Neutron diffraction research in NPI ASCR, v.v.i. in Řež – history and present status

P. Mikula

Nuclear Physics Institute ASCR, v. v. i. and Research Centre Řež, Ltd., 250 68 Řež)
mikula@ujf.cas.cz

Keywords: neutron source, neutron diffraction, neutron radiography

Abstract

In 2007 we commemorate the 50th anniversary of starting the operation of the research reactor in Řež. Its commissioning in 1957 has opened a new area for scientists in the field of basic and applied neutron research. After construction of the first diffractometer SPN-100 it resulted in an enormous expansion of neutron scattering investigations. The present paper describes short description of the author of the history and the present status of activities in condensed matter investigations by neutron scattering

Thermal neutron investigations at the Řež´ research reactor

Theoretical and experimental research in the field of neutron scattering started after the Second World War when first intensive neutron sources – nuclear research reactors were constructed. Soon, however, neutrons have appeared as excellent probes of all kinds of matter. At present, many variations of the scattering process are used which give the technique of neutron scattering enormously wide applicability in studies of structure and properties of the condensed matter. Therefore, at each research reactor or pulsed neutron source there are installed many dedicated experimental devices. This year it is just 50th anniversary of starting the operation of the research reactor in the former Czechoslovakia when the first chain reaction was realized in it on September 25, 1957. The commissioning of this reactor of the Russian type VVR-S and of the power of 2 MW belongs to the key milestones in the development of research activities in neutron physics (generally), reactor physics and production of radioisotopes in our country. Naturally, it has opened a new area for scientists in the field of basic and applied neutron research. Later on, after two reconstructions the present tank type and light water reactor LWR-15 operates at the mean power of 10 MW when using decreased ^{235}U - enrichment from 80 % to 36 %.

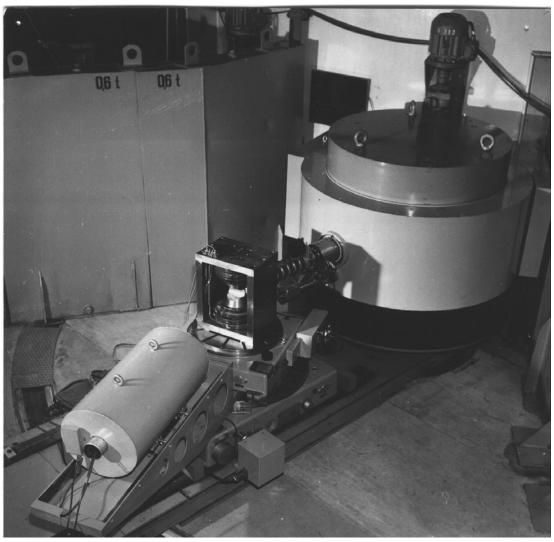

Figure 1. Diffractometer SPN-100 after its introduction into operation in 1965 for studies of magnetic properties of crystalline materials by polarized neutron diffraction.

First neutron investigations were focused to pure nuclear and reactor physics. Even at present, three important research activities of the basic and interdisciplinary (or applied) research are carried out at the facilities installed at the reactor. Namely, they are: Thermal neutron depth profiling facility which is used as a nuclear analytical technique for surface studies. It utilizes the existence of isotopes of elements that produce prompt monoenergetic charged particles upon capture of thermal neutrons. From the energy loss spectra of emitted products the depth distributions of light elements can be reconstructed. Neutron activation analysis facility is dedicated to both short- and long-time irradiations performed in vertical channels of the reactor which are located at the outskirts of the reactor core. This technique provides a highly accurate and low-level characterization of various materials by determining up to 40 elements. Nuclear radiative capture facility is used for prompt gamma activation analysis and gamma-gamma coincidence measurements. The former investigations are focused mainly to analysis of ^{10}B in biological samples as an important part of the boron neutron capture therapy medical treatment and the latter ones to structure studies of nuclei. However, after construction of the first diffractometer SPN-100 in 1965, according to the trends in the world, an enormous expansion of investigations in the field of condensed matter physics and neutron optics by neutron scattering have been recorded. At present, there are installed 6 scattering devices of NPI ASCR at 5 horizontal beam channels of the reactor LWR-15. Besides the neutron optics the research program carried out at the diffractometers is mostly focused to material research as e.g. residual phase specific strain/stress studies, in-situ studies of martensitic transformation in shape memory alloys, studies of structure inhomogeneities by small-angle neutron scattering, texture measurements, etc. In 2005 the neutron interferometry investigations were stopped and instead of the interferometer facility a new multipurpose high and ultrahigh resolution diffractometer is constructed. Similarly, instead of the old facility for texture studies a new medium resolution powder diffractometer equipped with a multidetection system is installed. Both new diffractometers are expected to be fully operational until the end of 2007. Several experimental facilities are offered to external users in the frame of the FP6-NMI3 ACCESS Transnational Program. Fig. 2 shows

