User Survey
2018/2019
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KFS User Survey 2018/2019

1. Preface

The German Committee for Research with Synchrotron Radiation (KFS) is an elected board that represents the interests of synchrotron users (including FEL) in Germany to ministries, society and facilities. Synchrotron radiation plays an increasing role in many areas of physics, chemistry, crystallography, biology, materials sciences and technical applications. Due to the high financial effort, there are only few synchrotron radiation sources available on national and international basis. Therefore, research with synchrotron radiation and its application needs trans-regional coordination and evaluation. The KFS deals with important overriding issues of the development of research with synchrotron radiation on the national and international level. This survey was conducted to show the orientation of research and the needs of the community so that it can find its way into strategic planning.

2. Summary

The KFS has asked the German users of synchrotron radiation for their needs in its survey 2018/2019. We wanted to know on which topics and in which fields of science they do their research with synchrotron radiation, which methods they use, how they judge the data management and which expectations they have for the future of research with photons. About one fourth of the user community has taken part in the survey. This selection gives valuable hints on the needs of the users, which will be presented in the following based on the survey results.

The survey shows that the research with synchrotron radiation has a highly diversified user community. Scientists from universities, governmental institutions and industry use a variety of methods to work on their problems concerning materials, energy, technology, health, information and other challenges. Not only physicists, chemists and biologists, but also engineers, geo- and environmental scientists, researchers in art & culture and interdisciplinary researchers depend on the methods of synchrotron radiation.

The different scientific problems require different methods and sources. According to the survey results, no single synchrotron radiation source can offer all energy ranges, beam properties, instruments and off-line infrastructure. Therefore, it is extremely important that the users can choose among sources with different orientation such as PETRA III in Hamburg, BESSY II in Berlin, ESRF in France, European XFEL and FLASH in Hamburg, DELTA in Dortmund, KARA in Karlsruhe and other sources in Europe (e.g. Diamond, SLS, Soleil and Elettra).
3. Data Basis

The German Committee for Research with Synchrotron Radiation (KFS) has conducted a survey among the users of synchrotron radiation in Germany in the end of 2018 and in the beginning of 2019.

General

894 users have taken part in the survey, which corresponds to about a fourth of the synchrotron radiation users who are registered with KFS. To get a feeling of how representative the survey is, we have compared our data with data from some large synchrotron radiation facilities (DESY, HZB, European XFEL and ESRF, see also chapter 4). The order of magnitude of the registered users is accordance with the user numbers of the facilities. The three most important facilities for the users are PETRA III (DESY), BESSY II (HZB) and ESRF, of which 12% do experiments both at PETRA II and at BESSY II. The overlap of PETRA III and European XFEL is in the same range.

Representation

Who has taken part in the survey? The participants come from all areas of research with synchrotron radiation. It seems that the distribution is shifted a bit towards the more experienced researchers, and probably also towards the facilities. The only clear discrepancy in comparison to the facility data is in the number of researchers who work in biology. We assume that the “biologists” are underrepresented.

Bias effects

Detailed queries were conducted to estimate the influence of the survey participant’s distribution.

Experienced scientists have answered most questions in more detail that their younger colleagues, but the results as such did not differ between those two groups in a significant way. It can be assumed that the slight bias towards the more experienced scientists actually increases the reliability of the results.

In addition, the results of users from academia and national or international research institutes were compared, and the answers differed only in some cases, which will be mentioned below.

Since we assume that the users who do biological research with synchrotron radiation (for simplification, we call them “biologists”) are underrepresented, it is especially important to look at their needs. Therefore, they were considered separately and will be mentioned where they differ from the general tendencies.
4. Results

Social or economic challenge / field of application

To which social or economic challenge does or could your research contribute?

Multiple choices were possible

Scientific field

In which scientific field can your research be identified?

Multiple choices were possible

Systems

Multiple choices were possible

Fig. 1: Research topics and scientific fields
Fig. 2: Consideration of the research topics and scientific fields in the different institutions (in parentheses the total number of participants from the institutions). Academia = Academic Institution (University, Fachhochschule), Research institute = International Research Institute (EMBL, European XFEL, ESRF etc.) + National Research Institute (Helmholtz, MPI, Fraunhofer etc.), Industry = Industry. *12 participants are too few for a representative result.
The survey participants could choose multiple answers to all these questions. Therefore, the results do not relate to single users but they show general frequencies.

