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Transmission of X- ray Polarization Through Glass Capillary Fibers –part 2

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Beamline: X14A

Introduction: Using improvements in both the polarimeter and experimental technique, this work extends preliminary measurements reported in NSLS Abstract Bene 370. We wished to learn if the multiple glancing-angle reflections occurring during transmission through straight and bent glass capillary fibers could depolarize incident synchrotron-radiation x-rays. The glass fibers are the type used for focusing and collimating x-rays used principally for fluorescence measurements with conventional laboratory sources, for which these results could be useful. The fibers enclosed of order 10^3 capillaries with diameter 10 μm.

Methods and materials: As before, the polarimeter employed 90^0 Rayleigh-Thomson scattering of x-rays emerging from the fiber by an amorphous carbon foil. The polarization is determined by measuring the maximum and minimum counting rates from a proportional counter which rotated around the beam as axis, here called an angular scan. In contrast to the earlier work, the present polarimeter left fiber and cylindrical holder fixed, while the carbon foil and proportional counter rotated around the emergent beam as axis. Counter and foil were mounted on an arm attached to a commercial rotating stage, and the angle φ between incident polarization and an imaginary line joining the foil and counter centers was measured by the rotating-stage protractor. This arrangement eliminated the previous need for frequent re-alignment and gravitational effects on a bent fiber. A single choice of deflection was used to bend the18 cm long fibers: 2 cm over 10 cm, leaving straight sections near the ends. The rotating stage with foil and counter attached was mounted on a shelf attached to the main cylinder , which permitted the stage to be rotated and translated in order to track the exit end of the fiber when bent, .and have it remain as the axis of the stage. The plane of the bent fiber could be changed from horizontal to vertical by rotating the cylindrical holder through 90^o around the beam as axis. Angular scans were made for 11.5 and 7 keV x-rays emergent from either straight and bent fibers, as well as for the fiber axis slightly misaligned with respect to the incident beam (to increase wall collisions).

Results: All data could be represented as $I = K_1\cos^2 \varphi + K_2$, where I is proportional to the counting rate, angle φ was defined above, and K_1 and K_2 are constants. The polarization P of the x-rays emerging from the fibers is obtained as $\mathbf{P} = [I_{max} - I_{min}] /[I_{max} + I_{min}]$, where I_{max} and I_{min} are, respectively, the maximum and minimum counting rates in an angular scan $\{ P= K_1 /[K_1 + 2K_2] \}$. In the vicinity of 0^o, 90^0, 180^0 and 270^0, count rates were measured in clusters of three. Apart from the preliminary 8 keV straight-fiber data, all the measured values of P lie between 0.82 ± 0.02 and 0.86 ± 0.01, the latter for the direct beam at 11.5 keV. Actually, this latter value is lower than nearly one expected for a synchrotron, and is probably due to less than ideal geometry for the polarimeter and non-uniformities in the foil; however, direct-beam values serve as useful standards for the effect of the capillaries. There is no evidence for any rotation of the polarization plane by the fiber: I_{max} and I_{min} occur at the same φ angles as the direct beam.

A simulation program[1] modified for the synchrotron beam divergence[2] indicates that the number of x-ray collisions varies from about 22 to 150 for, respectively, straight and bent fibers.

Conclusions: Incident beam polarization is transmitted almost without attenuation through glass fibers of lengths useful for collimating and focusing optics, and therefore useful for reducing background in materials characterization by x-ray fluorescence. This work has stimulated measurements with complete optics and a ray-tracing calculation which includes the electric-field vectors, to understand the present data, and to predict the fiber geometry for which the multiple reflections would have a significant effect on polarization or intensity losses. This has been accepted by *Review of Scientific Instruments* and is in press.

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References: 1.Qi-Fan Xiao, I. Y, Ponamarev, A. I. Kolomitsev, and J. C. Kimball, “Numerical simulations for capillary-based x-ray optics,” SPIE Proc. **1736,** 227 (1992). 2. Ki-Sup Chung, Jianming Bai, Cullie J. Sparks, and Gene E. Ice, "Increased Performance on Beamline X14A with 12-mrad sagittal-focusing monochromator, 11th Synch. Rad. Conf., 219-222, AIP Press, New York (2000).