MRes in Physics at the Nanoscale
Course CPPNS1 (X-Rays)

David Parker

In ALL the questions below, you should provide appropriate comments on your answers.

1. A plasma is produced by focusing a pulsed laser beam, of energy $E = 100\,\text{mJ}$ and duration $\tau = 100\,\text{ps}$, to a spot of diameter $d = 10\,\mu\text{m}$ on a plastic (CHO) target. Calculate the irradiance, in watts per square metre.

2. The emission from the plasma of question 1 is dominated by lines from hydrogen-like ions of carbon and oxygen. Describe, qualitatively, how you would expect the emission spectrum to change if each of the following parameters was gradually reduced while the others were maintained constant at the above values:

   (a) The beam energy.

   (b) The pulse duration.

   (c) The focal spot diameter.

   (d) The laser wavelength.

(no 3s line)

3. Observed emission lines from hydrogenic carbon are due to atomic levels with binding energies of 490.00 eV (1s), 857.50 eV (2p), 925.54 eV (3p) and 949.36 eV (4p). Calculate the wavelengths of all of the lines due to electric-dipole transitions between these levels, and state which of them you would expect to be the strongest. Determine the corresponding wavelengths of emission from hydrogen-like oxygen.

4. Look up the optical constants δ and β at the carbon 2p-1s transition energy for tungsten (W) and carbon (C). Then answer the following questions, which all refer to this energy.

   (a) Determine the critical, θ_c, and Brewster, θ_B, and angles for W and C.

   (b) Calculate the ratio of the s- and p-polarised reflectivities for both W and C at θ_c and θ_B.

   (c) *Estimate*, stating your assumptions, the *maximum* number of layer pairs of a W/C periodic multilayer that would contribute to the overall reflectivity.

   (d) A C zone plate is made with a diameter of $100\,\mu\text{m}$ and an outer zone width of 20 nm. Determine the first-order focal length, the first-order focal spot size (assuming a source size of $10\,\mu\text{m}$ at a distance of 1 m), the thickness of C required to give optimum efficiency, and the corresponding efficiency.

Answers (one copy), showing full working, must be handed in to Julia Kilpatrick by 17:00 on Friday 11 December 2009. You should **not** assume that a late submission will automatically be marked **unless** there is a medical or other extenuating reason for lateness, supported by an appropriate medical certificate or documentation.
Remember that you are being trained in research techniques; these include the ability to discuss problems with your colleagues. You are therefore encouraged to do this, before asking members of staff for assistance/hints. Remember, however, that the work submitted MUST be your own.

Professor AG Michette 09/11/2009