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Characterizing SASE X-ray Pulses Using Machine Learning

Accurate online characterization of the intensity, spectral distribution, and temporal structure of X-ray pulses is crucial for free-electron lasers. We propose a novel approach for characterizing temporal profiles of X-ray pulses at the free-electron laser FLASH in Hamburg, using β-Variational Autoencoder (β-VAE) [1] networks in conjunction with a Transverse Deflecting Structure (TDS).

The TDS in combination with a dipole spectrometer allows the measurement of time and energy variations of electrons with femtosecond resolution after they pass through the undulator, providing valuable insights into the temporal structure of the electron bunches influenced by the lasing process. [2]. To obtain a XUV power profile, a lasing off reference is required. However finding a suitable lasing off reference may prove challenging due to stability issues and drifts. For highly fluctuating electron beam properties, this matching may not be possible at all.

To address this challenge, we demonstrate the effectiveness of β-VAE networks in identifying key principles within the dataset. By training artificial neural networks on datasets comprising both lasing on and lasing off shots, we can artificially create matching lasing off images for each shot. The β-VAE networks exhibit noise reduction capabilities, uncovering hidden data artifacts and enabling enhanced analysis of the temporal structure of the electron bunches, thereby helping to obtain temporal characteristics of SASE X-ray pulses in a non-invasive manner.

References:

[1] Higgins, I. et al. B-VAE, conference paper at ICLR 2017
[2] Behrens, C. et al. Nat Commun 5, 3762 (2014)

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no

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