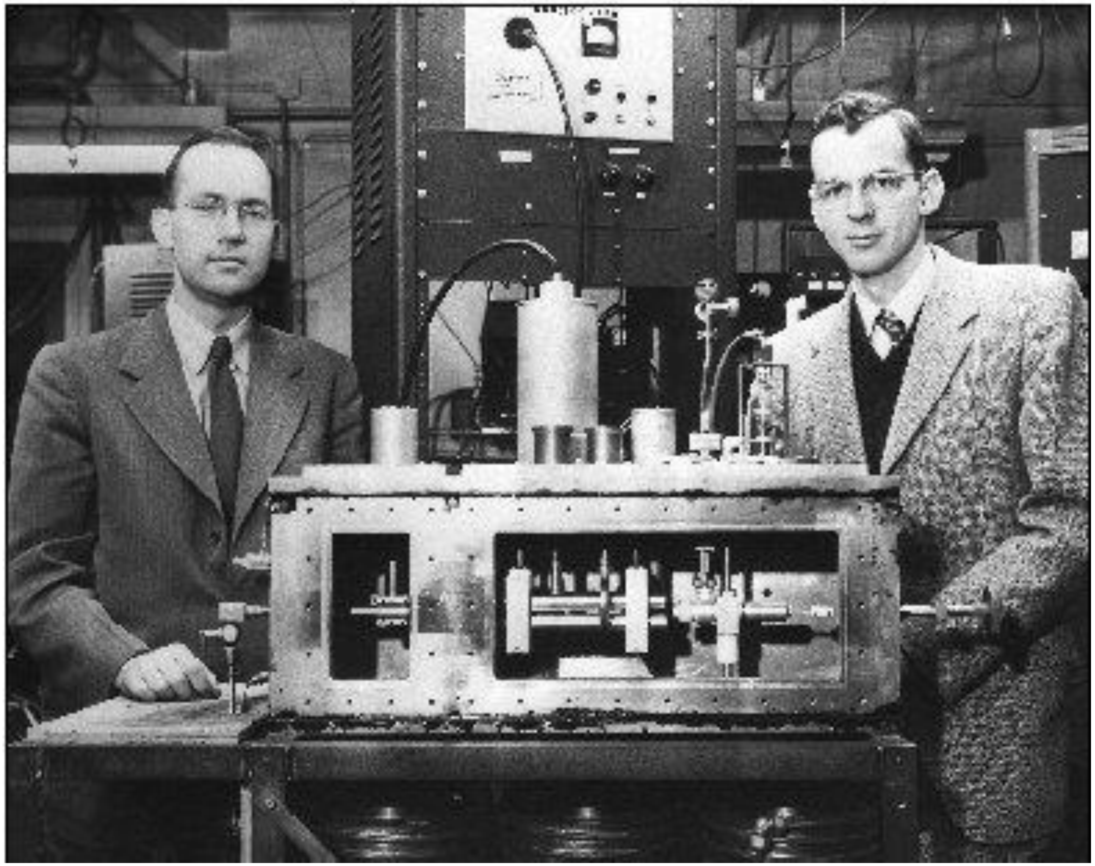


Albert Einstein



Charles H. Townes

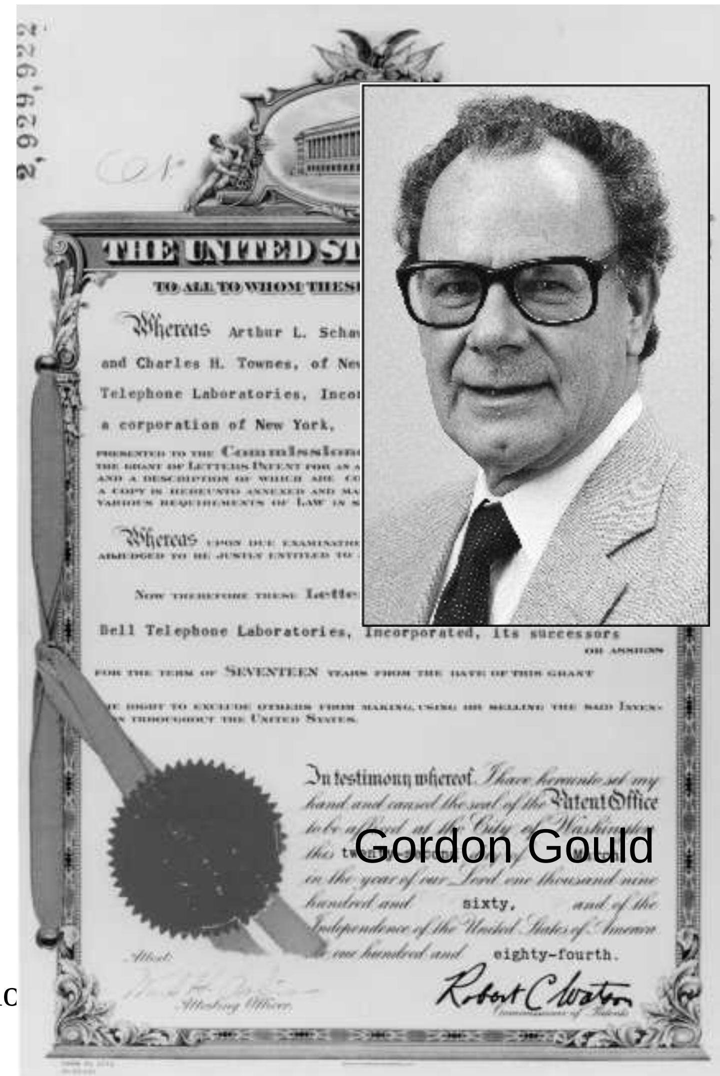
Arthur L. Schawlow



Charles Townes (left) and James P. Gordon proudly display their maser, a device that greatly amplifies microwaves

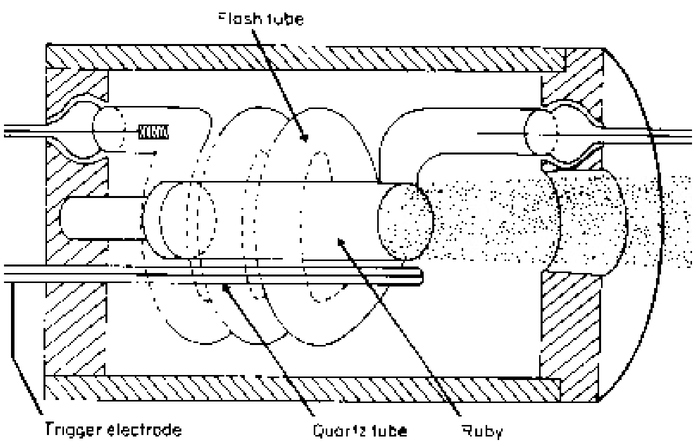
History of Lasers

- Laser Patent War
  - Gordon Gould – then 37-year-old Columbia graduate student - wrote down his laser ideas - including a definition of "laser" as Light Amplification by the Stimulated Emission of Radiation - in late 1957, and had them notarized. Filed for patent in 1959, but was rejected.
  - The laser patent was later bitterly disputed for almost three decades in “the patent wars” by Gordon Gould, and his designated agents.
  - Gordon Gould eventually received the US patent for optical pumping of the laser in 1977 since the original laser patent did not detail such a pumping procedure. In 1987 he also received a patent for the gas discharge laser, thereby winning his 30 year patent war. His original notebook even contained the word “laser”..



History of Lasers (Cont'd)

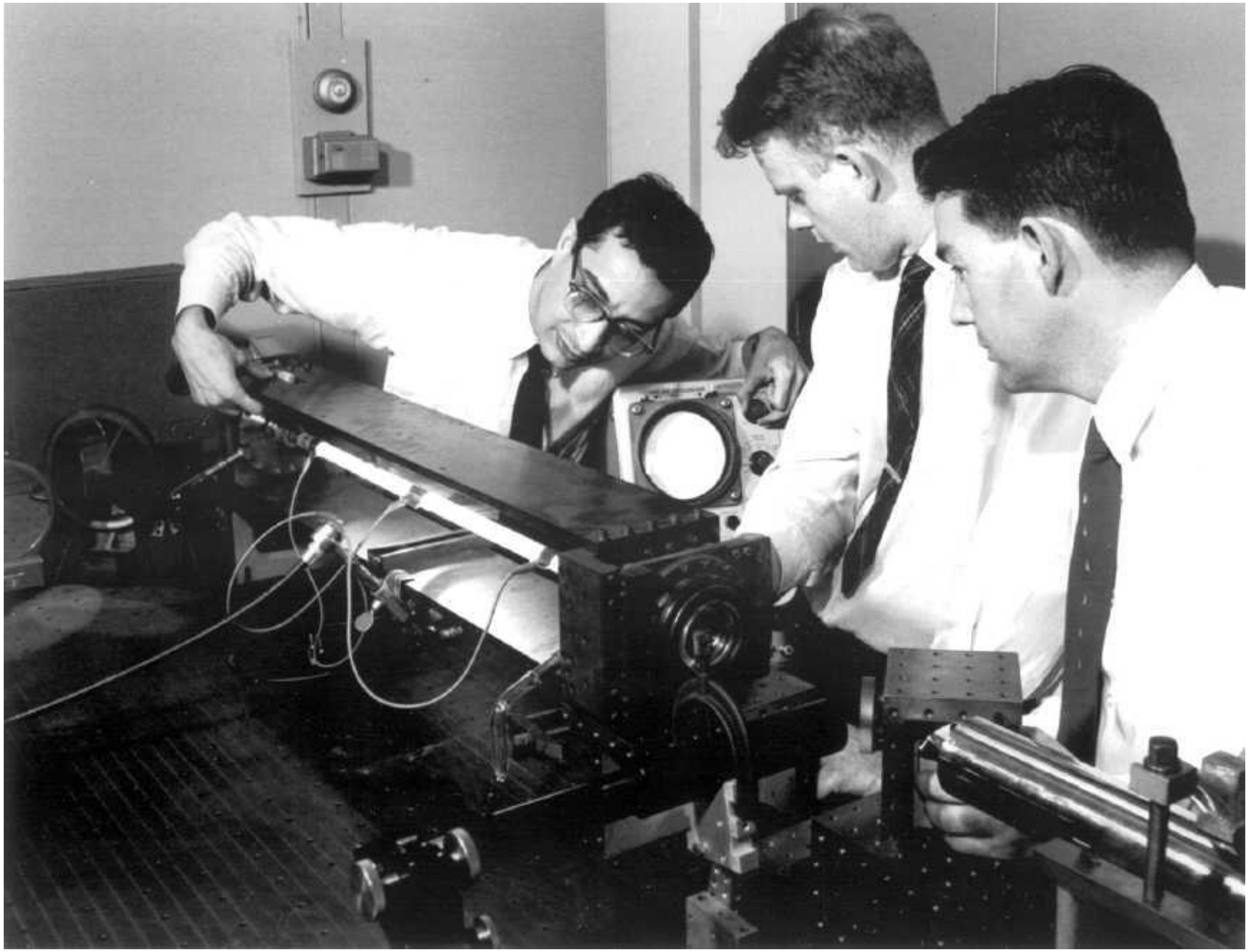
- 1960
  - Theodore H. Maiman (Hughes Research) made the first working laser – Ruby laser @ 0.69 μm



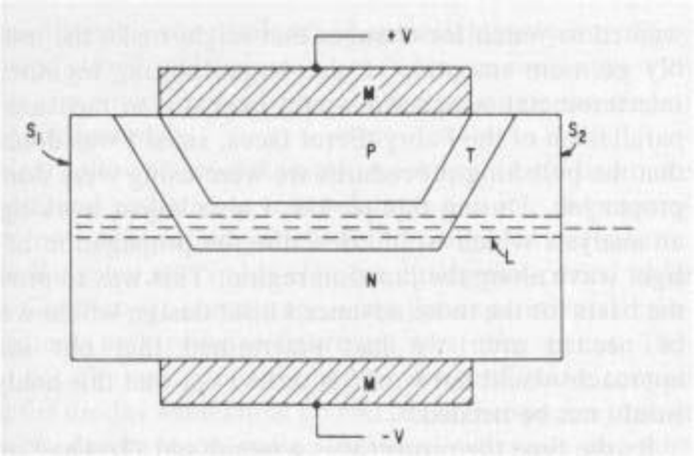
The first Ruby laser in the world

Theodore H. Maiman

Ali Javan and his associates William Bennett Jr. and Donald Herriott at Bell Labs were first to successfully demonstrate a continuous wave (cw) helium-neon laser operation (1960-1962). (Courtesy of Bell Labs, Lucent Technologies.)

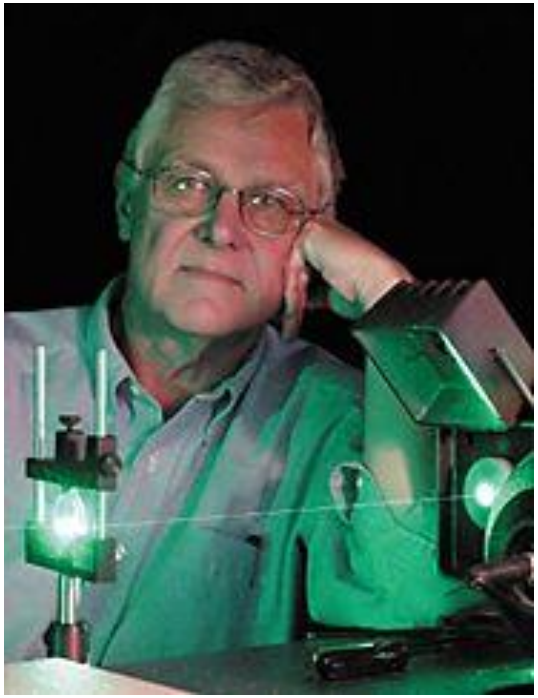


- In 1962 Robert Hall invented the semiconductor injection laser, a device now used in all compact disk players and laser printers, and most optical fiber communications systems.



