PRESS RELEASE

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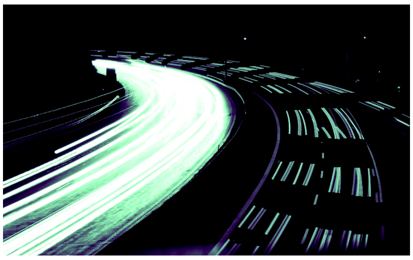
X-ray pulses on demand from Electron Storage Rings

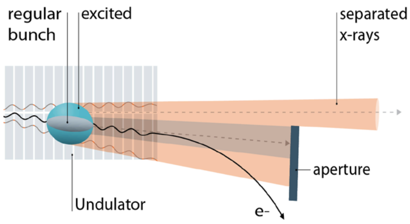
HZB physicists recently devised a new method to pick single x-ray pulses out of the pulse trains usually emitted from synchrotron radiation facilities. The technique is very useful to support studies of electronic properties of quantum materials and superconductors and paves the way for future synchrotron facilities with variable pulse lengths.

Everything we know nowadays about novel materials and the underlying processes in them we also know thanks to studies at contemporary synchrotron facilities like BESSY II. Here, relativistic electrons in a storage ring are employed to generate very brilliant and partly coherent light pulses from the THz to the X-ray regime in undulators and other devices. However, most of the techniques used at synchrotrons are very "photon hungry" and demand brighter and brighter light pulses to conduct innovative experiments. The general greed for stronger light pulses does, however, not really meet the requirements of one of the most important techniques in material science: photoelectron spectroscopy. Physicists and chemists have been using it for decades to study molecules, gases and surfaces of solids. However, if too many photons hit a surface at the same time, space charge effects deteriorate the results. Owing to these limits, certain material parameters stay hidden in such cases. Thus, a tailored temporal pattern of x-ray pulses is mandatory to move things forward in surface physics at Synchrotrons.



Some contemporary Synchroton Radiation methods need pulsed x-rays with a specific time structure. HZB-users at BESSY II can use them now on demand. Graphics: Highway at night, K. Holldack/HZB

Scientists from HZB's Institute for Methods and Instrumentation in Synchrotron Radiation Research and the Accelerator Department have now jointly solved the gordic knot as they published in the renowned journal Nature Communications. Their novel method is capable of picking single pulses out of a conventional pulse train as usually emitted from Synchrotron facilities. They managed to apply this for the first time to time-of-flight electron spectroscopy based on modern instruments as developed within a joint Lab with Uppsala University, Sweden.



Schematic illustration of pulse picking by resonant excitation (PPRE):
In regular operation the non-excited bunches (grey) emit undulator radiation on-axis. A detour in the electron beam (bump) makes that this regular radiation is emitted off-axis and dumped into an aperture. Only the part of the radiation from a quasi-resonantly excited bunch (blue) can enter the beamline mimicking a turn-by-turn single bunch emission.
Graphics: Ela Strickert/HZB

Picking single pulses out of a pulse train

The pulse picking technique is based on a quasi resonant magnetic excitation of transverse oscillations in one specific relativistic electron bunch that – like all others – generates a radiation cone within an undulator. The selective excitation leads to an enlargement of the radiation cone. Employing a detour ("bump") in the electron beam path, the regular radiation and the radiation from the excited electrons can be easily separated and only pulses from the latter arrive – once per revolution - at the experiment. Thus, the arrival time of the pulses is now perfectly accommodated for modern high resolution time-of-flight spectrometers.

Users will be able to examine band structures with higher precision

"The development of the Pulse Picking by Resonant Excitation (PPRE) was science driven by our user community working with single bunch techniques. They demand more beamtime to improve studies on e.g. graphene, topological insulators and other "hot topics" in material science like the current debates about high T_c-Superconductors, magnetic ordering phenomena and catalytic surface effects for energy storage. Moreover, with pulse picking techniques at hand, we are now well prepared for our future light source with variable pulse lengths: BESSY-VSR, where users will appreciate pulse selection on demand to readily switch from high brightness to ultrashort pulses according to their individual needs" says Karsten Holldack, corresponding author of the paper.

First tests successful

The researchers have proven the workability of their method with ARTOF-time-of-flight spectrometers at different undulators and beamlines as well as in BESSY II's regular user mode. "Here we could certainly benefit from long year experiences with emittance manipulation", says Dr. P. Kuske acting as head of the accelerator part of the team. Thanks to accelerator developments in the past, we are capable of even picking ultrashort pulses out of the bunch trains in low-alpha operation, a special operation mode of BESSY II. At last, the users can, already right now, individually switch - within minutes – between high static flux and the single pulse without touching any settings at their instruments and the sample.

The work has now been published in **Nature Communications:** Single Bunch X-ray Pulses on Demand from a Multibunch Synchrotron Radiation Source, K. Holldack et al. **DOI 10.1038/ncomms5010**

The Helmholtz-Zentrum Berlin für Materialien und Energie (HZB) operates and develops large scale facilities for research with photons (synchrotron beams) and neutrons. The experimental facilities, some of which are unique, are used annually by more than 2,500 guest researchers from universities and other research organisations worldwide. Above all, HZB is known for the unique sample environments that can be created (high magnetic fields, low temperatures). HZB conducts materials research on themes that especially benefit from and are suited to large scale facilities. Research topics include magnetic materials and functional materials. In the research focus area of solar energy, the development of thin film solar cells is a priority, whilst chemical fuels from sunlight are also a vital research theme. HZB has approx.1,100 employees of whom some 800 work on the Lise-Meitner Campus in Wannsee and 300 on the Wilhelm-Conrad-Röntgen Campus in Adlershof.

HZB is a member of the Helmholtz Association of German Research Centres, the largest scientific organisation in Germany.