

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

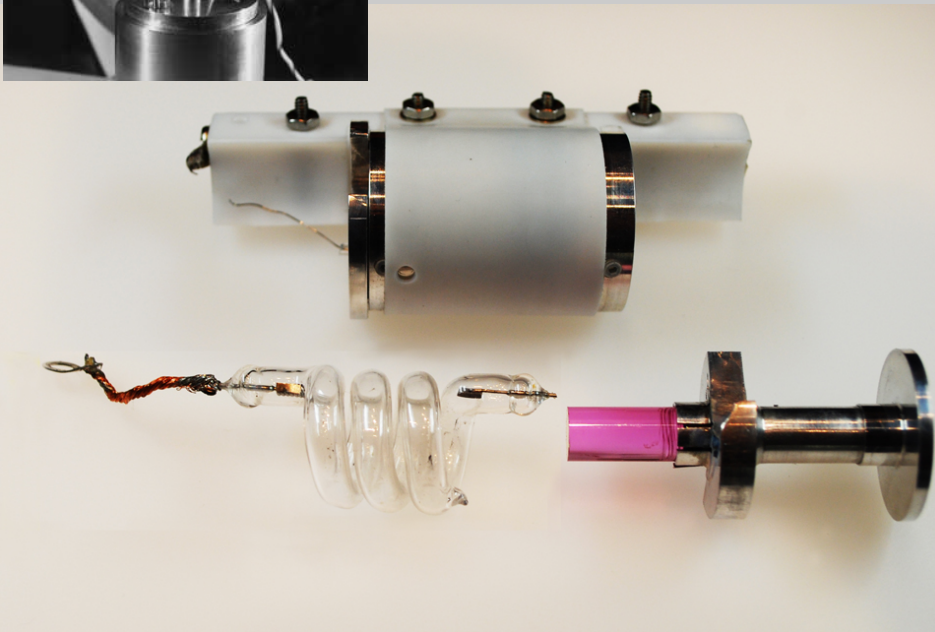
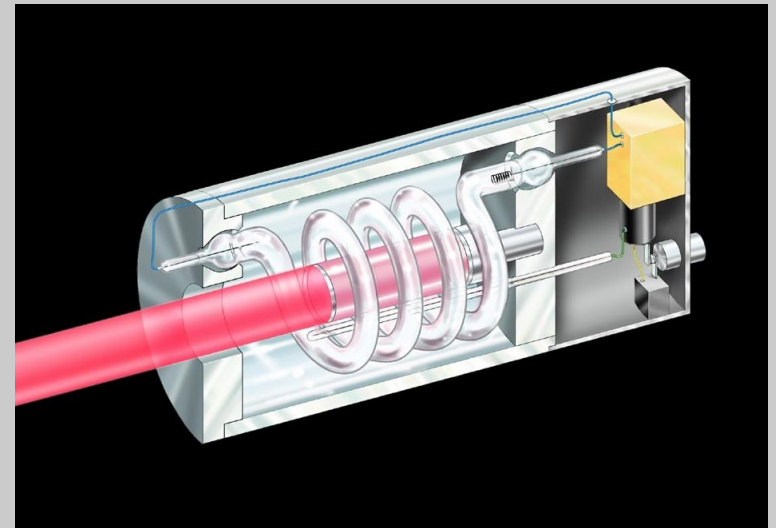
- Milestones:
 - 1900 Planck: light energy is proportional to the frequency, comes in packets, or “quanta” (photons)
 - 1917 Einstein: proposes the process of stimulated emission
 - 1954 Townes: ammonia MASER
 - 1957 Schawlow/Townes: propose idea of making an IR or visible version

