Advanced Radiation Sources - PHSY761

Summary

Laboratory demonstration:
HeNe laser

Exercise 03

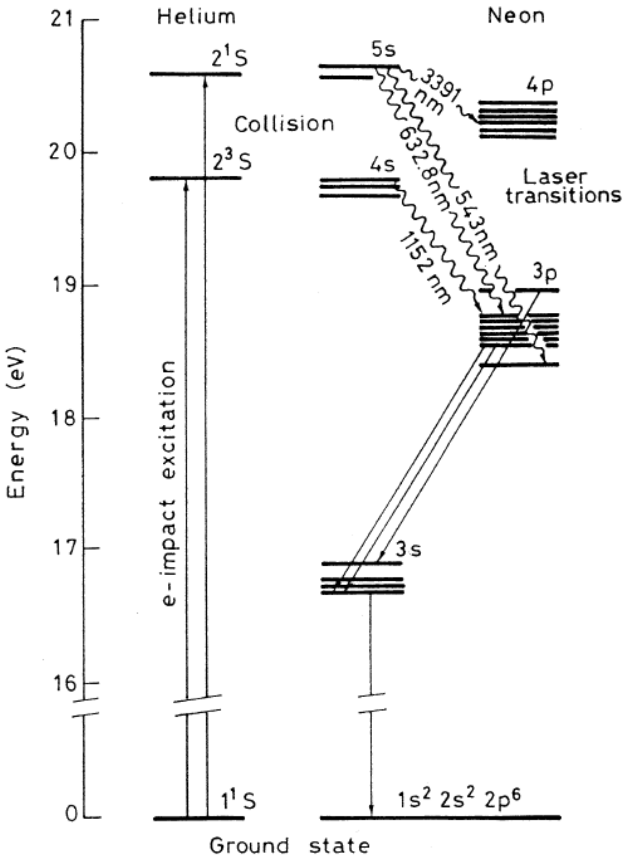
05 October
2023

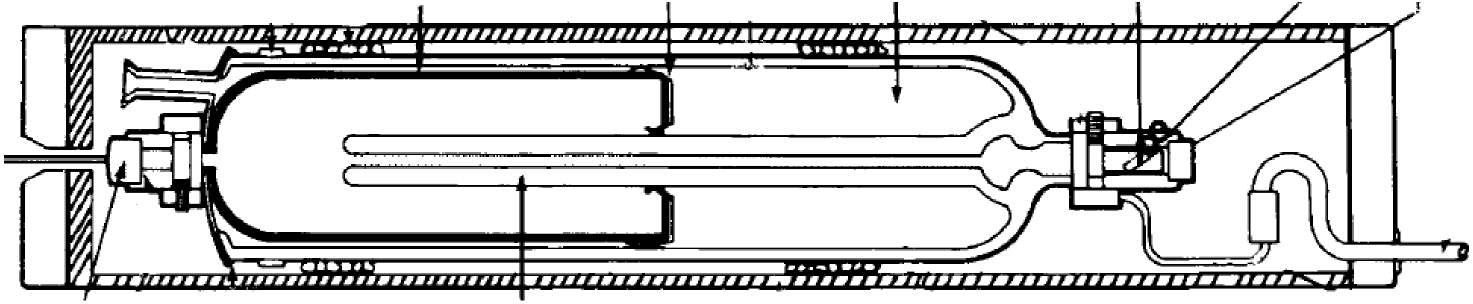
Michele Puppin

He-Ne laser

Gases-> narrow absorption bands, hard to "pump" with incoherent light

- Electron excitation of He and Ne by discharge in a gas tube
- Long lived He 2^1S, 2^3S : "energy reservoir" for the inversion
- Resonant energy transfer between He and Ne





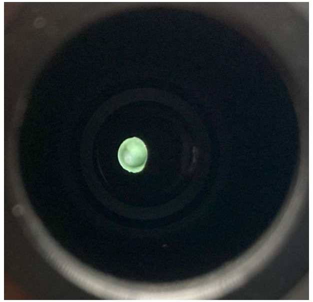
Large Cathode

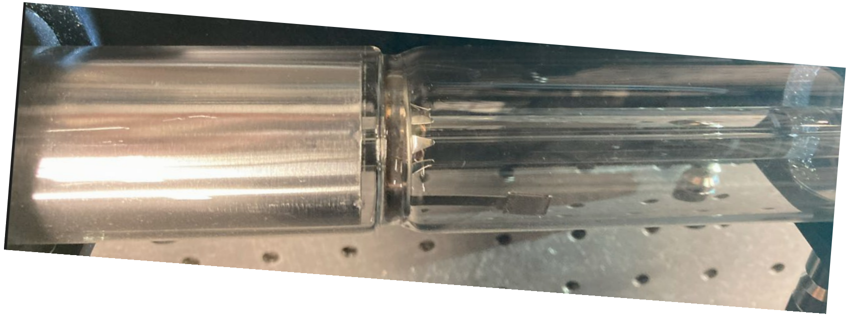
Reservoir
(ground state atoms)

