Summary of the recent conference on thin-film neutron optical devices

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ABSTRACT: The proceedings of the conference of the International Society for Optical Engineering on Thin-Film Neutron Optical Devices: Mirrors, Supermirrors, Multilayer Monochromators, Polarizers and Beam Guides, which was held in San Diego, California in August, 1988, are summarized here.

Introduction

Substantial efforts have been made in recent years in the development of reflecting guide tubes for cold neutrons and of multilayered thin-film structures for use as neutron monochromators and polarizers. With new cold-neutron facilities presently under construction and next-generation reactor and pulsed sources currently being planned, it was considered timely to hold a conference specifically on the important applications of thin films and multilayers as neutron optical devices. A two-day conference was consequently organized by the International Society for Optical Engineering (SPIE) as part of its 32nd Annual International Technical Symposium. A synopsis of the proceedings of this conference[1], which are relevant to the present workshop, follows.

Supermirrors

The subject of the first of four sessions was the theoretical design, fabrication, and actual performance of both polarizing and non-polarizing supermirrors and was chaired by Feri Mezei. To begin, Gian Felcher of Argonne National Laboratory gave a general introduction on the principles of neutron reflectivity for magnetic and nonmagnetic materials. The formalism to calculate the reflectivity from a sample composed of stacked flat layers and, inversely, to calculate the stacking from reflectivity measurements was described. Feri Mezei next spoke about very high reflectivity supermirrors and their applications involving multiple reflections and transmission geometries. In particular, the design and characteristics of several novel devices such as polarizing cavities, beam compressors, and splitters were discussed. For example, the polarizing cavity, which utilizes polarizing supermirror coatings on transparent single-crystal Si substrates within an ordinary Ni guide but inclined at the proper angle, can be used to polarize the entire flux transported by a guide with high efficiency over a relatively broad wavelength range. Roger Pynn then reviewed the widespread use of mirrors and supermirrors at the Institut Laue-Langevin in beam handling or transport through guides as well as in specific instrumental applications such as polarization analyzers. In the following paper by John Hayter and Herb

Mook, a new method of designing supermirrors based on a consideration of the contribution of each bilayer to the extinction in a given stack of bilayers was presented, including the derivation and solution of the discrete set of equations governing the selection of layer thicknesses. Anand Saxena then talked about the fabrication of non-polarizing singlespacing multilayer monochromators in the 60 to 200 Å range with reflectivities greater than 95% and compared the calculated and observed diffraction profiles from which it could be concluded that the multilayers had a significant degree of imperfection. The last paper of the session was by John Keem, et al., on an investigation of the microstructure of vapor deposited Ni-Ti multilayers and supermirrors using neutron and x-ray diffraction in addition to transmission electron microscopy. The measured neutron reflectivities of supermirrors were less than predicted. The study showed very convincing evidence of the formation of cusps in the Ni layers. This important finding strongly suggests that the reduction in reflectivity is due primarily to layer roughness.

Neutron guides

The topic of the second session, chaired by Tasso Springer, was neutron guides. The first paper, by Ebisaiva, et al., described both conventional Ni-coated guides and a Ni-Ti supermirror guide tube installed at the Kyoto University Research Reactor in Japan. A detailed comparison of the actual performance of the two types of guides was given. Next, Francois Samuel gave a detailed description of the construction and installation of neutron guide networks at a number of European neutron scattering facilities. A thorough analysis of losses within a guide due to less than perfect Ni film reflectivity, spatial and angular misalignments, and gaps was presented. The third paper of the session, by Alefeld, et al., described the new neutron guide laboratory at the KFA, Jülich, FRG, and its special beam-forming devices. The measured neutron fluxes in the ^{58}Ni guides were given along with a technical layout of the guide system, which supplies 10 instruments with cold neutrons from the hydrogen cold source. In addition, the design and performance of a neutron-guide junction at the entrance of the guide network, a multislit-bender with a radius of curvature of 57 m, and conical-focusing neutron guides coated with supermirror were discussed. The last two papers of the session were concerned with the calculation and measurement of the performance of converging neutron guides. Ian Anderson spoke first and gave a simple analytic approach to determine the flux gain that may be achieved in such a system as a function of the ratio of the entrance and exit widths, which also determines the wavelength dependence. The second paper, by Copley, et al., discussed the spatial and angular distributions of a beam emerging from a converging guide, which are generally nonuniform and wavelength-dependent. Analytic and numerical methods of calculation were considered and the results of selected Monte Carlo numerical calculations were presented. Measurements on a scaled-down version of a converging guide system were reported and found to compare well with calculation. It was found that flux gains as high as a factor of four (in two dimensions) using supermirror converging sections at the end of an ordinary guide are possible.

