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Poland at the European Synchrotron Radiation Facility: 30 years of history and future prospects

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The European Synchrotron Radiation Facility (ESRF) is a research infrastructure located in Grenoble, France (Figure 1). It is a state-of-the-art European radiation source with a wide range of radiation energy, extremely high brightness, and excellent beam stability. Construction and operation of this unique infrastructure were possible due to the creation in 1988 of the international consortium. Twelve countries took part in the construction: France, Germany, Italy, United Kingdom, Belgium*, The Netherlands*, Denmark **, Finland**, Norway**, Sweden**, Spain, and Switzerland. These countries became member states, individually or through consortia like Benesync, as indicated by *, and Nordsync, indicated by **. Starting from 2004, Poland has been one of eight associated members together with: Austria, Israel, Portugal, India, the Czech Republic, South Africa, and Hungary. Russian Federation was admitted as a new member in 2014. However, presently is suspended by the decision of the ESRF council.

Polish presence in the ESRF is ensured by the grants from the Ministry of Education and Science led by the National Consortium of Scientific Institutions Interested in the Use of the European Synchrotron Radiation Source in Grenoble represented by the Institute of Physics Polish Academy of Sciences. The current grant will expire in March 2026. More information can be found on the website: http://www.ifpan.edu.pl/esrf/Local_Publish/

Figure 1. The main entrance to the ESRF. Photo by W. Paszkowicz.

The ESRF research facility is used for fundamental and applied research in physics, materials research, chemistry, molecular biology, and other life sciences. In particular, the ESRF now offers unique capabilities for studying of the structure and its function in biological materials, the real-time course of chemical reactions, X-ray tomography of materials with the spatial resolution of single nanometers, and the properties of materials at extreme pressures and temperatures. Research techniques such as time-resolved and high-pressure diffraction as well as X-ray absorption and emission, magnetic circular polarization, Cryo-EM electron cryomicroscopy, and many others, are available to users.

The first light at the ESRF was observed in 1992. The facility was made fully available to researchers in 1994 with 15 end stations. It is noteworthy that immediately in 1994 Polish scientists published their scientific articles describing the results obtained at the ESRF[1,2].

The decision on the preparation to upgrade was taken after 20 years of activity in the frame of a roadmap aiming to keep the world leadership as a synchrotron radiation source and support the development of European science[3,4]. In 2008, the ESRF Council decided on a comprehensive upgrade to be split into two phases. The first stage, performed in 2009-2015 and described in the Purple Book[5], concerned the upgrading and allocation of research stations to prepare them to exploit the new capabilities of the X-ray source[6-9]. The described source upgrading in the Orange Book was successfully carried out in 2019-2020. Despite the obstacles caused by pandemic-related restrictions, the work was completed to replace the accumulation ring two months ahead of schedule. The new accumulation ring has virtually the same circumference as the previous one. Still, thanks to an array of innovative new magnets designed at the ESRF, it is able to guide and focus electrons so that the brightness and coherence of the X-rays are increased by a factor of 100 compared to that obtained before. What is interesting, with the new design, the machine is also much more energy-efficient which results in about a 30% reduction in electricity consumption compared to the previous one. On 25th August 2020, the beam was made available to users at almost all beamlines (except a few under construction or reconstruction), completing both phases of the ESRF upgrade. With the completion of the accumulation ring upgrade, the ESRF-EBS (EBS stands for Extremely Brilliant Source) has become the representative of the newest generation of synchrotron radiation sources.