Annular Anode

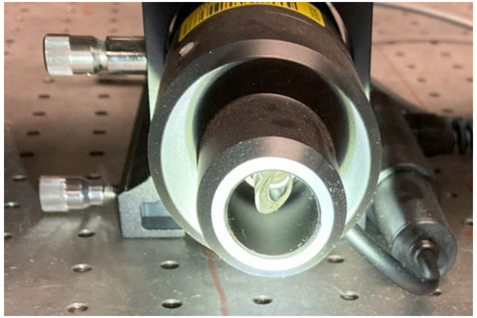
Capillary -> glow discharge (no “arcing”)

(population inversion)





Brewster window: polarized output



Contributions linewidth of 632.8 nm transition of He-Ne laser

632.8 nm -> 474 THz (300 nm <-> 1 PHz)

Homogeneous contribution:

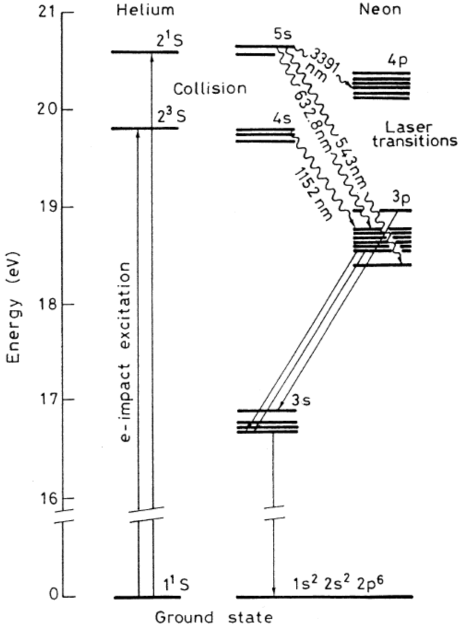
Natural linewidth: 19 MHz (lifetimes of s,p states)

Pressure broadening: 0.6 MHz

Inhomogenous contribution:

Doppler broadening in the gas: 1500 MHz (1.5 GHz)

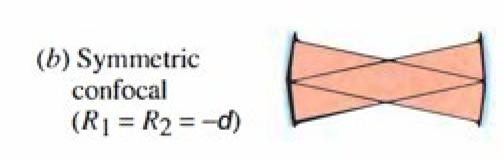
Very narrow line, 1.5 / 474000 -> 10^{-6}



How does this compare with the longitudinal mode spacing (frequency spacing between cavity modes)

In our case: Two mirror with the same radius R1=R2= -700 mm

Assume a “confocal” geometry



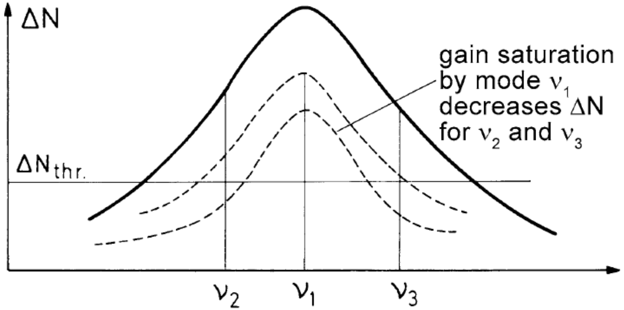
Mode spacing = c/2d = 3 x10^8 (m/s)/ (2x0.7 m) = 2.14 x 10^8 s^{-1}

0.2 GHz -> compare with the linewidth 1.5 GHz

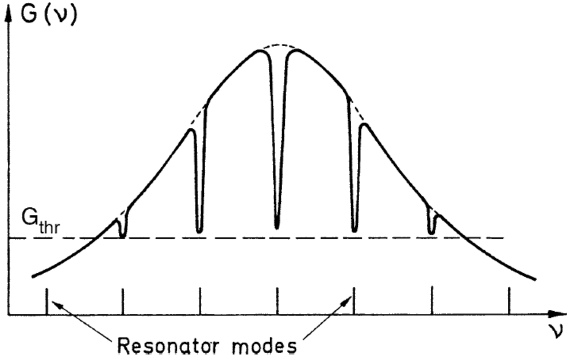
7-8 cavity modes below the line.

Who is lasing?

