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Past and present of time-of-flight small-angle neutron scattering at IBR-2

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Abstract

A historical overview of MURN-YuMO instrument (including some technical and scientific development prospects) is presented. Numerous references are cited which demonstrate a tireless activity on the first in the world SANS machine functioning at a neutron pulsed reactor. The relevant scientific activity trajectories of Yu.M. Ostanevich and his colleagues are retraced and put into perspective.

It is a great pleasure for us to give a brief introduction to Prof. Yu.M. Ostanevich scientific activity related to small-angle neutron scattering. Three of the authors of this introduction (AK, AI and VG) knew and worked with him, two of us (TM and MB) came to the Laboratory when he has left us, but we all appreciate very much the beautiful science, the YuMO instrument and scientific spirit, which Yu.M. Ostanevich created for us and our colleagues. Recall that the acronym YuMO of small angle neutron scattering spectrometer (MURN) was given in honour of Yu.M. Ostanevich.

Prof. Yu.M. Ostanevich had a broad knowledge and deep understanding of physics. This allowed him to enter quickly into a new scientific field and work there efficiently. He started his research in the sixties with the studies of Mössbauer effect in condensed matter. One of his activities was investigation of the effect of gravity on self-diffusion at critical point of water and neutron resonances. Since 1974 he was concentrated on creating a first time-of-flight small-angle spectrometers at IBR-30 and IBR-2 pulsed reactors. We and our colleagues, who are working at the YuMO SANS instrument at IBR-2, admire outstanding quality and longevity of Yu.M. Ostanevich's scientific and technical ideas

lying in the basis of the instrument. Already first SANS studies done by Yu. Ostanevich and his colleagues were impressive and showed how wide were his scientific interests. The publications on the studies of biological macromolecules [1-3], polymers [4-6], lipid membranes [7,8], small molecules [9,10] and micelles [11-13] profoundly illustrate this point.

In our opinion, the series of articles, which have been written quite long time ago by N.I. Gorskiy and Yu.M. Ostanevich, are still very interesting today [11-13]. N. Gorskiy and Yu. Ostanevich applied remarkable ability of the surfactants to form invert micelles in hydrophobic solvents for study of size effects at nanoscale.

Another example of fruitful activity of Yu.M. Ostanevich is the review written together with I.N. Serdyuk [14]. It has been written before SANS spectrometer at the IBR-2 was commissioned, was very timely and appreciated by the biological scientific community interested in applications of SANS to their biological objects. In that review the authors examined theoretical and practical problems of application of small-angle scattering in biology.

Yu.M. Ostanevich actively applied SANS to studying small molecules [15,16]. Such experiments are not trivial because the scattering from small objects is weak and such experiments require excellent experimental skills, which certainly were inherent to Yu.M. Ostanevich.

Investigations of polymers at the MURN spectrometer have been started by J. Plestil and Yu.M. Ostanevich with polyelectrolytes. Hydration and local structure of polyions, binding of counterions to polymers were the first problems addressed in [17,18]. The interpolyion correlations and size of polyions were obtained in [19,20]. The Nylon-6 in swollen state [21] and thermosensitive gels [22,23] were studied by SANS at the MURN instrument.

More detailed account about the investigations of polymers as well as block copolymer micelles (corona micelles, three-layer micelles and nanoparticles) can be found in the papers and reviews by J. Plestil, who was one of the closest co-workers of Yu.M. Ostanevich [24,25] and short review [26].

At present, the investigation of polymers at the YuMO spectrometer at the IBR-2 is one of the most



Figure 1. Detector system of the CsOK spectrometer.
On the photo: Yu. Ostanevich (right) and L. Cser (left).

active fields. It is also worth to mention here important studies done by the known polymer schools of Prof. A.R. Khokhlov and Prof. A.N. Ozerin. Among these works are investigations of self-assembly polyelectrolyte rods in polymer gel and in solution [27] and a new type of polymers – dendrimers [28-34], the charge-induced microphase separation in polyelectrolyte phenomena [35-37], poly(ethylene oxide)/poly(propylene oxide) copolymers in aqueous solution [38].

