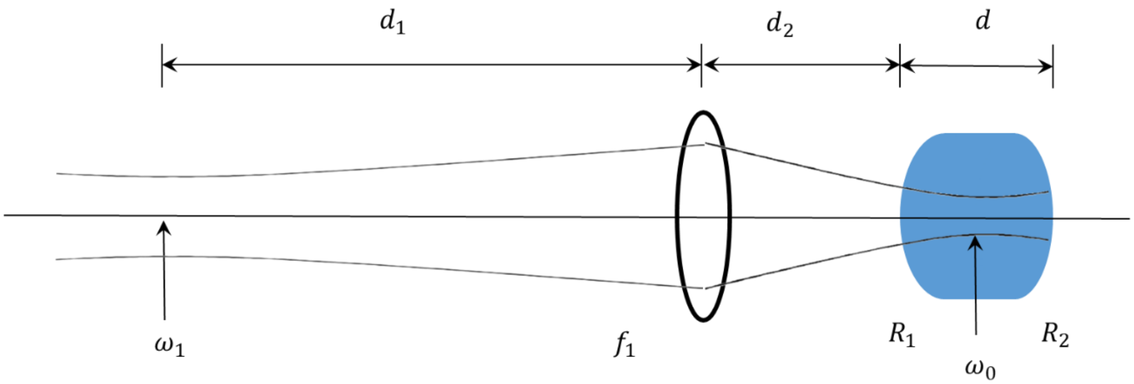
Midterm Exam of the Quantum Electronics

Nov. 14, 2016

1. Gaussian Beam and Optical Resonator

Let's consider the optical material with the index of refraction n and mirror coating at both of ends as shown in the following figure.



(a) Find the condition for the stable cavity in terms of R_1, R_2, d and n.

(b-d) Let's consider the parameters of the cavity as R_1 = 9 cm, R_2 = 12 cm, d = 3 cm, n = 3, and $\lambda = 1\mu\text{m}$

(b) Find the Radius of curvature and the beam radius near mirror R_1.

(c) Find ω_0 of the cavity and the distance d_0 between the mirror R_1 and the location of ω_0.

(d) When we ignore *n,* the index of refraction of the optical material, show the following relations.

$d_1 = f_1 \pm \frac{\omega_1}{\omega_0}\sqrt{f_1^2 - f_0^2}$ and $d_3 = f_1 \pm \frac{\omega_0}{\omega_1}\sqrt{f_1^2 - f_0^2}$, where $f_0 = \frac{\pi\omega_1\omega_0}{\lambda}$, and $d_3 = d_0 + d_2$.

(e) When $\omega_1 = \frac{20}{\pi}\omega_0$, and $f_1 = 250\ mm$, find the proper distances of d_1 and d_3

(f) If we do not ignore the *n,* the index of refraction of the optical material, what are the proper distances of d_1 and d_3?

2. Energy relations in optical cavities.

Let's think the same optical material shown in the figure of above problem. The reflection coefficients of the mirrors R_1 and R_2, are r_1 and r_2, respectively. The power loss of laser beam in the material is given as $\frac{dP}{dz} = -\alpha P$, where α is the absorption coefficient.

(a) Find the electric field inside of the material near the mirror R_1.

(b) Find the intensity of laser inside of the cavity near the mirror R_1.

(c) Find the full width half maximum (FWHM), $\Delta\nu_{1/2}$, of the laser intensity and calculate the Finesse that is defined by $2\pi/\Delta\nu_{1/2}$.

(d) The thickness of the material *d* is 3 cm, the absorption coefficient is 1/600 cm^{-1}, and the reflection coefficient of the mirror R_2 is $r_2 = 0.99$. Find the reflection coefficient of r_1 to make the impedance matching condition.

(e) What is the resolution of the frequency that this material can distinguish?

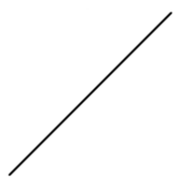
(f) For the case that the impedance is matched, find the amount of enhancement on the intensity of the circulating laser.

(g) When the input laser beam is turned off instantaneously, what will be the decay time of the laser power inside the material?

3. Optical polarization

(a-c) I found the polarization of my laser beam is as follows. Can you find a way to change the polarization to a vertical linear polarization without the loss of laser power? Please properly use half wave plates or quarter wave plates.

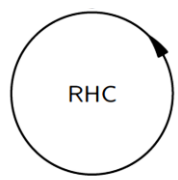
(a)



$E_x = \cos\omega t;\ 1$

$E_y = \cos\omega t;\ 1$

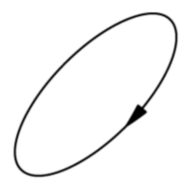
(b)



$E_x = \cos\omega t;\quad 1$

$E_y = \sin\omega t;\quad -i$

(c)



$\cos\omega t;\qquad 1$

$\cos\left(\omega t + \frac{\pi}{4}\right);\ e^{i\pi/4}$

(d) When we want to measure the intensity of the reflected laser beam of problem 1, what input polarization should I use? What kind of wave plate should I use for the purpose in the following figure and what angle of it should I use for the maximum reflection? All angles are defined with respect to horizontal plane.