X-ray interferometry, a new tool for optical constant determination

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As is well known, the interaction of light with matter is partly described by the f_1 form factor, which results in *phase* changes of propagating wavefronts. Despite this direct connection between f_1 and phase, the determination of f_1 (or equivalently of the refractive index n, or =1-n) always relies in some way on energetic measurements, i. e. absorption or reflectivity. Indeed, exact determinations are in theory allowed by the Kramers-Kronig (KK) relations. But, their practical inversion suffers, especially in the region of absorption edges, of several drawbacks which should make any *direct* determination welcome. In particular, comparing the result of basically different approaches might be a test of the validity of models and computation techniques needed when inverting KK. Also, the fact that one index value is obtained by one single measurement (and not from a large set of absorption or reflectivity data) should give easier access to experimental values from "real" materials.

As interferometry is the choice method for index determination in visible optics, we have proposed in 1990 (after an early principle experiment by Aoki in 1986)[1,2] to implement an interferometric system for the direct determination of the optical thickness of a thin sample. The interferometer, which was implemented since 1992, does not use any beamsplitter, because it belongs to the wavefront division class. It is a Fresnel mirror set-up; recourse to grazing incidence makes it applicable to a wide range of wavelengths. The source is the SU7 undulator line of the Super-ACO synchrotron radiation ring, at Orsay (France). As usual, the introduction of a thin transmitting sample into one arm produces a shift of the fringe pattern. In the first experiments (1992-1995), interferograms were recorded on photographic plates and then processed to extract the fringe shift. This experiment has produced the first *direct* demonstration of the fact that the index of carbon crosses 1 near the K-edge (=4.4 nm).

However, photographic detection is clearly unsuitable for routine determination. We have recently (1996) designed and implemented a dedicated optoelectronic detection system, which provides directly a measurement of the fringe shift due to the sample. The system is based on the spatial moiré between the aerial X-ray fringe pattern and a grid with the same spatial frequency. It made it possible to plot the low absorption part of the dispersion curve of carbon at the K edge, in a reasonable time.[3]

The sensitivity of the optical thickness determination is presently about 1/200 fringe in the best case (and might still be improved). For a carbon sample in the 4.4 nm region, this corresponds to $5.\ 10^{-5}$ on absolute index values (for a 500 nm thick sample), or 0.05 electron/atom on f_1 (for a 100 $\mu g/cm^2$ sample). We are presently improving the method to ensure that, even at large sample absorption on the high energy side of the edge, accuracy is not impaired by spurious signals from the detection system, and by spectral pollution of the SR beam.

[1] S. Aoki, S. Kikuta, AIP conf. proc. **147**, 49 (1986)
[2] F. Polack, D. Joyeux, in *X-ray Microscopy III*, A. G. Michette, G. R. Morrison, and C. J. Buckley eds. (Springer series in optical science vol. 67, Springer, 1992)
[3] D. Joyeux, F. Polack in: *X-ray Microscopy V,* XRM 96, conference on X ray microcopy, Würzburg (Germany), 19-23 august 1996, to be published (Springer).