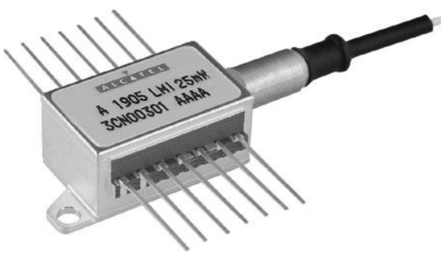
1964: **C. K. N. Patel shown here with the high-power 10.6 micron carbon dioxide laser which he developed at Bell Labs.**

1964 **William Bridges Invention of Argon Ion LASER a Hughes Labs.**

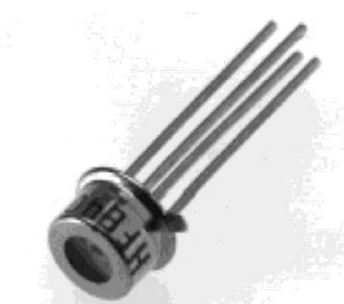


Diode laser

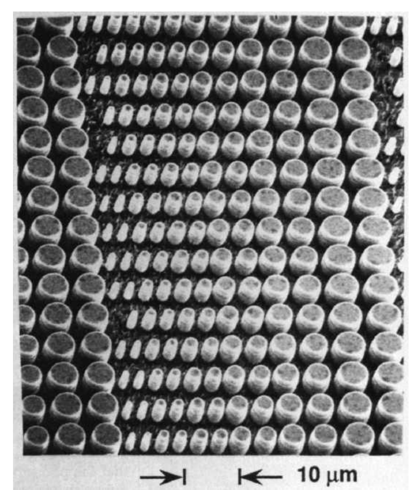
A laser diode pigtailed to a fiber. Two of the leads are for a back-facet photodetector to allow the monitoring of the laser output power.(Courtesy of Alcatel)



A 1550 nm MQW-DFB InGaAsP laser diode pigtail-coupled to a fiber



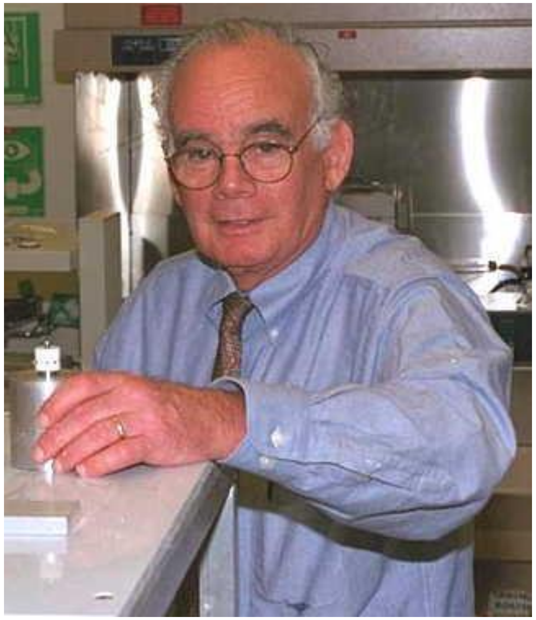
An 850 nm VCSEL diode



SEM (scanning electron microscope) of the first low-threshold VCSELs developed at Bell Laboratories in 1989. The largest device area is 5 μm in diameter

Diode laser

- Coherent light emission from a semiconductor (gallium arsenide) diode (the first *laser* diode) was demonstrated in 1962 by two US groups lead by Robert N. Hall at the General Electric research center and by Marshall Nathan at the IBM T.J. Watson Research Center



375 nm – excitation of Hoechst stain, Calcium Blue, and other fluorescent dyes in fluorescence microscopy
405 nm – InGaN blue-violet laser, in Blu-ray Disc and HD DVD drives
445 nm – InGaN Deep blue laser diode recently introduced (2010) for use in high brightness data projectors
473 nm – Bright blue laser pointers, still very expensive, output of DPSS systems
485 nm – excitation of GFP and other fluorescent dyes
510 nm - Green diodes recently (2010) developed by Nichia for laser projectors.
532 nm – AlGaAs-pumped bright green laser pointers, frequency doubled 1064 nm Nd:YAG laser or (more commonly in laser pointers) Nd:YVO_4 IR lasers (SHG)
593 nm – Yellow-Orange laser pointers, DPSS（ Diode Pumped Solid State）
635 nm – AlGaInP better red laser pointers, same power subjectively 5 times as bright as 670 nm one
640 nm – High brightness red DPSS laser pointers
657 nm – AlGaInP DVD drives, laser pointers
670 nm – AlGaInP cheap red laser pointers
760 nm – AlGaInP gas sensing: O_2
785 nm – GaAlAs Compact Disc drives
808 nm – GaAlAs pumps in DPSS Nd:YAG lasers (e.g. in green laser pointers or as arrays in higher-powered lasers)
848 nm – laser mice
980 nm – InGaAs pump for optical amplifiers, for Yb:YAG DPSS lasers
1064 nm – AlGaAs fiber-optic communication
1310 nm – InGaAsP fiber-optic communication
1480 nm – InGaAsP pump for optical amplifiers
1512 nm – InGaAsP gas sensing: NH_3
1550 nm – InGaAsP fiber-optic communication
1625 nm – InGaAsP fiber-optic communication, service channel
1654 nm – Inga Asp gas sensing: CH_4
1877 nm – GaSbAs gas sensing: H_2O
2004 nm – GaSbAs gas sensing: CO_2
2330 nm – GaSbAs gas sensing: CO
2680 nm – GaSbAs gas sensing: CO_2

Inventors of different Lasers

- 1961
  - Ali Javan (Bell Labs) invented the first gas or helium neon laser
- 1962
  - Robert Hall (GE Research) invented semiconductor lasers
- 1964
  - J.E. Geusic invented the first working Nd:YAG laser
- 1966
  - William T. Silfvast invented the first metal vapor laser – blue He-Cd laser
- ……

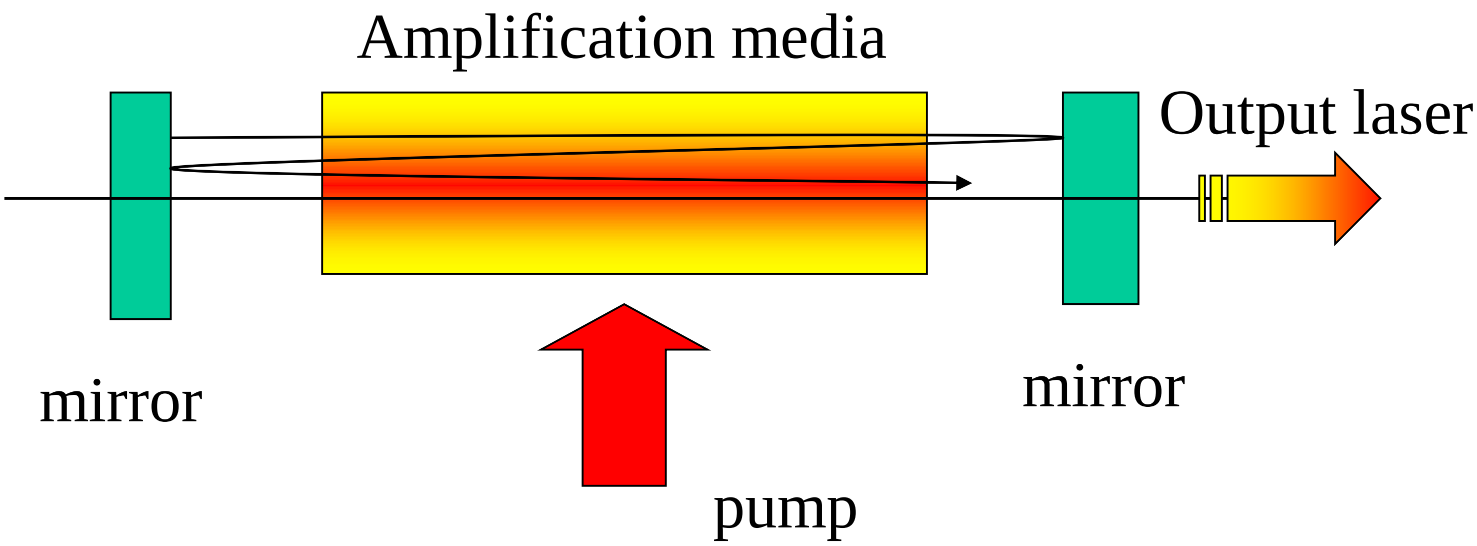
The history of laser in China

1961年中国红宝石激光器（王之江）

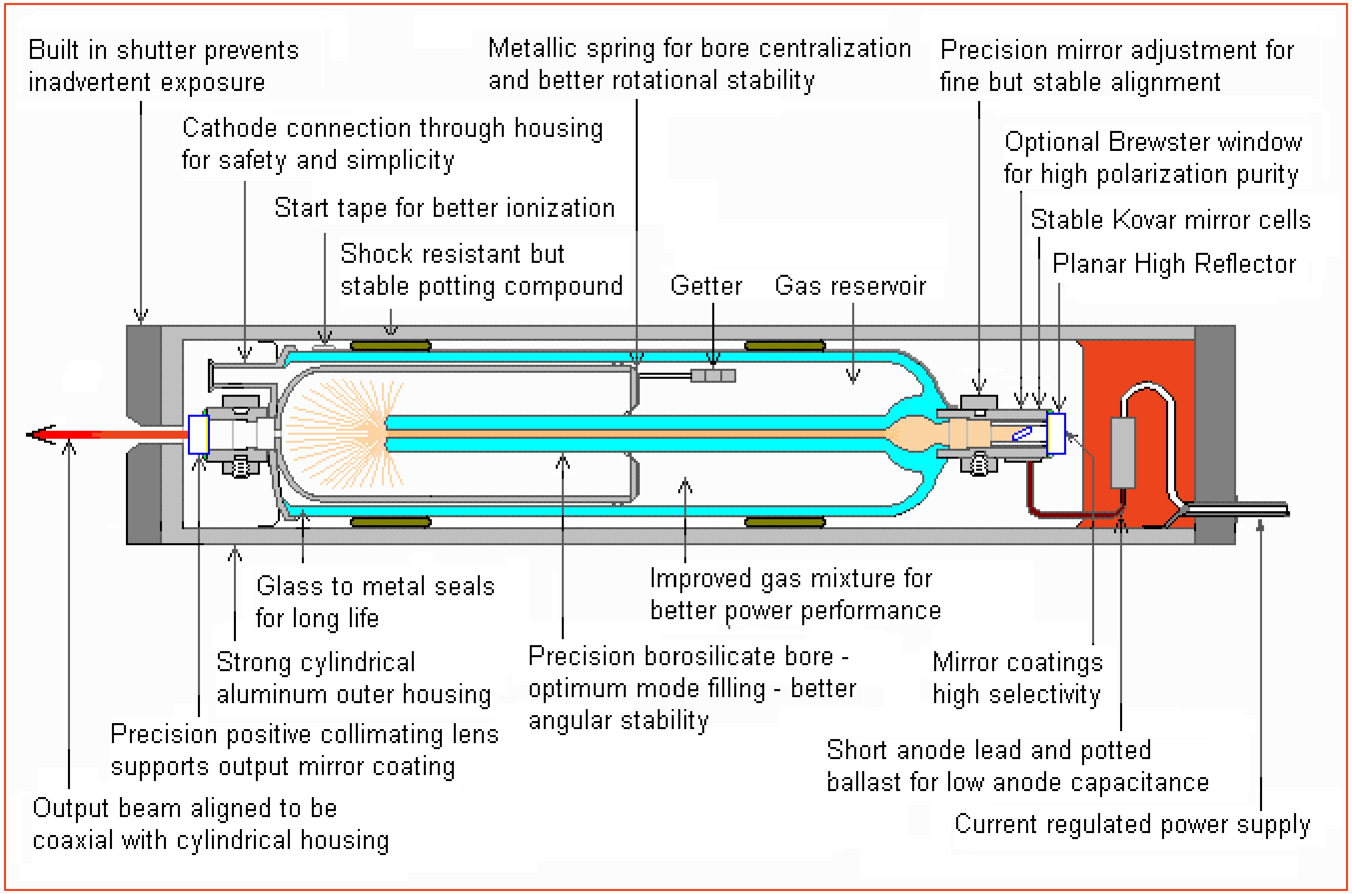
The first different kind of laser in China

Lasers	Invention time	Inventor
He-Ne laser	1963年7月	邓锡铭等
掺钕玻璃 laser	1963年6月	干福熹等
GaAs semiconductor laser	1963年12月	王守武等
Pulse Ar+ laser	1964年10月	万重怡等
CO_2 laser	1965年9月	王润文等
CH_3I chemical laser	1966年3月	邓锡铭等
YAG laser	1966年7月	屈乾华等

