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Memorable Years for Synchrotron Radiation at the Institute of Nuclear Physics in Novosibirsk

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Figure 1: G. Kulipanov(left) and A. Skrinsky in the 1970s.

In the early 1970s, the Institute of Nuclear Physics (INP) in Novosibirsk was a unique place in the world of accelerator physics. There were three operational electron-positron storage rings at the institution. All together, they covered beam operational energies from 200 MeV up to 2.2 GeV. It was not a big surprise for the developers of these state-of-the-art machines when the first users of synchrotron radiation showed up at the doorsteps of the Institute of Nuclear Physics, eager to take advantage of such unique radiation sources. And how very unique they were! Compared with several already relatively well-established operational synchrotrons around the world, such as DESY in Hamburg, NINA in Darsbury, and three synchrotrons in the Soviet Union—one at the Physical Institute in Pakhra, another at the Tomsk Polytechnical Institute, and a third at the Erevan Physical Institute—the storage ring sources provided much more stable and brighter radiation beams. Several storage rings built at that time in locations such as Japan, the US, and France were also on the verge of becoming available for synchrotron radiation users.

The very first external synchrotron radiation users of INP storage rings found out that there were physicists and engineers who had already used that radiation quite extensively. For many years, the visible part of synchrotron radiation had been used for e-beam diagnostics. In fact, every bending magnet vacuum chamber at one of the newly built INP storage rings had at least two synchrotron light ports to measure the position of electron or positron beams, as well as their bunch lengths. Developed by E. Zinin, these systems took full advantage of the unique properties of synchrotron radiation, and were very advanced for their time. There was also an INP group of plasma physicists who planned to utilize predictable properties of synchrotron radiation for the calibration of detectors in the vacuum ultraviolet wavelength region. When the INP "opened its doors and storage tunnels" to accept the first synchrotron radiation users in 1972, they were able to capitalize on the unique experience of many INP physicists and engineers.

The very first request for the use of INP storage rings for synchrotron radiation experiments came from biophysicists of the Kurchatov Atomic Energy Institute in Moscow. The INP director, A.M. Budker, and his deputy, A.N.Skrinsky, who was responsible for the accelerator departments, responded favorably to that request. But users got really lucky when the task to build the first INP X-ray synchrotron beamline was passed to Gennady Kulipanov (Figure 1), the head of the VEPP-3: 2.2 GeV storage ring department. He began work on the project with all of his abundant energy and enthusiasm, and by virtue of being an excellent accelerator physicist familiar with engineering details of storage rings, and free of any "high-energy physics snobbism and arrogance," Gennady became a powerful catalyst in the multitude of developments that eventually resulted in the formation of the Siberian Center of Synchrotron Radiation.

