NTHU Electrical Engineering Department

EE3360 Optoelectronic Devices Spring 2019

HW #2

1. (a) Suppose that frequency spectrum of a radiation emitted from a source has a central frequency v_0 and a spectral width Δv. The spectrum of this radiation in terms if wavelength will have a central wavelength λ_0 and a spectral width $\Delta\lambda$. Since $\Delta\lambda \ll \lambda_0$ and $\Delta v \ll v_0$, using $\lambda = c/v$ show that the line width $\Delta\lambda$ and hence the coherence length l_c are

$$\Delta\lambda = \Delta v\frac{\lambda_0}{v_0} = \Delta v\frac{{\lambda_0}^2}{c} \quad \text{and} \quad l_c = c\Delta t = \frac{\lambda_0^2}{\Delta\lambda}$$

(b) Calculate $\Delta\lambda$ for a laser pointer that has $\lambda_0 = 532$ nm and $\Delta v \approx 2.1$ THz. Find its coherence time.

(c) Find the coherence length of an LED emitting at 1310 nm with a spectral width 90 nm.

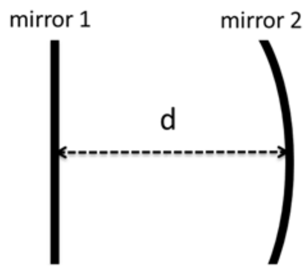
(d) Find the coherence length of a multimode He-Ne laser with a spectral frequency width of 1.5 GHz.

2. (a) The light emitted from a laser at wavelength of 1064nm is a Gaussian beam of 1-W optical power and beam divergence $2\theta_0$=1 mrad. Determine the beam radius, the Rayleigh length, the maximum intensity, and the intensity on the beam axis at a distance z = 100 cm from the beam waist. (b) Assume there is a 1-W spherical wave produced by a small isotropically emitting light source located at z = 0. Compare the optical intensity of the laser in (a) with this isotropic source at z = z_0

3. A Gaussian beam of wavelength λ_0 = 1064 um has widths w_1 = 1.699mm and w_2 = 3.380 mm at two points separated by a distance d = 10 cm. Determine the location of the waist and the waist radius.

4. Determine the ratio of the power contained within a circle of radius w(z) in the transverse plane to the total power in the Hermite-Gaussian beams of order (0,0), (1,0), and (0,1).

5. An optical cavity is shown below, where d is 1/2 of the radius of curvature of mirror 2. The reflectivity of mirror 1 is 0.99 and the reflectivity of mirror 2 is 0.98.



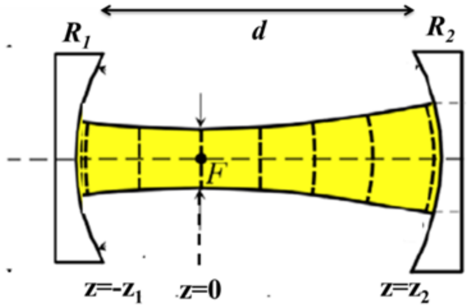
(a) Starting from the resonant condition, please derive an expression of the longitudinal resonant frequencies of the Gaussian beam with TEM_{00} of the cavity.

(b) If the radius of curvature is 1.2 m and the wavelength is 600 nm, please calculate the FSR in MHz.

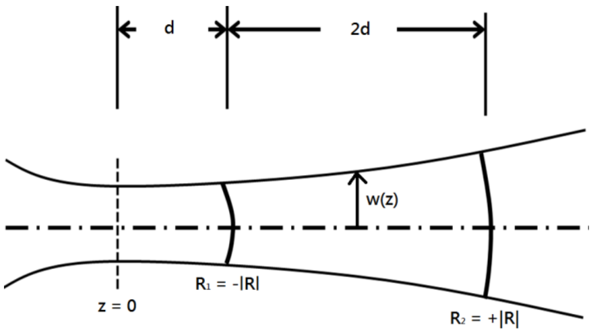
(c) Please plot the peak closest to 600 nm for 4 values if R_1=R_2=R=0.97, 0.85, 0.7, and 0.6. For each case find the spectral width Δv, the finesse F and Q. (You may want to use a graphing software for this problem.)

6. Laser cavity provides feedback for building up laser emission. In the simplest case, the cavity consists of two mirrors with the active medium located between them. To design the optical cavity, normally we choose a set of mirrors and adjust their positions and curvature so that their surfaces exactly match the surfaces of constant phase of the beam. Since the rays associated with this Gaussian beam impinge perpendicular to the mirror surface, they

will be reflected back on themselves. This is an important procedure for design a stable cavity for light oscillation. Given the radius of curvature of the mirrors R1, R2, and cavity length d, please express z0, z1, and z2 in terms of R1, R2, and cavity length d.



7. Consider the optical cavity shown in the diagram below in which the variation of the spot size w(z) is also shown. Note that the beam waist occurs at a distance d to the left of M1 and that the mirrors have curvature of opposite signs.



(a) Assume that the cavity is stable. Solve for the ratio d/R and evaluate the parameter z_0^2.

(b) Please write down the resonant condition of $TEM_{\ell,m,q}$ mode in the cavity and derive a formula of the resonant frequency.

(c) If d = 100cm and z0 = $100\sqrt{2}$ cm, what is the difference between $TEM_{0,0,q}$ and $TEM_{1,0,q}$ resonant frequencies.

8. Interferometers are widely used in optics and many related fields. In class, we have briefly discussed Michelson interferometer. Please list two other types of interferometers, illustrate the scheme, explain how it works, and give an example of its usage in an application or device.

Remarks:

Radius of curvature of curved mirrors:

by convention, R is negative for concave mirrors and positive for convex mirrors