PHY4311 ASSIGNMENT 5

MOHAMMED CHAMMA 6379153
FEBRUARY 4TH 2015

You are given a CO_2 laser which will be used in a manufacturing plant to weld the frame of cars. You are told that the laser has a small signal gain of $3\%/cm$ and a cavity with $L = 1m$ with one cavity mirror. The laser mirrors are as follows: one mirror has $(r_1, s_1, t_1) = (0.95, 0.1, 0.04)$ and the other has $(r_2, s_2, t_2) = (1.0, 0, 0)$. The saturation intensity you are told is $I_s = 100W/cm^2$.

Problem 1. Please calculate the output power per unit area of the laser

$$\begin{aligned} I^{out} &= \frac{t}{2} I_{sat}\Big(\frac{2g_0\ell}{t+s} - 1\Big) \\ &= \frac{0.04}{2}(100W/cm^2)\Big(\frac{2(0.03cm^{-1})(100cm)}{0.04+0.01} - 1\Big) \\ &= 238W/cm^2 \end{aligned}$$

Problem 2. How much power is deposited in the output window?

$$\begin{aligned} I^{window} &= sI^+ = \frac{s}{2} I_{sat}\Big(\frac{2g_0\ell}{t+s} - 1\Big) \\ &= \frac{0.01}{2}(100W/cm^2)\Big(\frac{2(0.03cm^{-1})(100cm)}{0.04+0.01} - 1\Big) \\ &= 59.5W/cm^2 \end{aligned}$$

That's a lot!

Another way to get this is to notice $s = \frac{1}{4}t$ so

$$I^{window} = sI^+ = \frac{1}{4}tI^+ = \frac{1}{4}I^{out} = \frac{238}{4} = 59.5W/cm^2$$

Problem 3. Please compare the power deposited in the window with a reasonable estimate of that deposited in a window by a 100W lightbulb.

The 100W lightbulb gives about 10W of light power. If the window is a meter away the lightbulb deposits

$$P_L = \frac{10W}{4\pi(1m)^2} = \frac{10W}{4\pi(100cm)^2} = 7.96 \times 10^{-5}W/cm^2$$

Over a million times weaker than the laser!

Problem 4. For the laser just described, assume the loss is always 1%. Find the transmission coefficient for the mirror that will optimize the light output (highest power per unit area) and find this optimum output.

The optimal transmission coefficient is

$$\begin{aligned} t_{opt} &= \sqrt{2g_0\ell s} - s \\ &= \sqrt{2(0.03cm^{-1})(100cm)(0.01)} - 0.01 \\ &= 0.23 \end{aligned}$$

But we need to make sure that the gain at this transmission coefficient is larger than the small signal gain. This is equivalent to checking

$$\begin{aligned} g_0 &> \frac{s}{2\ell} \\ 0.03cm^{-1} &> \frac{0.01}{2(100cm)} \\ 0.03cm^{-1} &> 0.00005cm^{-1} \end{aligned}$$

and indeed it is. This means the laser can operate at the optimal transmission of $t = 0.23$.

The optimal output is

$$\begin{aligned} I^{out}_{max} &= I_{sat}g_o\ell \\ &= 100W/cm^2(0.03cm^{-1})(100cm) \\ &= 300W/cm^2 \end{aligned}$$