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

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

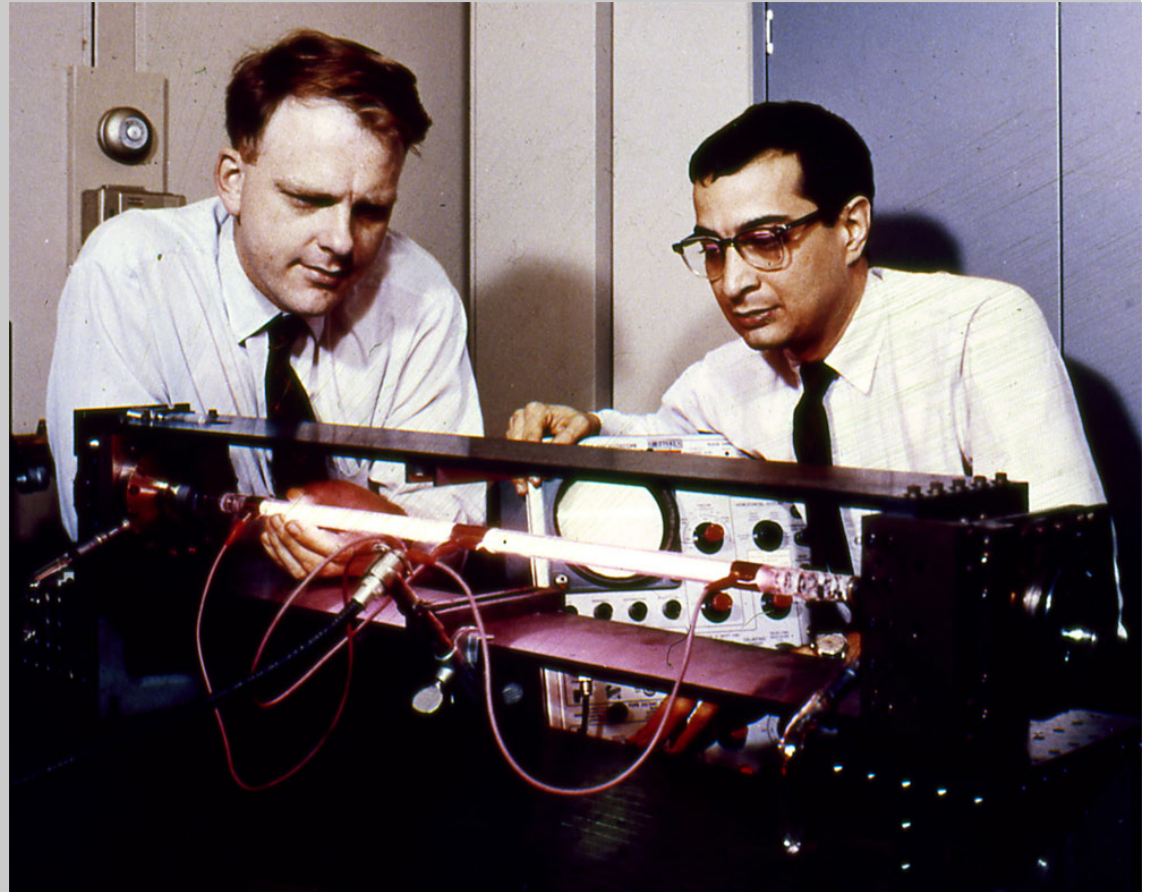
Invention of a working laser

- 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 μm



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

Further milestones

- 1960 Peter Sorokin: U:CaF₂, Sm:CaF₂
- 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

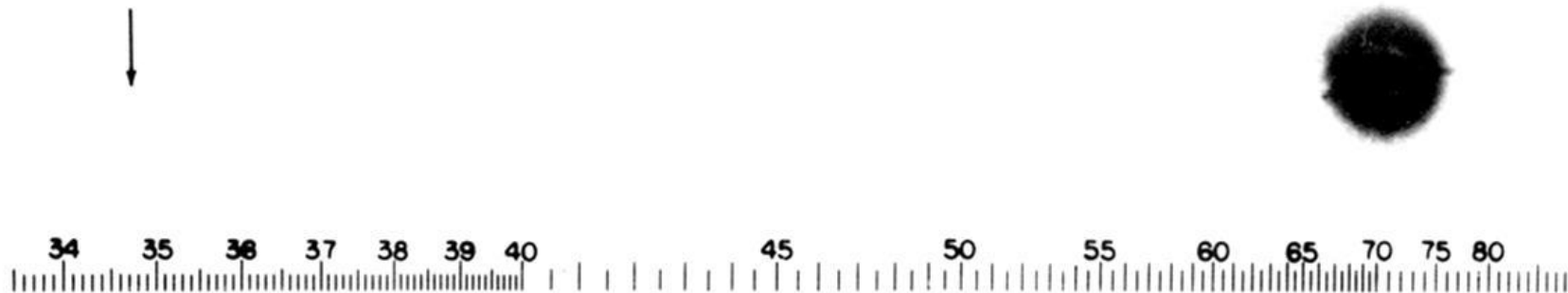
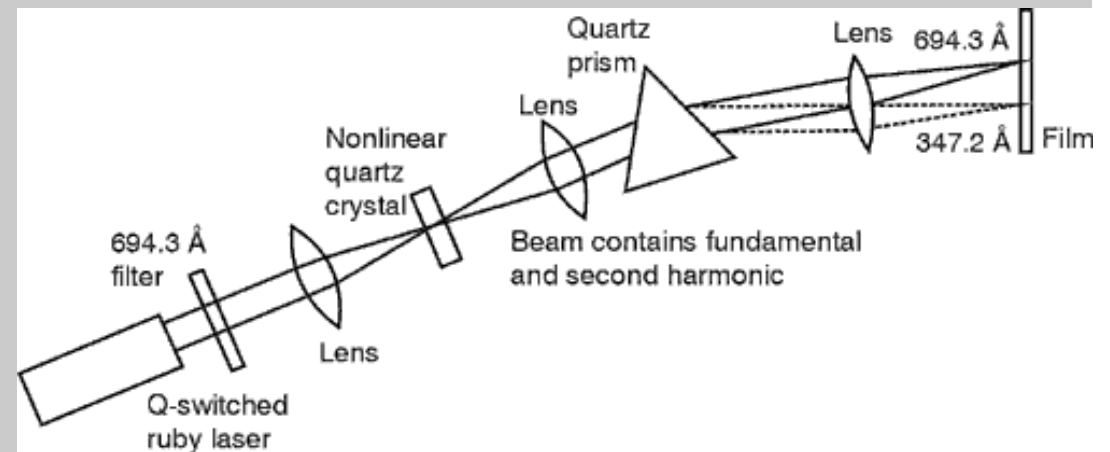


