Spatial Coherence Measurement of Soft X-ray Undulator Radiation

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Introduction

The latest generation of synchrotron sources, such as APS, have been designed and built to produce very bright, highly coherent light, particularly in the x-ray region. The dream of creating highly coherent x-ray synchrotron sources is to make possible new and unique coherence-based experiments. It is hoped that this will stimulate the renaissance that occurred in visible optics research with the introduction of the laser. The types of experiments that are possible and are being conducted include scanning microscopy, interferometry, coherent scattering, and phase measurement. In this research, we have been concerned with measuring spatial coherence. Here we present results of a classical Young's two-slit experiment with x-rays.

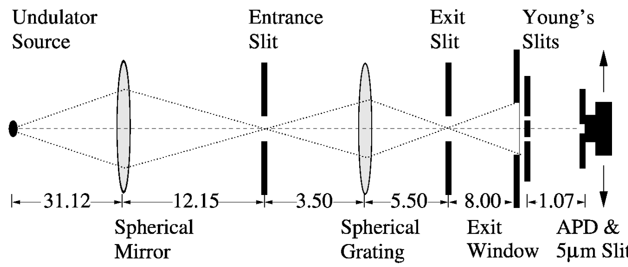


FIG. 1. The 2-ID-B beamline and Young's experiment at the APS, showing beamline optics depicted as thin lenses in the horizontal plane. Distances shown are in meters. The total distance from the undulator to the experiment is 60.3 m.

Methods and Materials

The experiments were performed at the SRI-CAT beamline 2-ID-B at APS in collaboration with B. E. Allman, P. J. McMahon, J. Lin, C. T. Chantler, and K. A. Nugent (researchers from the University of Melbourne, Australia). Figure 1 shows the positioning of the optical components in the horizontal plane along the beamline and the experiment apparatus. For these experiments, we fabricated an array of seven slit pairs (10, 20, 50, 80, 100, 150, and 200 µm separation) in a 1.6-µm-thick gold layer. This very accurate lithography was also conducted at SRI-CAT by N. Moldovan and D. C. Mancini. The intensity patterns were obtained by scanning an avalanche photodiode detector (APD) with a 5-µm slit placed directly in front of it, both of which were mounted on a translation stage.

In these experiments, we investigated the beamline spatial coherence dependence by altering the exit slit located down stream of the multilayer spherical grating monochromator. Narrowing the exit slit has two effects: (1) the degree of monochromation is increased, and (2) the size of the secondary effective source is reduced for experiments located downstream.

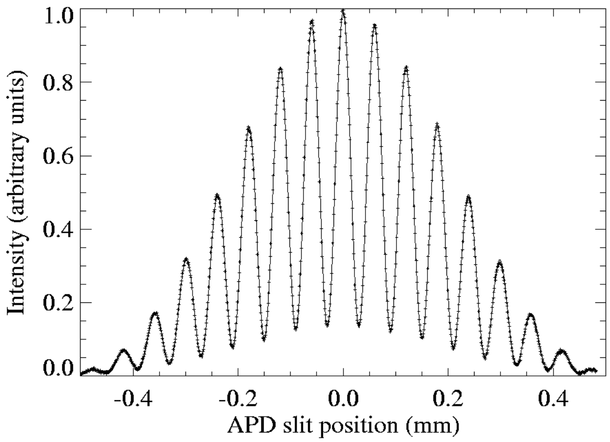
Results

The degree of spatial coherence $|\mu_{12}|$ is directly related to the fringe visibility of a Young's experiment. If we compare the graphs in Fig. 2(a) and 2(b), we can see the difference in fringe visibility as the Young's slits are separated by larger distances.

