High resolution soft X-ray spectrometer for FEL characterisation and optimisation

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Abstract: A high resolution ($\Delta E < 100$ meV) single shot spectrometer for the soft X-ray at SwissFEL is reported. Use of this high fidelity single shot data to develop new modes of operations of operation is described.

1. Introduction

X-rays produced by Free electron lasers (FELs) such as SwissFEL [2] originate from a process called self-amplification of spontaneous emission (SASE) resulting in a pulse to pulse fluctuation in central energy, bandwidth, spike distribution and spectral intensity profile. Furthermore, electron beam trajectory and compression can lead to a spatial chirp and loss of transverse coherence across the X-ray pulse. In order to both optimise and develop new state of the art modes of operation, high fidelity pulse to pulse measurements of soft X-ray spectra are required. To achieve this a high resolution spectrometer has been built on the soft X-ray branch of SwissFEL called Athos [1]. The X-ray pulses are dispersed using the beamline monochromator, while 2 imaging systems simultaneously measure the dispersed photons.

2. Imaging systems

A scintillation screen at the disperse plane of the beamline monochromator is imaged with both a 2D CMOS detector and 1D line scan CMOS. The 2D system samples the dispersed spectrum over the horizontal coordinate, allowing spatial chirp across the beam to be measured. The 1D system samples only a section across the horizontal coordinate but with a higher spatial resolution ($< 20\mu$m).

3. Spectral measurement

An example single shot X-ray spectrum is shown in figure 1 using the 2D imaging system with the FEL centred at 532 eV. The 2D plot shows the dispersed FEL spectrum and the spectral distribution over the horizontal FEL profile. A spatial chirp as well as a change in the mode structure can be seen and is plotted in the line plots.

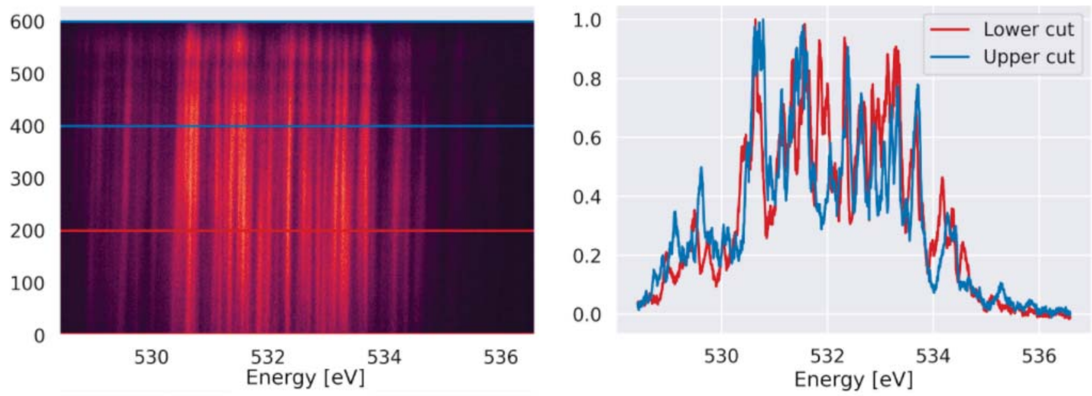

Fig. 1. Left: spatial resolved dispersed FEL spectrum across the horizontal coordinated. Vertical axis in pixels. The none uniform spike structure and a spatial chirp can be seen. Right: Integrated signal from 2D image. Red between 0:200 pixels and Blue between 400:600 pixels.

For online monitoring of the FEL bandwidth during monochromatic operation, a split screen can be inserted in the dispersed plane of the monochromator. The screen has a horizontal gap in line with the exit slit opening allowing the set energy of the monochromator to pass, while measuring the wings of the FEL spectrum. This allows online optimisation of the X-ray SASE bandwidth to maximise the pulse spectral intensity passed by the exit slit opening.

4. New modes of operation

High-resolution single-shot spectral measurements are fundamental to setup and optimize the standard SASE mode for minimum bandwidth. This device will be particularly relevant to implement new operation modes with extremely low bandwidths such as the High-Brightness SASE and seeding schemes. Moreover, the number of spikes and the spike width provided by the spectrometer are a very important information to estimate the pulse duration, which will be specially important for the development of short-pulse modes.