FIG. 1. A direct reproduction of the first plate in which there was an indication of second harmonic. The wavelength scale is in units of 100 Å. The arrow at 3472 Å indicates the small but dense image produced by the second harmonic. The image of the primary beam at 6943 Å is very large due to halation.

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

Spectral range, types of lasers

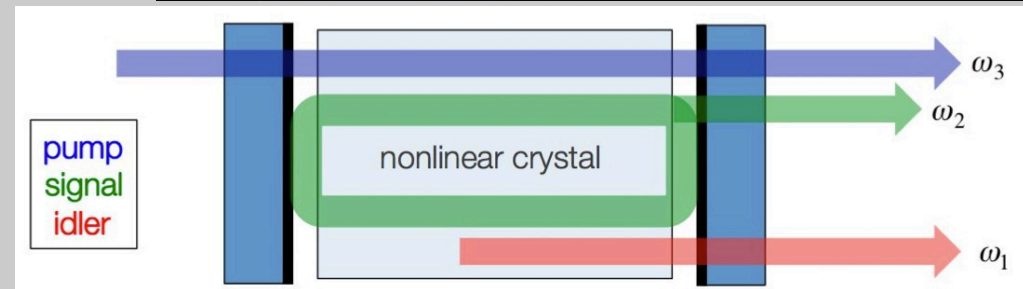
- Microwave: ammonia maser
- Far IR: CO₂, other molecules
- Mid IR: quantum cascade
- Near IR: Nd:YAG, Ti:sapphire
 - Other rare-earth (lanthanides): Er, Ho, Yb, Tm, Tb
 - Diode lasers
- Visible:
 - dye
 - gas discharge: Ar, Kr ion, HeNe HeCd, Cu vapor
- UV: excimer lasers XeCl, ArCl, KrF...
- X-ray: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

Nonlinear frequency conversion

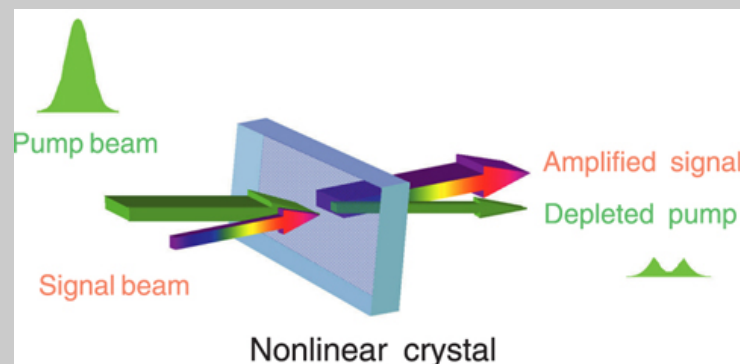
- With nonlinear optics, we are not forced to find lasers operating directly at the desired wavelength
- Harmonic conversion: frequency doubling, mixing



