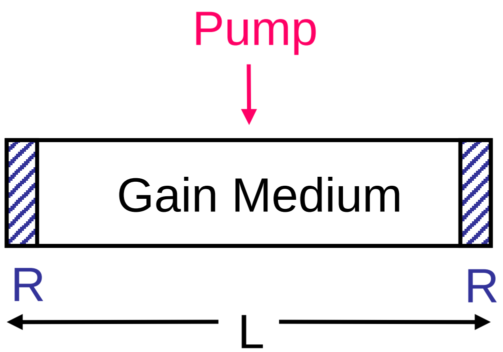
Lect. 19: Laser

LASER: Light Amplification by Stimulated Emission Radiation

LASER: Optical Amplifier + Mirror

Consider optical gain medium with two end mirrors



Optical property of gain medium: n, g

$$k = nk_0 + j\frac{g}{2}$$

g depends on λ and the amount of pumping

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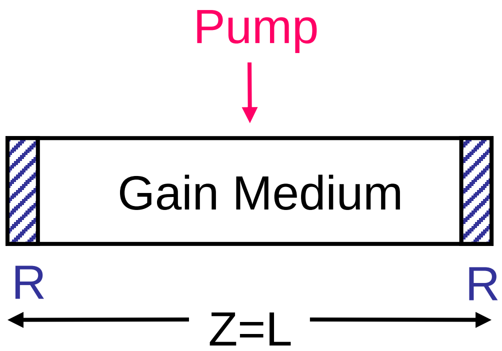

$$k = nk_0 + j\frac{g}{2}$$

Assume there is an initial photon moving in z−direction inside gain medium.

Condition for no loss after one round trip?

$$E_0 \cdot e^{-jkL} \cdot r \cdot e^{-jkL} \cdot r = E_0$$

$$r^2 \cdot e^{-j2kL} = 1$$

$$e^{-j2nk_0L} e^{gL} = \frac{1}{r^2} = \frac{1}{R}$$

$$e^{gL} = \frac{1}{R} \quad \text{and} \quad e^{-j2nk_0L} = 1$$

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From $e^{gL} = \frac{1}{R}$

$g_{\text{th}} = \frac{1}{L}\ln\frac{1}{R}$; Sufficient gain to compensate mirror loss

From $e^{-j2nk_0L} = 1$

$2nk_0L = 2m\pi \Rightarrow \frac{\lambda}{n} = \frac{2L}{m}$ or $L = m\frac{\lambda}{2n}$;

cavity length should be multiples of half wavelength

=> Identical photons are continuously produced at two outputs (mirrors)

Where does the initial photon come from?

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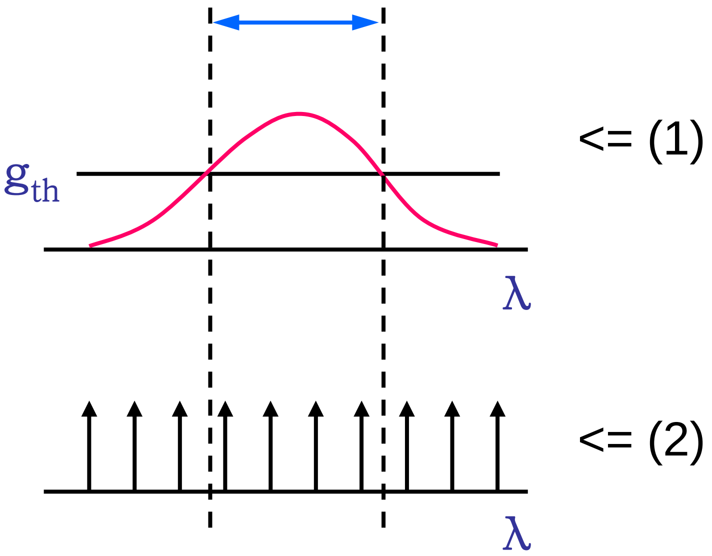
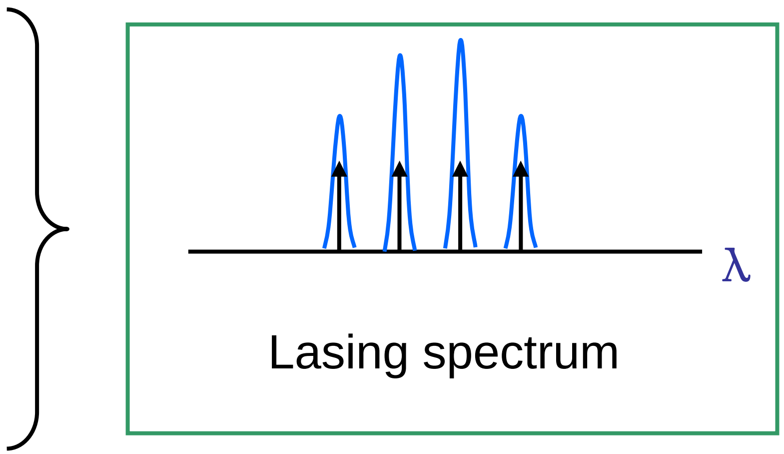
Two conditions for lasing: (1) $g_{th} = \frac{1}{L} \ln \frac{1}{R}$ and (2) $\frac{\lambda}{n} = \frac{2L}{m}$