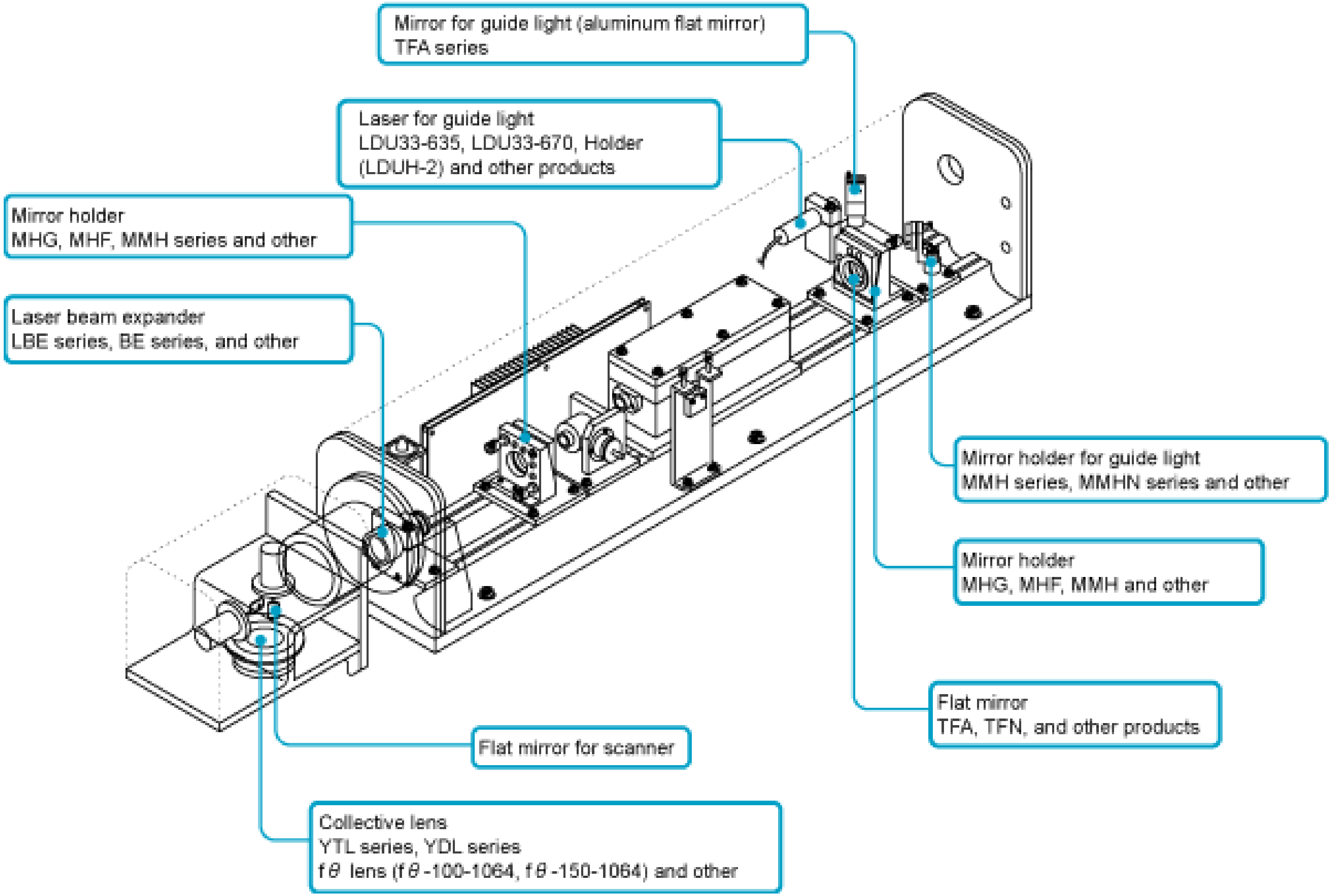
The basic components of laser



Gas laser (He-Ne)

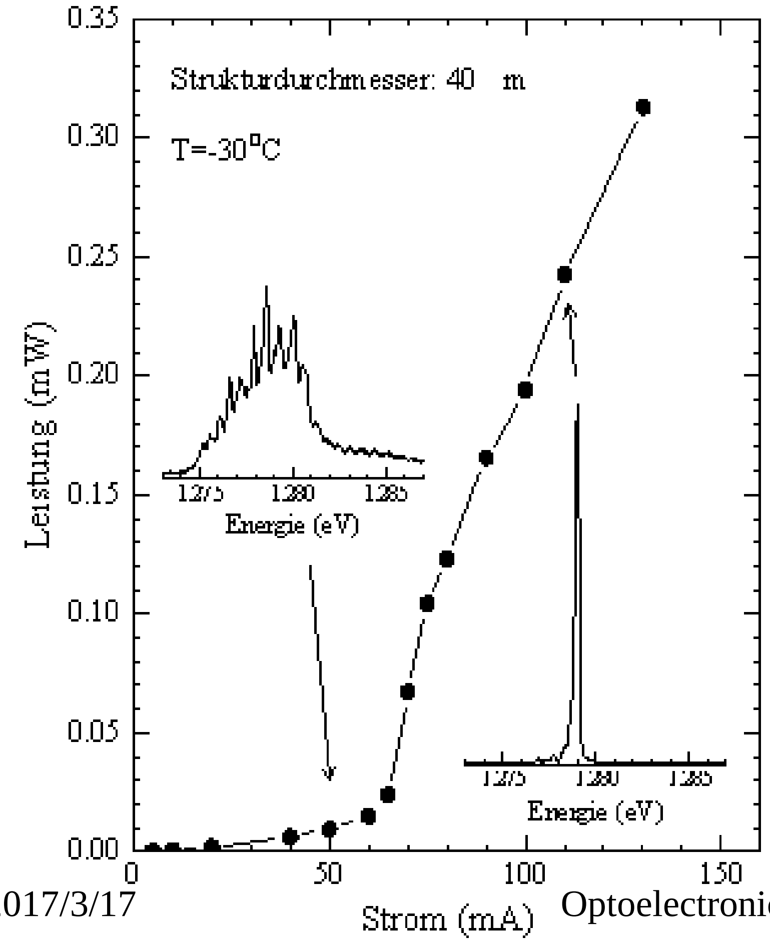


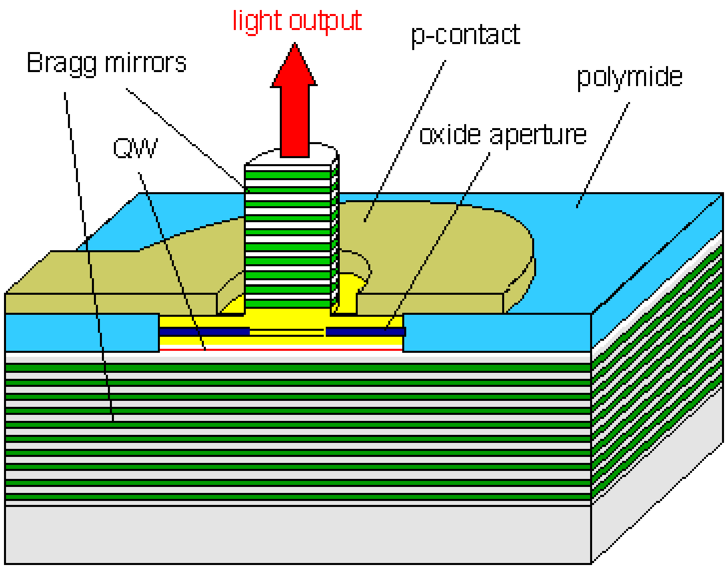
Cross Sectional View of a Melles Griot HeNe Laser Head Showing Details of the Plasma Tube


Mirror for guide light (aluminum flat mirror)
TFA series
Laser for guide light
LDU33-635, LDU33-670, Holder
(LDUH-2) and other products
Mirror holder
MHG, MHF, MMH series and other
Laser beam expander
LBE series, BE series, and other
Mirror holder for guide light
MMH series, MMHN series and other
Mirror holder
MHG, MHF, MMH and other
Flat mirror
TFA, TFN, and other products
Flat mirror for scanner
Collective lens
YTL series, YDL series
fθ lens (fθ-100-1064, fθ-150-1064) and other

Microcavity Laser Structure

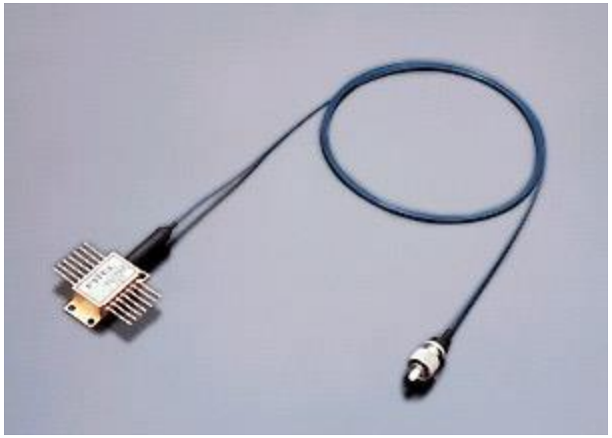
- Laser Emission Spectrum

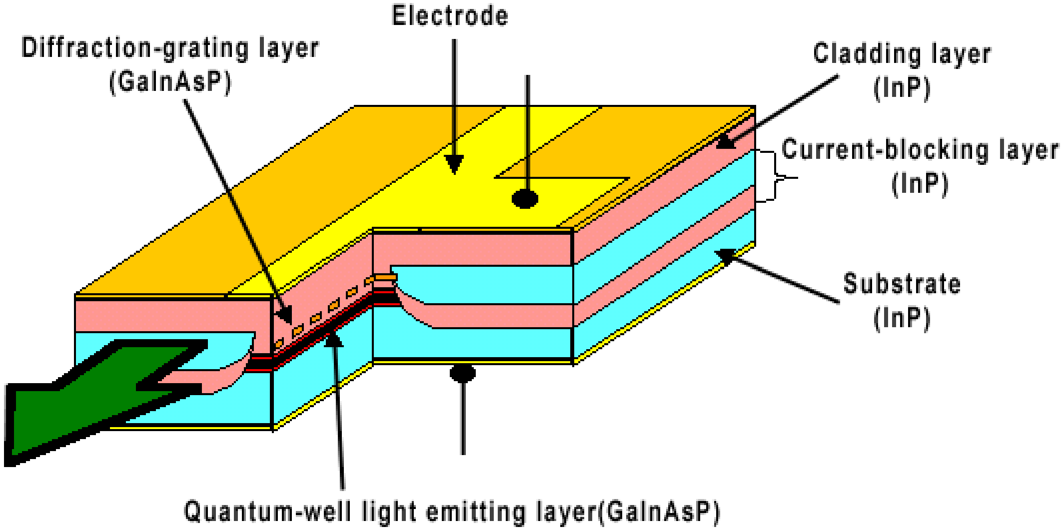




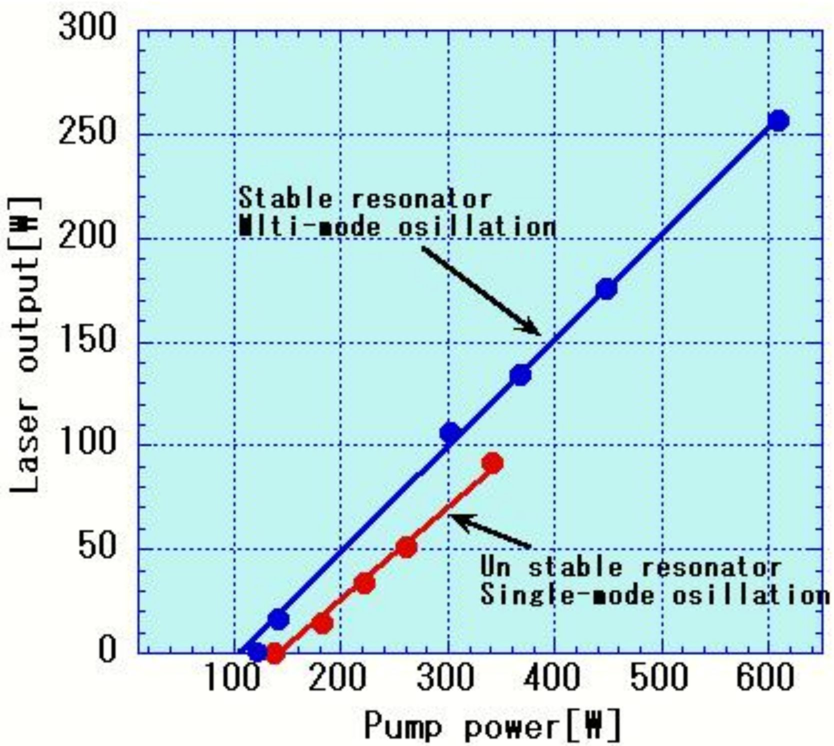
DFB (Distributed Feedback) laser

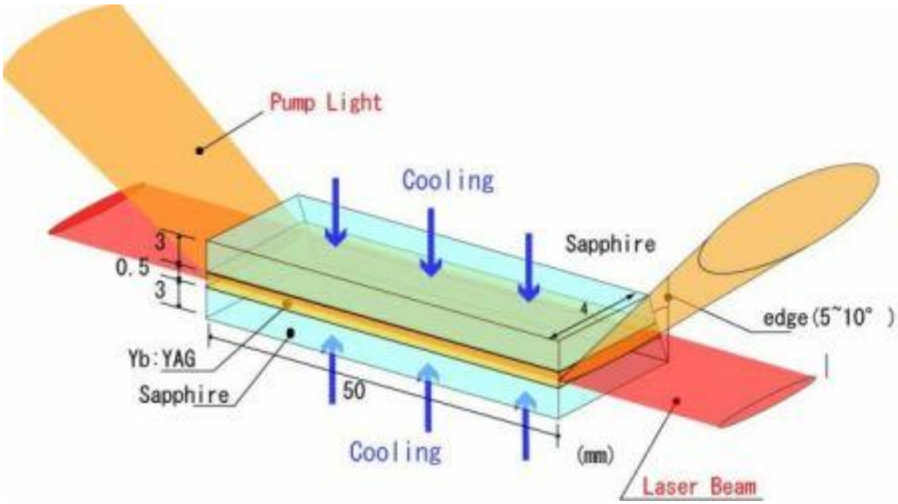
- **High output power**
  The high output power can compensate for various optical losses within DWDM systems, enabling configuration of multi-channel transmission systems and amplifier-less systems.
  Low power consumption
  Because of its low power consumption, the laser can substantially suppress wavelength fluctuation --an important parameter for signal light sources for DWDM systems, resulting in improvements of product reliability.
  Wavelength stability
  A DFB laser module is incorporating a wavelength stabilizing function The module can suppress wavelength fluctuations within 10 pico-meter.