**Social or economic challenge / field of application**

*To which social or economic challenge does or could your research contribute?*

The research problems that cause scientists to use synchrotron radiation for studying materials range from basic properties to technical applications. Therefore, “materials” is most often chosen (38 %, see fig. 1) when researchers were asked for the social or economic challenge they work on. There is a broad overlap (three quarters) with the other topics energy, technology, health, information and other challenges. The topics health and other challenges (e.g. environment and climate, basic research and archaeometry) have least overlap with the other topics. Energy is the second prominent topic (24 %), followed by technology, health, information and other challenges (15, 13, 7 and 3 %).

This distribution is quite similar at all types of institutions, see fig. 2. The 12 survey participants who work in industry do research on materials, technology and health.

The correlation of health and biology is strong, and it is the same for those who have only chosen biology and none of the other scientific fields.

**Scientific field**

*In which scientific field can your research be identified?*

Physics is the prominent scientific field (37 %), followed by chemistry (22 %), methods of photon science (17 %), biology (11 %), engineering (8 %), geo- and environmental sciences (4 %) and arts and culture (1 %). About half of the survey participants work interdisciplinary.

A third of the „physicists“ have also entered chemistry, as well as methods of photon science. 10% of the „physicists“ have chosen all three scientific fields. The overlap of physics and biology is in the same order of magnitude.

The proportion of participants who have only chosen a single scientific field is greatest in physics and biology (35 % of all clicks in the respective area). The overlap is greater in geo- and environmental sciences (27 % have only chosen this field), chemistry and engineering (both 25 %). Arts and culture (12 %) and methods of photon science (8 %) are even more interdisciplinary.

Comparison with data from the facilities tells us that the proportion of biologists would be higher if they had taken part in the survey to the same extent as the users from other scientific areas.

Chemistry and biology are slightly more common at the research institutes (International Research Institute (EMBL, European XFEL, ESRF etc.) + National Research Institute (Helmholtz, MPI, Fraunhofer etc.)). There, in turn the proportion of methods of photon science is larger, probably because some of the governmental institutions host synchrotron radiation sources. Yet, also at universities, the development of methods of photon science is substantial, i.e. 16 % of users there, in comparison to 40 % of the users at national and international research institutes. (The percentages in fig 2. Do not relate to the number of users in the institutions but to the total number of clicks).
**Studied systems**

*Systems*

The focus of research with synchrotron radiation is on studying solids (34%). Interfaces (18%), biological systems (14%) and soft matter (10%) are also important, followed by atoms / molecules / gas phase (8%), fluids (7%) and other systems (e.g. instrumentation, optics and lasers, 5%) and warm dense matter (1%).

The distribution of the survey participants from academia and governmental research institutions on the studied systems are similar. The common topics are a bit more abundant among the users from academia, while atoms / molecules / gas phase, fluids and warm dense matter are a more common among the users at governmental research institutions. “Other systems” were most often chosen additionally, which becomes clear from the accompanying comments. The high percentage of “other systems” in industry is therefore misleading.

It is no surprise that biology correlates well with biological systems. Soft matter correlates less, but still more than with the other scientific fields. All other systems are more common for scientists from other scientific fields.

**Synchrotron radiation sources**

*Which synchrotron sources do you use? Please enter the mean number of experiments per year.*

The mean number of experiments per year was interpreted in different ways. Therefore, there is a high degree of uncertainty connected to the evaluation of this question. Looking at the usage of the sources as such shows that 36% of the survey participants do experiments only at one source, especially at BESSY II, KARA, PETRA III and FLASH. In total, these sources were mentioned most abundantly: PETRA III, ESRF, BESSY II, European XFEL and other sources in Europa (especially Diamond, SLS, Soleil and Elettra).

Subject to the uncertainties that we mentioned above, the number of experiments at the two largest sources PETRA III and BESSY II are highest, followed by ESRF, KARA, European XFEL, FLASH, DELTA and others.
**Future (% of participants)** Do you expect any of the following to become more important...

![Chart showing future expected changes](chart_future.png)

**Limitations (% of participants)** I am limited in my research ...

![Chart showing limitations](chart_limitations.png)

**Data management (% of participants)** What are your data management requirements?

![Chart showing data management requirements](chart_data_management.png)

Fig. 3: Future, expected changes, limitations and data management requirements
Future

Do you expect any of the following to become more important for your future research?

About half of the survey participants think that these developments will become more important in the future: in situ/operando studies, real time studies, X-ray imaging and microscopy. A bit less than a third chose automated experiments, which is especially important to the “biologists”. Multi-parameter/methods experiments are also future-oriented (24%), as well as the study of transient and irreversible processes (21%) and non-linear X-ray physics (11%).

I require no change to my experiments in the future

To be able to estimate the need for further development, the users were asked if they do not require change to their experiments in the future. Only 9% of the participants checked this box, which means that the overwhelming majority of survey participants expects changes to their experiments.