Lasing peaks (modes) has non-zero linewidth

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Various LASERs: Any optical gain material with mirrors can form a laser

Ruby doped with Cr (Al_2O_3:Cr^{3+}) :
First Laser

Maiman with first laser in 1960.

Optical Gain: Cr in Al_2O_3
Pump: Flash Lamp

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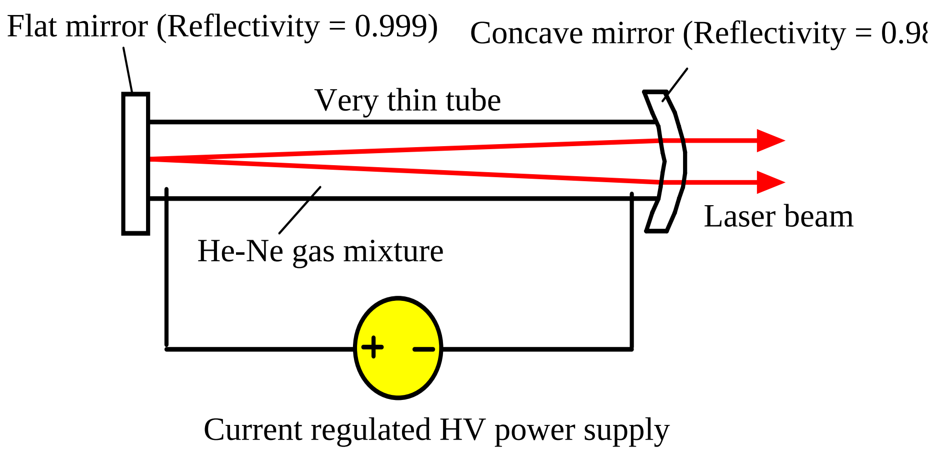
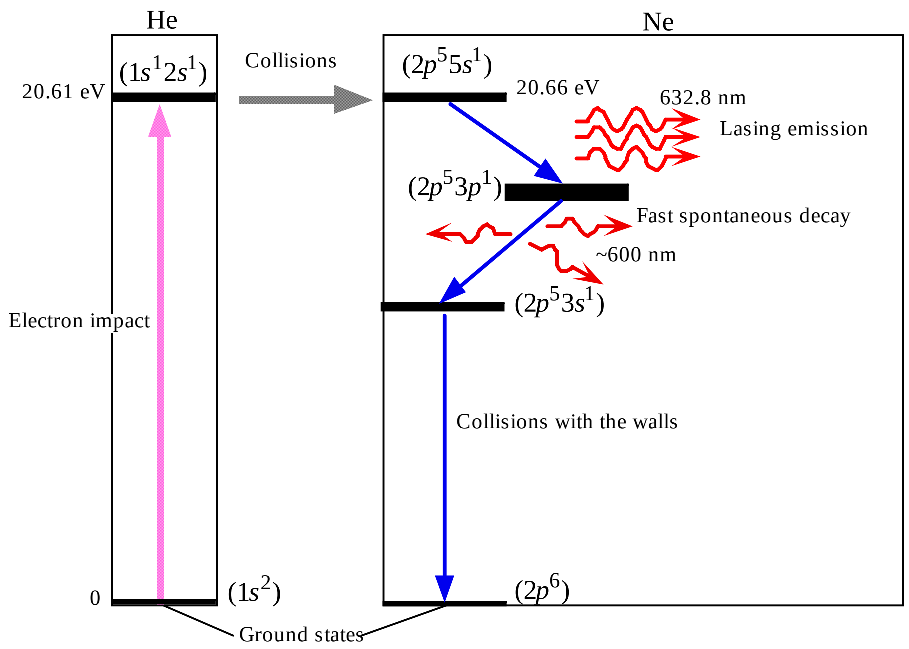
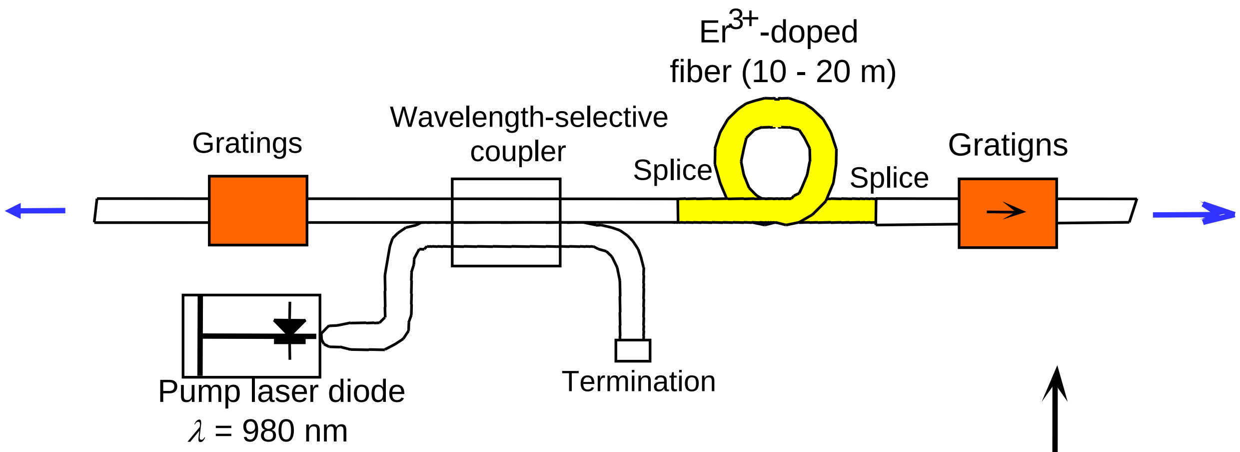
Gas Laser (HeNe)