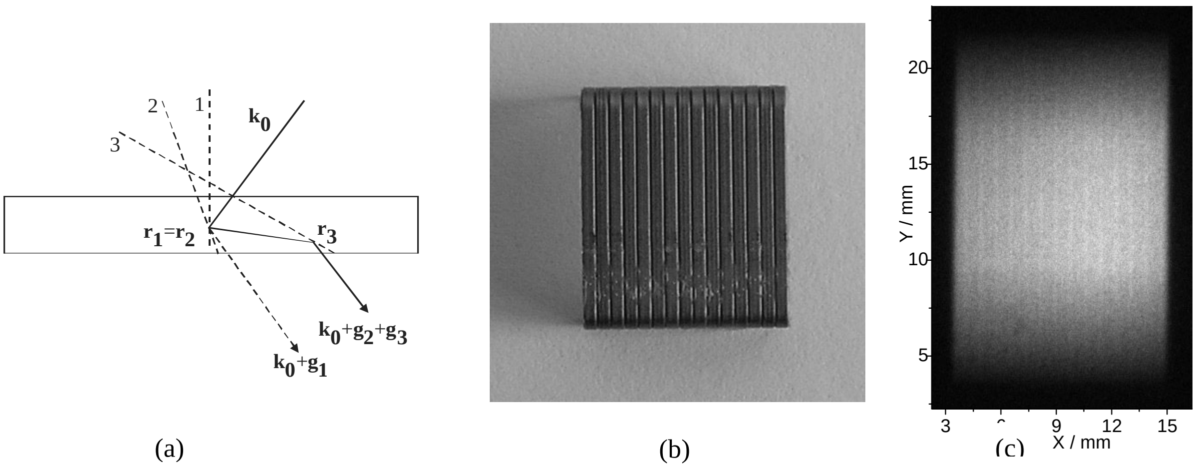

Figure 2. Schematic diagram of a two-step multiple Bragg reflection of neutron of the wave vector $\mathbf{k_0}$ simulating a weak or forbidden reflection (a) and an example of the radiography image (c) of the office staples 24/6 (b) taken by the image plate at the distance of 70 cm from the sample. The numbers 1, 2 and 3 correspond to the primary, secondary and tertiary reflection planes and $\mathbf{g_1}$, $\mathbf{g_2}$ and $\mathbf{g_3}$ are the corresponding scattering vectors, respectively.

the latest result of high resolution neutron radiography obtained on the newly constructed multipurpose diffractometer employing a special monochromator based on a strong dispersive double-reflection process [1-4]. The double reflection was excited in an elastically bent perfect Si-crystal. Such monochromator provides very high $\lambda-$ and $\theta-$resolution making $\Delta\lambda$ and $\Delta\theta$ of the monochromatized beam very small without use of any collimators. In relation to the value of the bending radius, the obtained doubly reflected beam has a narrow band-width $\Delta\lambda/\lambda$ of 10^{-4} - 10^{-3} and $\Delta\theta$ -collimation of the order of minute of arc. This result shown in Fig. 2 is a demonstration of the new type of the so called phase contrast radiography based on the refraction contrast [5] which appears to be complementary to the absorption radiography.

References

1. Shih-Lin Chang, *Multiple Diffraction of X-rays in Crystals*, Springer Verlag, Berlin, 1984.
2. P. Mikula, M. Vrána, V. Wagner, *Physica B*, **350**, (2004), e667.
3. P. Mikula, M. Vrána, V. Wagner, *Zeitschrift für Kristallogr.* Suppl. **23, (**2006), 199.
4. P. Mikula, M. Vrána, In Proc. of the Int. Conf. ICEM-13, July 2-7, 2007, Alexandroupolis, ed. E. Gdoudos, in print.
5. N. Kardjilov, S.W. Lee, E. Lehmann, I.C. Lim, C.M. Sim, P. Vontobel, *Nucl. Instrum. Methods in Phys. Research* **A 542,** (2005), 100.

Acknowledgements

Neutron research is supported by the projects AV0Z10480505 and MSM2672244501.