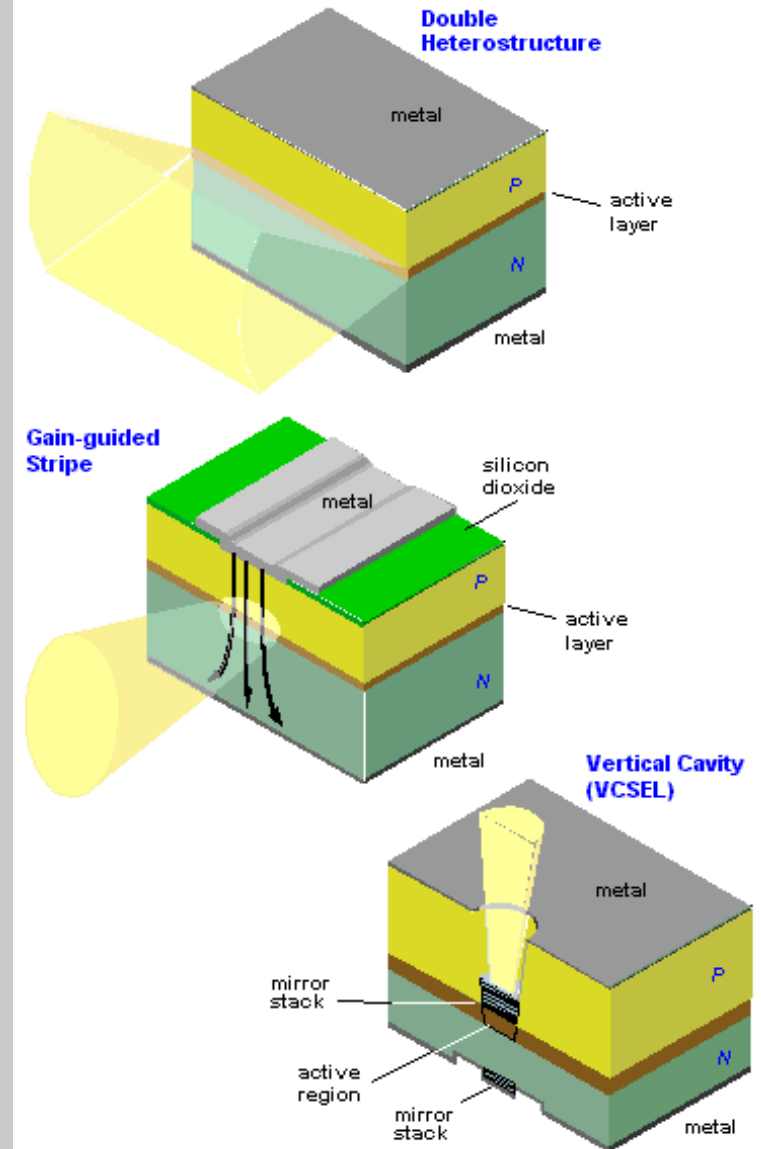
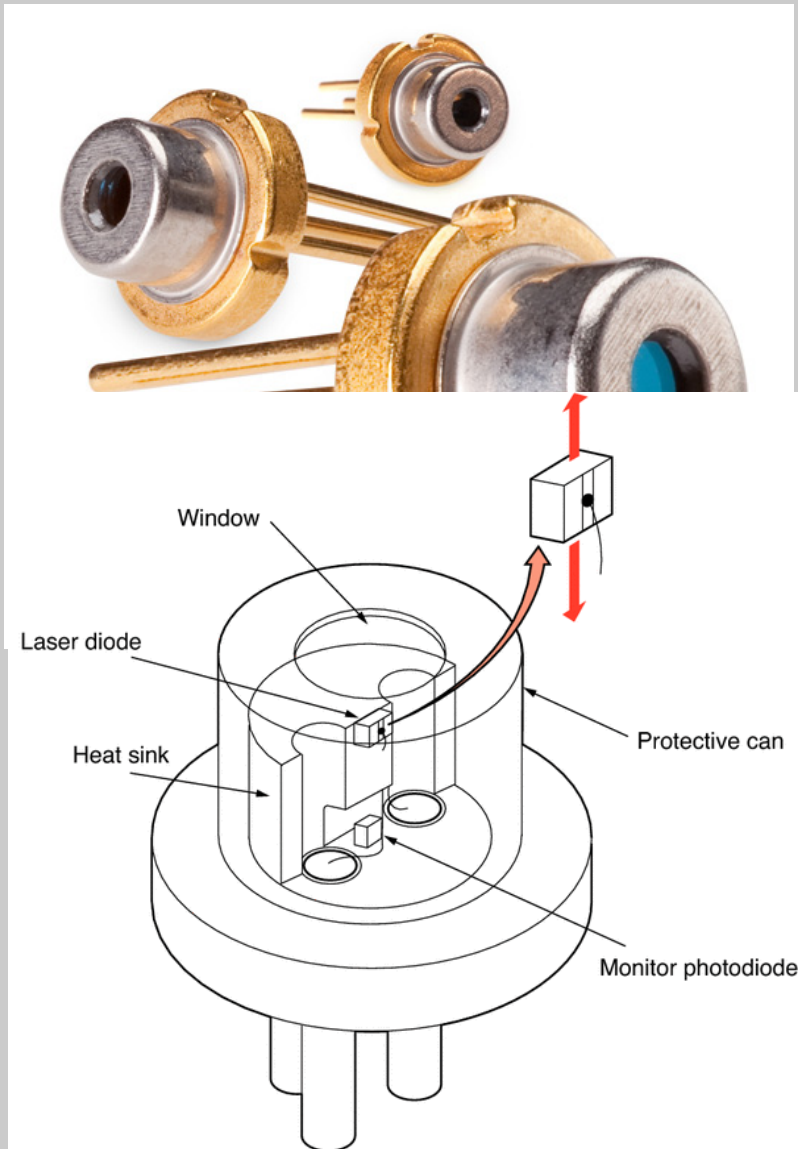
- Optical parametric oscillator (OPO)