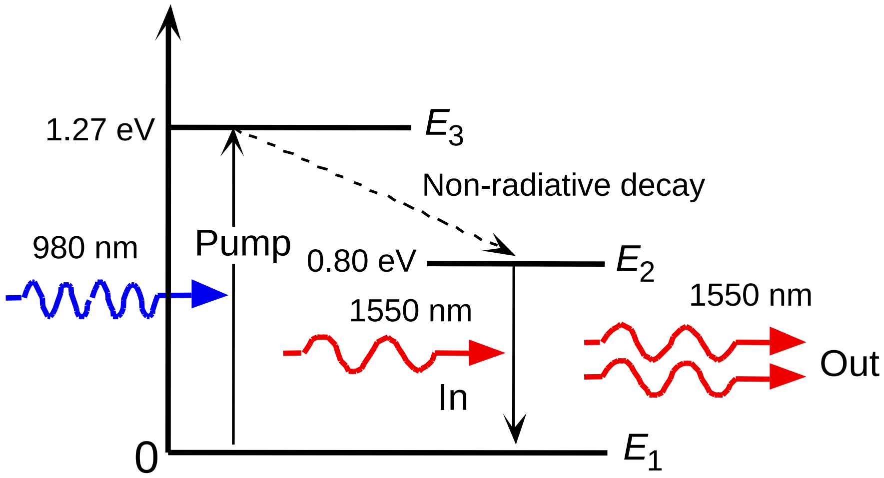


A schematic illustration of the He-Ne laser



Fiber Laser


Er3+-doped
fiber (10 - 20 m)
Gratings
Wavelength-selective
coupler
Splice
Splice
Gratigns
Pump laser diode
λ = 980 nm
Termination


1.27 eV
E3
Non-radiative decay
980 nm
Pump
0.80 eV
E2
1550 nm
1550 nm
Out
In
0
E1