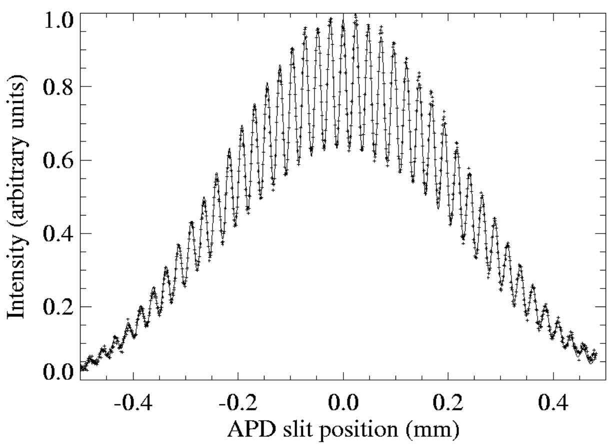
Discussion

The degree of coherence for the various Young's slit separations is plotted for two exit slit settings in Fig. 3. The results for various Young's slit separations can also tell us something about the size and shape of the undulator source. In our research, we compare our experimental results with models predicting the coherence that should be produced by various undulator source sizes and shapes. The predicted coherence was found to be in good agreement with the experimental results [1]. The radiation at the exit of the beamline is shown to have very high spatial coherence at transverse separations up to 100 µm.

A complete measurement of the coherence function requires the degree of coherence to be determined for the full range of slit separations and locations over the 2-D beam cross section. This is an extremely time-consuming and therefore impractical experiment that uses Young's slits, and a more efficient method for determining coherence properties of x-ray radiation is required. This is the focus of our continuing research at Sector 2. Ultimately, a complete measurement of the undulator beam provides a detailed understanding of the undulator

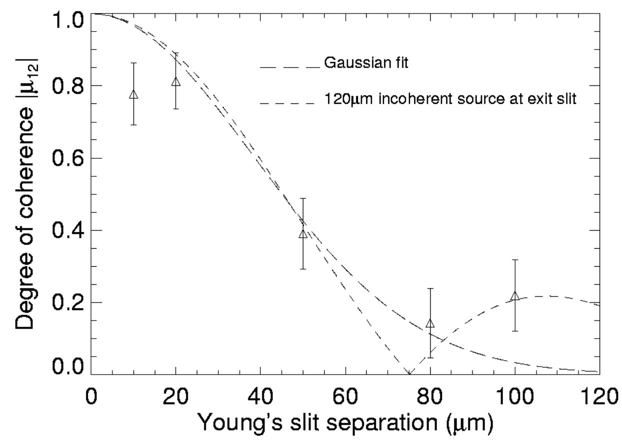


(a) Young's slit separation of 20 μm.

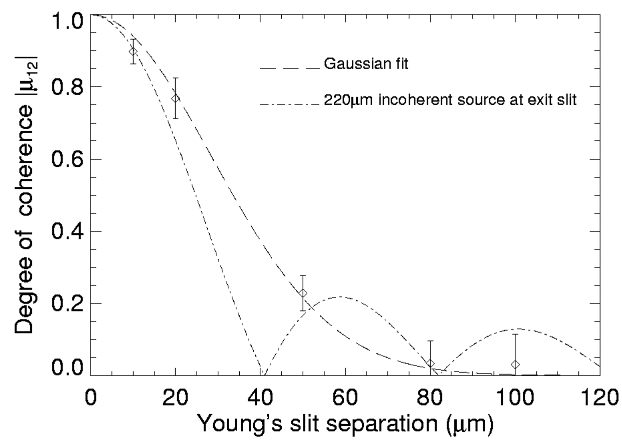


(b) Young's slit separation of 50 μm.

FIG. 2. Young's two-slit diffraction pattern for 1.1-keV x-rays as detected by an avalanche photodiode detector. The data are represented with crosses, and the solid line is a theoretical fit to the data.



(a) Exit slit width is 100 μm.



(b) Exit slit width is 200 μm.

FIG. 3. Spatial coherence measurements for two exit slit settings.

source itself. This, in turn, can provide important feedback for improving the characteristics of the synchrotron ring.

Acknowledgments

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References

Extracted from D. Paterson, B. E. Allman, P. J. McMahon, J. Lin, N. Moldovan, K. A. Nugent, I. McNulty, C. T. Chantler, C. C. Retsch, T. H. K. Irving, and D. C. Mancini, "Spatial coherence measurement of x-ray undulator radiation," Optics Communications **195,** 79 (2001).