1. Introduction to Laser Physics

Logistics

What is a laser?

A brief history of lasers

Short tour of different types of lasers

What is a laser?

- Acronym: LASER

"Light Amplification by Stimulated Emission of Radiation" coined by Gould 1959

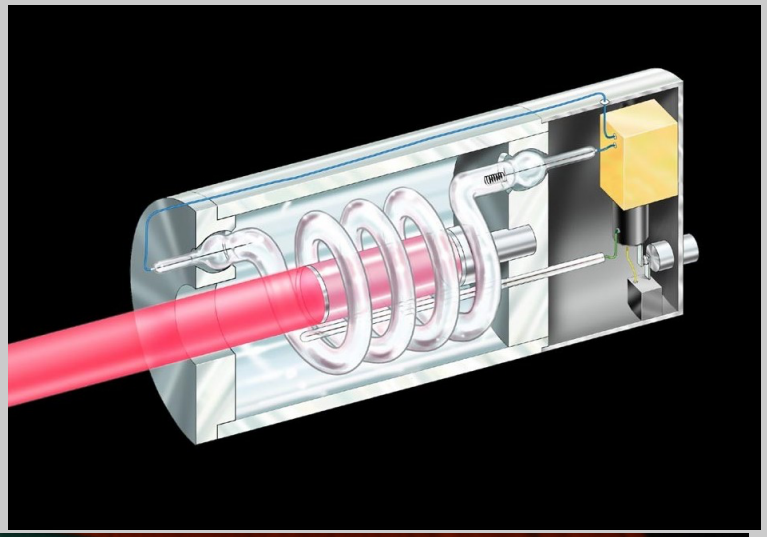
- Milestones:
  - 1900 Planck: light energy is proportional to the frequency, comes in packets, or "quanta" (photons)
  - 1917 Einstein: proposes the process of stimulated emission
  - 1954 Townes: ammonia MASER
  - 1957 Schawlow/Townes: propose idea of making an IR or visible version

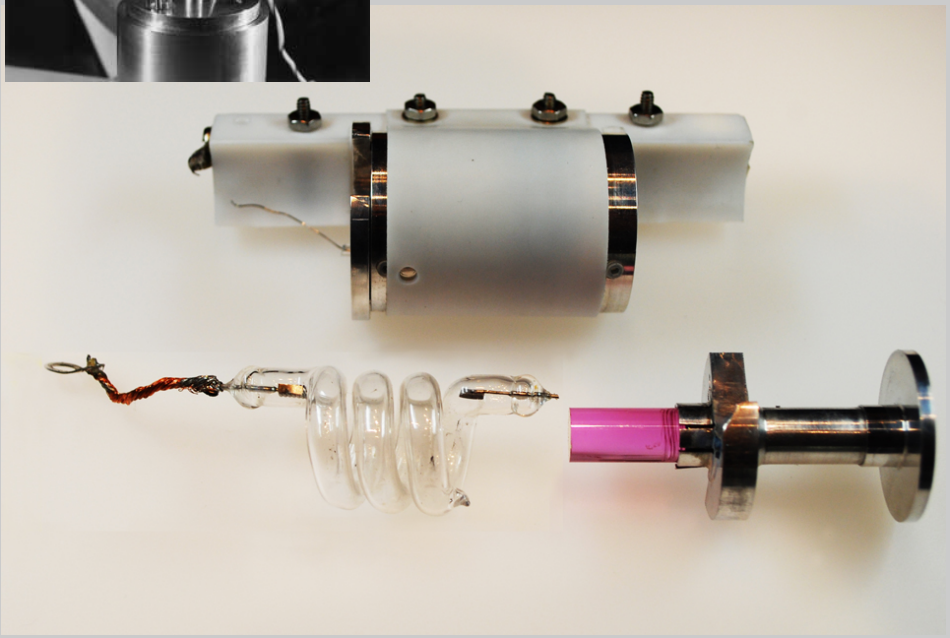
http://www.photonics.com/Article.aspx?AID=42279