Multi-mode CW lasing: some concepts

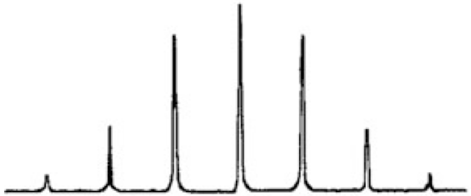


Purely homogenous broadening

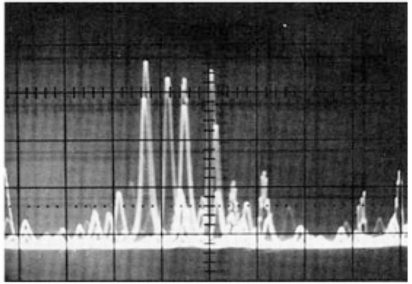


Inhomogenous broadening : spectral hole burning

He-Ne laser:

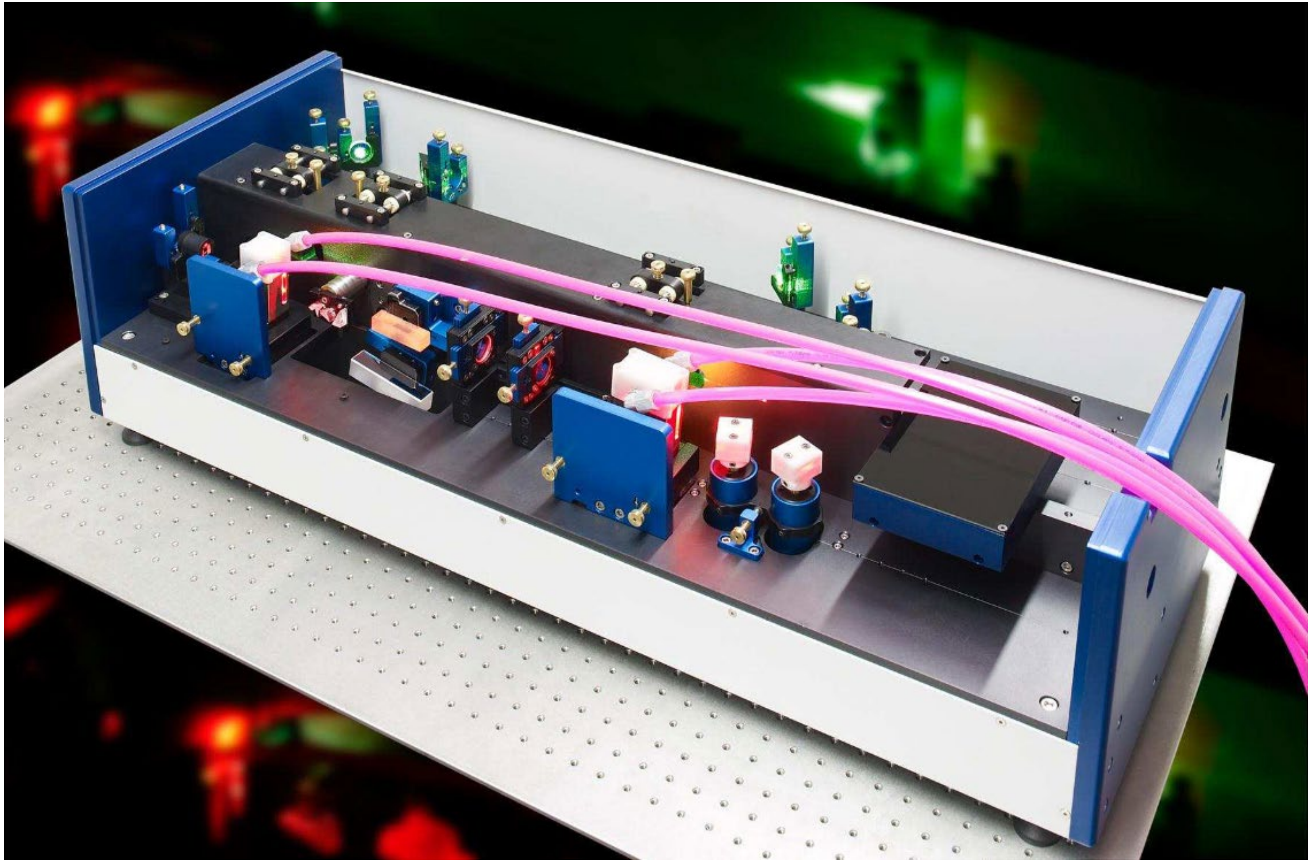


Ar ion laser:



Independent lasing (stable multimode) if mode spacing > homogenous contribution

Dye laser

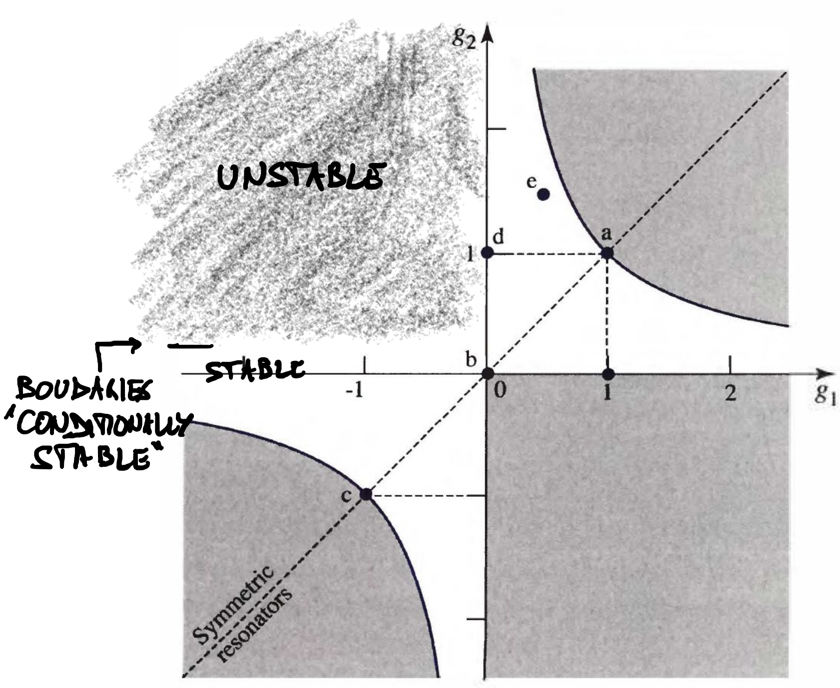


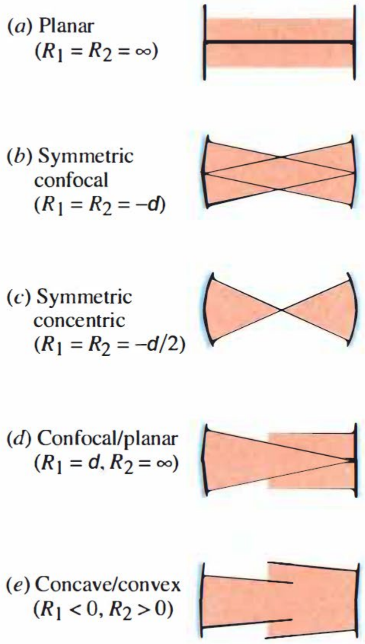
Stability criterion for curved mirror resonators

$$0 \le \underbrace{\left(1+\frac{d}{R_1}\right)}_{g_1}\underbrace{\left(1+\frac{d}{R_2}\right)}_{g_2} \le 1$$

Two mirror resonator with the same radius

R1=R2= -700 mm



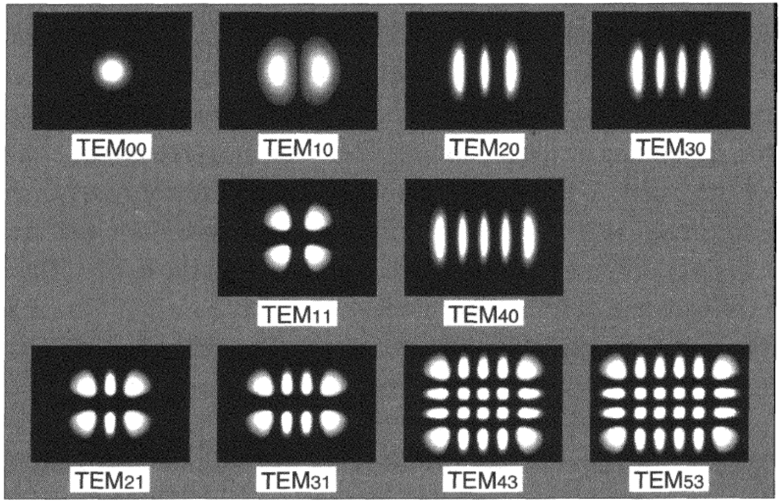


- We still don't know anything about the mode spatial shape and spectral structure!

The Transverse Electromagnetic Modes (TEM)

$$U_{pq}(x,y) = H_p\left(\frac{\sqrt{2}x}{w}\right)H_q\left(\frac{\sqrt{2}y}{w}\right)e^{-(x^2+y^2)/w^2}$$

H_n HERMITE POLINOMIALS



- TEM$_{lm}$ modes can be calculated for every longitudinal mode n,
- The mode frequency v_{nlm}, depends more strongly on n, but also on l and m
- Also the transverse mode are important in the laser dynamics: higher order can be minimized by cavity design, but this is not optimal for every application.