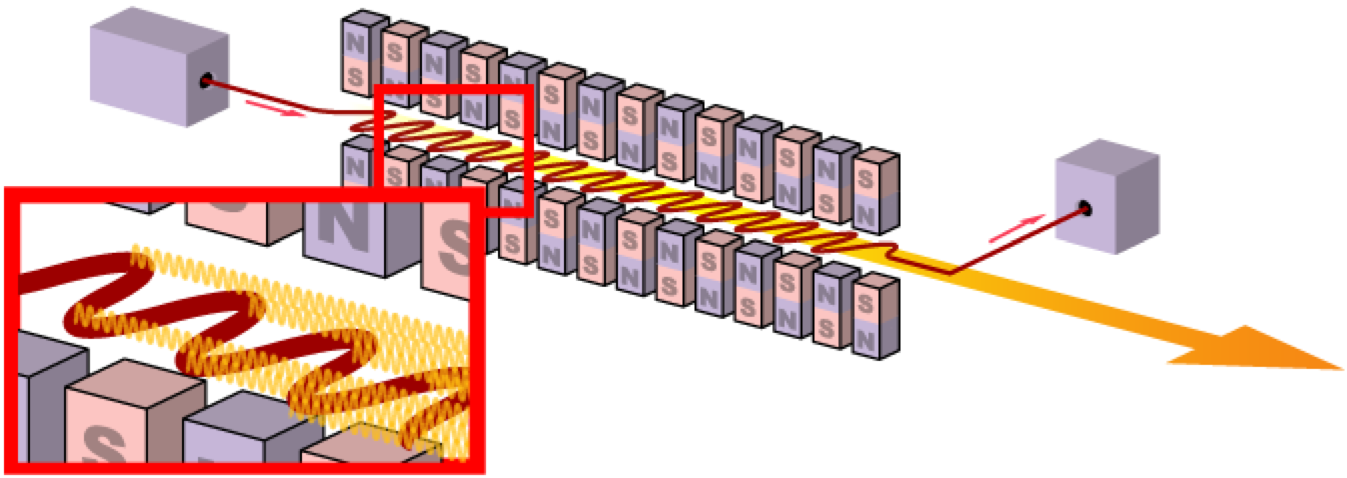
Structure of sub-millimeter-thickness slab





Free-electron laser

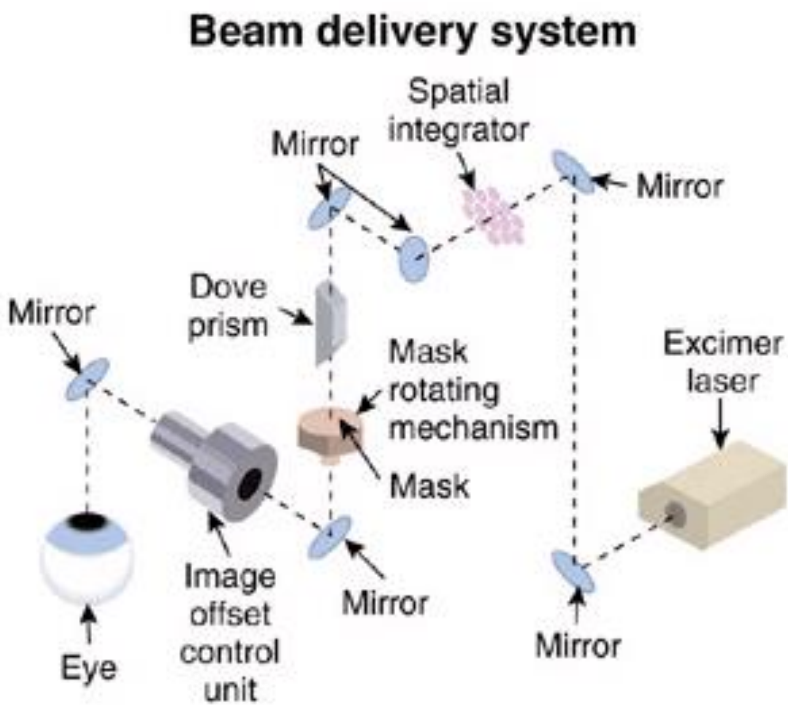
- FELs use a relativistic electron beam as the lasing medium which moves freely through a magnetic structure, hence the term *free electron*. The free-electron laser has the widest frequency range of any laser type, and can be widely tunable, currently ranging in wavelength from microwaves, through terahertz radiation and infrared, to the visible spectrum, to ultraviolet, to X-rays

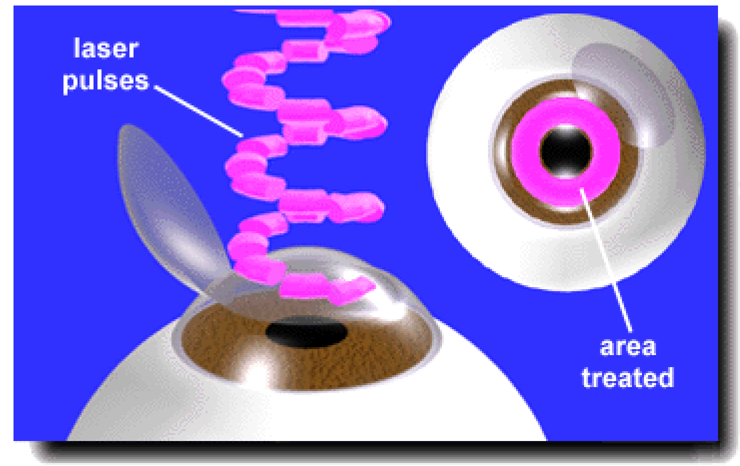


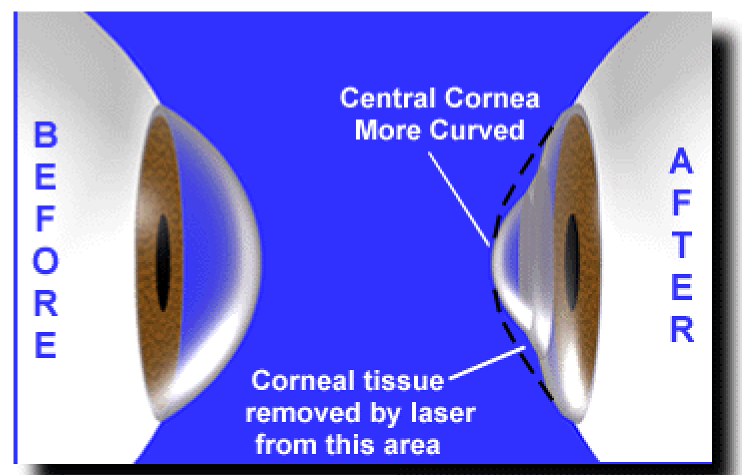
Laser classification

- Gas laser
- Solid state laser
- Semiconductor laser
- Dye laser
- Free electron laser
- Fiber laser
- Photonic crystal laser