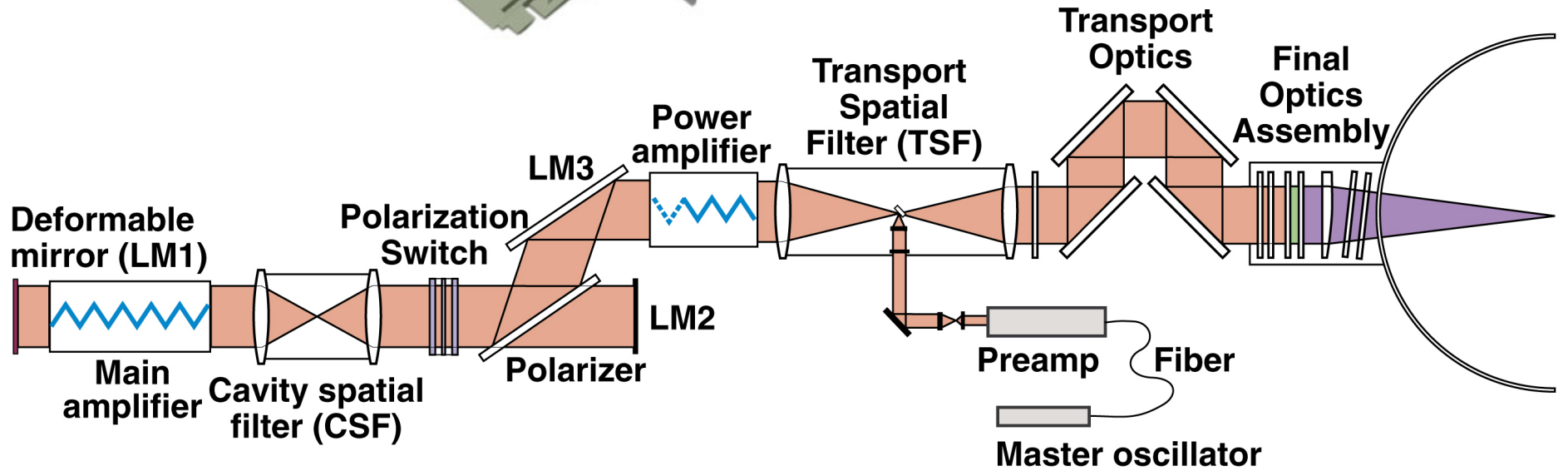
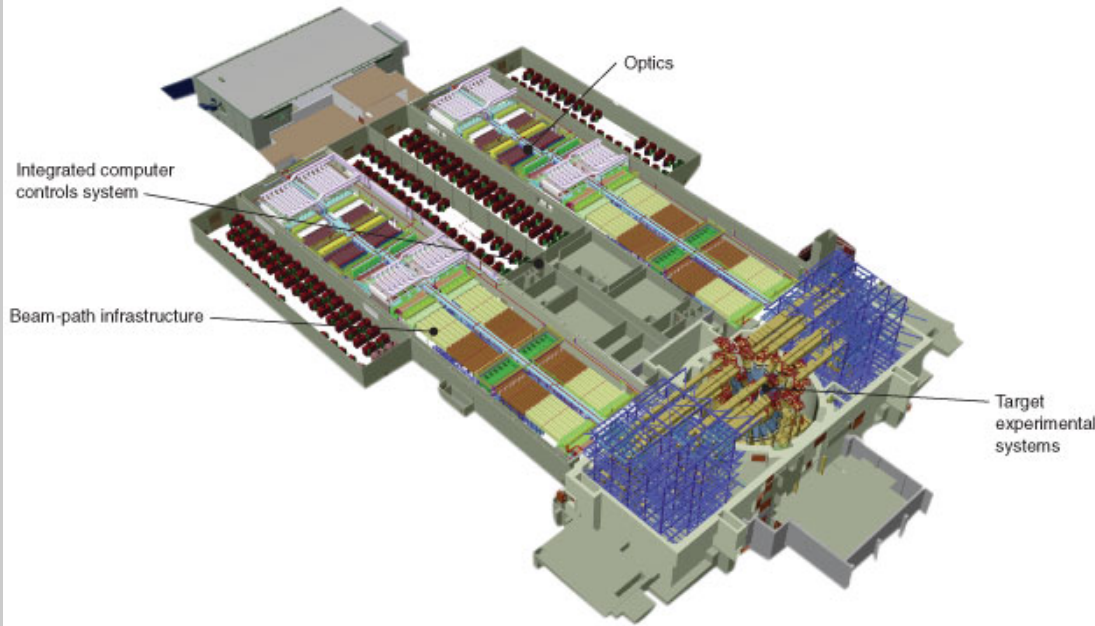
- Optical parametric amplifier (OPA)



