CHARACTERIZING SUB-FEMTOSECOND X-RAY PULSES FROM THE LINAC COHERENT LIGHT SOURCE

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INTRODUCTION

Motivation
- Recent developments of sub-fs x-ray capabilities at LCLS requires temporal diagnostic with attosecond time resolution

Angular Streaking
- Asec x-ray pulses interact with gas molecules and ionizes photoelectrons
- IR circularly polarized laser angularly streaks the photoelectrons – provide an angular momentum kick:

![Illustration of angular momentum streak](image)

“Angle-Resolved Streaking for Complete Attosecond FEL pulse characterization”, Nick Hartmann, Gregor Hartmann, et int, and Wolfram Helml, manuscript in preparation.

- Velocity map imaging (VMI) spectrometer measures the photoelectron momentum distribution – mapping the particles momentum to a 2D detector regardless of their initial position.

VMI DESIGN

STREAKING SIMULATION

- We use Lewenstein model to calculate transition amplitude to continuum states

\[ b(\vec{p}) = -i \int_{-\infty}^{\infty} dt \, \vec{E}(t) \cdot \vec{d}(\vec{p} + \vec{A}(t)) \exp \left\{ -i \int_{-\infty}^{t} dt' \left[ (\vec{p} + \vec{A}(t'))^2 / 2 + \vec{p} \right] \right\} \]

VMI measures the photoelectrons’ 3D momentum distribution projected onto a 2D detector at the end of the VMI spectrometer:

\[ B(p_x, p_y) = \int dp_z |b(p_x, p_y, p_z) b^*(p_x, p_y, p_z)| \]

![Simulated VMI image varying relative phase between x-ray pulse and streak pulse](image)

X-RAY RECONSTRUCTION

Electric field basis function:

\[ \alpha_{\omega_l t_j}(t) = \left( \frac{1}{2\alpha \pi} \right)^{\frac{1}{2}} \exp \left[ -\frac{1}{4\alpha} (t - t_j)^2 - i\omega_l t \right] \]


\[ \vec{E}_{\text{recon}} = \sum_{i,j} Q_{i,j} \alpha_{\omega_l t_j} n = ij \]

Qij is a rearrangement of Cn. The problem is to solve complex coefficients Cn.

- We use nonlinear fitting algorithm (Matlab’s fminunc function) to minimize the cost function:

\[ \text{cost} = \sum_{p_x, p_y} \left| M(p_x, p_y) - B(p_x, p_y) \right|^2 \]

![Example of x-ray time and frequency domain reconstruction from a simulated VMI image of an x-ray pulses, generated by FEL code GENESIS. Pulse duration is ~ 300as. The effect of counting noise is shown on second row.](image)

More information in paper WEP060