Proc. Int. Symposium on Neutron Optics and Related Research Facilities, Kumatori, 1996
J. Phys. Soc. Jpn. **65** (1996) Suppl. A pp. 325-326

Summary of Chapter 1 (Fundamental Physics of Neutron Optics), Chapter 2 (Neutron Interferometry), and the Related Poster Sessions.

Helmut Rauch

Atominstitut der Österreichischen Universitäten, A-1020 Wien, Austria

NOK'96 was a truly outstanding Symposium with respect to the scientific standard represented and the organizational endeavours. It is clear that *Neutron Optics* is a lively field of research with close connections to the exciting field of *Quantum Optics*, and promises very profound consequences for the understanding of quantum mechanics and for the development of advanced neutron instrumentation.

Valuable contributions came from laboratories operating small, medium, and high flux neutron sources. The specific strengths of the various laboratories concerning their relation to education, contacts to industry, and basic research should form a necessary symbiosis for neutron research in future. The whole family of sources will be needed to achieve this goal (figure 1).

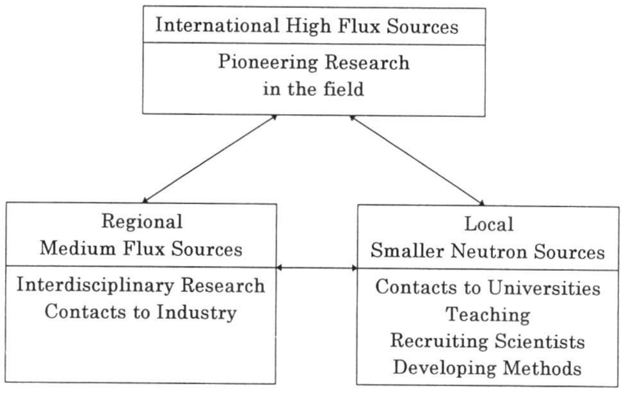

Fig. 1. Symbiosis of various classes of neutron sources.

The well-known author of the book "Neutron Optics", *Vallery F. Sears*, presented the fundamentals of neutron optics, giving special attention to the effective field correction on the index of refraction which results from an interplay of waves scattered from different nuclei in the sample. *Vladimir K. Ignatovich* treated multiple wave scattering effects, whereby he identified deviations from the standard Fermi-formulation of the index of refraction, which become measurable for ultra cold neutrons. The contribution of *Alexander I. Frank* and *Vadim G. Nosov* dealt with diffraction-in-time effects, which become observable for cold and ultra cold neutrons when, after diffraction from rapidly moving gratings or from rapidly changing magnetic structures, the energy distribution is measured. Here it must be mentioned that *Johann Summhammer et al.* (PRL 75 (1995) 3206) recently measured, with an interferometric Fourier method, the multiphoton exchange within an oscillating magnetic field. *Mikio Namiki* dealt with the problem of the quantum mechanical wave function collapse in the case of a measurement. He introduced a decoherence parameter which progressively changes a physical situation from a quantum state to a mixture. Further details of that formalism were given for a dissipative phase shifter in a poster contribution by *Hiromichi Nakazato et al. Ferenc Mezei* showed that spin precessions which are different from ordinary Larmor precessions can be achieved when nuclear and magnetic interactions with the neutron occur simultaneously.