Small

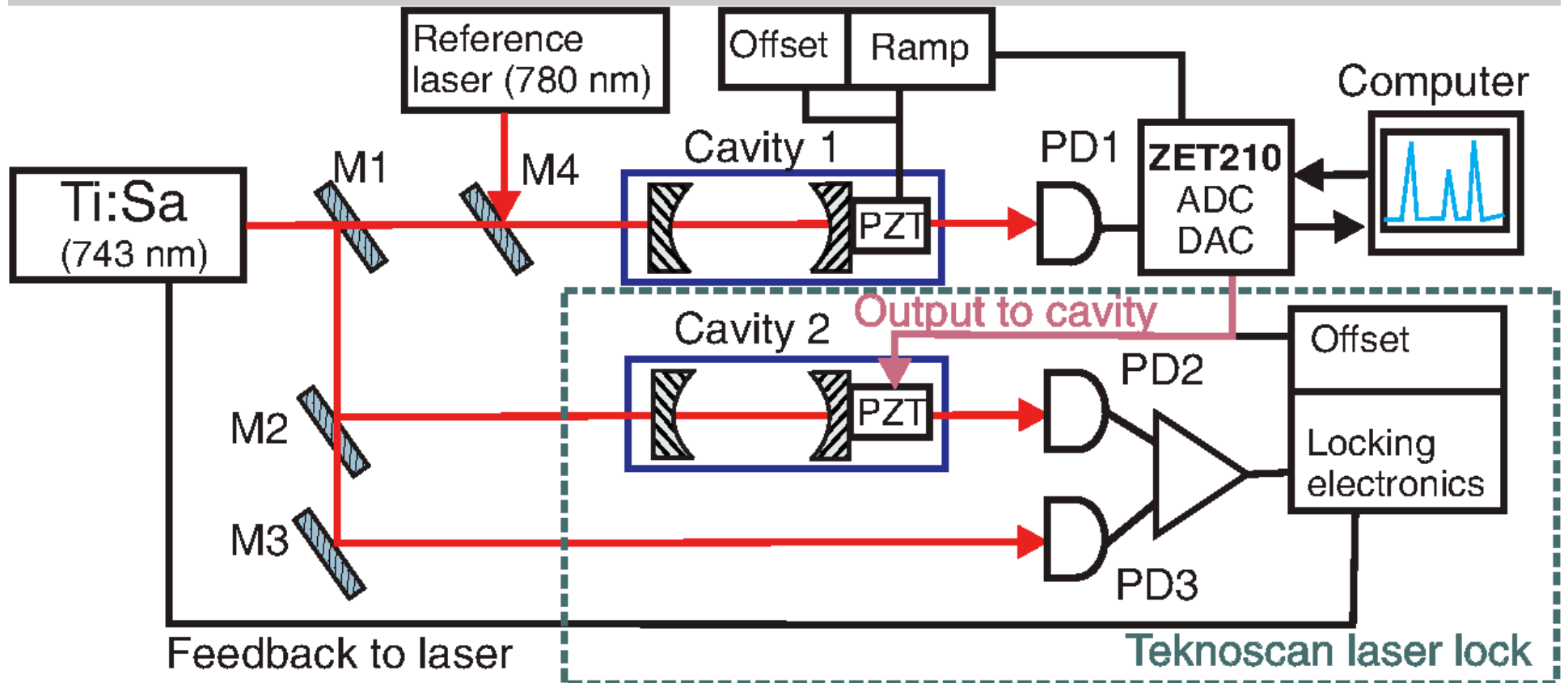


large



Linewidth

- Ultrastable lasers ~ Hz linewidth

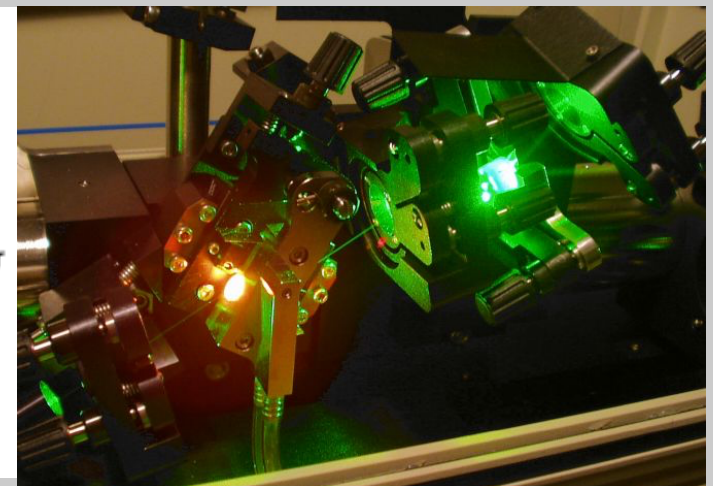
