Homework #9
OPTI 370
3/23/2022
(due date: 3/30/2022)

Problem 1:

Continue the discussion of a Nd^{3+}:YAG laser from the previous homework assignment, but with different parameters. Assume again the cylindrical crystal rod to be of length 6.8 cm and radius 1.2 mm. Furthermore, the spontaneous decay time $t_{sp} = 230\,\mu s$, the cross section $\sigma(\nu_0) = 2.8\times10^{-19}\ cm^2$, and the pump rate is $R = 5.15\times10^{19}\ s^{-1}cm^{-3}$ Use the lasing frequency given in the book (Fig. 13.1-9). Assume you have a laser with an ideal resonator that does not contribute any loss other than the light leaving the resonator. The mirrors are mounted directly on the end facets of the crystal rod and have mirror reflectivities of $\mathscr{R}_1 = 1,\ \mathscr{R}_2 = 0.982$. What is the power (units of Watts) outside the resonator under these idealized conditions? Additional question: Nd^{3+}:YAG laser typically emit green light; does the wavelength you are using correspond to green light?

(10 points)

Problem 2:

Assume you have a laser including a Ti^{3+}:Sapphire gain medium (refractive index 1.5) with a gain bandwidth of $\Delta\nu = 92\ THz$ and resonator of length 157cm. Assume the gain medium to occupy only a small portion of the resonator, so that the refractive index inside the resonator can be chosen to be approximately 1. Assuming the laser generates a mode-locked pulse train, determine the temporal period (repetition time) and repetition frequency as well as the pulse duration. Assume, for simplicity, that all resonator modes within the gain bandwidth contribute to the pulse with equal amplitude.

(10 points)

Problem 3:

This problem is meant as a preparation of our upcoming discussion of polarization optics. Until now, we have dealt with scalar waves with real-valued wave functions $u(\vec{r},t)$ and corresponding complex functions $U(\vec{r},t)$. Assume now you have an electric field (a vector) propagating in z-direction with

$\boldsymbol{\varepsilon}(z,t) = \boldsymbol{\varepsilon}_x \hat{\boldsymbol{x}} + \boldsymbol{\varepsilon}_y \hat{\boldsymbol{y}}$. For the case of simple plane waves, we have

$$\boldsymbol{\varepsilon}(z) = \mathrm{Re}\,\boldsymbol{E}(z)e^{j\omega t} \;,\; E_x(z) = a_x\, e^{-jk_1 z} \;,\; E_y(z) = a_y\, e^{-jk_2 z}.$$

Here, we assume the medium to be anisotropic in the sense that the refractive index for x-polarized light differs from that for y-polarized light. Let the refractive index for x - polarized light be $n_1 = 1.503$, that for y - polarized light $n_2 = 1.507$, and the wavelength in vacuum $\lambda_0 = 0.79\mu m$. Determine the propagation distance after which the x and y components have acquired a phase difference of π relative to each other. We will discuss the derivation of equations governing this kind of propagation in class soon, but even without that discussion you should be able to do this problem.

(10 points)