The reports of this summary showed, in the neutron interferometry session, how neutron optics effects can be interpreted in terms of quantum optics. The Wigner-functions can be used to identify squeezed and Schrödinger-cat-like states which have been observed experimentally in the course of interferometric post-selection experiments. The question of coherence was discussed separately by an ad hoc panel, in which the three-dimensional feature of coherence, and its connection to the experimental preparation procedure were of central interest. The general outcome of this panel was that coherence properties can be defined for neutron beams, in a way similar to that in light optics, by means of correlation functions. *Samuel A. Werner* reported about gravity and rotational-induced phase shifts, noting that future experiments are requested to solve an often discussed discrepancy between calculated and measured phase shifts. He discussed the difficulties of going from a quantitative experiment to a precision experiment, where absolute numbers have to be extracted. Further details were reported in the poster session by *Kenneth Littrell et al.*, who used different wavelengths to measure the gravity effect, and by *Brendan Allman et al.*, who searched for quaternion contributions to quantum mechanics. Polarized neutron interferometry was the topic of *Gerald Badurek's* contribution. The 4π-symmetry of spinor wave functions, superposition experiments for spinor states and coupling to resonance fields were discussed. The measurement of the scalar Aharonov-Bohm effect and the first direct verification of the geometrical (Berry) phase were major achievements among polarized neutron interference experiments. The very elegant method for the measurement of the geometric and dynamical phase by means of properly oriented spin rotators was shown in detail in a special poster contribution by *Apoorva G. Wagh et al.* Another poster contribution by *Yuji Hasegawa et al.* showed that the phenomenon of geometrical phases also appears and can be measured in the case of coupled interferometer loops, which are characteristic of four-plate interferometers. A proposal for the measurement of the Levy-Leblond phase, which is caused by spatial confinement of the neutron beam within narrow tubes, was presented by *Anthony G. Klein et al.* A close connection between neutron interferometry and advanced micro-technology was demonstrated by *T. Ebisawa et al.*, who reported on a new type of interferometer for cold neutrons which was based on multilayer mirrors. Light-induced macroscopic lattices in polymers are another example of artificially produced structures which can be used for neutron optics (*R.A. Rupp et al.*) . The following figure 2 shows which kinds of optical components have been used for neutron interferometry.

In the poster session, many further interesting developments were presented. Simultaneous nuclear and magnetic interactions produce polarization effects in the beams behind the interferometer (*Shinichiro Nakatani et al.* - see also *G. Badurek et al.*, (PR D14 (1976) 1177). Neutron optical transmission effects can be used for broadband cold neutron polarization (*Alexander Ioffe et al.*). The measurement of the pair correlation function behind and inside a perfect crystal interferometer represents a further step towards time-resolved interference experiments and possibly towards delayed choice experiments with neutrons (*David L. Jacobson et al.*). In this connection, an interferometer experiment performed with synchrotron radiation by *Yuji Hasegawa et al.* (PRL 75 (1995) 2216), using resonant nuclear scattering from Fe-57, should be mentioned. In this case, single photons are absorbed collectively in many Fe-57 nuclei of the absorber foil, and released coherently with a time delay of about 100 ns, and yet they still exhibit a complete coherent interference pattern (see figure 3).

A Fabry-Perot interferometer for energy selective experiments with ultra cold neutrons was proposed by *Ilja V. Bondarenko et al.* Further contributions in this area dealt with the reflectivity from artificially magnetized surfaces (*Dmitri K. Korneev et al.*), the test of the Schrödinger equation using ultra cold neutrons (*Shin Takagi*), and the tunneling time of neutrons through various barriers (*Ichiro Ohba et al.* and *M. Hino et al.*).

It can be concluded that many new experiments in the field of neutron optics have been performed in the last few years, and many new ideas were presented during the symposium which guarantee a bright future for this interesting field of research.

