Laser Physics I — Homework 4
Due Wednesday, October 18, 2023

1 Dye laser

The gain medium of a dye laser is a flowing dye jet. This is the gain medium with the largest damage threshold, since it is continuously replenished. It can be considered as a three level system, pumped from the ground state (which is also the lower lasing level) to a group of upper levels, from which there is a very fast (near instantaneous as compared to all other time constants) relaxation to the upper lasing level. The pump is provided by green laser (up to 20 W), focused onto a 200 micron thick jet. The following parameters are given:

- gain molecule concentration: $6 \cdot 10^{17}$ cm^{-3}
- relaxation time of upper lasing level: $T_1 = 2.5$ ns
- cross section of the focused beam: 30 μm^2 (which is also the cross section of the waist of the cavity located in the jet)
- Absorption cross section of the pump beam $\sigma_p = 1. \cdot 10^{-16}$ cm^2
- Gain cross section (for the lasing beam): $\sigma = 5. \cdot 10^{-16}$ cm^2
- Pump wavelength 514 nm
- Lasing wavelength 590 nm
- Reflectivity of the output mirror: 80%

Find the pump power required to have zero gain/zero absorption

Hint: use the two-level rate equations for the population difference modified to represent a three level system. The zero gain condition defines the initial population difference. The equilibrium condition leads to R'. Backtrack the changes in variable to arrive at the pumping rate R and the pump intensity I_p.

Find the pump power required for threshold

Find the gain required to compensate the loss (due only to transmission through the output coupler). Given the gain and cross-section leads to the inversion ΔN_{eq}. From there the procedure for finding the pump power is the same as above.

What is the output power at a pump power of 6 W?

Hint: Find the pump intensity, then the pump rate R. Follow the changes in variable to find successively T_p, I'_s and R', which leads to the equilibrium inversion ΔN_e. The condition that this inversion saturated to the threshold value (previous question) leads to the intensity.