1) A Kerr cell filled with nitrotoluene is placed between crossed polarizers. The electrodes are 3 cm long and 5 mm apart. If the Kerr constant for nitrotoluene at $\lambda = 589$ nm is 2.44×10^{-12} m V^{-2} what applied voltage will provide the maximum transmission at this wavelength?

2) An optical isolator is constructed using two polarizers set at 45° with a piece of phosphate crown glass of thickness 5 cm in between. If the Verdet constant for the glass is 1.61×10^4 arc mins Tesla^{-1} m^{-1} for $\lambda = 589$ nm what magnetic field must be applied to give maximum transmission at this wavelength? What will the reverse transmission be if the magnetic field is 90% this value?

3) Show that material dispersion in a fibre optic gives a time delay:

$$\Delta t = \frac{-L\lambda\Delta\lambda(\frac{d^2n}{d\lambda^2} - \frac{2}{n}(\frac{dn}{d\lambda})^2)}{c(1 + \frac{\lambda}{n}\frac{dn}{d\lambda})^2}$$

where $\Delta\lambda$ is the bandwidth of the light and L is the length of the fibre. Give an approximation for Δt if the second derivative of the refractive index is much larger than the square of the first derivative and the first derivative itself is $<< 1$.

4) Calculate the electric field at a distance of 1 nm from a proton (E_1). A powerful pulsed laser beam is focused down to a spot size 1×1 μm. What pulse power will generate the same electric field amplitude E_1 in the focused spot. If the beam is focused into a dielectric what is likely to happen?

5) In a photon-number squeezing experiment optical pulses of duration $\sim$2.0 ps, bandwidth 1.25 nm and wavelength 1.455 μm are produced at a rate of 100 MHz. The pulses are injected into a single-mode, polarization preserving, optical fibre of length 1.5 km with a mode field diameter of 9 μm and core refractive index $n_o = 1.5$, $n_2 = 3 \times 10^{-22}$ V^{-2}m^2. Within the fibre the pulses propogate as solitons. On leaving the fibre the pulses are found to have a duration of 1.5 ps, a spectral bandwidth of 1.65 nm and an energy of 12 pJ. The pulses are detected using a photodiode and the noise on the pulses (fluctuations from pulse to pulse) is measured using a stable reference pulse.

(i) Estimate the maximum electric field generated by the solitons in the fibre.

(ii) Estimate the maximum non-linear perturbation to the refractive index generated by the solitons.

(iii) Estimate the number of photons in each pulse.

(iv) Estimate the number of SiO_2 molecules contained within the pulse.

(v) What is the expected level of shot noise if no squeezing occurs?