http://physics.aps.org/story/v15/st4

Invention of a working laser

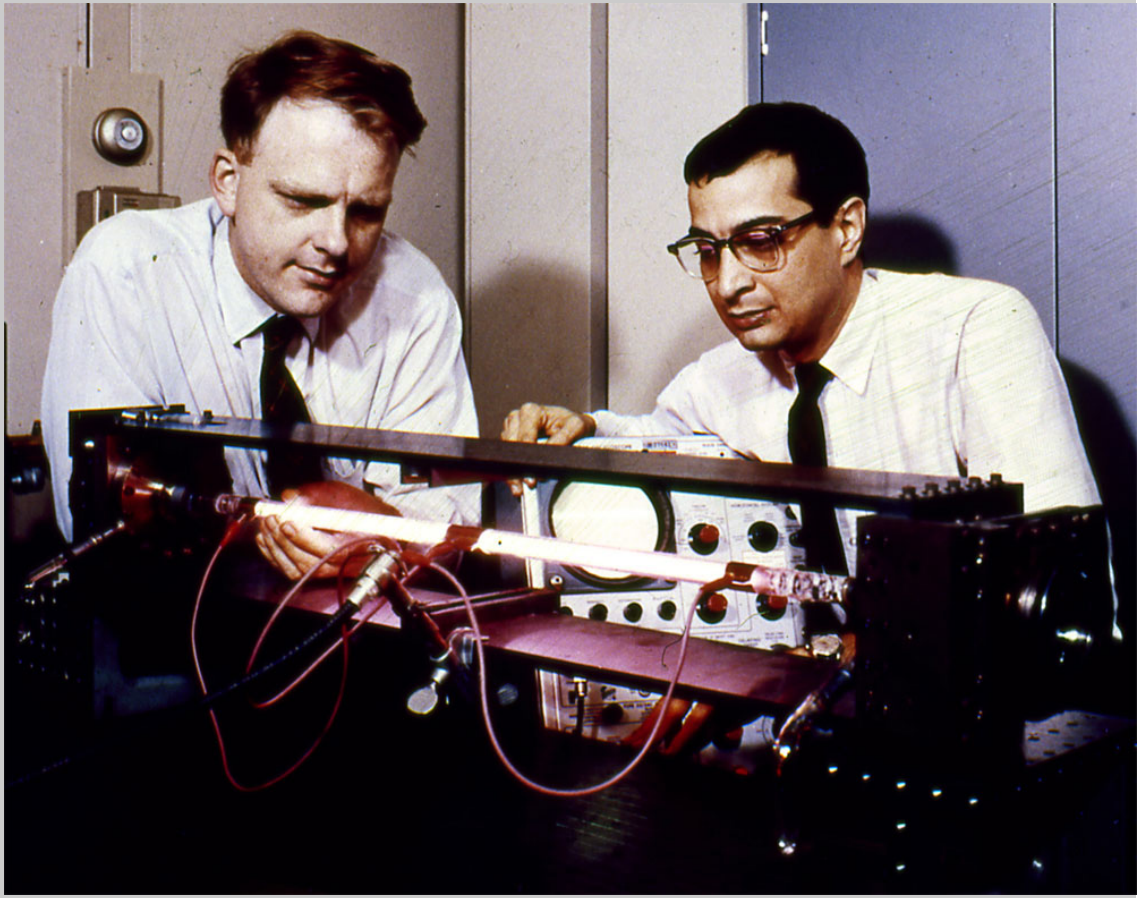
- 1960 Theodore Maiman (Hughes Research Labs)





HeNe laser

- 1960 Ali Javan, William Bennett (Bell Labs)
  - A few months after the ruby laser
  - First CW laser
  - 1.15 um



http://physics.aps.org/story/v26/st24

Further milestones

- 1960 Peter Sorokin: U:CaF_2, Sm:CaF_2
- 1961 Hellwarth: Q-switched ruby laser (“giant pulse”)
- Snitzer: Nd:glass laser
- 1962 Robert Hall: injection semiconductor laser
- 1963 first mode-locked laser
- 1964 Kumar Patel: CO2 laser
- Geusic: Nd:YAG laser
- Argon ion laser

Birth of nonlinear optics

- Peter Franken: observation of second harmonic light

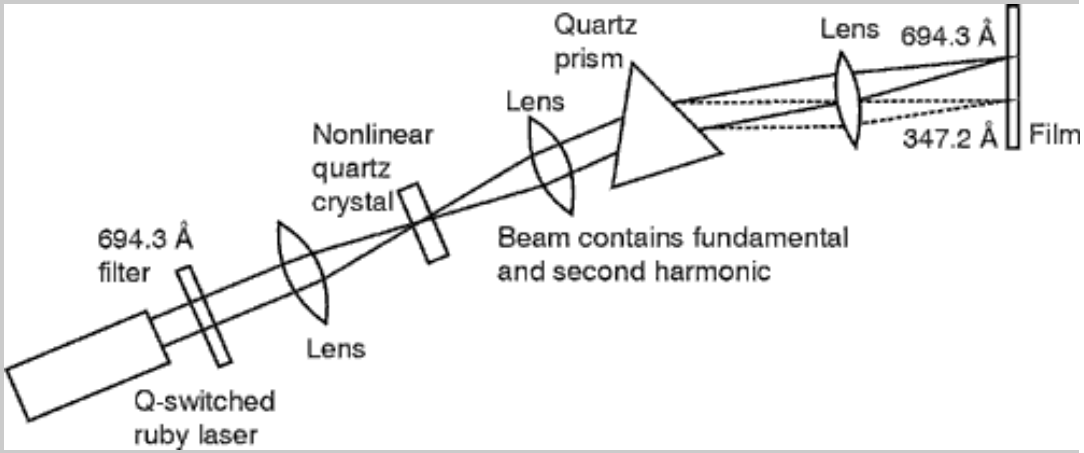


FIG. 1. A direct reproduction of the first plate in which there was an indication of second harmonic. The wavelength scale is in units of 100 A. The arrow at 3472 A indicates the small but dense image produced by the second harmonic. The image of the primary beam at 6943 A is very large due to halation.