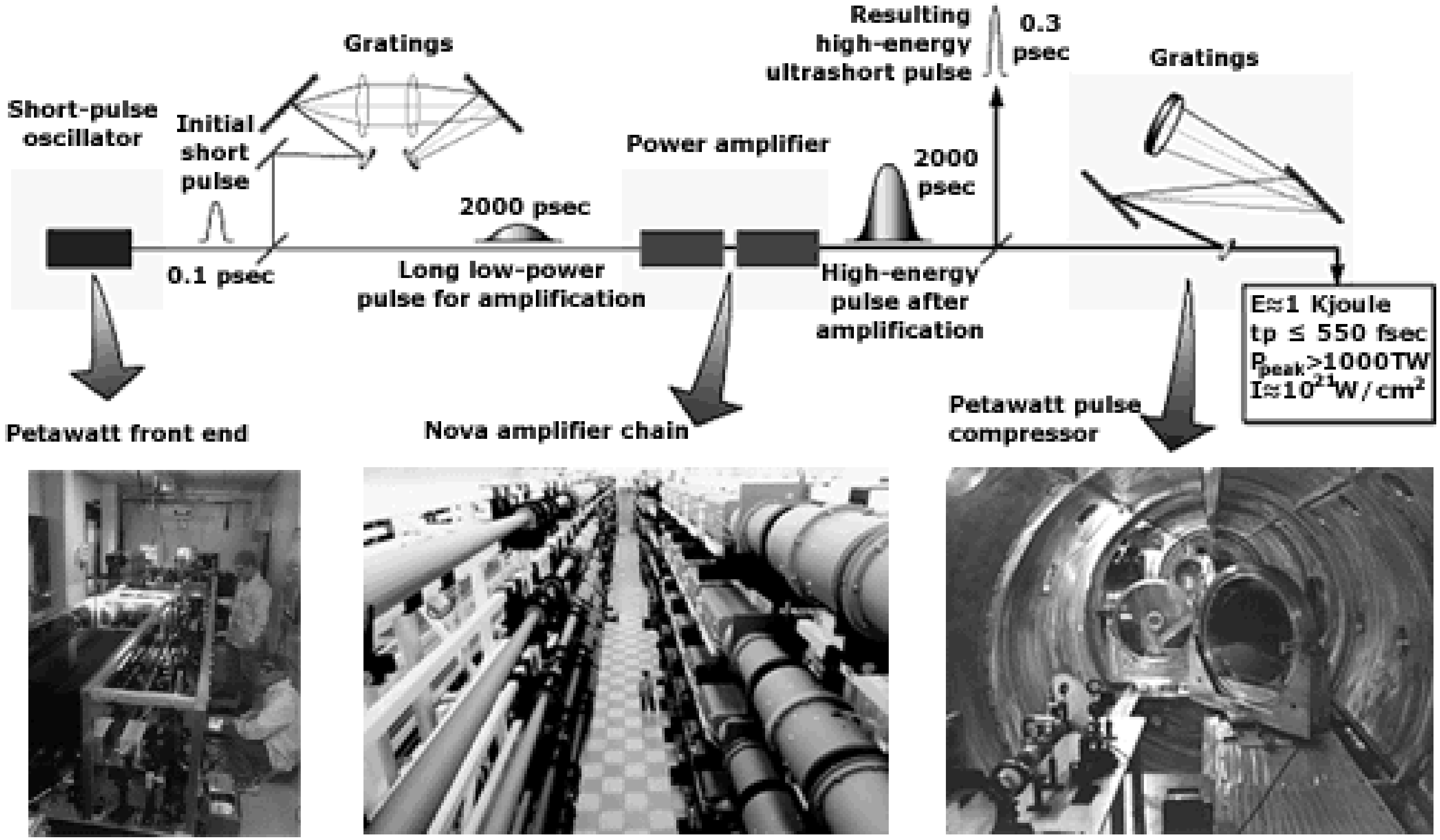
Excemer laser （ultraviolet）



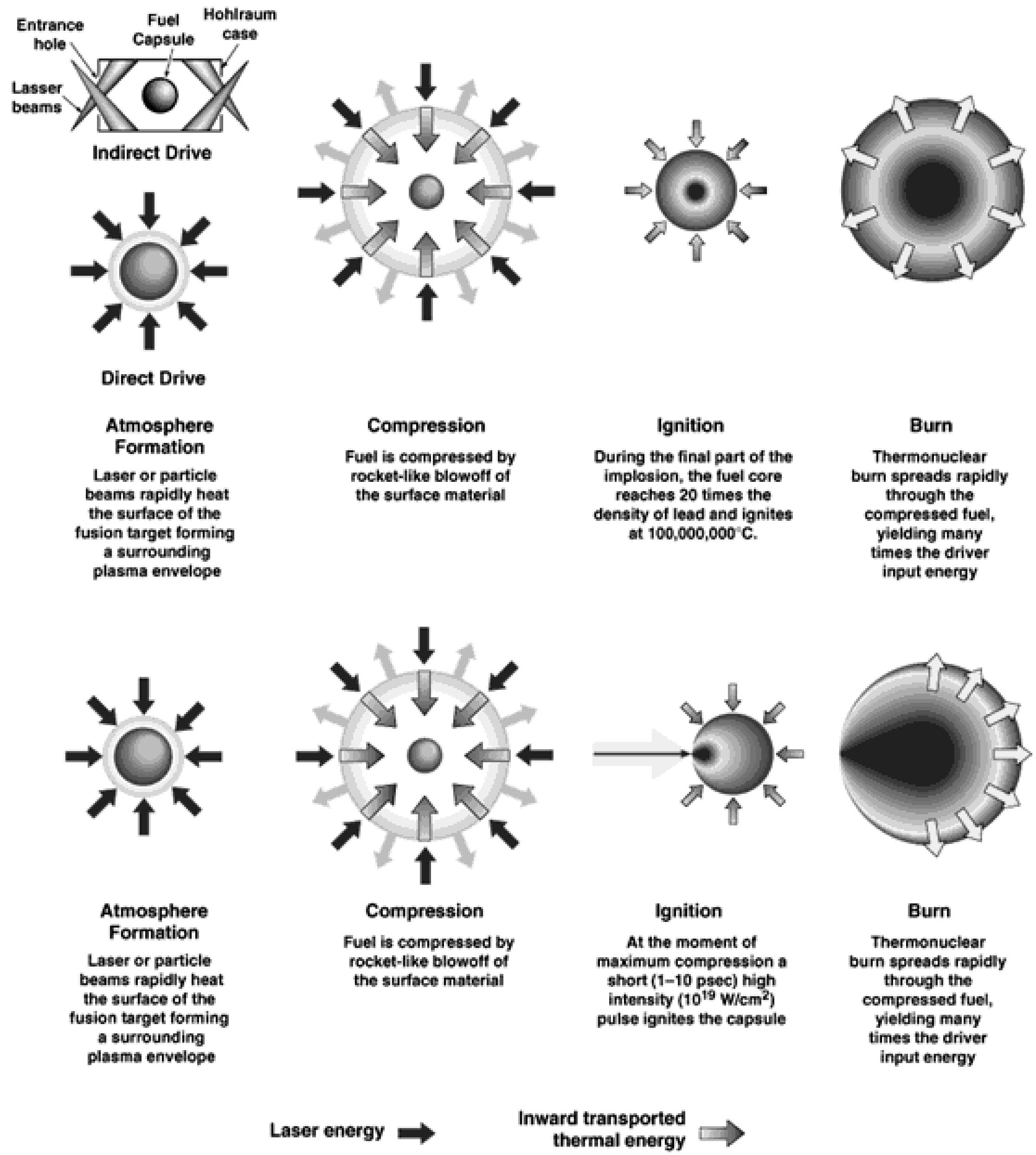




Laser fusion (new energy)



- Schematic of conventional inertial confinement fusion; (bottom row) Schematic of the fast ignitor concept



National Ignition Facility

Laser machine

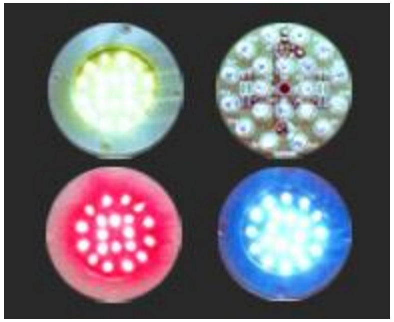
Lasing Materials	Applications
CO_2	Boring Cutting/Scribing Engraving
Nd	High-energy pulses Low repetition speed (1 kHz) Boring
Nd-YAG	Very high energy pulses Boring Engraving Trimming
Fiber laser	Convenience in the application

Light sources

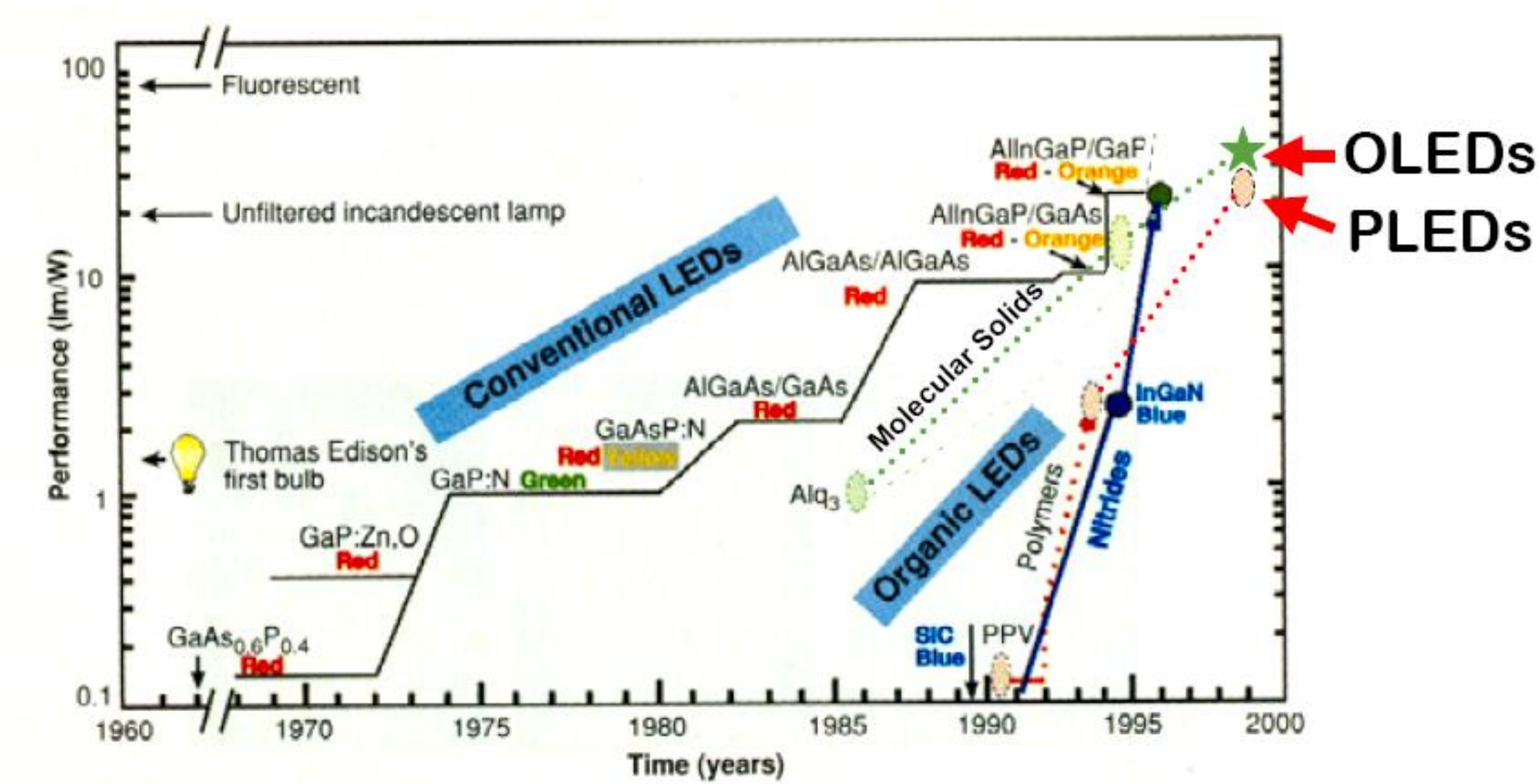
- Incandescent lamp

- Gas discharge lamp

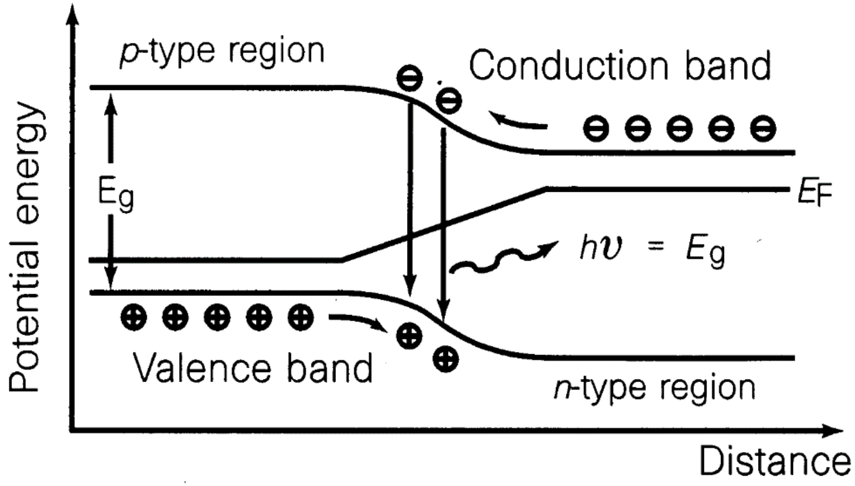
- Semiconductor light source

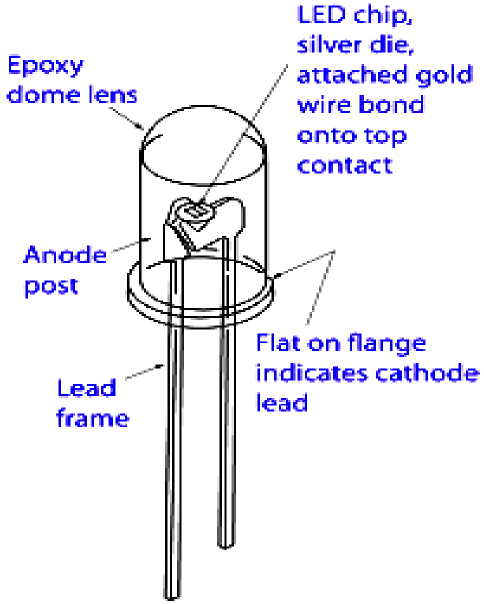


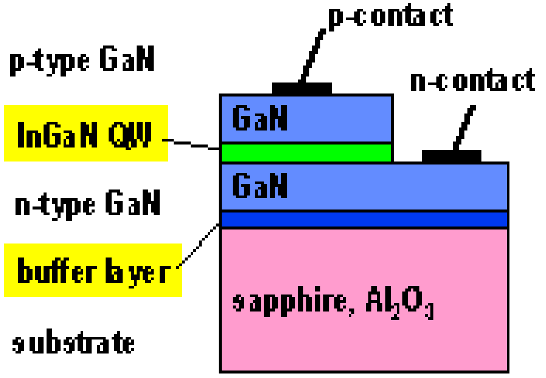
Progress in LED Efficiency

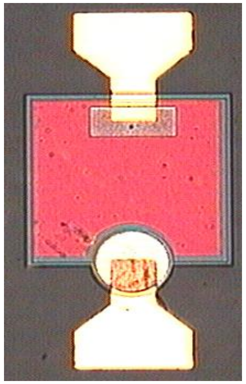


LED（light emitting diode）

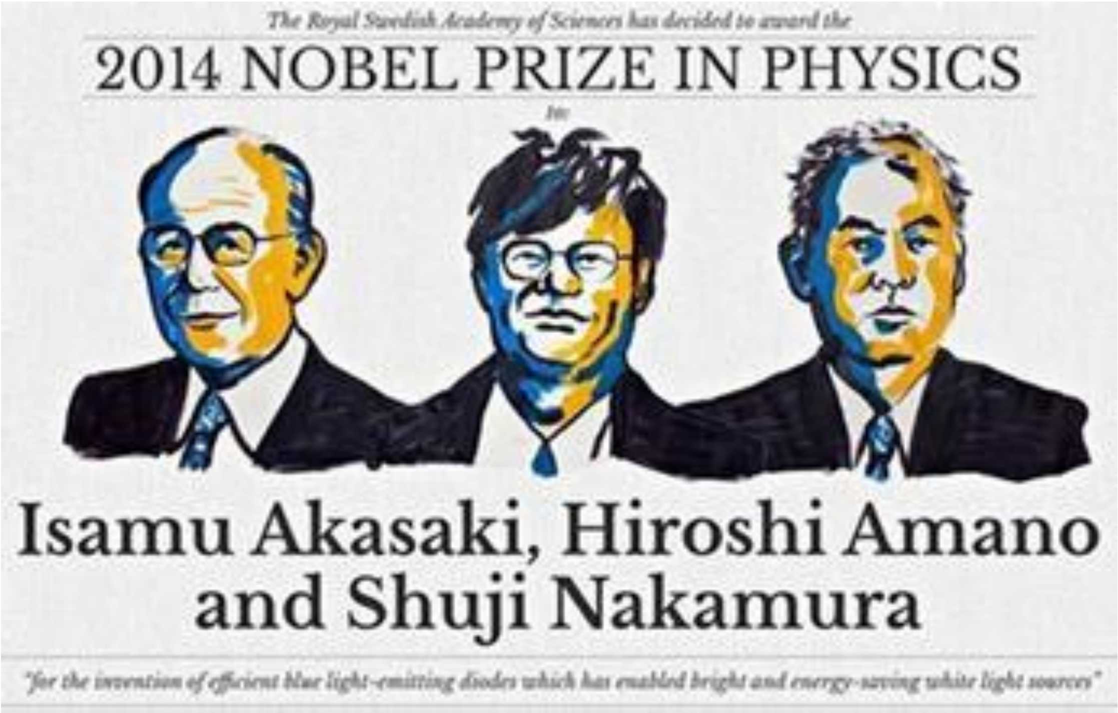








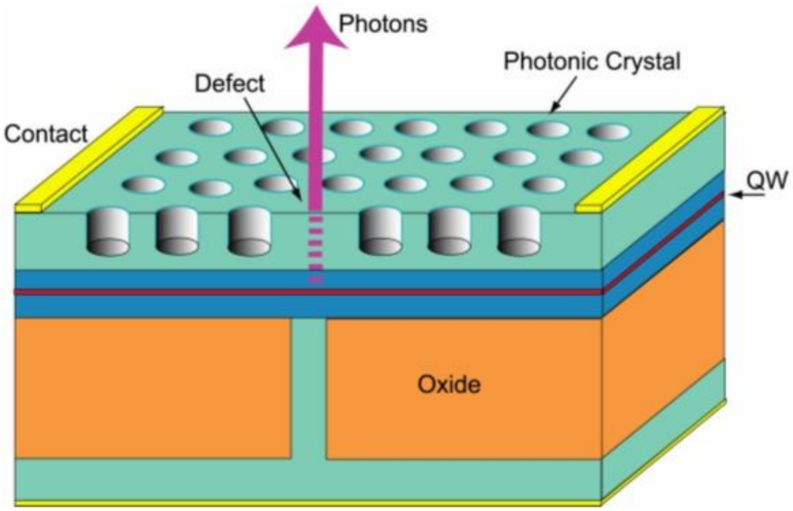
2014 Nobel Price (Physics)