Small angle neutron scattering is the powerful method to study different types of objects with typical sizes of nanometers in biology, polymers, colloids and materials science field.

It is known that the first SANS machine on steady-state reactor was constructed at ILL. First machine on “white” neutron beam was constructed at JINR at reactor IBR-30 on beam N5 [39-43]. Neutron wavelength on such reactors is determined using time-of-flight (TOF) method based on start (pulse) - stop (registration of events on the detector). The idea of spectrometer belongs to Yuri M. Ostanevich and Laszlo Cser. They suggested that TOF spectrometer must have a lot of advantages in comparison with fixed-wavelength machines. In particular, using white neutron beams with high wavelength resolution allows reducing uncertainty of neutron momentum transfer at scattering processes to geometrical parameters of the spectrometer. It is interesting to point out that the first spectrometer got the name “CsOK”, after the names of its principal creators – Cser Laszlo, Ostanevich Yuriy and Kozlov G.A. Word “CsOK”, by the way, is conformable with Hungarian “csok”, which means “kiss”. Imagine, the spectrometer had been build from “zero” level in short period of a couple of months! CsOK consisted of detector system, built from 8 boron counters (NMI-52 type), situated on the left and right sides from the direct beam (see Picture 1). Such geometry of SANS installation is called “rectangular”. The central part of the detection plane with central beam passing through it, remains free from counters and any construction materials. Using this type of construction, an effective reduction of the direct beam background in the detector space can be achieved. It was the idea that could be used for ring-wire detectors for spectrometer MURN (YuMO) at IBR-2. In addition to these detectors, the moved counter for measurements of the direct beam and symmetry center of the detectors (prototype of direct beam detector at MURN spectrometer) was used. The first experiments on the CsOK were done with biological objects, namely, hemoglobin solution, 50S ribosome and collagen (taken from a rat’s tale moistened with light water and heavy water). For hemoglobin and 50S ribosome, an average value for the radius of gyration was obtained. For collagen with 400 fibers was obtained the value of 65.4 nm for wet samples and 64 nm for dry ones. The first experiments with proteins in solutions confirming the method as well as the basic characteristics of the spectrometer were briefly described in the published work. It is interesting to note that a new type of detector of thermal neutrons for the SANS instrument, circular multi-wires He³ detector with a central hole, was presented before this publication. Namely, such a detector has been the main part of data acquisition system of SANS instrument at IBR-2 during more than 20 years. Later, this type of detectors allowed us to propose and experimentally realize in 2000 a new approach to the collection of time-of-flight SANS data by using two detector systems at the YuMO [44]. The SANS group tried to preserve this good tradition performing modernization of the instrument, installation of a two-detector system as well as a new type two dimensional position sensitive detector at the YuMO [45]. First experiments with magnetic fluids realized at MURN using contrast variation method [46-48] give the perspective to improve the sample environment, in particular, using magnetic field [49].

Yu.M. Ostanevich devoted continuous attention to the development of time of-flight methodology and the instruments at IBR-30 and IBR-2 pulsed reactors. The first ideas and experimental results of Yu.M. Ostanevich and his colleagues on time-of-flight SANS have been published in 1976 [50].

Yu.M. Ostanevich was an outstanding scientist and he understood well the users of the instrument, being deeply involved into nearly all experiments done on the machine. He always was trying to make improvements of the instrument without shutting down the machine when the reactor was in operation. The SANS group was saving this good tradition during modernization of the instrument, installation of two detector system as well as a new type two dimensional position sensitive detector at the YuMO [45] and during the shutdown of IBR-2, in particular through preparing the conditions for its modernization in the nearest future.

We know now how much of additional efforts Yu.M. Ostanevich had to apply to keep the instrument in operation, continuously modernizing it.

Yu.M. Ostanevich has created one of the most efficient scientific schools at the Laboratory working for a very wide scientific society in Russia, JINR member countries and others. We hope that the participants of the Workshop will devote an additional time in order to suggest some interesting new ideas about principal modernization of YuMO.

We also hope that one of the most productive methods and instruments at the IBR-2, YuMO, launched by Yu.M. Ostanevich and further developed by his team, will get a sufficient support and will be ready for the future successful work when the IBR-2 will be in operation again.

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