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

Problem Sheet E

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

You will need to look up suitable values for the parameters of state-of-the-art visible wavelength lasers.

It is proposed to undertake holographic imaging of hydrated biological material using a plasma-based short wavelength laser with the following properties:

Wavelength: $\lambda = 4.16\,nm$
Bandpass: $\Delta\lambda/\lambda = 2\times10^{-4}$
Plasma column length: 5 cm
Plasma column diameter: 200 μm
Pulse length: 50 ps

1. *Estimate* the maximum thickness of a hydrated biological specimen that could be imaged in transmission (non-holographically) at a wavelength of 4.16 nm.

2. Determine as fully as possible the coherence properties of the short wavelength laser. Compare these, in a quantitative way, with those of visible light lasers used in holography.

3. Discuss whether the specified short wavelength laser would be useful for holographic imaging. Which properties should be changed, and in what way (i.e., increased or decreased), in order to improve the performance?

4. Look up the optical constants δ and β at a wavelength of 4.16 nm for germanium (Ge) and aluminium (Al). Then answer the following questions, all of which refer to this wavelength.

    (a) Determine the critical, θ_c, and Brewster, θ_B, and angles for Ge and Al.

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

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

    (d) A Ge zone plate is made with a diameter of 300 μm and an outer zone width of 15 nm. Determine the first-order focal length, the first-order focal spot size (assuming a source size of 200 μm at a distance of 2 m), the thickness of Ge required to give optimum efficiency, and the corresponding efficiency.

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