Homework #8

OPTI 370

3/16/2022

(due date: 3/23/2022)

Problem 1:

Consider a Nd^{3+}:YAG laser. Assume the small-signal gain to have a Lorentzian lineshape with $\gamma_0(\nu_0) = 0.030\ cm^{-1}$ and $\Delta\nu = 1.22\times10^{11}\ Hz$. Inside a laser resonator, only resonator modes for which the gain exceeds a threshold given by the resonator loss (we have called it α_r) can be amplified. Assume $\alpha_r = 0.014\ cm^{-1}$. Sketch the small-signal gain profile $\gamma_0(\nu)$ and indicate the threshold (similar to Fig. 15.2-4, but you should label the axes properly and indicate all relevant numerical values). Determine the frequency range B for which $\gamma_0(\nu) \geq \alpha_r$. (Hint: you have to show first that $B = \Delta\nu\sqrt{(\gamma_0(\nu_0) - \alpha_r)/\alpha_r}$).

(10 points)

Problem 2:

Continuing Problem 1, determine (approximately) the number of resonator modes whose gain exceeds the loss for a Fabry-Perot resonator of length 14cm. The refractive index of the crystal is 1.75.

(10 points)

Problem 3:

Assume your Nd^{3+}:YAG laser medium is a cylindrical crystal rod of length 6.5 cm and radius 1.8 mm, and that you pump it optically with a 1.47 W laser diode. For simplicity, assume the pump light to have a single (average) frequency of 2 eV. Assuming that all the light from the laser diode induces 2 eV transitions, how many transitions do you have per cm^3 and per second; in other words, what is the pump rate R_2 (units of $s^{-1}\ cm^{-3}$)? Using the spontaneous decay time $t_{sp} = 230\ \mu s$ and cross section $\sigma(\nu_0) = 2.8\times10^{-19}\ cm^2$, determine the small-signal population inversion N_0 (using the assumptions made in class that the spontaneous decay dominates over non-radiative decay) , the small-signal gain at resonance (i.e. at ν_0), and single-pass amplifier gain.

(10 points)

Problem 4:

Continuing the example of the Nd^{3+}:YAG laser, determine the light intensity (assumed to be at frequency $\nu_0 = 2.8\times10^{14}\,\text{Hz}$) in the amplifier medium at which the gain (at resonance) has dropped to 1/2 of the small-signal gain (this is an example of gain saturation), i.e. at which the inversion is $N = N_0/2$.

(10 points)