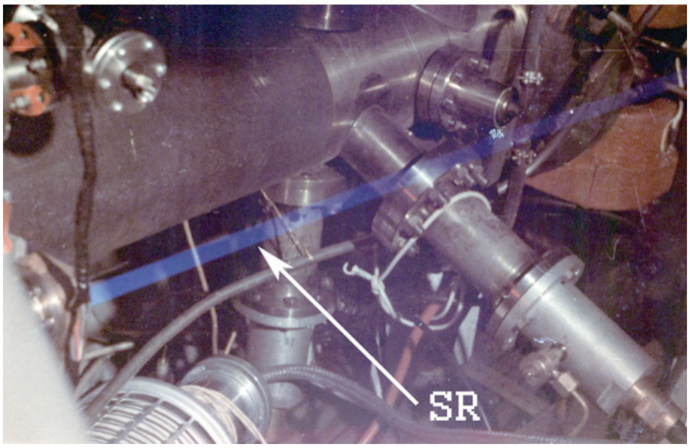


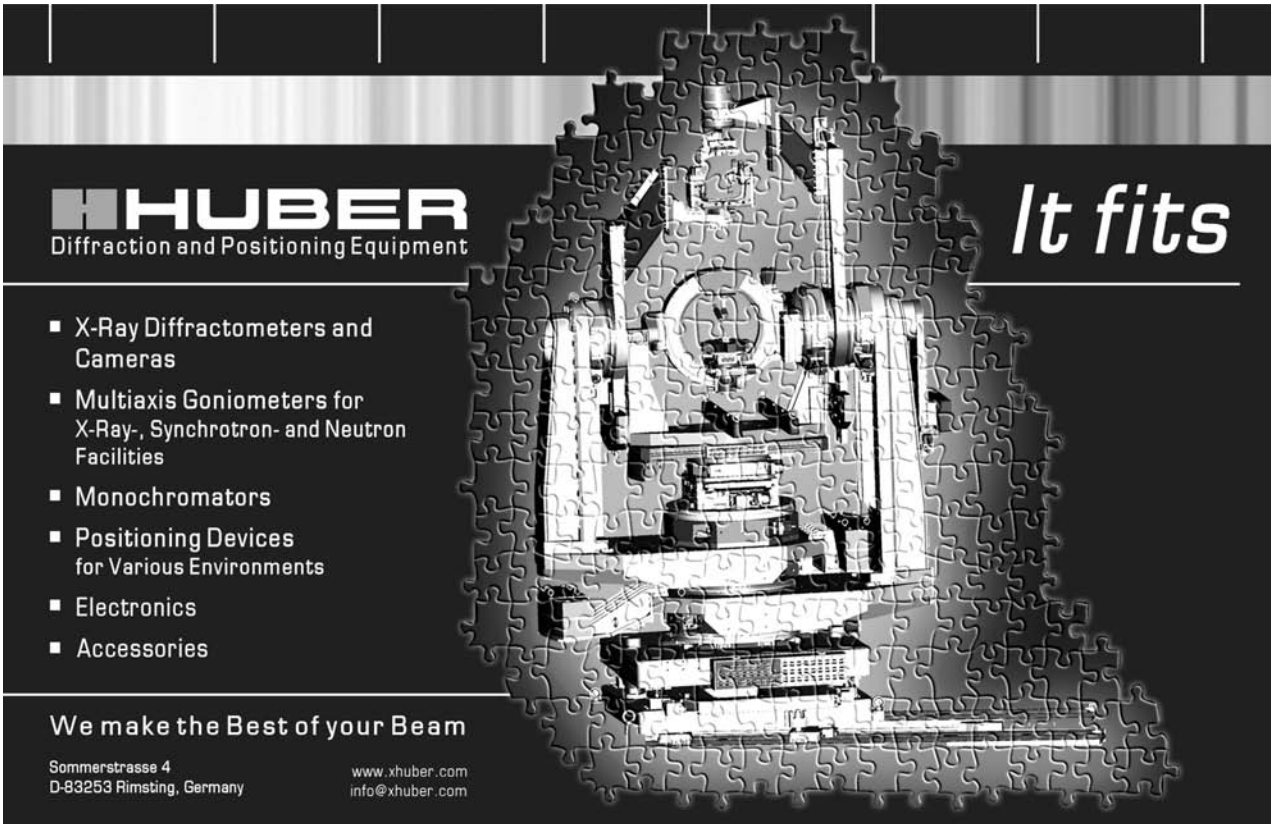
Figure 2: X-ray synchrotron radiation beam from VEPP-3.

The first synchrotron radiation beamline for user experiments at the INP was built at the VEPP-3 storage ring in July 1973. The spectacular blue, ribbon-like picture (Figure 2) of X-rays coming out of the bending magnet beamline port and ionizing air was an exciting illustration of the power of this new source.

That same year, the beamline was first used by a group of biophysicists from the Kurchatov Atomic Energy Institute led by M. Mokulsky. In record time, they obtained the first diffraction patterns of DNA sodium and cesium salts. In one of those first experiments, during a sample alignment with the beam on, M. Mokulsky had first-hand experience with how powerful the X-ray beam was: he inadvertently exposed three fingers on his hand to the beam and was instantly burned—not in a health-threatening manner, but powerful enough for him to have a memory of it for quite some time.

