IMA Optics

OL02. Laser Beam Characteristics

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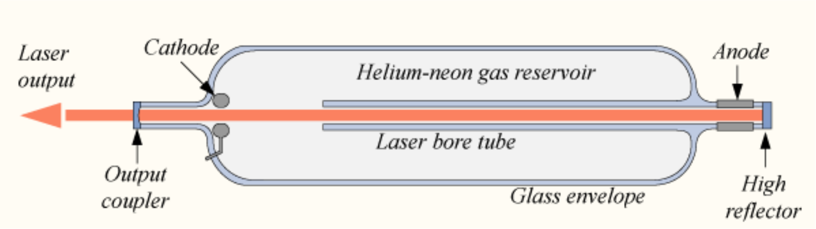
Laser Beam

You will be using a Helium-Neon (HeNe) gas laser for this experiment.

This gas laser has an output of 633nm (red) and power 2mW

CAUTION: NEVER LOOK DIRECTLY INTO THE BEAM: IT COULD DAMAGE YOUR EYES!



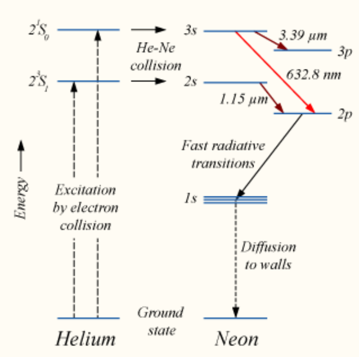
Laser Basics

1. Production of coherent light: a quantum process
2. Amplification: a “resonant cavity” for light: mirrors
3. Gain: appropriate lasing medium that makes up for cavity losses

1. Production of coherent light

Stimulated emission (Einstein)

1. Energetic electrons collide with He atoms on GS and excite them
2. Collision between He and Ne atoms causes energy transfer to Ne from He.
3. So Ne atoms are excited, with more atoms in the excited state than in the GS: Population inversion.



1. Production of coherent light

3. Ne atom decaying to GS produces a photon that stimulates emission of more photons of same wavelength, phase, polarization and direction (COHERENT)
4. Gain in the medium is proportional to the population inversion and to the Einstein A coefficient (related to the lifetime of the excited state)

2. Amplification

Resonant Optical Cavity

1. Parallel mirrors on opposite ends of the lasing material: light reflects back and forth, in each pass it stimulates more emission: gain
2. Form of the wavefront: determined by superposition conditions
3. Solution of the 3-d wave equation in a cylindrical box
4. The waves that fit into such a cavity: Hermite functions modulated by a Gaussian.
   00 mode: just Gaussian

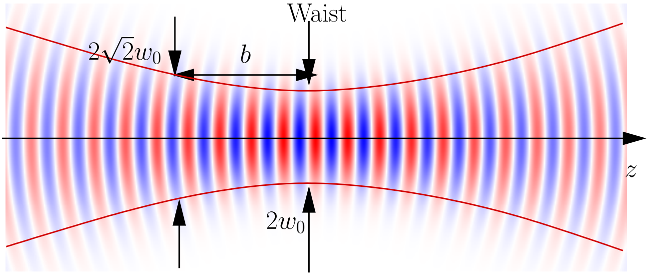
Gaussian Beams

If axis of cavity is z, the propagation direction and $\rho^2 = x^2 + y^2$, Electric field amplitude

$$\begin{aligned} E(\rho, z) &= U_0 e^{-\rho^2/w^2(z)} \\ \text{where } U_0 &= i\frac{E_0 w(0)}{b w(z)} e^{i(kz-\omega t)} e^{i\alpha} e^{ik\rho^2/2R(z)} \end{aligned}$$

- $w^2(z) = 2\dfrac{z^2+b^2}{kb}$, $w(z)$ is the beam diameter at z: Spot Size,
- $b = \pi w(0)^2/\lambda$: a parameter dependent on the cavity geometry
- $R = (z^2+b^2)/z$: radius of the wavefront.

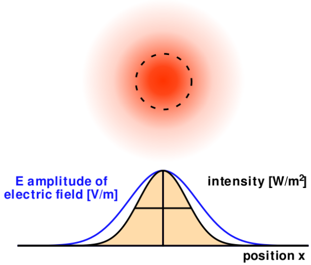
Gaussian Beam



- tends to focus to a spot of least diameter $w(0)$ at the waist
- The divergence can be understood as due to diffraction.

Gaussian Beam

- Intensity reduces as $w(z)^{-1}$ as beam spreads
- Angular spread from the waist is $\Theta \approx \lambda / w(0)$
- Spherical wavefront: “fit” inside a cavity with spherical end mirrors, so the beam is returned along itself and gets amplified



Report Template

- Aim
  - intensity profile
  - spot size
  - beam divergence
- Apparatus
- Setup (procedure followed, for each property)
- Observations: Tabulate (for each separately, after setup)
- Calculations, including error analysis
- Result, in bold, for each property. Quote error bars for each result.
- Precautions
- Discussion