http://www.nature.com/milestones/milephotons/full/milephotons10.html

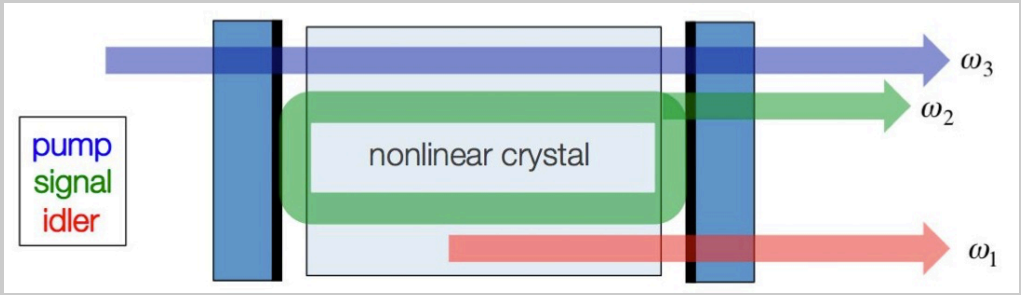
Spectral range of lasers

- Microwave: ammonia maser
- Far IR: CO2, other molecules
- Mid IR: quantum cascade
- Near IR: Nd:YAG, Ti:sapphire
  - Other rare-earth (lanthenides): Er, Ho, Yb, Tm, Tb
  - Diode lasers
- Visible:
  - dye
  - gas discharge: Ar, Kr ion, HeNe HeCd, Cu vapor
- UV: excimer lasers XeCl, ArCl, KrF…
- X-ray: laser plasma

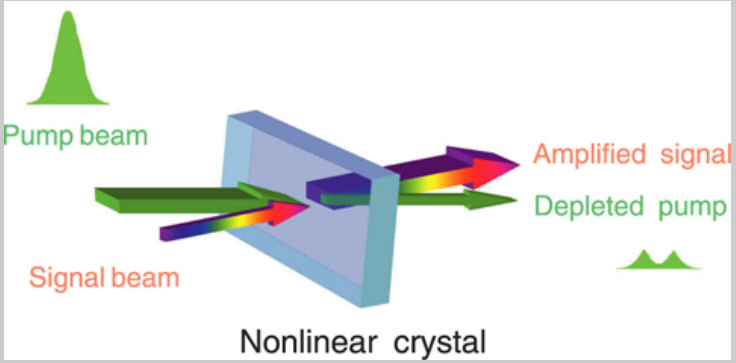
Nonlinear frequency conversion

- With nonlinear optics, we are not forced to find lasers operating directly at the desired wavelength
- Harmonic conversion: frequency doubling, mixing

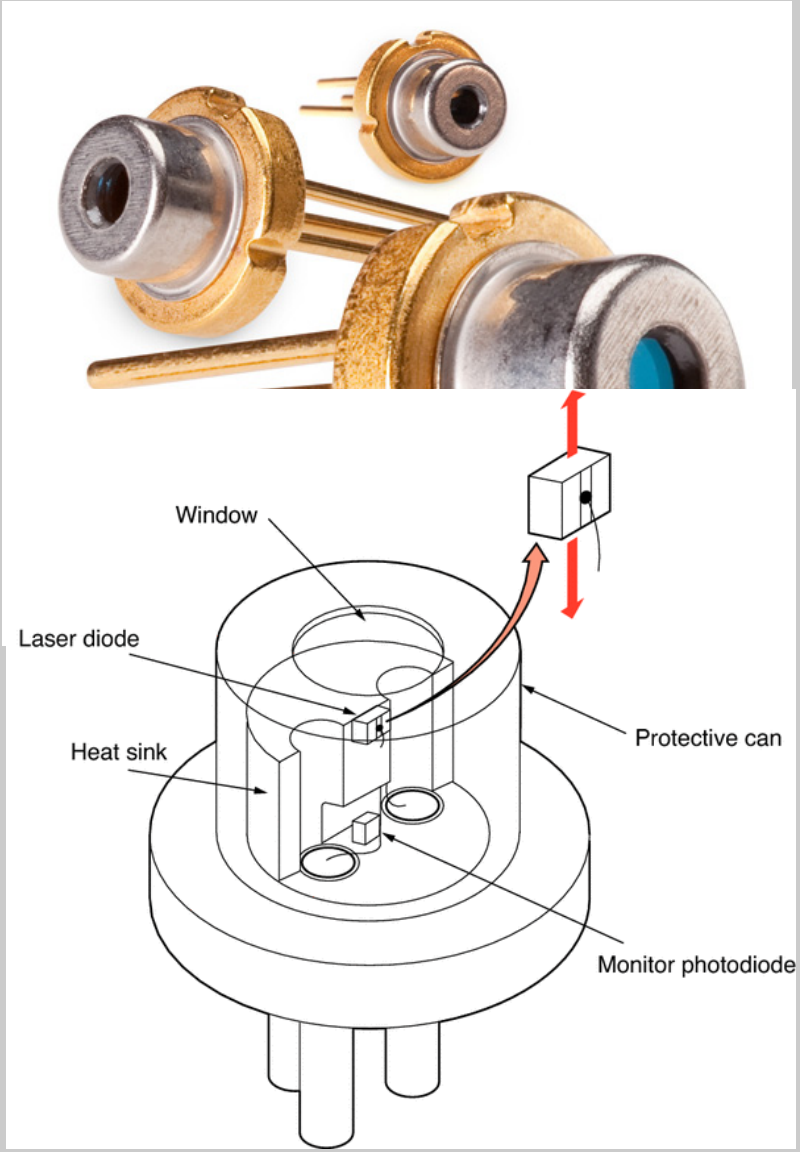
- Optical parametric oscillator (OPO)

