Semester S1 – Module 3

Module Fundamentals of coherent photonics

TUTORIAL

LASERS_1

LASER EFFICIENCY

Exercise 1

A Fabry-Perot laser made up of two mirrors M_1 and M_2 and a 4-level amplifying medium. M_2 is the rear mirror of reflectivity R_2. M_1 is the output coupler of reflectivity R_1.

1-a) Give the expression of the small-signal gain coefficient in the case of a four-level laser as a function of ΔN_0 and then as a function of the pumping rate Wp. We give the expression of population inversion in the case of low pumping $\Delta N_0 = \tau N_a W_p$.

1-b) The pump power is related to the pumping rate by the relationship $W_p = \eta_P \frac{P_{pump}}{V N_a h\nu}$. η_P is the intrinsic efficiency, i. e. the percentage of the pump power transformed into laser power by removing the losses introduced by the resonator and by the output coupler. V is the pumping volume.

Find a new expression of the small-signal gain coefficient as a function of pump power and saturation intensity.

2-a) From the expression of the intracavity intensity seen in class, put the intracavity power in the form $P = SI_{sat}\left(\frac{2\gamma_0 d}{\delta - \ln R_1} - 1\right)$ where S is the useful area of the gain medium, d is the length of the amplifying medium and δ the losses that do not include the output coupler. We will give the expression of δ.

2-b) Calculate P_{out}, the output power of the laser, as a function of P_{pump} the pump power and of the transmission coefficient T_1 of the output coupler. The reflectivity R_1 of the output coupler is considered to be close to one.

2-c) Plot P_{out} according to P_{pump}. What does the abscissa at the origin represent?

3) The amplifying medium is a Nd:YAG crystal. The saturation intensity is 2.9 kW/cm^2. The reflection coefficient of the output coupler is $R_1 = 0.9$, the intrinsic efficiency η_p is 73% and the losses are $\delta = 5\%$. The diameter of the laser beam in the crystal is 300 µm. Calculate the pump power at the threshold, the slope of the curve and the output power of the laser when the pump power is 2W.

Exercise 2

The laser output power is a function of the power transmission coefficient T_1 (or reflection coefficient R_1) of the output coupler.

1) Explain why there is an optimal value T_{1opt} of T_1 for which the output power P_{out} is maximum.
2) Determine T_{1opt} and the corresponding power $P_{out,\,opt}$ corresponding as a function of γ_0, d and δ. We will assume that R_1 is close to one. We recall the expression of the intracavity power $P = SI_{sat}\left(\frac{2\gamma_0 d}{\delta - \ln R_1} - 1\right)$.
3) Make digital applications for Isat = 2.9 kW/cm2, $2\gamma_0 d = 1$, $\delta = 0.1$, S = 0.4 cm^2.
