Contribution ID: **54** Contribution code: **WEP36**

Type: **Contributed Poster**

AI Methods for an Improved Evaluation of FEL Diagnosic Data

Wednesday 24 August 2022 16:00 (20 minutes)

Free electron lasers (FEL) serve a broad user community in many scientific fields ranging from atomic and molecular physics to plasma and solid state physics as well as chemistry and biology. Many experiments could benefit from a non-destructive online photon diagnostic of the provided x-ray pulses. Especially, for free-electron lasers that are operated in the self-amplified spontaneous emission (SASE) regime, where the pulse characteristics fluctuate from pulse to pulse [1], reliable online information on the intensity, spectral distribution, and temporal structure of each individual pulse can be crucial. A fast feedback can significantly improve an on-the-fly evaluation of user experiments. In addition, subsequent sorting of measurement data by, for example, intensity or wavelength can reveal signatures of physical processes that would otherwise be hidden in the fluctuation. Finally, real-time information about the pulse can give a direct feedback for FEL beam tuning.

Neural networks became popular as a powerful analysis tool in all categories of science [2]. This is due to their ability to recognize complex relationships in large datasets. There are various architectures of neural networks, each with its own focus on specific tasks. What they all have in common is that they need to be trained during a training process in order to recognize patterns and correlations. A special case of training is performed in unsupervised learning, where the network does not need any expert knowledge about the data. This can be done for example with autoencoder networks [3]. These networks consist of an encoder and a decoder. The encoder learns during the training phase to compress data to lower dimensionality, the so-called latent space, the decoder to reconstruct the input from this compressed representation. This means that, given the decoder, the latent space contains all information needed to reconstruct an input sample. A special form of autoencoder networks are β Variational Autoencoder (β-VAE) networks [4], that allow to balance between the goal of a perfect reconstruction of the data and a perfect disentanglement of the latent space vector components. These networks are found to be able to find the key principles in an unlabeled data set, even if these principles were not known before.

We demonstrate the usage of β-VAEs to characterize SASE X-ray pulses of the free electron laser FLASH in Hamburg. We combine data from different diagnostic devices. We evaluate measured data from the online photoionization spectrometer OPIS [5], that uses 4 electron time of flight spectrometers to monitor each individual FEL pulse. In addition, we include data from an X-band transverse deflecting mode cavity diagnostic system (XTCAV). The latter is similar to the XTCAV at the Linac Coherent Light Source [6]. This device measures the position and kinetic energy of the electrons after they have passed the undulator and is therefore able to monitor the differences in the temporal structure of the electron bunches due to the lasing process. We demonstrate that a β-VAE can detect key principles in the XTCAV and the OPIS data, like pulse duration and central wavelength and compare them to other diagnostic devices such as data from a gas monitor device (GMD) [7] and THz field-driven streaking [8]. Without a-priori knowledge the network is able to find directly human-interpretable representations of single-shot FEL spectra, remove noise as well as reveal data artefacts and hence allows for an improved in-depth analysis of photon diagnostics data.

I have read and accept the Privacy Policy Statement

Yes

Author: GOETZKE, Gesa (Deutsches Elektronen-Synchrotron)

Co-authors: DÜSTERER, Stefan (Deutsches Elektronen-Synchrotron); ROENSCH-SCHULENBURG, Juliane (Deutsches Elektronen-Synchrotron); TIEDTKE, Kai (Deutsches Elektronen-Synchrotron); VOGT, Mathias (Deutsches Elektronen-Synchrotron); HARTMANN, Gregor (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH); LEVER, Fabiano (Univerisity of Potsdam, Institut für Physik und Astronomie); MÖLLER, Felix (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH); BIDHENDI, Mahdi (Deutsches Elektronen-Synchrotron); BRAUNE, Markus (Deutsches Elektronen-Synchrotron); GUEHR, Markus (Univerisity of Potsdam, Institut für Physik und Astronomie); VIEFHAUS, Jens (Helmholtz-Zentrum Berlin für Materialien und Energie GmbH)

Presenter: GOETZKE, Gesa (Deutsches Elektronen-Synchrotron)

Session Classification: Wednesday posters

Track Classification: Photon beamline instrumentation & undulators