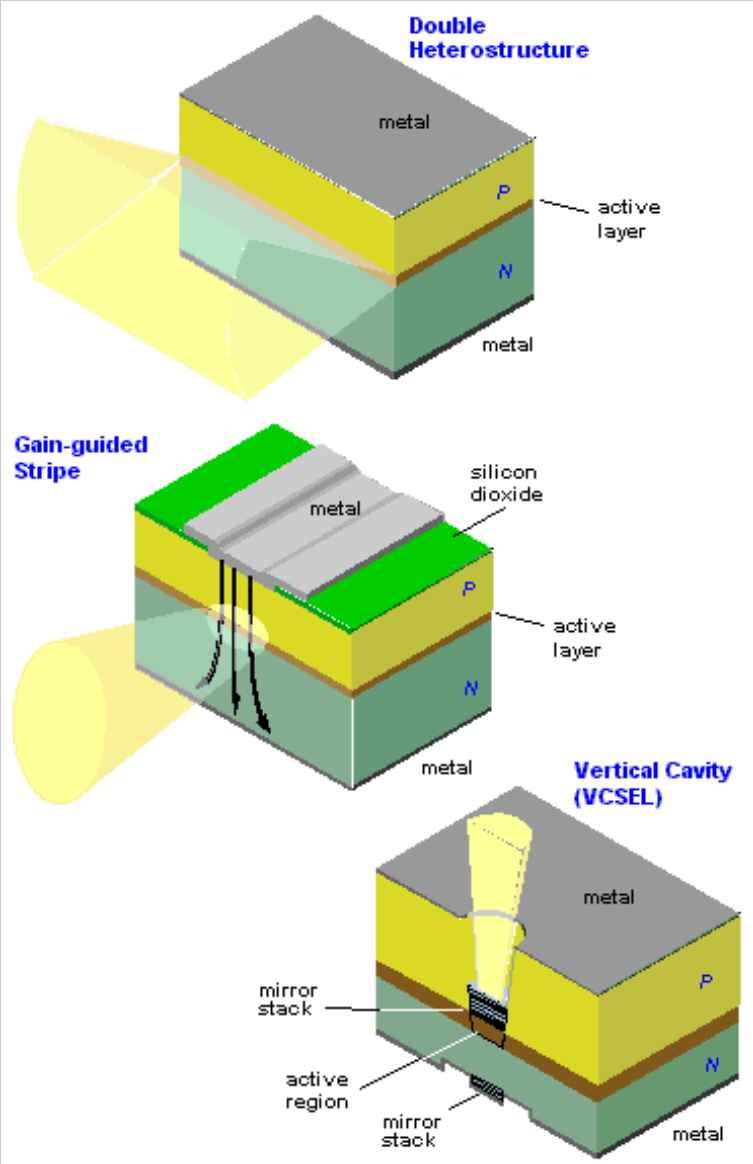


- Optical parametric amplifier (OPA)

