Fundamentals of Optical Sciences

WS 2015/2016 **7 . Exercise** **30.11.2015**

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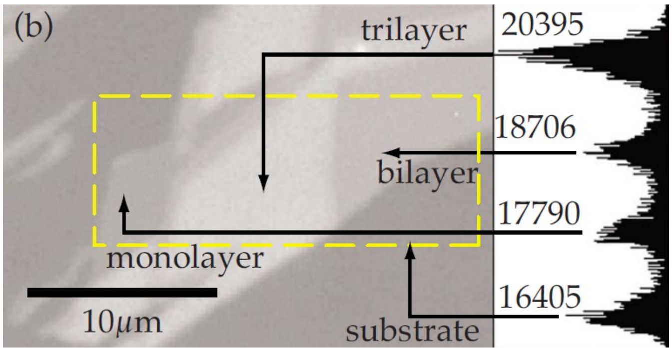
Prepare your answers for the excercise on 07.12.2015.

Exercise 1

Exfoliated graphene on glass

Exfoliation of single graphene flakes from graphite is a wide-spread preparation technique. A simple tool to find and characterize even such thin layers is optical microscopy (see figure taken from DOI: 10.1063/1.3115026). Use the reflection-summation model to calculate the



contrast of a single graphene flake in an ordinary light microscope. Assume, that graphene was exfoliated onto perfectly smooth (and infinitely thick) glass. For simplicity neglect all illumination and detection angles other than normal incidence. Further, restrict the illuminating wavelength to only green light of 550 nm. For this wavelength consider a refractive index for glass of $n_{\text{glass}} = 1.5$, for graphene of $n_{\text{gr}} = 2.5 - i1.5$ and for air of $n_{\text{air}} = 1$, respectively. Find potential further relevant numbers at Wikipedia.

Exercise 2

Plot the intensity reflection coefficients as a function of λ_0 for light incident from air onto crown glass with a double-layer antireflection coating. The thin-film stack consists of a $\lambda/4$ layer of ZrO_2 ($n = 2.1$) directly on top of the crown glass, followed by a $\lambda/4$ layer of CeF_3 ($n = 1.65$). Assume a design wavelength of 550 nm (in vacuum) and extend the plot over the visible spectrum (400-700 nm). Consider only the case of normal incidence. How thick are the layers in nm? (After finding the necessary matrices and parameters for the system under the given conditions, use software to plot the reflectance *vs.* λ as directed. You do not need to write out the entire expression for the reflectance.)

Exercise 3

a) Show that the Fraunhofer approximation is more restrictive than the Fresnel approximation by taking $\lambda = 0.5\ \mu$m, and assuming that the object points lie within a circular aperture of radius $b = 1$ cm and the observation points lie within an aperture of $a = 2$ cm. Determine the range of distances d between the object plane and the observation plane for which each of these approximations is applicable.

b) Compute the far-field (Fraunhofer) diffraction pattern on a screen at location z due to a rectangular aperture of width w and height h at $z = 0$. Assume the aperture is uniformly illuminated by a plane wave at normal incidence to the aperture. What are the widths between the first dark fringes of the pattern?

Exercise 4

Cavity Basics

Consider a planar cavity of nominal length $d = 1$ cm. The cavity is resonant with light of $\lambda = 1\ \mu$m.

a) What is the finesse F for mirror reflectivities of 95%?

b) Compute the ratio Q/F for this cavity at this wavelength.

c) Suppose that you change the wavelength by $\Delta\lambda$ before you find the next cavity resonance. What is $\Delta\lambda$?

d) Suppose that the mirrors have very high reflectivity, so that the cavity is "good." State whether the following quantities would be larger, smaller, or the same as for a "bad" cavity of the same geometry.

   1. survival probability
   2. Q factor
   3. finesse
   4. round-trip time
   5. free spectral range
   6. resonance width ($\delta\nu_{\mathrm{FWHM}}$)
   7. photon lifetime