PHYS 5130, Homework Set 5, due at 5 pm on Thursday, May 5$^{\text{th}}$.

1. Peak magnetic fields of pulses.
(a). (10 points) Using a 800 nm probe beam incident on a 10 μm thick $\langle 110 \rangle$-oriented ZnTe crystal ($r_{41} = 3.9$ pm/V, $n_{\text{NIR}} \approx 2$), we find that a 2 THz beam creates a (maximum) Faraday rotation of $\frac{\pi}{6}$. What is the maximum electric field (in V/cm) and magnetic field (in T) of this THz beam?
(b). (10 points) Compare your answer in (a) to the calculated electric field and magnetic field for the pulse conditions given in HW 4, problem 4 (consider the pulse inside of the semiconductor).
(c). (5 points) For a $g = 2$ spin, what static magnetic field (B_0) is necessary to generate a Zeeman splitting that is resonant to transitions at the frequency of the pulse in (a)? What about in (b)?

2. (15 points) For the sech pulse shape, derive the relation between the FWHM pulse duration, τ_p, and the pulse width, τ_s, where $\mathcal{E}(t) = \mathcal{E}_0 \operatorname{sech}(t/\tau_p)$.

3. (10 points) What is the separation between gratings, D, that is necessary to compensate a spatial dispersion of $dS/d\lambda = 10^5$ for a pulse centered at 600 nm? Assume a 30° angle of incidence and gratings with 1000 grooves/mm.

4. A Gaussian-shaped pulse, centered at 600 nm with a pulse width, τ_G, of 500 fs, is propagated through an optical fiber with an index of refraction of 1.5.
(a). (5 points) What is the spatial extent of this pulse just inside the fiber?
(b). (15 points) After traveling a distance, z_1, the pulse width has increased by a factor of 2 from linear dispersion ($dn/d\lambda = 10^3$ cm^{-1}). Find z_1. Hint: The temporal broadening due to dispersion, $\Delta\tau_G$, is: $\Delta\tau_G = z_1 \frac{\Delta n}{c}$, where Δn the change of the index of refraction over the bandwidth of the pulse.

5. Estimation of electric non-linear susceptibility.
As a first guess, one might expect that for $P^{(2)}$ to be comparable to $P^{(1)}$ when the applied electric field is of the order of the characteristic atomic electric field, $E_{at} = \frac{e}{4\pi\epsilon_0 a_0^2}$ (in MKS units), where a_0 is the Bohr radius.
(a). (5 points) Find E_{at}.
(b). (10 points) Assuming $\chi^{(1)}$ is of the order of 1 (very reasonable estimate for condensed matter), what is $\chi^{(2)}$ and $\chi^{(3)}$ in units of m/V and m^2/V^2, respectively?