EE 119 Homework 9

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Due Tuesday, April 20th 2010
(Please submit your answers in EE119 homework box located in 240 Cory Hall)

1. A laser consists of two nearly perfectly reflecting mirrors, M, and a gain medium, G, of bandwidth Δf centered at f_0.
   (a) What are the allowed frequencies for laser operation in this optical cavity? Express you answer in terms of τ, the time takes light to make one round trip in the cavity.
   (b) If it is desired to produce a pulse of one picosecond (10^{-12} sec) duration at a wavelength of 6000 Å, what bandwidth Δf is required? [Hint: Use uncertainty principle $\Delta f \times \Delta t \sim 1$] What is the corresponding band of wavelengths? And how many laser modes would this involve? (Let L=1.5 m)

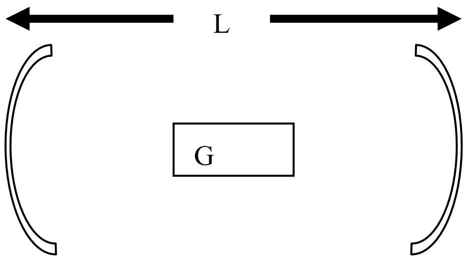

Figure 1

2. 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).

3. A TEM_{00} (Transverse Electric Mode) He-Ne laser (λ=632.8nm) 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 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 intensity (W/m^2) at the position where $z_{FF} = 50(\pi w_0^2/\lambda)$?

4. The laser resonator shown in Figure 2 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 of the laser in mrad if the lens is not present?
   (b) What are the spot size and wavefront radius of curvature of the output laser beam on the lens?
   (c) What is the wavefront radius of 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 1.5cm 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 after the beam passes through the focus?

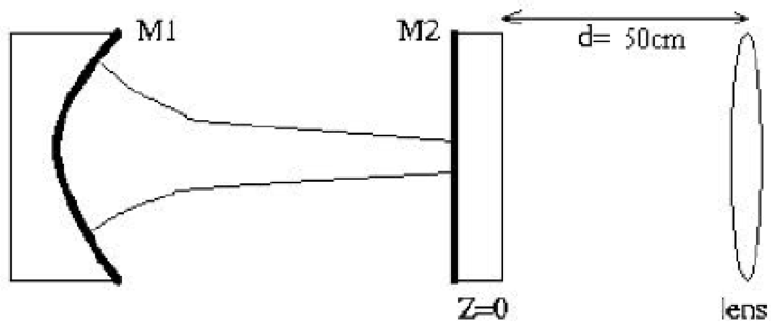

Figure 2

5. Compare the irradiance at the retina that results when looking:
   (a) Directly at the sun. The sun subtends an angle of 0.5 degree. At the earth's surface, the sun's irradiance is $1kW/m^2$. Assume that the pupil of the bright-adapted eye is 2mm in diameter and focal length is 22.5mm.
   (b) Into a 1-mW 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 $\mu W/cm^2$.

6. [Hecht 13.26] A He-Ne c-w laser has a Doppler-broadened transition bandwidth of about 1.4 GHz at 632.8 nm. Assuming n = 1.0.
   (a) Determine the maximum cavity length for single-axial mode operation.
   (b) What is the transition rate for the neon atoms in the laser if the power output is 1.0 mW and the energy drop is 1.96 eV?