

6.602/6.621 Fundamentals of Photonics

Spring 2010

PROBLEM SET 5

Issued: *March 11, 2010*

Due: *March 18, 2008*

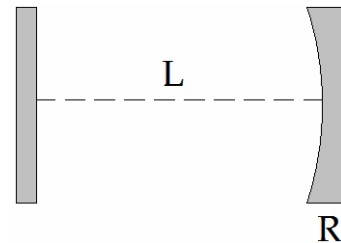
Problems marked with (G) are advanced problems for undergraduate students but must be worked on by graduate students

Suggested reading: Class notes: 2.5 - 2.6.5

Problem 5.1: Resonator of a Microchip Laser

The plano-spheric resonator built by a plane and a curved mirror with radius of curvature, $ROC=R$, is the simplest possible stable resonator.

- (a) Over what range can the cavity length L be varied while maintaining resonator stability?
- (b) Derive an expression for the beam radii on both mirrors 1 and 2 in terms of R , L and λ .
- (c) Plot the beam radii at mirrors 1 and 2 as a function of the ratio L/R . Consider $\lambda=1500$ nm and $R=5$ cm.

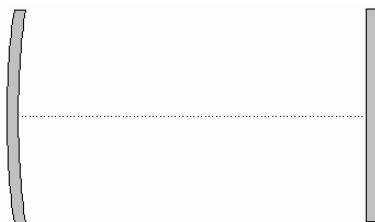


Problem 5.2: Gaussian Beams and a Two Mirror Resonator

- (a) What are the characteristics of a Gaussian beam at the waist?
- (b) What is the physical meaning of the Rayleigh range z_R of a Gaussian beam?
- (c) In the resonator shown below the spot size of the mode is larger at mirror 2. Is the waist of the beam situated closer to mirror 1 or mirror 2? Why?



Now consider the stable plano-concave resonator shown below. The fundamental mode of the resonator at wavelength $\lambda = 1\mu\text{m}$ is a Gaussian beam with the waist radius w_0 .



- (d) How will the waist radius of the mode change if λ is increased to $10\mu\text{m}$? Show your reasoning.
- (e) How will the divergence angle of the beam change if λ is increased to $10\mu\text{m}$?
- (f) **(G)** Suppose you need to design a *two-mirror* resonator for a high-power laser operating at $\lambda = 1\mu\text{m}$. You have at your disposal 3 pairs of mirrors: *two* spherical mirrors with *ROC* (radius of curvature) of 1m , *two* spherical mirrors with *ROC* = 2m , and *two* plane mirrors (*ROC* = ∞). There are two requirements that must be satisfied:
- (i) for a given power, the intensity at the mirrors must be as small as possible to avoid mirror damage;
 - (ii) to achieve most effective amplification, the gain medium with radius $r = 0.7\text{mm}$ is placed into the *waist region* of the Gaussian beam. The waist size must not be too small, otherwise the beam will fill just a part of the gain medium, and it also must not be too large, otherwise only a fraction of the beam will be amplified. Suppose that the optimum waist radius is half the gain medium radius, $w_0 = r/2 = 0.35\text{mm}$. Thus the waist radius of the beam is fixed by the gain medium and cannot be varied in the resonator design.
- Which two of the available mirrors would you choose for the resonator? Why?
 - Approximately what length of resonator would you choose?

Problem 5.3: Mode Selection

The transverse modes TEM_{mn} with $m, n > 0$ of a confocal resonator possess different mode diameters than the fundamental mode TEM_{00} . Despite the larger diffraction losses

experienced by the transverse modes in comparison to the fundamental mode it is sometimes still possible that the discrimination is too low and those modes start lasing together with the fundamental mode, which deteriorates the beam profile. To avoid that an iris can be put into the cavity, which leads to additional higher losses for the transverse mode in contrast to the fundamental mode.

We assume the laser cavity consists of two identically curved mirrors with $ROC=5\text{m}$, and the distance between the mirrors is 1m .

a.) Compute the loss introduced by the iris onto the TEM_{00} and the TEM_{01} or TEM_{10} mode as a function of the radius of the iris opening. Plot both functions.

b.) What is the lower limit on the loss of all transverse modes if the iris closed so far that the loss of the fundamental mode is 0.5% ?