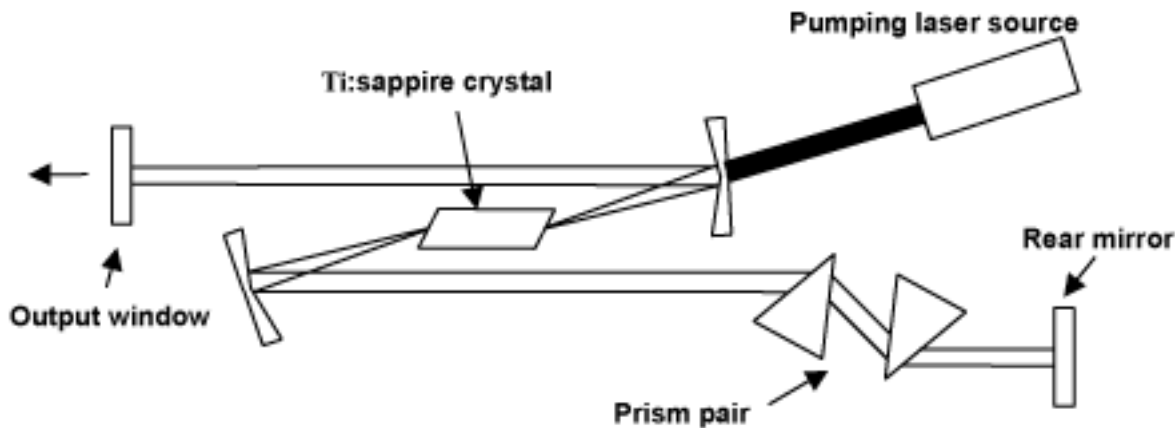
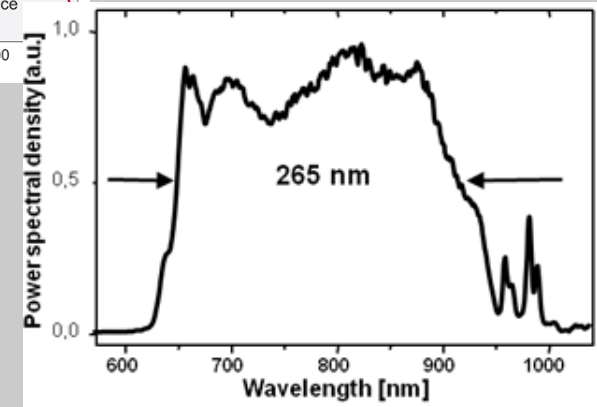
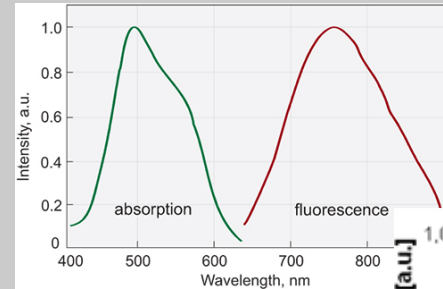