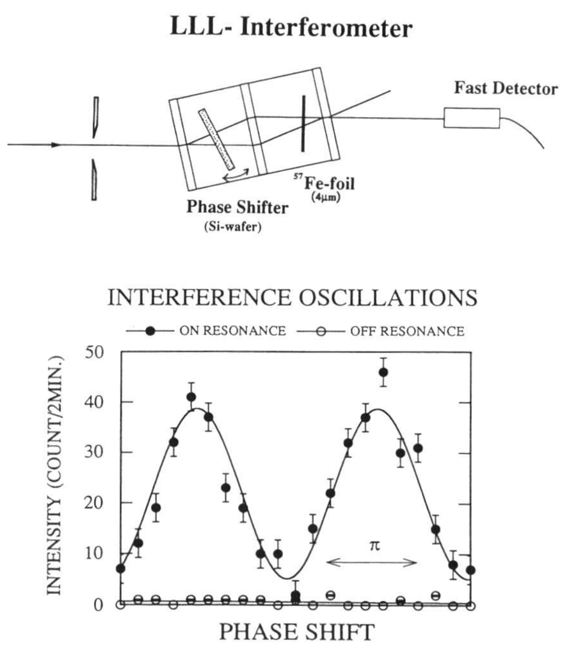

Fig. 3. Interference pattern of synchrotron radiation after resonance absorption (scattering) from Fe-57.

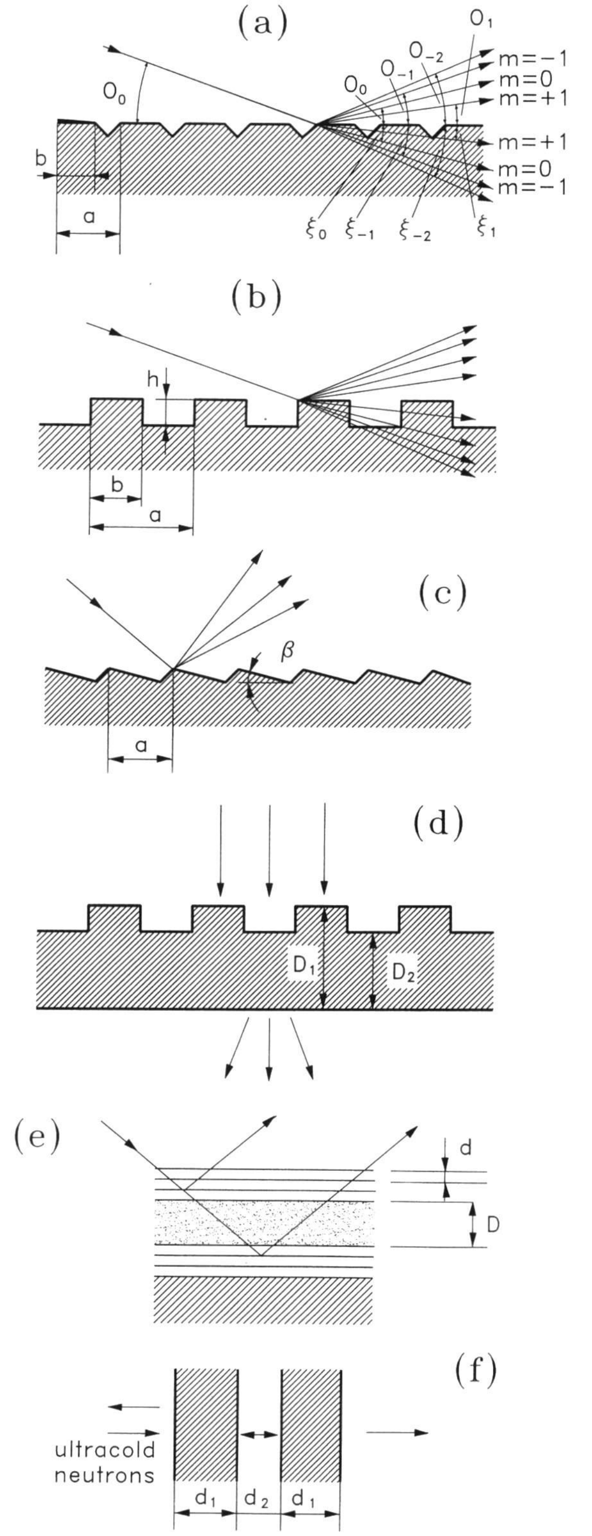

Fig. 2. Various micro-fabricated components used for neutron optical instruments