References

1. R. Abela, A. Alarcon, J. Alex, C. Arrell, V. Arsov, S. Bettoni, M. Bopp, C. Bostedt, H.-H. Braun, M. Calvi, T. Celcer, P. Craievich, A. Dax, P. Dijkstal, S. Dordevic, E. Ferrari, U. Flechsig, R. Follath, F. Frei, N. Gaiffi, Z. Geng, C. Gough, N. Hiller, S. Hunziker, M. Huppert, R. Ischebeck, H. Jöhri, P. Juranic, R. Kalt, M. Kaiser, B. Keil, C. Kittel, R. Künzi, T. Lippuner, F. Löhl, F. Marcellini, G. Marinkovic, C. Ozkan Loch, G. L. Orlandi, B. Patterson, C. Pradervand, M. Paraliev, M. Pedrozzi, E. Prat, P. Ranitovic, S. Reiche, C. Rosenberg, S. Sanfilippo, T. Schietinger, T. Schmidt, K. Schnorr, C. Svetina, A. Trisorio, C. Vicario, D. Voulot, U. Wagner, H. J. Wörner, A. Zandonella, L. Patthey, and R. Ganter. The SwissFEL soft X-ray free-electron laser beamline: Athos. *Journal of Synchrotron Radiation*, 26(4):1073–1084, July 2019. Number: 4 Publisher: International Union of Crystallography.
2. Eduard Prat, Rafael Abela, Masamitsu Aiba, Arturo Alarcon, Jürgen Alex, Yunieski Arbelo, Christopher Arrell, Vladimir Arsov, Camila Bacellar, Carl Beard, Paul Beaud, Simona Bettoni, Roger Biffiger, Markus Bopp, Hans-Heinrich Braun, Marco Calvi, Ariana Cassar, Tine Celcer, Majed Chergui, Pavel Chevtsov, Claudio Cirelli, Alessandro Citterio, Paolo Craievich, Marta Csatari Divall, Andreas Dax, Micha Dehler, Yunpei Deng, Alexander Dietrich, Philipp Dijkstal, Roberto Dinapoli, Sladana Dordevic, Simon Ebner, Daniel Engeler, Christian Erny, Vincent Esposito, Eugenio Ferrari, Uwe Flechsig, Rolf Follath, Franziska Frei, Romain Ganter, Terence Garvey, Zheqiao Geng, Alexandre Gobbo, Christopher Gough, Andreas Hauff, Christoph P. Hauri, Nicole Hiller, Stephan Hunziker, Martin Huppert, Gerhard Ingold, Rasmus Ischebeck, Markus Janousch, Philip J. M. Johnson, Steven L. Johnson, Pavle Juranić, Mario Jurcevic, Maik Kaiser, Roger Kalt, Boris Keil, Daniela Kiselev, Christoph Kittel, Gregor Knopp, Waldemar Koprek, Michael Laznovsky, Henrik T. Lemke, Daniel Llorente Sancho, Florian Löhl, Alexander Malyzhenkov, Giulia Fulvia Mancini, Roman Mankowsky, Fabio Marcellini, Goran Marinkovic, Isabelle Martiel, Fabian Märki, Christopher J. Milne, Aldo Mozzanica, Karol Nass, Gian Luca Orlandi, Cigdem Ozkan Loch, Martin Paraliev, Bruce Patterson, Luc Patthey, Bill Pedrini, Marco Pedrozzi, Claude Pradervand, Peter Radi, Jean-Yves Raguin, Sophie Redford, Jens Rehanek, Sven Reiche, Leonid Rivkin, Albert Romann, Leonardo Sala, Mathias Sander, Thomas Schietinger, Thomas Schilcher, Volker Schlott, Thomas Schmidt, Mike Seidel, Markus Stadler, Lukas Stingelin, Cristian Svetina, Daniel M. Treyer, Alexandre Trisorio, Carlo Vicario, Didier Voulot, Albin Wrulich, Serhane Zerdane, and Elke Zimoch. A compact and cost-effective hard X-ray free-electron laser driven by a high-brightness and low-energy electron beam. *Nature Photonics*, 14(12):748–754, December 2020. Number: 12 Publisher: Nature Publishing Group.