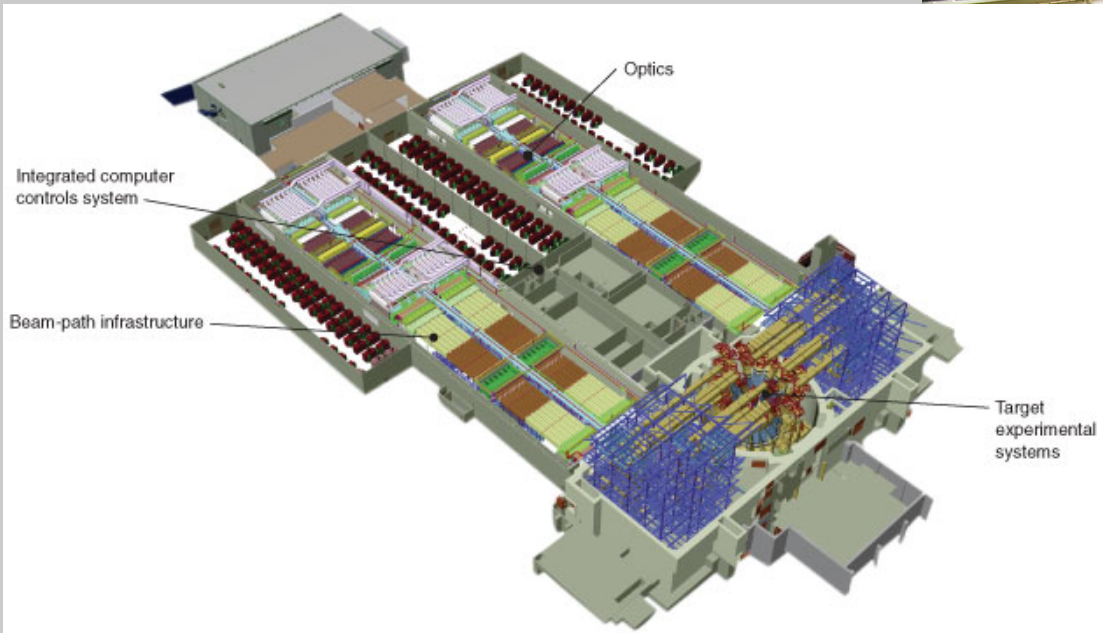


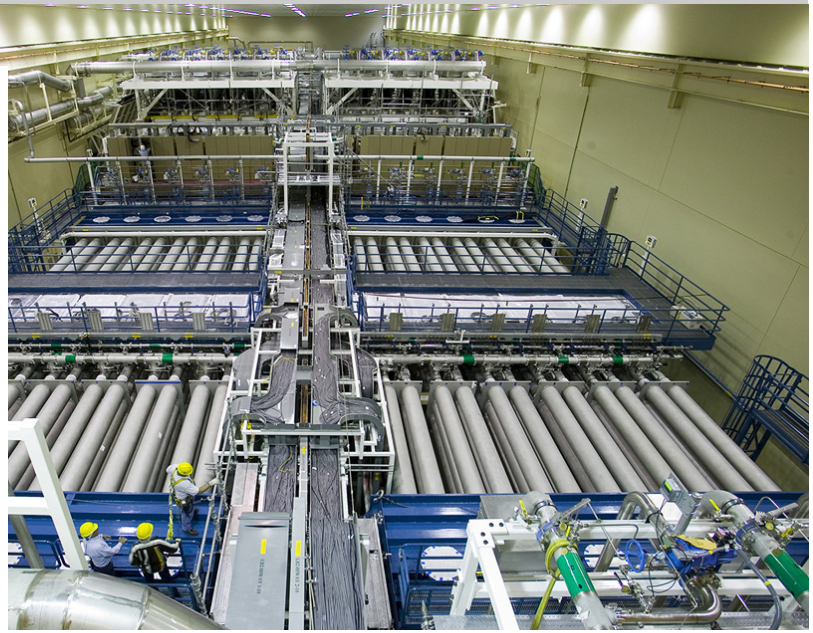
Small

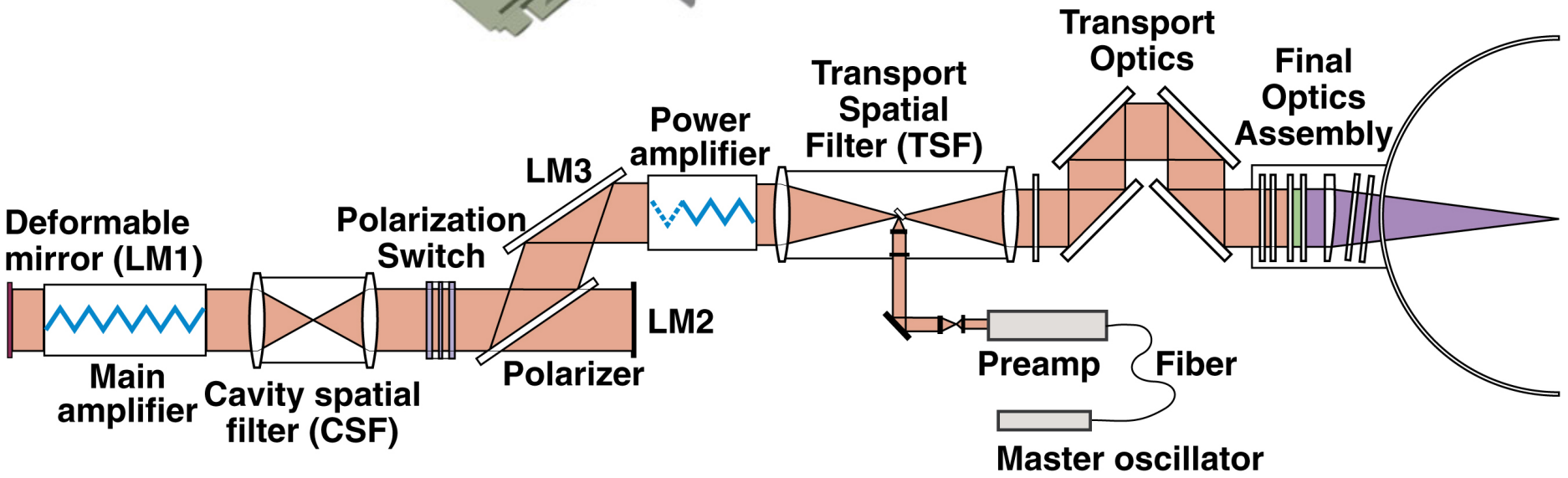

Window
Laser diode
Heat sink
Protective can
Monitor photodiode


Double Heterostructure
metal
P
active layer
N
metal
Gain-guided Stripe
silicon dioxide
metal
P
active layer
N
metal
Vertical Cavity (VCSEL)
metal
mirror stack
P
N
active region
mirror stack