Year later, another group of biophysicists arrived from the Biophysics Institute near Moscow. The group, led by A. Vazina, had pioneered the small-angle diffraction of muscle polymers with 2 msec time resolution. The success of both groups opened the door for many others, including chemists, geologists, and biologists. In a short period of time, it became clear that just one experimental station would not be able to satisfy even a small portion of the interested users. Thus, G. Kulipanov launched an ambitious project to build a synchrotron radiation laboratory with multiple stations.

Almost at the same time that the first X-ray beamline was under construction at the VEPP-3, a group of scientists from the Novosibirsk Institute of Inorganic Chemistry and Leningrad State University requested access to the newly built 700 MeV VEPP-2M storage ring. One of the authors of this article (E.G.) and A. S. Vinogradov from the Physics Department of Leningrad State University suggested a drastic improvement of the capabilities of soft X-ray absorption spectroscopy by combining a high-quality grazing incidence grating monochromator with the VEPP-2M bending magnet source. The head of the VEPP-2M storage ring, G. Tumaykin, was very hesitant to accept the proposal because the monochromator's vacuum chamber had to be directly integrated with the storage ring vacuum system. Finally, after careful consideration of possible modes of failure, integration in the design of fast vacuum gate valves, and with an extra push from G. Kulipanov, the proposal was accepted. The construction of the beamline and the modification of the monochromator started in 1973 and were completed in 1974. The beamline was only about 3 m long in order to take advantage of the existing common foundation with the storage ring. As a result, the monochromator was very close to the storage ring (Figure 3), and since the preparation of the experiment and its partial monitoring required a regular access to the monochromator, the radiation shielding turned out to be minimalistic but adequate to pass radiation safety scrutiny. Soon after commissioning of this beamline, the first ultra-high-resolution spectra of thin films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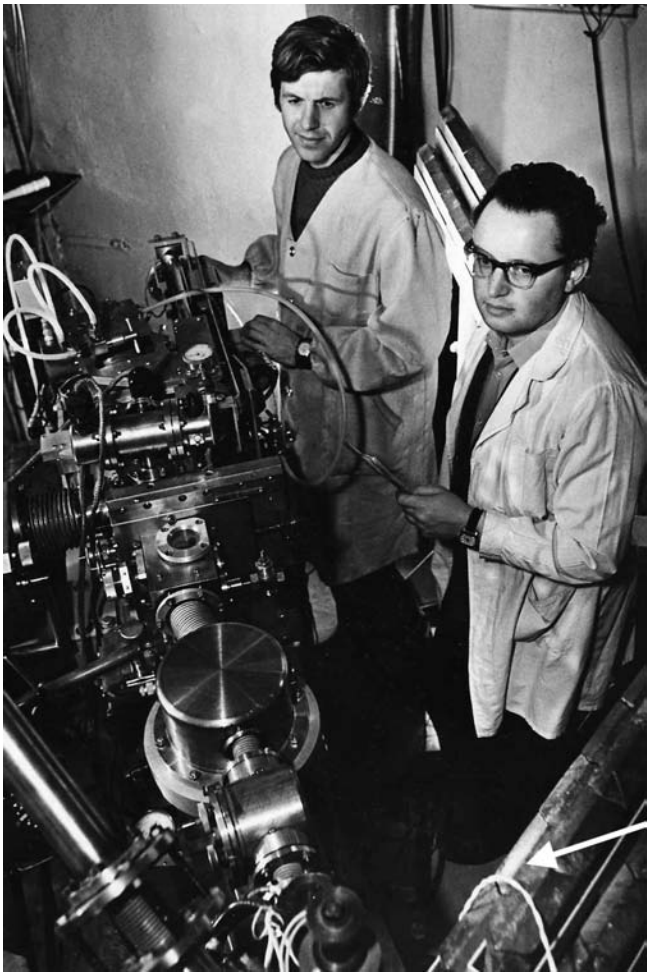

Figure 3: Part of the beamline and soft X-ray monochromator at the VEPP-2M. E. Gluskin is in front and graduate student V. Kochubei is behind.

and later of simple two- and three-atom molecules were obtained. The innovative optics of this beamline became an important stepping-stone to future soft X-ray monochromators, such as SX700.