Limitations

I am limited in my research by the amount of beamtime

I am limited in my research by the performance parameters of the existing sources

About half of the survey participants is limited in their research by the amount of beamtime, and about a third by the performance parameters of the existing sources. In relation to the numbers of users at the respective types of institutions, the lack of beam time is highest at universities and the limitation by the performance parameters of the existing sources is perceived most clearly at the governmental research institutions. Experienced and less experiences users answered this question in a similar distribution.

Data management

What are your data management requirements?

Please evaluate the present situation at the facilities with respect to your needs.

We asked for data management requirements to get an impression of problems and the awareness for this important issue.

It becomes apparent that about half of the participants are content with the present circumstances. This comprises data storage, data transfer, long term archiving, data reduction, analysis software and theory support. Most problematic is the evaluation of data and the software used for that aim. In addition, the transfer of measurement data from the facility to the home institution is an important issue, whereas this is most probably related to hardware. Data transfer and data storage are especially important to users from academia who are slightly underrepresented, as well as biologists, who are more clearly underrepresented.
**Energy regime** (% of participants) *Which energy regime do you use?*

- **hard X-rays**
- **soft X-rays**
- **high energy X-rays**
- **tender X-rays**
- **VUV**
- **IR / Thz**

**X-ray beam quality** (% of participants) *What are your particular requirements?*

- **X-ray beam quality**
  - **high intensity**
  - **micrometer focus**
  - **high energy resolution**
  - **nanometer focus**
  - **high coherence**
  - **low divergence**
  - **short pulse duration**
  - **large beam**
  - **unfocussed sufficient**
  - **other**

**Time scale** (% of participants) *What are your particular requirements?*

- **Time scale to be investigated**
  - **time resolved**
    - **s**
    - **min**
    - **ms**
    - **fs**
    - **ps**
    - **ns**
    - **us**
    - **as**
    - **hours**
    - **days**

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Fig. 4: Energy regime, X-ray-beam quality and time scale
**Energy regime**

*Which energy regime do you use?*

Hard X-rays (5-30 keV) are used most abundantly. This energy regime is especially important for biologists and geoscientists. The second most important energy regime are soft X-rays (< 2 keV). About 20 % of survey participants use soft and hard X-rays. (VUV+Soft X-rays / hard X-rays + high energy X-rays).

**X-ray beam quality**

*What are your particular requirements? X-ray beam quality*

A focused beam is the most often mentioned required beam quality. (micrometer / nanometer focus, together 69 %). Other important parameters are high intensity (63 %) and high energy resolution (43 %). High coherence, low divergence and short pulse duration are a topic for about a quarter of the survey participants, especially for the biologists.

**Time scale**

*Time scale to be investigated*

A third of the researchers use time resolved methods, in fact on all time scales. The shortest time scales are important for physics and methods of photon science, the middle range (ns, µs and ms) for biologists, and the longer time ranges, starting with seconds, for engineers, chemists and art and culture scientists.

**Methods**

*Which methods do you use?*

By far the most abundant method is X-ray absorption spectroscopy, followed by small angle scattering, wide-angle scattering, powder diffraction, photoelectron spectroscopy, crystallography in materials sciences, X-ray fluorescence (XRF) and X-ray microscopy and – tomography, see figure 5.

In general, the more specific methods such as emission and lithography are used mainly at governmental research institutions. On the other hand, powder diffraction, inelastic scattering, photoemission and X-ray absorption spectroscopy are strongly used in academia.

The most abundant methods in biology are small angle scattering, elastic incoherent scattering, crystallography on biological macromolecules, XRF, X-Ray tomography and X-ray microscopy / holography and –ptychography.
Fig. 5: Methods (% of survey participants)
Sample environment  What are your particular requirements? - Sample environment

Off-line infrastructures  How important are these off-line infrastructures for your experiments?

Fig. 6: Sample environment and off-line infrastructures (% of survey participants)
Sample environment

What are your particular requirements?

Sample environment

The traditional sample environments for temperature control and creating a vacuum are still most important. Chemical / reaction environment and in situ / operando and lasers (lasers in general and synchronized laser got 30 % together) come next. Particularly biologists use additional sample environments that were not part of the choices of the survey. Most often mentioned were “humidity control” and “liquid injectors“.

Off-line infrastructures

How important are these off-line infrastructures for your experiments?