metal

large

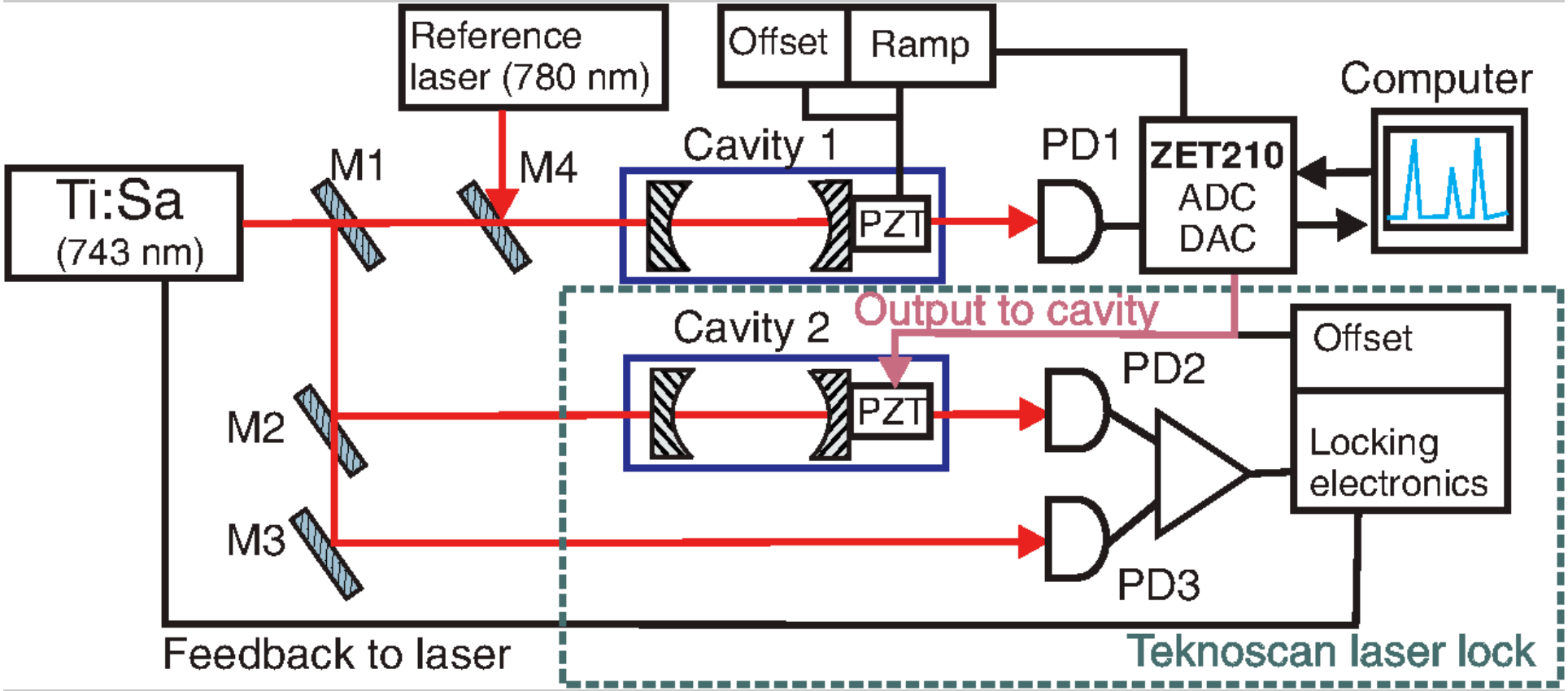

Optics
Integrated computer controls system
Beam-path infrastructure
Target experimental systems




Transport Optics
Final Optics Assembly
Transport Spatial Filter (TSF)
Power amplifier
LM3
Deformable mirror (LM1)
Polarization Switch
LM2
Main amplifier
Cavity spatial filter (CSF)
Polarizer
Preamp
Fiber
Master oscillator

