EE119 Homework 10: More on Lasers: Broadening, Gaussian Beams

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1. Identify each of the following broadening mechanisms as homogeneous or inhomogeneous. Explain your answer.
   (a) Collisions between atoms in a gas
   (b) Randomly spaced impurities in a semiconductor crystal
   (c) Temperature differences between different regions of the gain medium.
   (d) Vibrational relaxation within an energy band of an atom or semiconductor (this is the same thing as dissipation of electronic energy into phonons within an energy band).
2. Show that the magnitude of the radius of curvature of a Gaussian beam is changed upon reflection from a spherical mirror, unless (a) the mirror has infinite radius of curvature, or (b) the radius of curvature of the mirror equals that of the Gaussian beam.
3. A TEM00 He-Ne laser ($\lambda = 632.8$ nm) has a cavity that is 0.34 m long, a fully reflecting mirror of Radius R = 10m (concave inward), and an output mirror of radius R = 10 m (also concave inward).
   (a) From the symmetry of mirror geometries and the boundary condition that wavefront and mirror cavities match at the mirrors, determine the location of the beam waist in the cavity. Set z = 0 at this location to be the reference plane.
   (b) Determine the size of the beam waist (w_0).
   (c) Determine the beam spot size $w(z)$ at the left and right cavity mirrors.
   (d) Determine the half-angle beam divergence (θ) for this laser.
   (e) Where is the far field for this laser if you use the criterion $z_{FF} \geq 50(\pi w_0^2/\lambda)$?
   (f) If the laser emits a constant beam of power 5mW, what is the average irradiance at the position where $z_{FF} \geq 50(\pi w_0^2/\lambda)$?
4. Compare the irradiances at the retina that result when looking:
   (a) Directly into the sun. The sun subtends an angle of 0.5 degrees. At the earths surface, the suns irradiance is 1kW/m^2. Assume that the pupil of the bright-adapted eye is 2mm in diameter with focal length of 22.5mm.
   (b) Into a 1mW He-Ne laser. Assume the beam waist of the laser is 1mm, and the laser is located 1m from the eye.
   (c) Which one will damage your eye? Eye-damaging intensities are in the range of 10 μW/cm^2.

5. Gaussian beam/lens The laser resonator shown in the figure below with z = 0 located at the flat mirror and its output impinges on a lens of focal length 10cm. Assume the beam waist size, w_0=0.5mm; laser wavelength, λ = 632.8nm; and distance of the lens to laser output mirror, d=50 cm.

   (a) What is the far-field beam divergence in mrad?

   (b) What are the spot size and radius of the curvature of the output laser beam on the lens?

   (c) What is the radius of the curvature after passing through the lens?

   (d) What is the spot size at the focal point after the lens if the clear aperture of the lens is 1.5 cm in radius?

   (e) What is the beam radius if the laser beam is propagated 1m further after the focal point? And what is the far-field beam divergence with the lens?

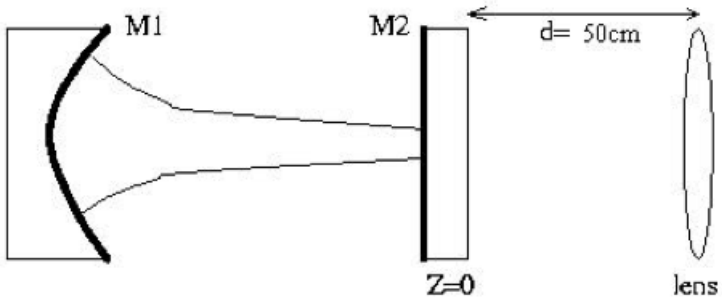

Figure 1: Laser Producing Gaussian Beam and 10cm focal length lens