Phys 532 Assignment 9 Due April 4

1. Consider an acousto-optic modulator made of TeO_2, which has an index of refraction $n = 2.35$ and sound velocity $v_s = 617$ m/s. The modulator is driven with a sound frequency of 80 MHz and is used to diffract light of (vacuum) wavelength 780 nm.
(a) Calculate the angle between the diffracted and undiffracted output beams.
(b) The rate at which the diffracted beam can be modulated is limited by the speed at which the sound waves traverse the beam. If the laser has a beam waist w of 200 μm, estimate the maximum modulation rate (in Hz).

2. If a pulsed laser with wavelength of 1064 nm has a pulse energy of 1 J, a pulse duration of 5 ns, a repetition rate of 1 Hz, and is focused to a spot size $w_0 = 50$ μm in vacuum, find the peak power, intensity and electric field of the pulses. Also, what is the average power output of the laser?

3. Recall the flashlamp-pumped Nd:YAG laser we discussed a few weeks ago. Lasers of this sort are commonly Q-switched to provide output pulses shorter than the flash durations.

Suppose such a laser has a cavity length $\ell = 30$ cm, a cavity loss per round trip of $\Gamma = 0.3$, and a gain medium of length $L = 10$ cm and area 1 cm^2. The Nd ions have a density of $N = 2 \times 10^{19}$ cm^{-3}, a radiative lifetime of $t_s = 10^{-3}$ s, and a transition linewidth of $\Delta\nu = 2 \times 10^{11}$ Hz. The laser transition is at $\lambda = 1064$ nm and the YAG host has an index of $n = 1.5$.

The laser is pumped with a flash of duration 5×10^{-4} s and energy $E_f = 20$ J. Suppose 1% of the flash energy is transferred to ions that end up in the proper excited state.
(a) Calculate the small signal gain per round trip g_0, using our usual formula for the gain coefficient

$$\gamma_0 = \frac{\lambda^2 \Delta N}{8\pi n^2 t_s \Delta\nu}$$

but recalling that for large gains, $g_0 = \exp(2\gamma L)$. Verify that $g_0 \gg \Gamma$.
(b) If Q-switching is used to suppress lasing until the end of the flash pulse, estimate the power and duration of the output pulse produced.

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4. Suppose a free-running laser has an inhomogeneously broadened output spectrum

$$P(\nu) \propto \exp\left[-\frac{(\nu - \nu_0)^2}{\sigma^2}\right],$$

where $P(\nu)$ is the power in a longitudinal mode at frequency ν. The longitudinal mode spacing itself is $\Delta\nu_L \ll \sigma$. If the laser is instead mode locked, determine the temporal pulse shape $P(t)$ for the resulting pulses.