Laboratories play an important role for many users of synchrotron radiation, since they have to prepare and characterize their samples. We have asked for chemistry labs, biology labs, clean rooms, stand alone characterization tools (AFM, STM, X-ray sources, UV/VIS,… ) and sample preparation (PVD, ALD, sputter tools, …), see figure 6. Most abundantly used are chemistry labs: A third of the survey participants need them and 80 % use them at least sometimes. Chracterisation tools and sample preparation is important for all scientific fields. Clean rooms and biological labs are more specific. The latter are essential to the underrepresented biologists, so their role importance should not be underestimated.
5. Comments

Comments

At the end of the survey, the participants could write a comment. 76 of 894 (9%) used the opportunity, of which 21 commented their personal situation or their answers in the survey. The other comments were grouped by topics (see figure 7) and will be passed on to the facilities after a review by the KFS.

6. Comparative Data from the Facilities

HZB: proposer, co-proposer, experimentalist for a proposal. All users, disregarding nationality, but from German affiliations, and all users of German nationality who work at the listed European facilities (ESRF, European XFEL, EMBL and ESS). Users who came to HZB, since there is hardly any remote access. Time span: three years.

European XFEL: users who took part in a proposal. Users with German affiliation or from common institutions (ESRF, European XFEL, EMBL and ESS). All users (also remote access). Time span: Since beginning of operation in 2017.

DESY: Users with German affiliation (including ESRF, European XFEL, EMBL and ESS) who have measured and came to Hamburg for it (excluding in-house in commissioning) Time span: 2015-2018

ESRF: Users from German affiliations and their accepted proposals in 2017 and 2018.
Conclusion: The users that were selected by the facilities corresponds quite well to the user community that KFS asked to participate in the survey. The agreement is best with HZB and European XFEL. At DESY and ESRF only users were taken into account who really did measurements (excluding in-house in commissioning).

7. Discussion and Summary of the Results

The results of the survey show that research with synchrotron radiation is indispensable not only for basic research, but also for applied and industrial research.

Synchrotron radiation of storage rings and free electron lasers gives insights into materials and processes to young and established scientists in many areas, such as physics, chemistry, biology, engineering, geosciences and arts & culture. The deeper understanding of properties of matter and relationships helps finding solutions for socioeconomic challenges like the development of new materials and technologies, the production, storage and usage of energy, health matters and problems relating climate and the environment.

The survey shows that the diversity of German synchrotron radiation sources (PETRA III, BESSY II, ESRF, European XFEL, FLASH, DELTA, KARA) is prerequisite for the users, because they need a range of energies (e.g. hard or soft X-rays), beam properties (focus, coherence and time structure), flux, instrumentation and off-line infrastructure for their experiments. The sources complement each other in these properties, so that all of them are needed to span the whole range. The great bandwidth of experimental possibilities should not disguise the fact that the demand for beamtime is even higher: About half of the survey participants state that they are limited in their research by the amount of beamtime, and a third of the participants felt limited by the performance parameters of the existing sources.

Due to the great importance for research and development, the further operation of the existing sources is essential. Furthermore, the development of new synchrotron sources like PETRA IV, BESSY III, ESRF-EBS, FLASH2020+ und the European XFEL (SASE 4 and SASE 5) are important for the future of research in Germany, since the parameters desired by the users will only be reached by these upgrades and these new sources will allow seminal experiments.

Dynamic measurements on complex objects in operando, in situ and in real time will gain even more importance, as well as highly resolved imaging methods and automated experiments. The survey participants identified these developments as promising for the future. They are connected to the expansion of data management, which reaches way beyond this research field, since new solutions will be implemented that will be applicable to many other areas in science and society.
8. The survey questions

User survey on current and future user needs in view of the planned upgrades at German synchrotron radiation facilities

The KFS represents the needs of all synchrotron (including FEL) users in Germany. Currently, updates are planned at all synchrotron facilities, so it is crucial to know what users need now and in the future.

This survey is very important for the future of photon science research in Germany and the results will be considered for our future KFS strategy. Your answers will help us to show the research funding agencies where photon science is currently focused and where the focus will move to in the coming years.

We kindly ask you to take the time to answer the questions below. Please click all boxes that apply.

Your email address Please enter your email address in case clarification is required.

Your Status
Please tell us which group of persons you belong to
- Undergraduate student
- PhD student
- Postdoc
- Scientist
- Senior scientist
- Junior professor
- Professor

Institution
At which sort of institution do you work?
- Academic Institution (University, Fachhochschule)
- National Research Institute (Helmholtz, MPI, Fraunhofer etc.)
- International Research Institute (EMBL, European XFEL, ESRF etc.)
- Private Research Institute
- Industry

Systems
- soft matter
- liquids
- solids
- interfaces
warm dense matter

- biological systems
- atoms, molecules, gas phase
- others

Other systems If you have chosen "others" above, please tell us which

Energy

Which energy regime do you use? Multiple choices are possible.