Linewidth

- Ultrastable lasers ~ Hz linewidth

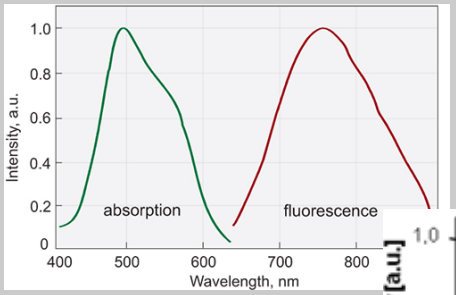


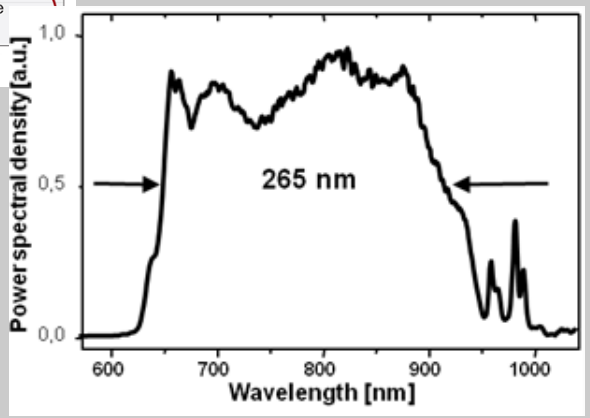
Pulsed operation

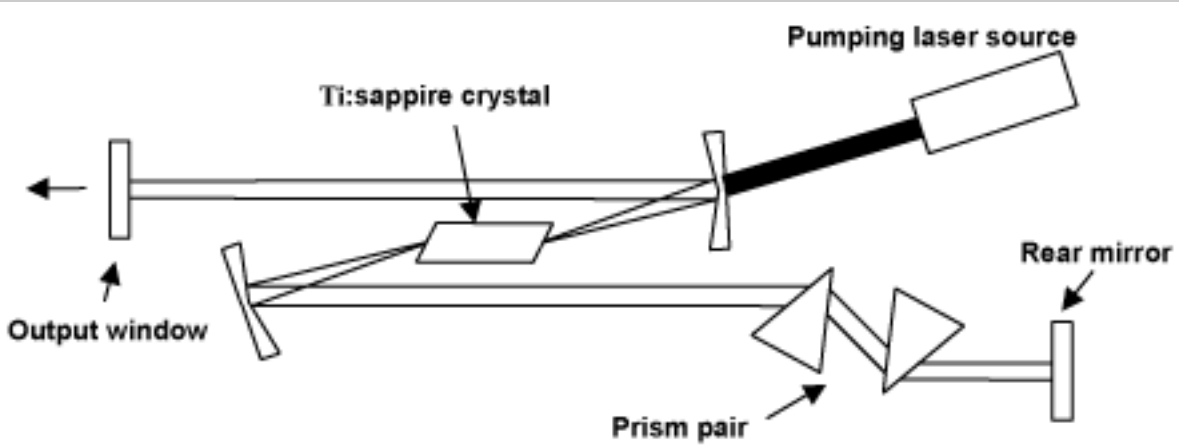
- Quasi-CW
- Gain switching
- Q-switching
- Active mode-locking
- Passive mode-locking
- Chirped pulse amplification
- Nonlinear pulse compression

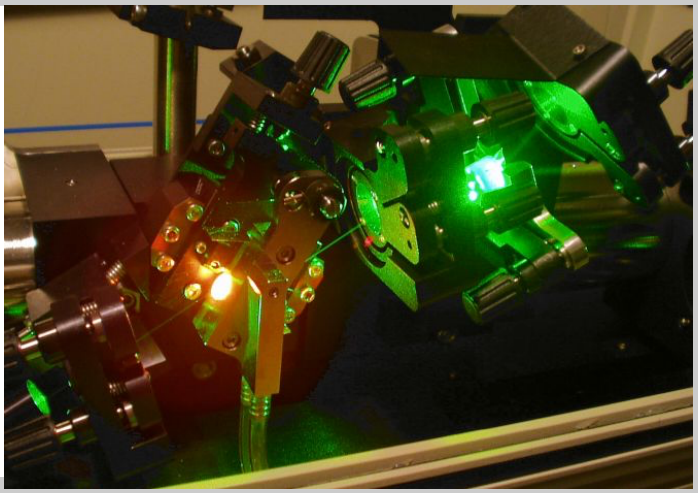
Broadbandwidth/ultrashort pulses

- Get the laser to run with wide bandwidth
- Synchronize all frequency components
- Align all frequency components
- Ultrashort pulse