Most of the INP's innovative and pioneering advances took place in the developments of radiation sources. In 1979, the very first 20-pole, 3.3 T wiggler (Figure 4) was installed at the straight section of the VEPP-3.

That unique ID (not only in terms of strength of the magnetic field, but also in terms of very small vertical aperture), developed by the group led by N. Mezentsev, delivered the most powerful (at the time) X-ray beam in the world, about 1 kW, which amounted to 200 times in flux increase compared to the bending magnet.

The picture of visible radiation emitted by the wiggler (Figure 5) made the front pages of scientific magazines, and unprecedented X-ray beam easily and almost instantly ablated a 10-cm-long piece of plastic (Figure 6).

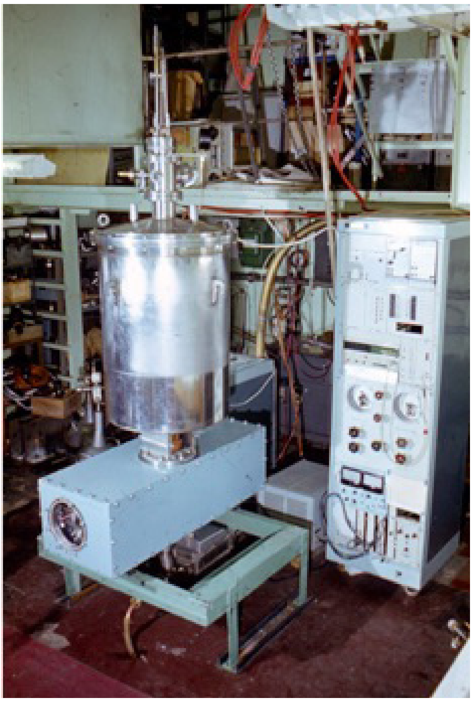

Figure 4: The first superconducting wiggler installed and used at the VEPP-3.

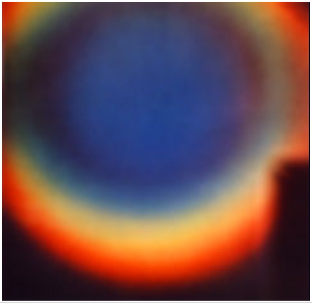

Figure 5: Visible light from the SC wiggler (E = 350 Mev).

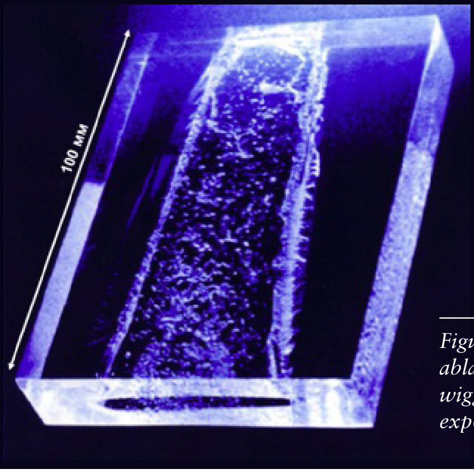

Figure 6: Plexiglas ablated under SC wiggler radiation exposure.