- IR / Thz
- < 50 eV (VUV)
- < 2 keV (soft X-rays)
- 2 - 5 keV (tender X-rays)
- 5 - 30 keV (hard X-rays)
- > 30 keV (high energy X-rays)

Sources

Which synchrotron sources do you use? Please enter the mean number of experiments per year.

PETRA III

BESSY II

ESRF (F)

European XFEL

FLASH

KARA

DELTA

Other sources (in Europe)

Which other sources in Europe?

Other sources (outside Europe)

Which other sources outside Europe?
In which scientific field can your research be identified?
- methods of photon science
- physics
- chemistry
- biology
- engineering
- geo / environmental science
- arts & culture

To which social or economic challenge does or could your research contribute?
- energy
- materials
- information
- technology
- health
- other

Which other social or economic challenge / field of application? Please think "grand challenges"

Methods
Which methods do you use?
Scattering
- Wide angle scattering
- Small angle scattering
- Magnetic scattering
- Inelastic scattering
- Nuclear resonant scattering
- Resonant inelastic x-ray scattering (RIXS)
- Elastic scattering
- Coherent scattering
- X-ray reflectivity
- Other scattering

Which other scattering?
- Diffraction
- Topography
Surface diffraction
- Grazing incidence diffraction (GID)
- Powder Diffraction
- Crystallography (material science)
- Crystallography (biological macromolecules)
- Other diffraction

Emission or Reflection
- X-ray fluorescence (XRF)
- X-ray emission spectroscopy (XES)
- X-ray excited optical luminescence (XEOL)
- Reflectrometry
- Polarimetry
- Ellipsometry

Resonant inelastic x-ray scattering (RIXS) is listed in the scattering section
- Other emission or reflection

Photoelectron spectroscopy
- Ultraviolet photoelectron spectroscopy (UPS)
- X-ray photoelectron spectroscopy (XPS)
- Angle-resolved PES (ARPES)
- Spin-resolved PES
- Photoelectron diffraction
- Other photoelectron emission

Imaging
- X-ray tomography
- X-ray microscopy, holography, ptychography
- THz near-field microscopy
- Photoemission EM
- Medical application
- IR Microscopy
Fluorescence imaging
Other imaging
Which other imaging?

Absorption
- X-ray magnetic circular dichroism (XMCD)
- Ultraviolet circular dichroism (UVCD)
- IR spectroscopy
- X-ray absorption spectroscopy (XAS, NEXAFS, XANES, EXAFS, fluorescence XAS)
Which other absorption?

Lithography
- X-ray lithography
- EUV lithography
- Other lithography
Which other lithography?

Ion Spectroscopy
- Mass spectrometry
- Ion imaging
- Other ion spectroscopy
Which other ion spectroscopy?

What are your particular requirements?
X-ray beam quality
- unfocussed is sufficient
- large beam (mm-range) is advantageous
- micrometer focus
- nanometer focus
- high energy resolution
- high intensity
- high coherence
- low divergence
- short pulse duration
- other
Which other X-ray beam quality?

Sample environment
- temperature control
- magnetic / electric field
- high pressure / strain & stress
- vacuum
- chemical / reaction environment, in-situ / operando
- laser
- synchronized laser
- other pump-probe
- other sample environment

Which other sample environment?

Time scale to be investigated
- time-resolved measurement
- fs
- ps
- ns
- μs
- ms
- s
- min
- other

Which other time scale?

How important are these off-line infrastructures for your experiments?
Chemistry labs
- not required
- good to have
- essential
Biology labs
- not required
- good to have
- **Clean room**
  - essential
  - not required
  - good to have
  - essential

- **Stand alone characterisation tools (AFM, STM, X-ray sources, UV/VIS, ...)**
  - not required
  - good to have
  - essential

- **Sample preparation at the facility (PVD, ALD, sputter tools, ...)**
  - not required
  - good to have
  - essential

**What are your data management requirements?**
Please evaluate the present situation at the facilities with respect to your needs

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limiting factor
Theory support
square sufficient
square could be better
square limiting factor
Restrictions
Does this apply to you?
---
check I am limited in my research by the amount of beamtime
check I am limited in my research by the performance parameters of the existing sources
---
Future
Do you expect any of the following to become more important for your future research?
---
check In situ / operando studies
check X-ray imaging / microscopy
check Real time studies Studying processes on the time scale they occur
check Transient and irreversible processes
check Non-linear X-ray physics
check Multi parameter / method experiments For example combining different time and length scales for complex systems
check Automated experiments
check Other type of study
Which other type of study?
---
check I require no change to my experiments in the future
---
Comments