Photonic crystal to increase the efficiency

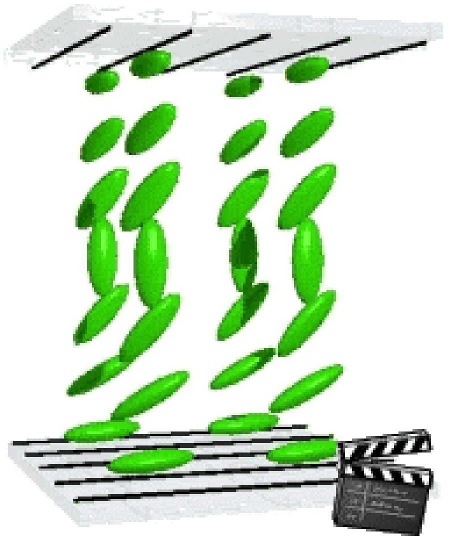
- Quantum efficiency

- Out coupling efficiency

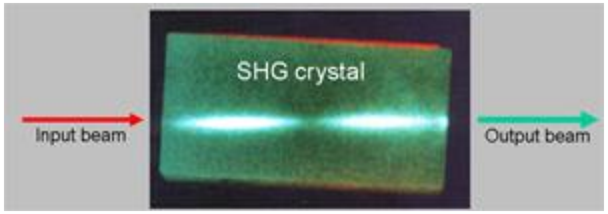


Electro-optical effect（Display）

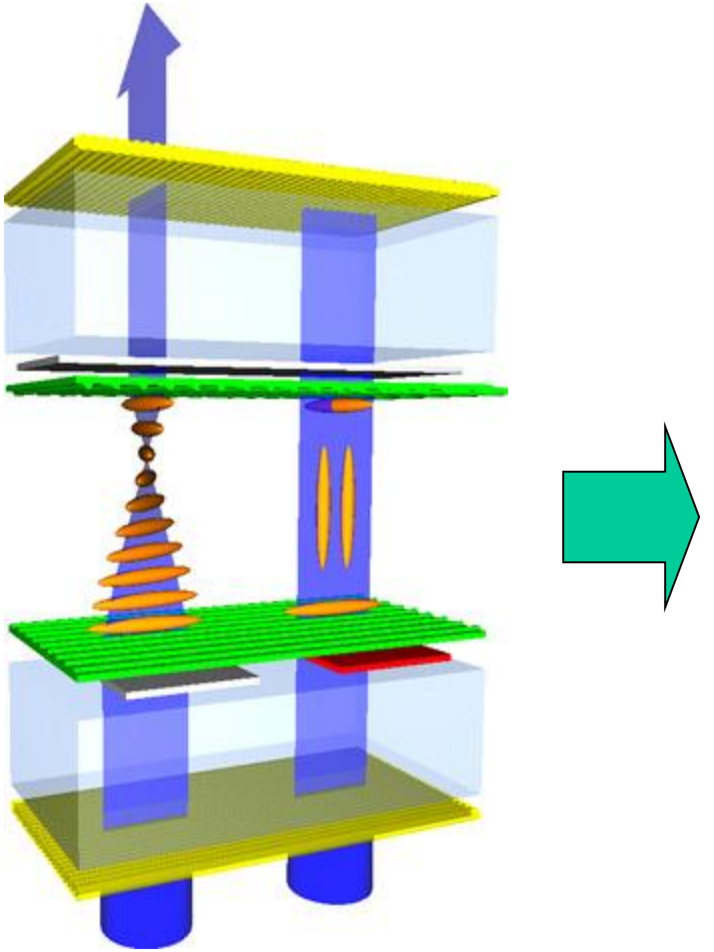
- Electro-optical modulation technique
  - EO crystal
  - Liquid crystal



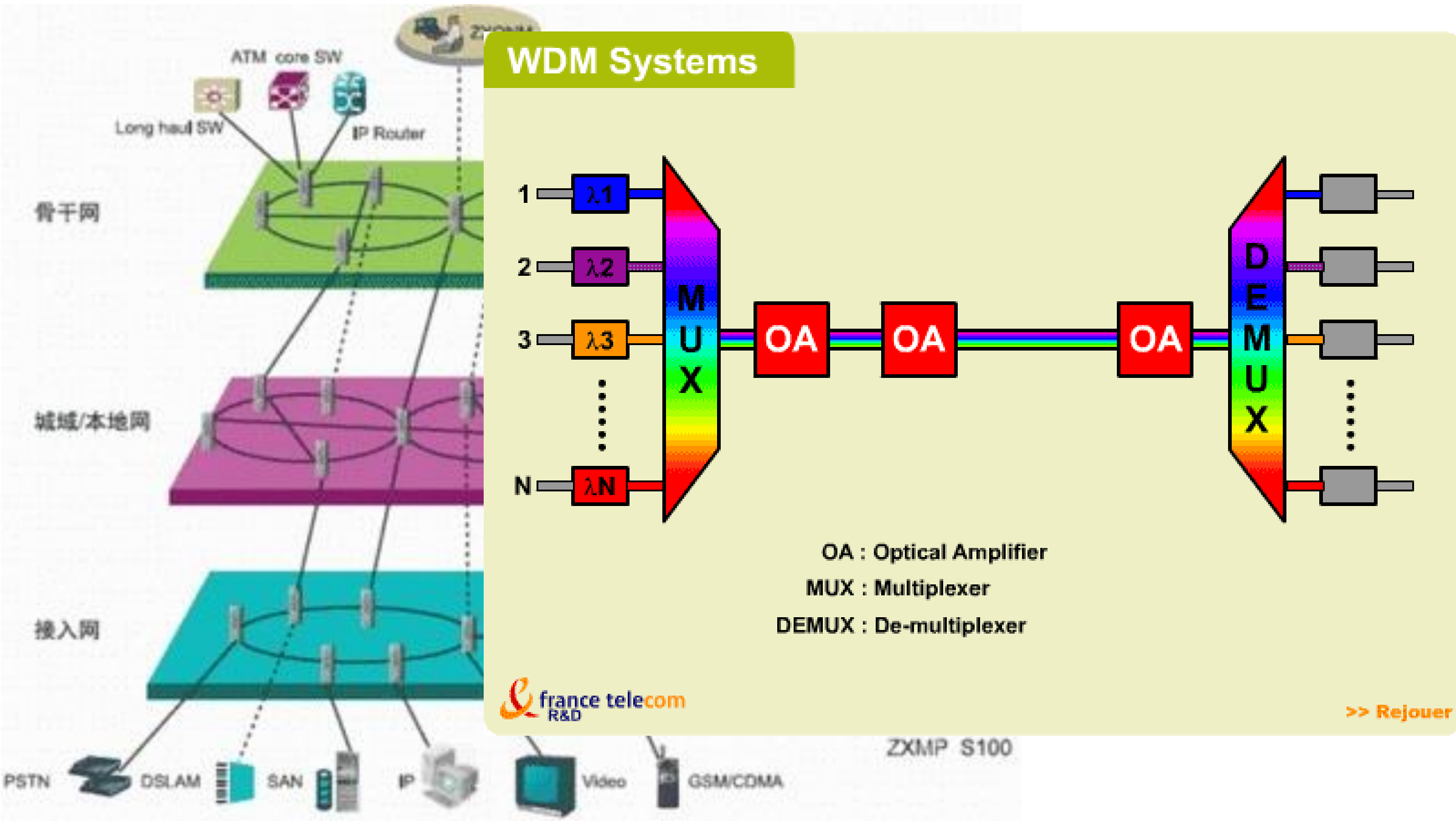
KDP crystal



液晶（Liquid Crystal）



Optical communication
(light sources, propagation and detection)



2009年诺贝尔物理奖

- 光纟 l

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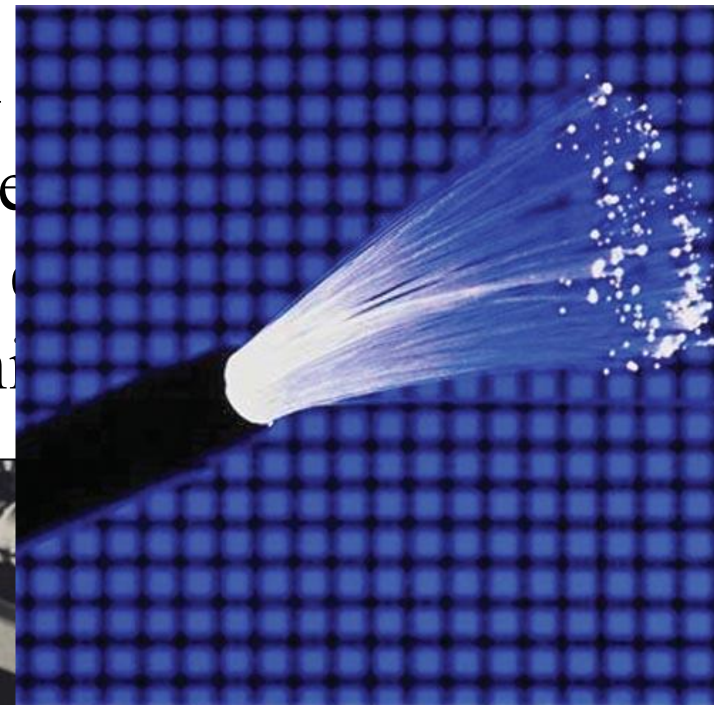
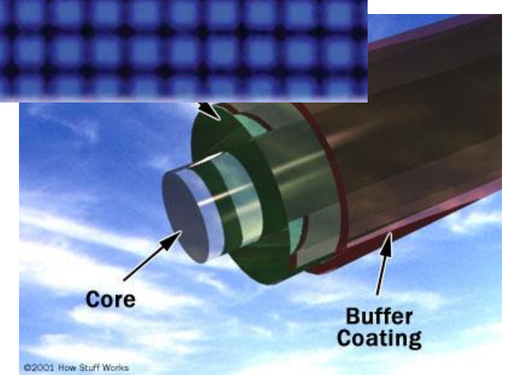