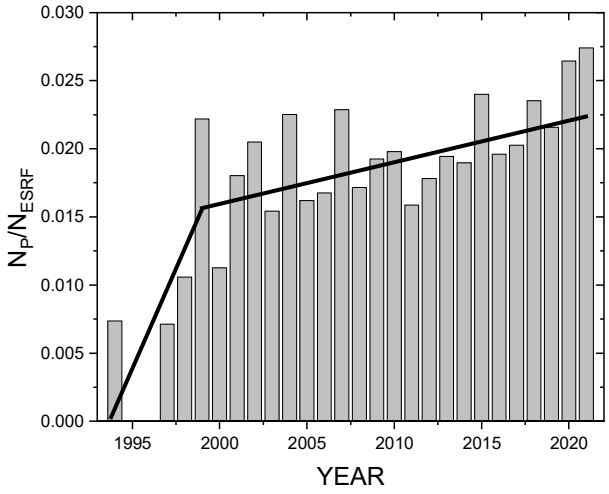

Figure 2. Fraction of publications (NP/NESRF), with the contribution of authors affiliated in Poland, referring to results of experiments performed at ESRF (NP). The NP is based on the ESRF library database, completed by extensive search in ISI and Scholar databases. NESRF corresponds to ESRF library data. The solid line is a guide to the eye showing the trend.

Four new so-called flagship beamlines were designed to take advantage of the properties of the EBS fully: EBSL1: Coherence applications – dynamics and imaging at the nanoscale; EBSL2: Hard X-ray diffraction microscopy on material complexity; EBSL3: High-throughput large-field phase-contrast tomography and EBSL8: Serial

synchrotron crystallography on macromolecular nanocrystals. They are under construction and are planned to be gradually open to users from the second half of 2022 to 2024.

Thanks to the grant of the Polish Ministry of Education and Science (decision no. 2021/WK/11), any researcher affiliated with the Polish scientific institution can submit a research project alone or in collaboration with scientists from other countries. All scientific proposals are evaluated by the International Peer Review Committee regarding the scientific merit. It is essential to realize that, according to the ESRF regulations, each member country can use only the fraction of the available beamtime equal to the contribution to the budget. What's more, in the case of collaboration with scientists from other countries, the percentage of the beamtime is divided proportionally between the countries depending on the affiliation of the scientists given as co-proposers.

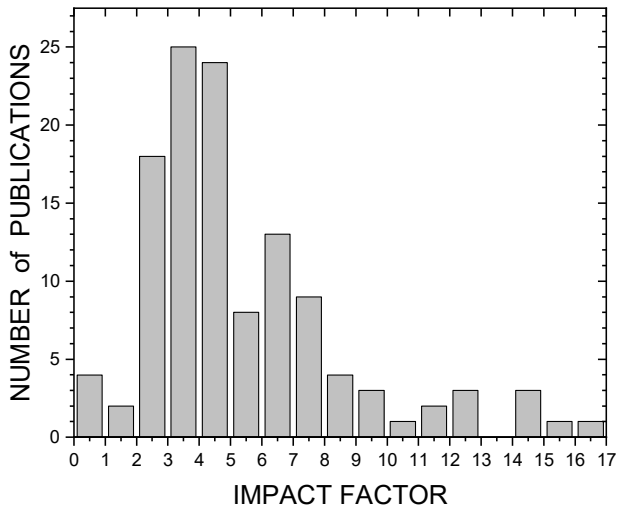

Figure 3. Number of publications from years 2019-2021, with contribution of authors affiliated in Poland in respect to the journal's Impact Factor.

The obtained results are published in scientific journals. Currently, the number of scientific articles with Polish affiliation is about 50 per year. Figure 2 displays this number (NP) as a fraction of all scientific articles produced with a contribution of the ESRF facility (NESRF) in a function of time. The fraction tends to increase with time and now is more than two times larger than the formal contribution of Poland to the ESRF budget (0.01). It shows that the Polish scientists use their beamtime with excellent efficiency. Figure 3 presents the number of publications from the years 2019-2021 in respect of the journal's Impact Factor. Most scientific articles in this period are published with the Impact Factor between 2 and 8.

For over 18 years, scientists affiliated with more than 40 scientific institutions from Poland have applied for beamtime at the ESRF. The total number of publications with Polish coauthors is more than 800 and shows a growing trend. They report the results of experiments on different types of materials and use various techniques. All this indicates how important for Polish researchers is access to the unprecedented opportunities of the ESRF beamlines.

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8. Raimondi, P. ESRF-EBS: The Extremely Brilliant Source Project. *Synchrotron Radiation News* 29, 8–15 (2016).
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