PHYC40210 Problem Sheet 2, due 5th April 2024

Q1. For a Gaussian laser pulse with intensity $I(t) = I_0 \exp[-2.77(t/\tau)^2]$, focussed into an optical fibre, calculate the maximum frequency shift that will be obtained and explain its dependence on laser pulse duration and fibre length. (I_0 is maximum intensity and τ is the FWHM of the pulse).

Q2. Extreme nonlinear optics occurs when the incident optical field approaches the characteristic atomic field $E = e/(4\pi\varepsilon_0)a_0^2$, where a_0 is the Bohr radius. At such high electric fields, the atom simply ionises.

i) Calculate E and its corresponding irradiance I.

ii) What is the pulse energy required to achieve this irradiance for a 25 fs laser pulse focused to 10 μm radius focal spot?

Q3. In an experiment to produce high harmonics a Ti:Sapphire laser pulse (λ = 820 nm) pulse was focussed to a power density of 10^{16} Wcm^{-2}.

If the ionisation potential of He is 24.587 eV, what will be the wavelength of the highest harmonic produced?

Q4 Consider the following laser pulses focused into a He gas jet:

Laser A: λ = 300 nm, pulse energy 5 mJ, pulse duration = 7 fs, focal radius =30 μm

Laser B: λ = 700 nm, pulse energy 5 mJ, pulse duration = 7 fs, focal radius =40 μm

Laser C: λ = 3200 nm, pulse energy 5 mJ, pulse duration = 35 fs, focal radius =60 μm

Which of the lasers would you expect to produce the highest energy harmonic?

Q5. Two high intensity pulses with the same wavelength, one with a pulse duration of 100 fs and the other with a pulse duration of 5.4 fs, are available for a high harmonic generation experiment.

What is the appropriate experimental technique(s) to ensure a single attosecond pulse is generated in the case of each laser.