1966

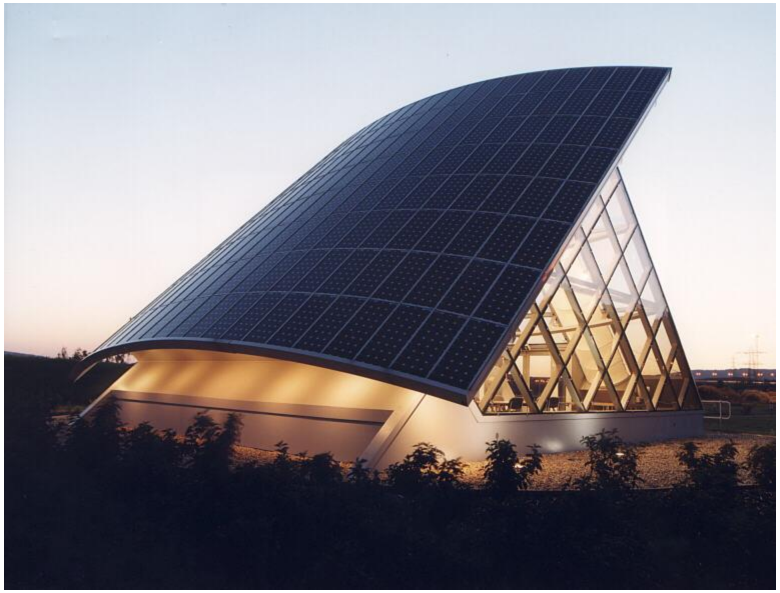


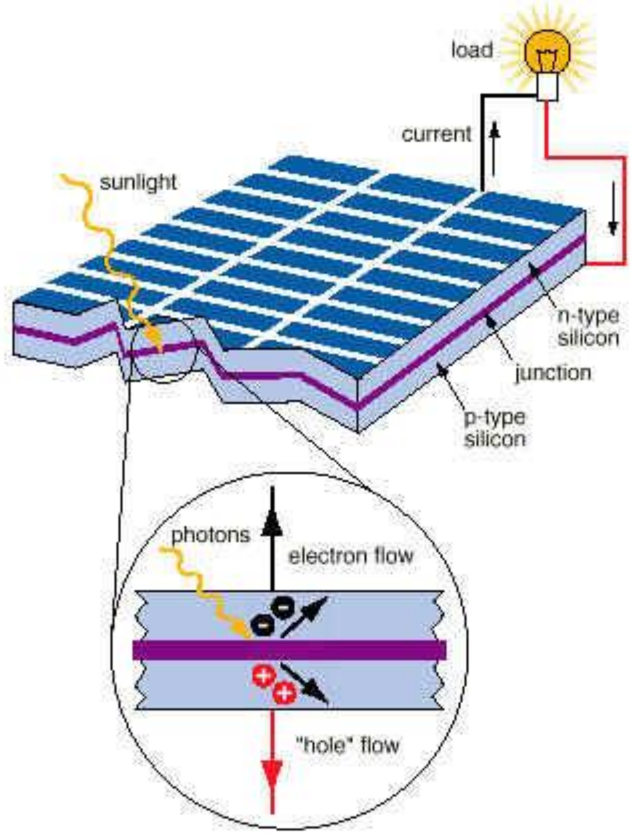
Optical Signal
to
Electric Signal

光电转换技术

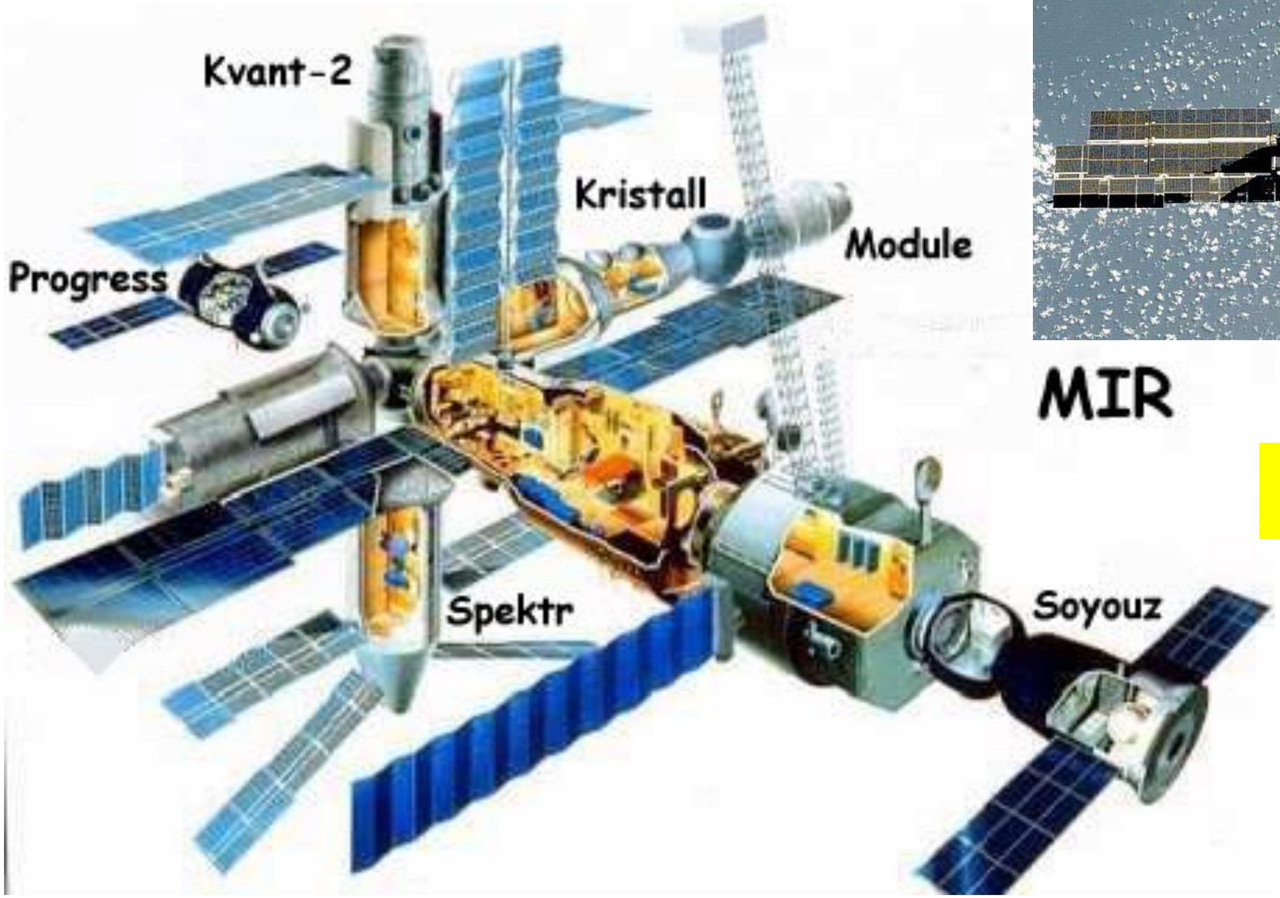
Photo detector

- Photovoltaic effect——Solar cell





Aerospace



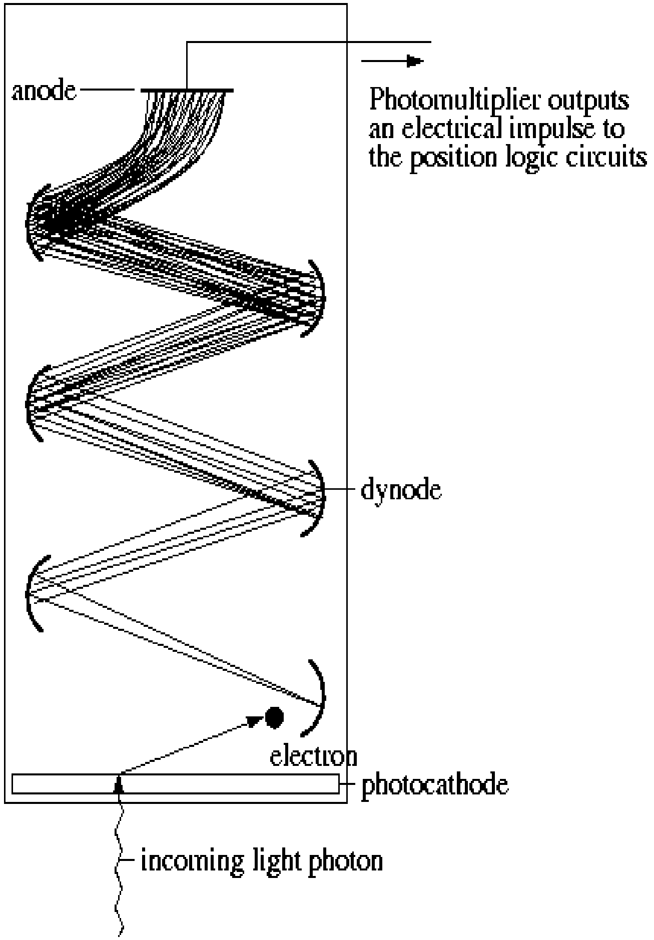
MIR

太空的基本能源

Photodetector（2）

- UV+visible+nIR
- PMT Photomultiplier tube

（vacuum + photocathode）



A Photomultiplier Tube

photodetector（2）

- CCD device

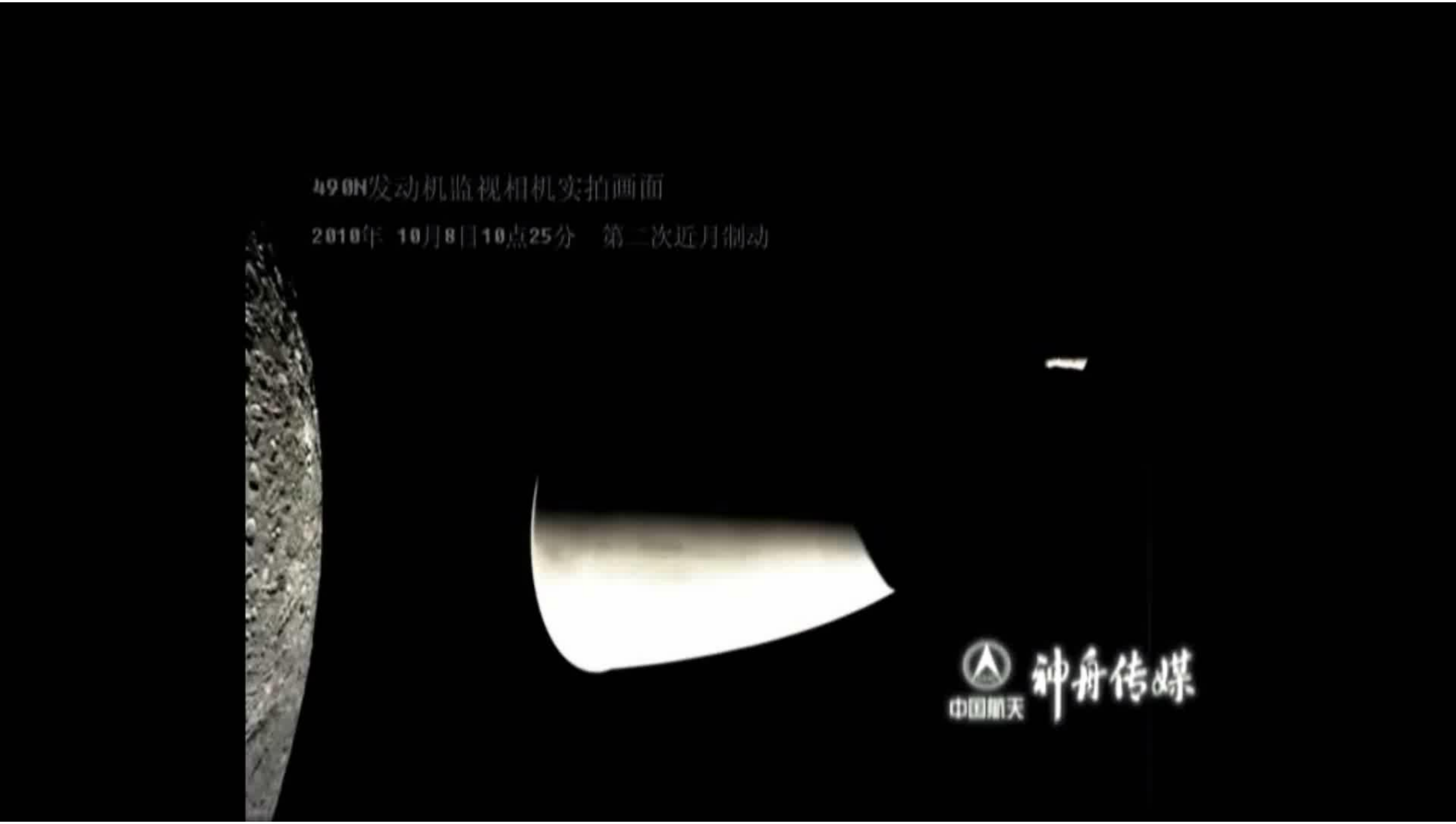
2009年诺贝尔物理奖

Willard S. Boyle

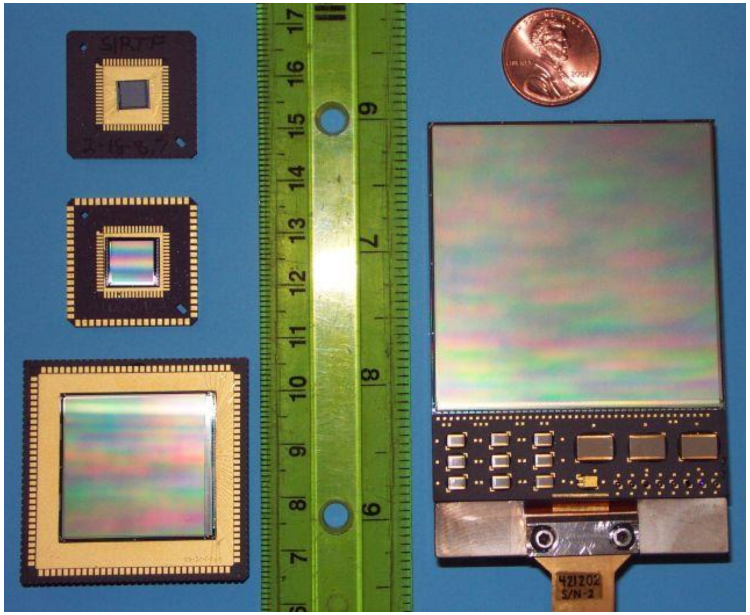
George E. Smith

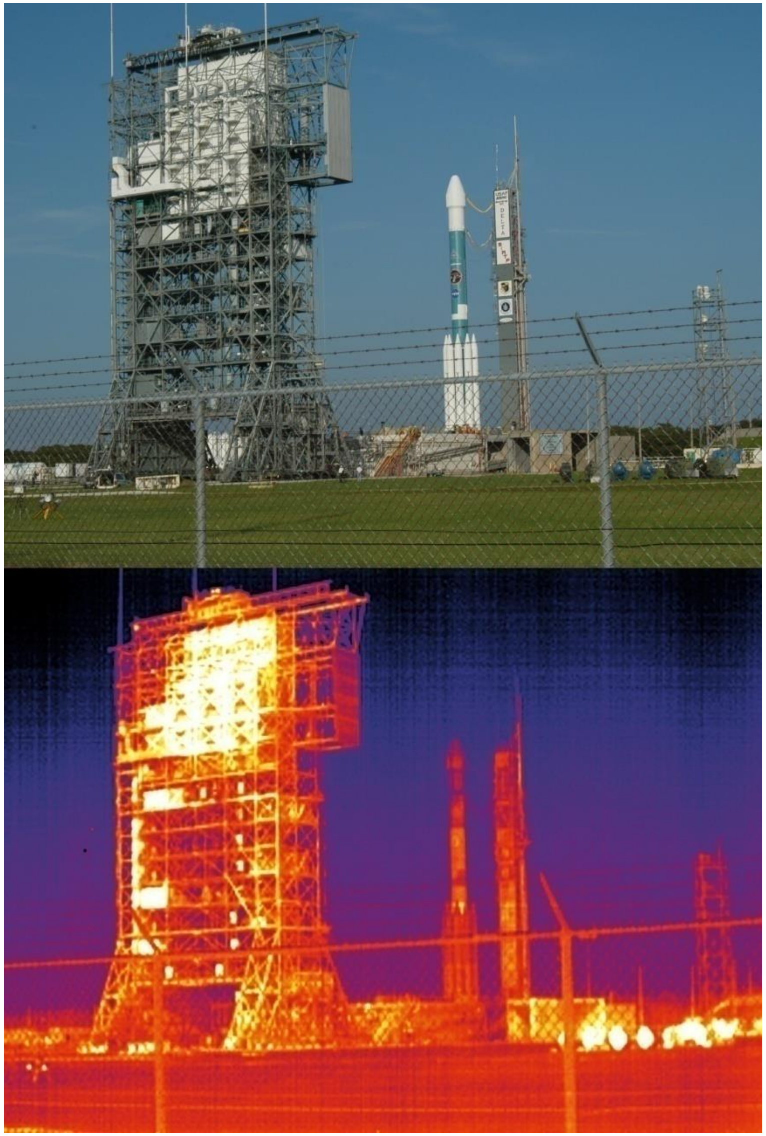
Bell Laboratories 1969

for the invention of an imaging semiconductor circuit – the CCD sensor"