Other devices and applications

Session 3 of the conference consisted of six presentations on other device applications. Albert Steyerl began with a report on the novel guides and mirrors for cold and ultracold neutrons, which were used for the new intense turbine source of very slow neutrons at the High-Flux Reactor of the Institut Laue-Langevin, Grenoble. Neutron mirrors are essential components for Doppler-shifting turbines and high-resolution ultracold neutron spectrometers. The instrumentation for neutron microscopy that makes use of imaging mirrors was described as well as the results of detailed investigations of specular and nonspecular components in mirror reflection from glass and metal-coated glass mirrors. These results were compared with the characteristics of zero-order diffraction from a planar-ruled diffraction grating. A paper by Utsuro, et al., then described the ultracold neutron facility at the Kyoto University Reactor in Japan, including the characteristics and performance of the curved Ni mirror guide, supermirror turbine, and gravity spectrometer. The paper by Alefled, et al., then considered the possibilities for focusing neutrons with curved mirrors. It was concluded from intensity calculations and experimental intensity profiles that focusing small-angle neutron scattering instruments with high-quality neutron mirrors will be superior to conventional pinhole instruments for high-scattering vector resolution $\Delta Q \leq 10^{-3}\text{Å}^{-1}$. Interesting experiments with a neutron "lens" and a microbender made up of multilayered thin film microguides were also discussed. A paper by Majkrzak, et al., then presented several applications of supermirrors and multilayers planned for the new Cold Neutron Project at the National Institute of Standards and Technology. Included in this presentation were descriptions of a novel polarized triple-axis spectrometer using a combination of supermirror polarizers and Drabkin resonance spin-flippers as monochromator and analyser, a neutron reflectometer, and a focusing mirror for a small-angle scattering spectrometer. Tasaki, et al., were the authors of a following paper on an interesting idea for a polarizing monochromator consisting of two multilayers in series. This combination serves not only as monochromator and polarizer, but collimator and beam bender as well. The final paper of the session was by DiNardo, et al., and dealt with the actual fabrication of polarizing multilayers by sputtering, in particular for the Fe-Si system, and compared observed reflectivities with predicted values.

Multilayer monochromators for X-rays and neutrons

The conference on neutron optics concluded in a joint session with another symposium conference on X-ray multilayers.[2] Andreas Freund opened the session with a talk on the common and disimilar aspects of beam-defining devices for x-rays and neutrons. Besides the intrinsic interaction properties of the two radiations with matter, the importance of the properties of the sources (e.g., neutron reactor or pulsed source and x-ray synchrotron) for the design of beam optics was discussed. Josef Feldhaus next gave an overview of soft x-ray monochromators for synchrotron radiation showing examples typical of various energy ranges and applications. A review of the theory of multilayer neutron monochromators was given by Varley Sears, in which both the kinematical and dynamical treatments were discussed. Two additional papers were presented, one by Smith, et al., on a W-C multilayer monochromator for x-rays and the other by Evans, et al., on the neutron reflectivity of Ni-Si multilayers.

Conclusion

The quality of the papers presented and the exchange of information that occurred between people attending the x-ray and neutron conferences contributed significantly, I believe, to the success of the meeting. It is hoped that a similar conference will be held in the future.

References

1. SPIE Proceedings Vol. 983, "Thin-Film Neutron Optical Devices: Mirrors, Supermirrors, Multilayer Monochromators, Polarizers and Beam Guides", C. F. Majkrzak and A. M. Saxena, Eds. (SPIE, Bellingham, WA, in press).

2. SPIE Proceedings Vol. 984, "X-ray Multilayers for Diffractometers, Monochromators, and Spectrometers", Finn E. Christensen et al., Eds. (SPIE, Bellingham, WA, in press).