Pulsed operation

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

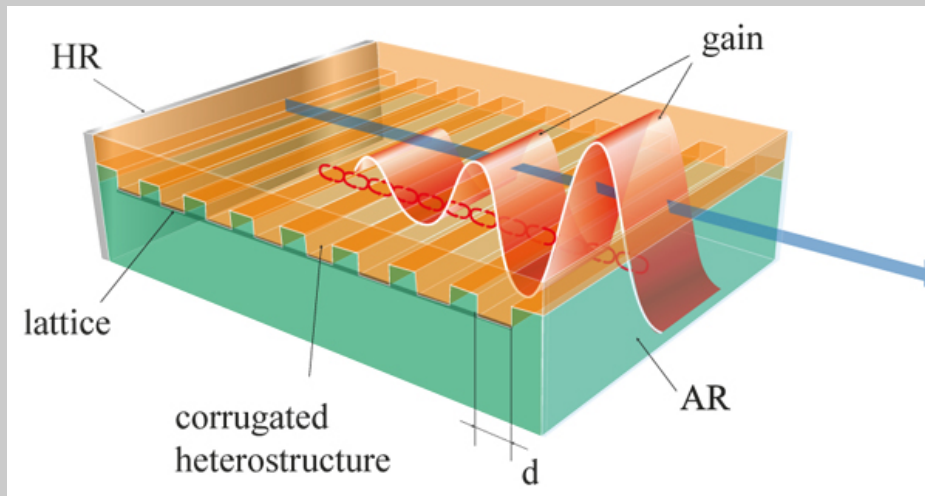
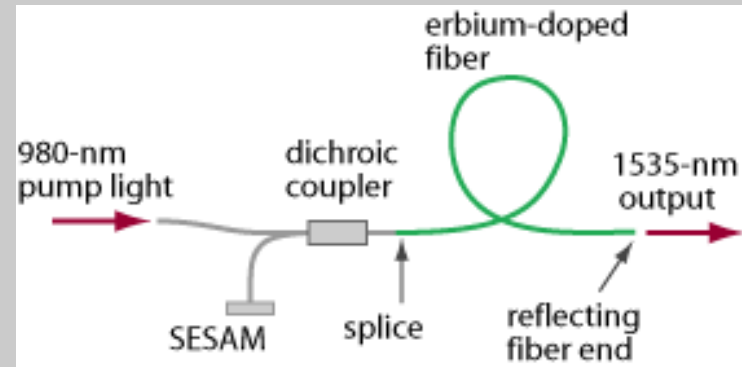
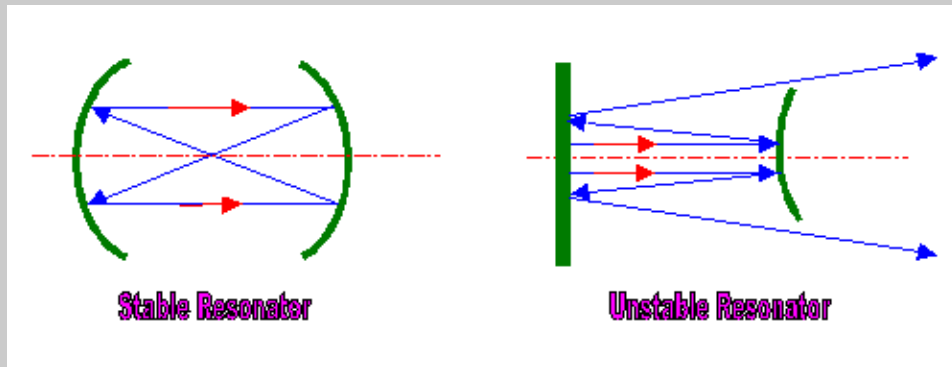
Broadbandwidth/ultrashort pulses

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

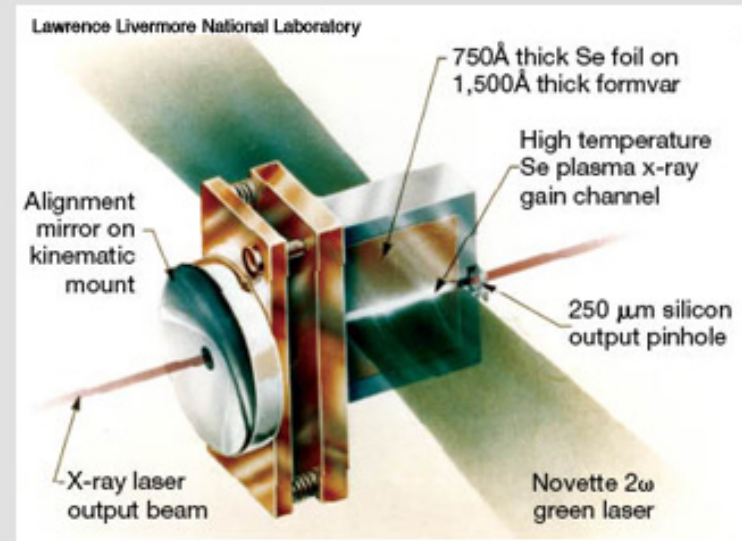


Resonators

- Give feedback to help build up laser oscillation



Distributed feedback laser



X-ray laser: no cavity