490N发动机监视相机实拍画面
2010年 10月8日10点25分 第二次近月制动
中国航天
神舟传媒

- Infrared array detector



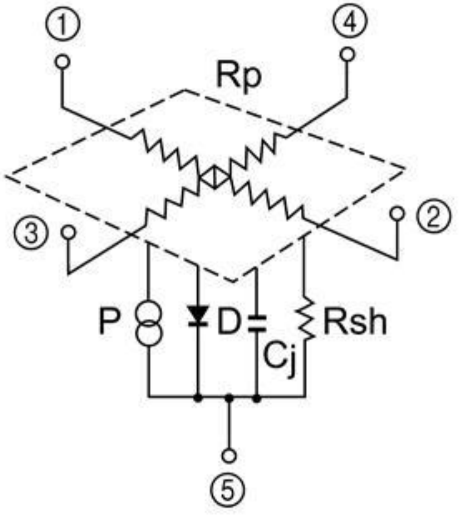


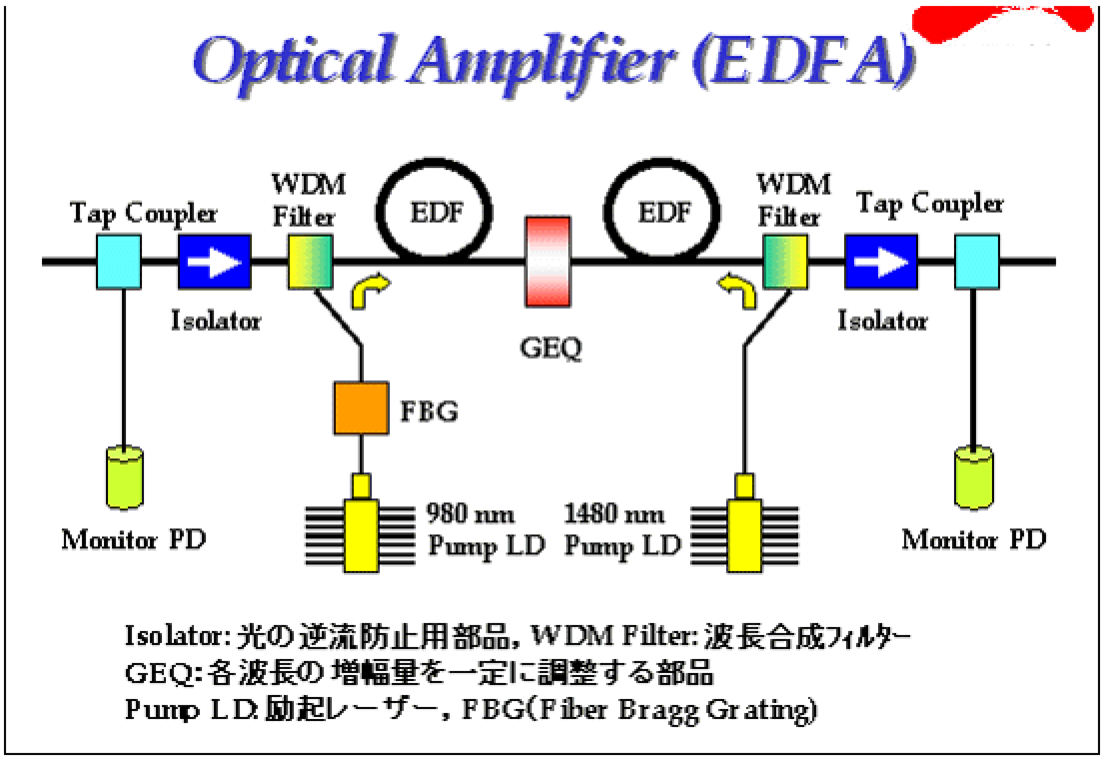
Photodiode & PIN

- **PIN** InGaAs

- PSD

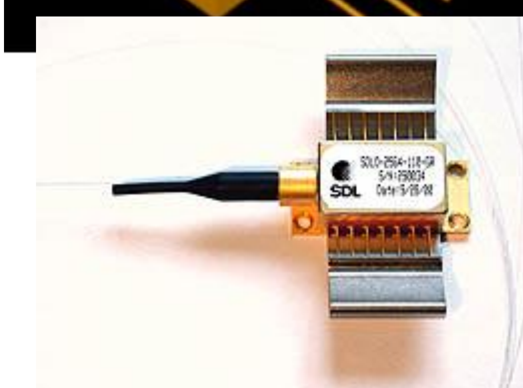
Position Sensitive Device




Optical Amplifier (EDFA)
Tap Coupler
Isolator
WDM Filter
EDF
GEQ
EDF
WDM Filter
Isolator
Tap Coupler
FBG
Monitor PD
980 nm Pump LD
1480 nm Pump LD
Monitor PD
Isolator: 光の逆流防止用部品, WDM Filter: 波長合成ﾌｨﾙﾀｰ
GEQ: 各波長の増幅量を一定に調整する部品
Pump LD: 励起レーザー, FBG(Fiber Bragg Grating)

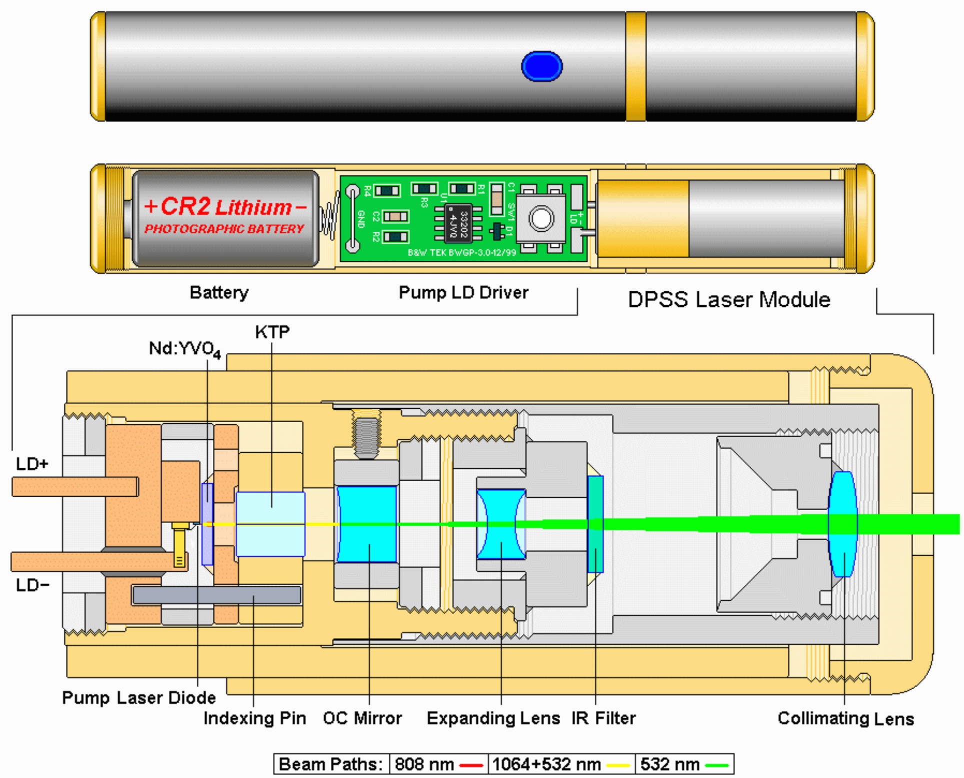

EDFAst


fiber
ferrule
thermistor
clip
substrate
PD
LD


SDL

Nonlinear optics and crystal

- Double frequency
- 3rd frequency
- We can almost get all the laser in any wavelength we like.
- Laser pointer



Edmund Scientific L54-101 Green DPSS Laser Pointer

Reference text books

- B. H. Salsh: ***Fundamental of photonics***
- W. Koechner: Solid-State Laser Engineering (Spring Verlag, 1999)
- A.E. Siegman: Lasers (University Science Books, 1986)
- W.T. Silfvast: Laser Fundamentals (Cambridge University Press, 1996)
- 克希耐尔，固体激光工程，科学出版社 2002
- 马养武，光电子学，浙江大学出版社，2001
- Self-edit textbook, 光电子学 (ver.2) 2011.2

http://opt.zju.edu.cn/optelec/index.php

The background industries of OEs

- Industry of laser
- Optical communication
- Display industry
- Imaging Industry
- Photo-detectors industry

The schedule of the course

- Times： two short terms, 3hs/week
- Home works: after each course
- Mid term examination: 28th April
- 2 projects

  visit :

  http://opt.zju.edu.cn/optelec/index.php
- Final exam: End of June.


光电子学 - Windows Internet Explorer
http://opt.zju.edu.cn/optelec/
文件(F) 编辑(E) 查看(V) 收藏夹(A) 工具(T) 帮助(H)
收藏夹 光电子学
光电子学
Optoelectronics
光电系网络课程
返回平台
课程首页 Index
理论教学 Course Intro
实践教学 Online Course
课程练习 Course Exercise
教学资源 Resource
课程建设 Course Development
光电百科 Encyclopedia
通知公告Announcement
刘旭/李海峰教授... [2011-06-19]
光电子学复习提纲 [2011-06-17]
关于光电子课后作业 [2011-03-11]
刘旭教授光电子学... [2011-03-03]
光电子课程建议以... [2010-06-17]
more
用户登录User Login
课程简介Course Description
本课程将给予学生在光电子学领域的专业教育与训练，要求学生掌握半导体物理的概念、激光振荡和放大的理论、激光技术、波导和光纤的基本特性、非线性光学基本理论，以及典型光电器件和光电系统的特性。通过物理概念和工程应用实例的介绍，以及课后的实践教学，培养学生综合分析、解决问题和动手的能力，为将来从事光电技术领域的科研、开发和应用工作奠定知识基础。
系网上的本课程正在建设中，当前学习用户可参考原课程网站：
快捷通道Fast Channel
作业互动
实验互动
网络课件
下载中心
交互园地
实验预约
9:00
2012/2/16

2018全国大学生光电竞赛

- **竞赛题目1：穿透毛玻璃的可见光成像系统**
- 竞技重点：

  在复杂介质成像过程中提取图像信息的能力。
- 竞赛说明：

  使用CMOS或者CCD成像系统透过毛玻璃对目标物体成像。
- 竞赛规则：

使用自行设计的CMOS或CCD成像系统，透过毛玻璃对目标物体成像。毛玻璃与目标物之间不可添加任何光学元件和照明光源。目标物体为打印在透明胶片上的5种字号的黑色“E”字符，每种字号的“E”有多个随机朝向。目标物体距离毛玻璃板5cm。

2018全国大学生光电竞赛

- **竞赛题目2：** 光电“寻的”竞技车
- 竞技重点：

  大视场目标快速捕获及定位的能力。
- 竞赛说明：

设计一辆光电“寻的”竞技车，要求能够从指定位置出发，快速搜寻场地周边的随机点亮的信号灯。信标灯（LED灯）亮灯顺序随机，且每个灯被灭后不再亮起。比赛过程中，两参赛队同时发车，竞争到达点亮的信标灯前，当某车抵达点亮的信号灯前后，信号灯随即熄灭。在此过程中，允许己方参赛车自主干扰对方的参赛车去争夺信标灯，为自己的赛车赢得更多的机会。

课程思考

- 光电子学包含的范围？
- 激光器对人类发展的贡献？
- 如何能够做到将激光的波长覆盖全光谱？
- 光电探测器的主要实现光－电的转换，如何实现 光－光的转换与控制
- 除光电转换外，人类对光的控制与利用还有其他的形式吗？效果如何？