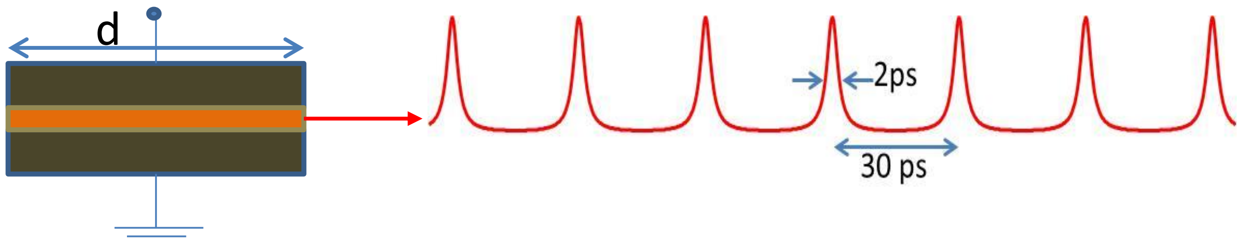
Laser Physics I (PHYC/ECE 464), Fall 2022

Homework #11, Due Monday, Dec. 5

1. An edge-emitting diode laser is mode-locked (e.g. by gain modulation), outputting a pulse train consisting of 2ps (bandwidth limited) pulses separated by 30 ps (as shown). The refractive index of the gain medium is n=4.



(a) What is the length (d) of the diode laser? (5 points)

(b) Qualitatively graph the power spectrum of the pulse train indicating the number of longitudinal modes that are lasing. (Be quantitative for the frequency axis). (10 points)

(c) The output of this laser is pigtailed to an optical fiber having β_2~100 ps^2/km. Describe (qualitatively draw) the pulse train after propagating through 100 m of this fiber. (10 points)

2. Consider the following *unidirectional* ring laser. The following parameters are known for the *homogeneously* broadened gain medium:

$\Delta\nu \cong 1\times10^{13}$ Hz , Gain cross section: $\sigma(\nu_0)=2\text{x}10^{-17}$ cm^2 , $\lambda_0=1$ μm.
Upper state lifetime ≈1 μs, spot size (w) inside the gain medium =100 μm (Gaussian beam) n(gain medium)=1.5. Cavity parameters are given in the Fig. A.

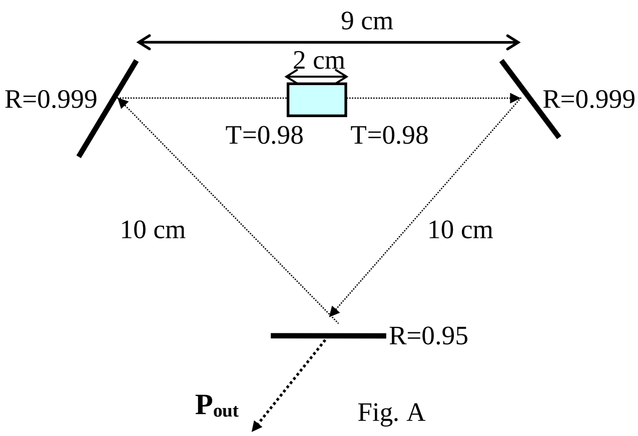


Fig. A

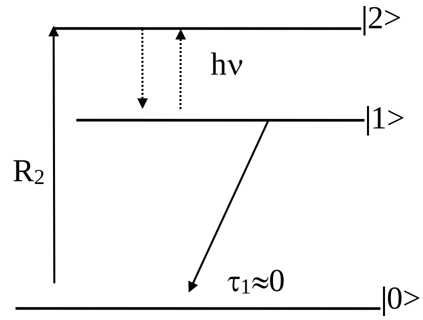
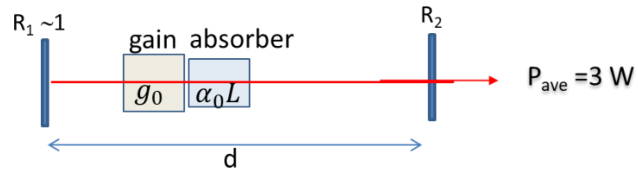


Fig. B

(a) What is the threshold upper state population (N_2^{th})?
(b) What is the cw output power if this laser were to be pumped ×6 above the threshold?
(c) Estimate the *minimum* excitation power required to sustain the output power in (b). Assume that the lower laser state (level 1 in Fig. B) is 3 eV above the ground state.
(d) If this laser were to be cw-modelocked, quantitatively describe (and graph) the temporal behavior of the output pulse-train. Assume the shortest possible pulse and ignore dispersion. Estimate the number of longitudinal modes that are oscillating. Estimate the peak output power if pumped at ×6 above the threshold.
(e) If this laser were to be Q-switched, estimate the pulse width.
(f) What is the spontaneous lifetime of the gain medium?

3. Consider the laser system below with an average CW output power of **3 Watts** with an optimized output coupling ($\boldsymbol{T_2^{opt}}$) when pumped at an integrated small-signal gain of $\mathbf{g_0=0.25}$. The only internal loss is from an intracavity absorber with $\boldsymbol{\alpha_0 L=0.02}$. All other intracavity surfaces are considered lossless (AR coated). The beam radius inside the cavity is **w~80 μm** inside the gain and absorber media.



(a) What is the output coupler reflectivity $\mathbf{R_2}$?

(b) What are g_{th} and γ_0/γ_{th} ?

(c) What is the *total intensity* inside the gain medium and the gain saturation intensity? (Assume and justify a high-Q cavity, and assume homogeneously broadened gain)

(d) Estimate the total power absorbed in the absorber.

This laser may be CW mode-locked to generate a train of pulses with **100 MHz** repetition rate and a peak pulse power of P_{peak}~ **300 kW**.

(e) Estimate the pulsewidth Δt_p ?

(f) What is the effective cavity length d (assume n_g=1) ?

(g) What is the saturation intensity of the absorber knowing that it saturates to **90%** to its unsaturated value when the laser is mode-locked.

(h) What *lifetime characteristics* render the gain and the saturable absorber suitable for modelocking?