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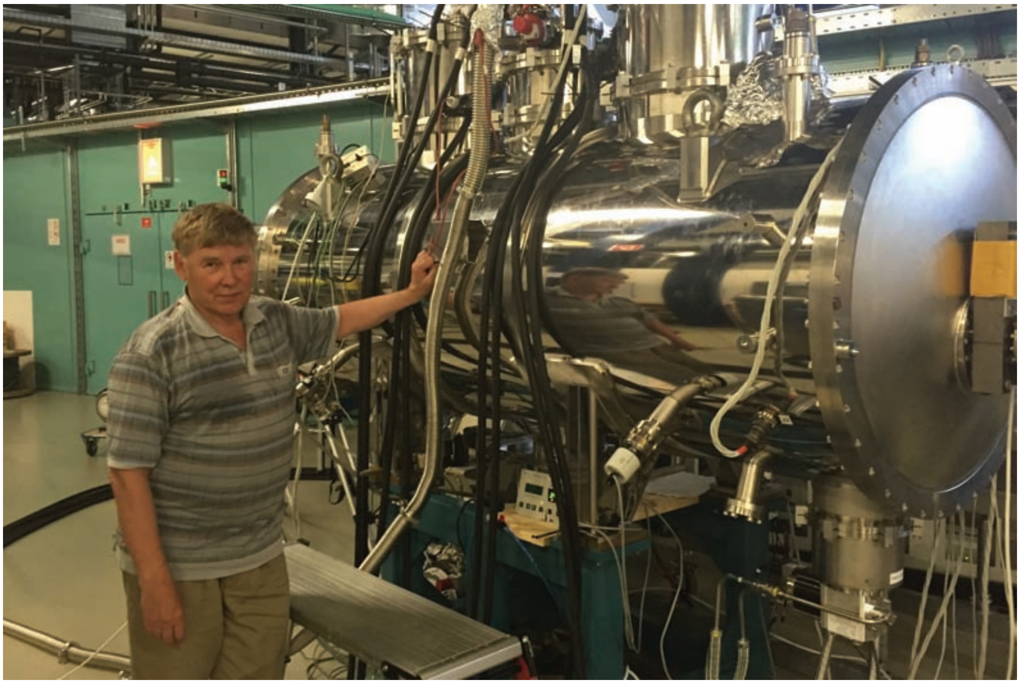

Figure 7: N. Mezentsev is next to a recently built SC wiggler at the ANKA light source, Karlsruhe, Germany.

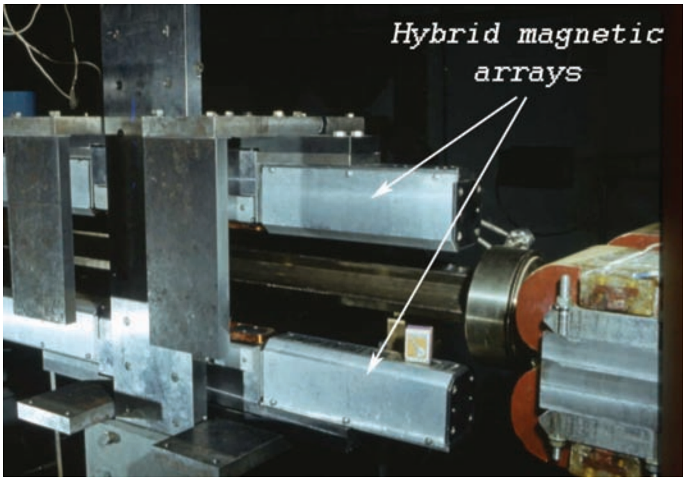

Figure 8: The first hybrid permanent magnet undulator with adjustable gap used at the "optical klystron" FEL.

N. Mezentsev and his colleagues became worldwide leading developers of superconducting wigglers (Figure 7), perfecting their designs and capabilities and building them for many synchrotron radiation facilities around the world.

In the mid-1980s, a group of physicists and engineers, led by Y. Shatunov, developed the first helical superconducting undulator that was installed at the VEPP-2M storage ring. Prior to that device, in the early 1980s, a conventional electromagnetic helical undulator was used at the same storage ring for demonstration-type experiments in X-ray microscopy and holography.

The culmination of novel radiation source development came with the invention of the "optical klystron." In 1977, N. Vinokurov and A. Skrinsky developed the idea of the free electron laser towards its implementation at storage rings. The experiments with the first storage-ring-based FEL at the INP (Figure 8) started in 1979 and continued for almost a decade.

These developments gave life to the first permanent magnet undulators, produced operational UV FEL for the first time, and opened the door for future high-power FELs. Several SR facilities around the world were later able to successfully duplicate this INP invention.

This short article cannot cover all of the innovative and pioneering developments that took place at the INP in the very exciting decade that began at the beginning of 1970s. A much more comprehensive review of them is under preparation by one of us (V.P.) for publication in the Russian journal *Advances in Physical Sciences*. ■

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