

1. **AOM:** 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 minimum time required to turn the diffracted beam on or off. What is the maximum modulation rate (in Hz) that can be obtained?

2. **Pulsed Laser:** 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 (over a long time) power output of the laser?

3. **Q-Switching:** 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 $d = 30$ cm, a cavity loss per round trip of $\Gamma = 0.3$, and a gain medium of length $\ell = 10$ cm and area 1 cm^2 . The Nd ions have a density of $N = 2 \times 10^{19}$ cm^{-3} , a radiative lifetime of $t_{sp} = 10^{-3}$ 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 in the upper laser level.

- (a) Calculate the small signal gain per round trip g_0 , using our usual formula for the gain coefficient

$$\gamma_0 = \frac{\lambda^2 \Delta N}{8\pi n^2 t_{sp} \Delta\nu} \quad (1)$$

but recalling that for large gains, $g_0 = \exp(2\gamma\ell)$. 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.