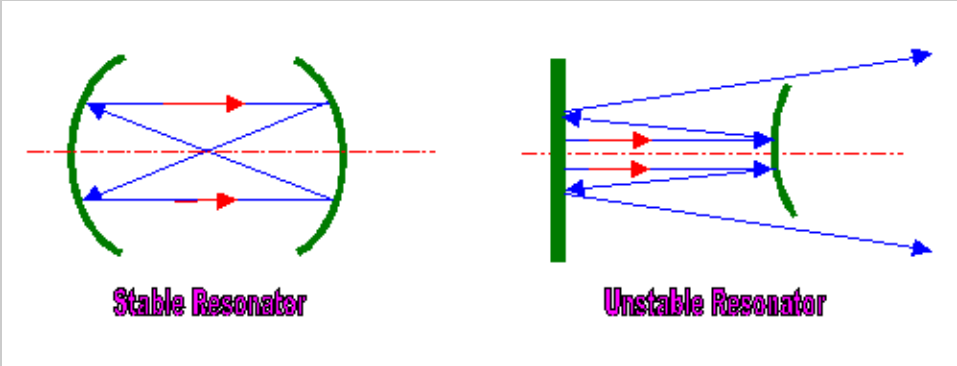


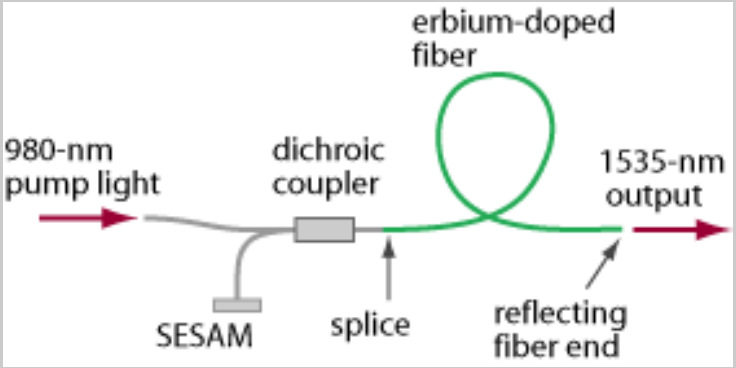


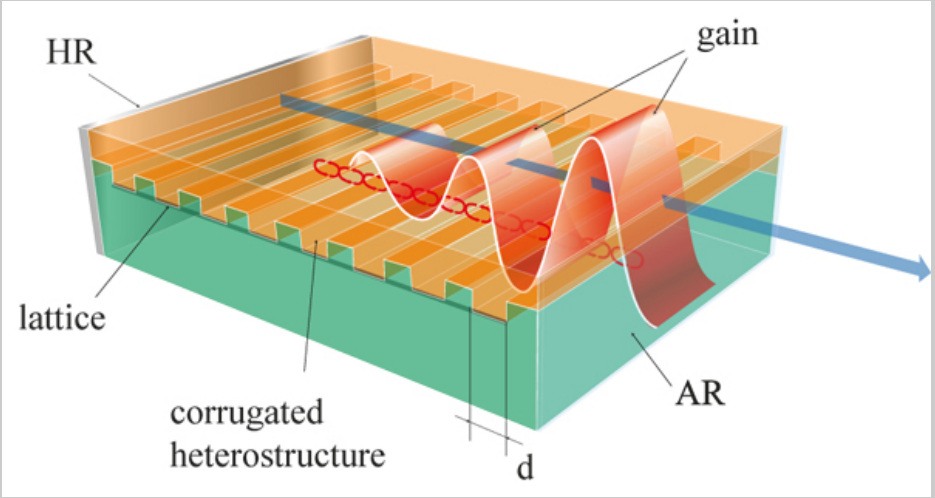


Resonators

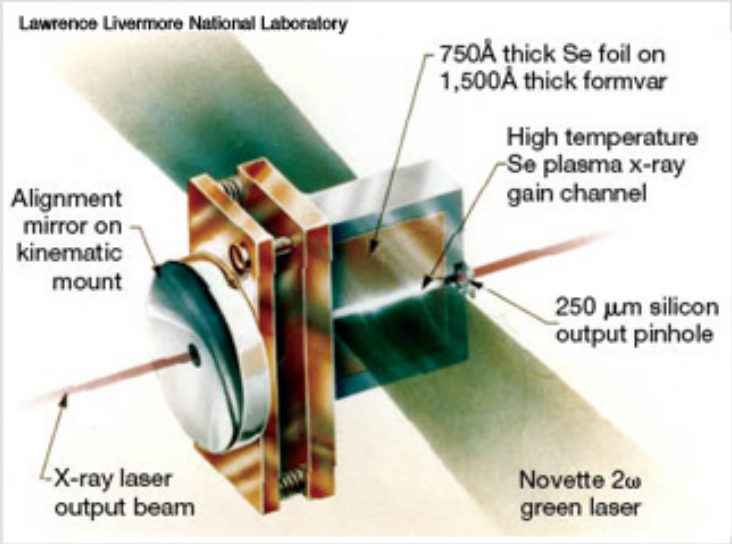
- Give feedback to help build up laser oscillation







Distributed feedback laser



X-ray laser: no cavity