EDITORIAL



# The next decade of XFELs

In this issue, we look back at the first decade of X-ray free-electron lasers (XFELs) and forward to the challenges and opportunities lying ahead.

Despite the similarities, XFELs are not next-level synchrotrons. The electron acceleration is different, the energy and coherence of the beams are distinct (see Comment by Claudio Pellegrini) and so are the requirements for the detectors. Furthermore, XFELs can probe spatial and temporal regimes beyond those accessible through synchrotron radiation. But the new opportunities are not challenge-free. To fully exploit the potential of XFELs, users and beam scientists need to undergo a cultural change and rethink future experiments and the operation of these facilities.

Synchrotron radiation has been used in experiments since the late 1950s. Synchrotrons as dedicated light sources have been continuously developing ever since. Today, there are dozens of synchrotron facilities worldwide catering for scientists from different disciplines in studies ranging from the determination of the structure of viruses and drug discovery to the examination of the mechanical integrity of aerospace components and the characterization of archaeological artefacts. Next-generation facilities, such as MAX IV in Sweden or the upgrade of the European Synchrotron Radiation Facility in France, are coming online. But, despite these evolving capabilities, synchrotron radiation cannot access the spatial and temporal scales of atomic and molecular motion that underpin many processes, such as energy conversion and storage. For this type of study, different light sources are needed: XFELs (see Comment by Jonathan Marangos).

Undoubtedly, XFELs have great potential, but they are also a huge investment (on the order of a US$1 billion), which will only be returned if they offer unique possibilities for research and are accessible to large numbers of users. Whereas synchrotrons have had decades to establish themselves as reliable tools for a broad user community and XFELs have come a long way during their first decade (see Timeline), they are only at the start of this process. With any new technology, come new challenges — both technological and in terms of how to manage and best exploit the potential to address the varied needs of different communities.

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On the technological side, the development of a new generation of detectors (see Comment by Bernd Schmitt, Anna Bergamaschi and Aldo Mozzanica) has been central to the successful operation of XFELs. The emerging XFELs with higher repetition rates (see Comment by Sakura Pascarelli, Serguei Molodtsov and Thomas Tschentscher) will generate even larger amounts of data than current experiments. This requires further advances in ‘intelligent’ detectors in conjunction with new methods of data analysis. It will no longer be possible to store and analyse all of the data generated (see Comment by Chi-Chang Kao). In this regard, machine learning can help and even provide entirely new approaches to running experiments (see Comment by Abbas Ourmazd). However, as Kao and Ourmazd point out, these developments could fundamentally change the way science is done at XFELs.

On the management side, one of the major challenges is the limited access to XFELs. At present, there are still too few facilities — each with only a few beamlines — and, unlike synchrotrons, there is a high expertise barrier to users. Kao and Pascarelli et al. describe how existing facilities, such as the Linac Coherent Light Source (LCLS) at SLAC and the European XFEL at DESY, are constructively engaging with user communities to lower the access barriers. A related issue is that of trying to translate problems typically studied using synchrotrons and ultrafast lasers to XFEL experiments. Kao points out that with this approach, we may be missing out on exploiting the full potential of XFELs and, therefore, facilities need to work with users to help them design new types of experiment. Different user communities have different needs, and their approaches to future experiments will shape the strategies for upgrades and the planning of new XFEL facilities. The XFEL community will need to find the best way forwards while balancing sometimes divergent requirements.

After the first 10 years of successful developments, “making XFEL science routine”, as Marangos puts it, with all that it involves, is the next big challenge that XFEL facilities will have to face.