NONLINEAR OPTICS (PHYC/ECE 568)

Fall 2017 - Instructor: M. Sheik-Bahae

University of New Mexico

Homework #1, Due: Monday Sept. 4

Problem 1. Nonlinear optical measurements show that an optical glass (SiO_2) has $\tilde{n}_2=1.3\times10^{-13}$ esu at λ=850 nm. The linear refractive index n_0=1.5

(a) What is n_2 in cm^2/W and m^2/W?

(b) What is $\chi^{(3)}$ in SI units?

(c) Estimate the peak index change (Δn) induced by a modelocked laser operating at 500 mW (average power), 20 fs laser pulsewith and 100 MHz repletion rate. The laser focused to a spot size of w_0=10 μm.

Problem 2. Extreme nonlinear optics occurs when the incident optical field approaches the characteristic atomic field $E_{at}=e/(4\pi\varepsilon_0)a_0^2$ where a_0 is the Bohr radius (read section 1.1 in Boyd). In this regime, we can no longer describe the nonlinearity by nonlinear susceptibilities as the process becomes non-perturbative. At such high electric fields, the atom simply ionizes.

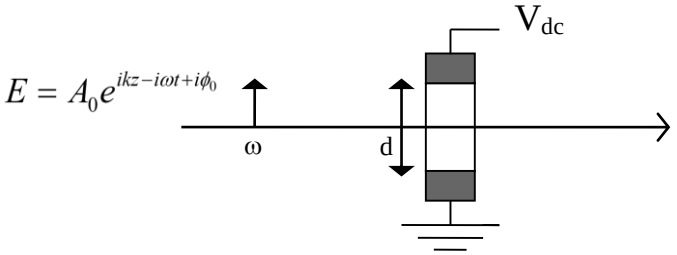
Calculate E_{at} and its corresponding irradiance I_{at}. What is the required pulse energy to achieve this irradiance for a 30 fs laser pulse focused to 20 μm spot size?

Problem 3. Pockel's Effect: A 2nd order nonlinear crystal with a known $\chi^{(2)}$, refractive index n_0 and a thickness L is used as an electro-optic modulator as shown below. Here a DC voltage (V_{dc}) is applied across two transverse electrodes (separated by d).
Ignoring anisotropy and tensor properties, show that the phase of the transmitted electric field will be modulated according to:

$$\Delta\phi(V) = \kappa V_{dc}$$

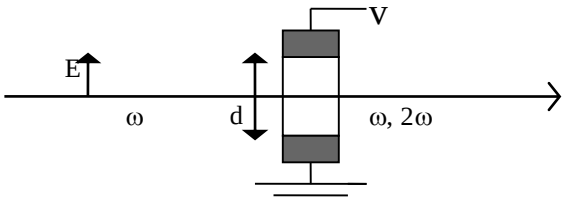
(a) What is κ (use SI notation)?

(b) For $\chi^{(2)}\approx$1 pm/V, find the required V_{dc} to achieve $\Delta\phi=\pi$ for L=1 cm, λ=500 nm. Assume d=10 mm, n_0=1.5.



Problem 4. EFISH: Electric-Field Induced Second Harmonic *(3 points)*

Consider a centrosymmetric and isotropic material (e.g. glass) for which $\chi^{(3)}(\omega_4; \omega_3, \omega_2, \omega_1)$ is known. In an experimental arrangement (as shown in the Figure) this material is sandwiched between two parallel electrodes while an intense laser beam is propagating parallel to the electrodes.



(a) By applying a large d.c. voltage (V), some second harmonic generation (2ω) is observed. Explain how this is possible.

(b) Assuming $\chi^{(3)} \approx 10^{-22}$ m^2/V^2, estimate the required voltage to produce a $\chi^{(2)}_{eff}$ equal to that of KDP ($\chi^{(2)} \approx 1$ pm/V). The electrode spacing d=10 mm.

(c) In the small signal regime (i.e. when the incident light intensity is very low), show that the phase of the transmitted beam is modulated by the applied voltage. Explain.