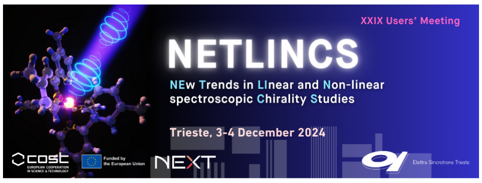

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Machine Learning-Assisted CEP Estimation in the Mid-Infrared for Ultrafast Chiral Spectroscopy

Ultrafast few-cycle lasers provide a versatile platform for probing and controlling the chirality of molecular and crystalline systems. Utilizing such pulses, high-harmonic generation (HHG) measurements grant valuable insights into ultrafast chiral dynamics. In these, the carrier-envelope phase (CEP) of the laser pulse plays a pivotal role. Precise CEP control allows manipulation of enantio-sensitive optical activity in the emitted harmonics, enhancing or suppressing chiral signals [1], and enables selective excitation of molecular states or coherent control over ionization processes [2]. Mid-infrared (MIR) lasers are particularly advantageous for these measurements, as they offer efficient subcycle control of slower nuclear dynamics predominant in complex molecules [3]. However, conventional CEP measurement techniques are often challenging to implement on-demand as additional metrology tools in intense few-cycle laser-matter interaction experiments. This is especially true in the MIR regime.

We present a machine learning (ML) driven method for real-time CEP estimation in the mid-infrared range, generalizable to any laser wavelength and scalable up to megahertz repetition rates [4]. Our approach relies on the observation of the spectrum of high harmonic generation (HHG) by a conventional spectrometer setup, and utilization of ML techniques to estimate the CEP of the laser. Once the ML model is trained, the method provides an inexpensive and compact solution for real-time CEP tagging. This technique can complement the otherwise sophisticated monitoring of CEP, and is able to capture the complex correlation between the CEP and the observable HHG spectra. Our approach thereby enables efficient in-situ measurement and control of CEP, which is essential for advanced chirality-oriented spectroscopy.

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