SLAC NATIONAL ACCELERATOR LABORATORY

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:

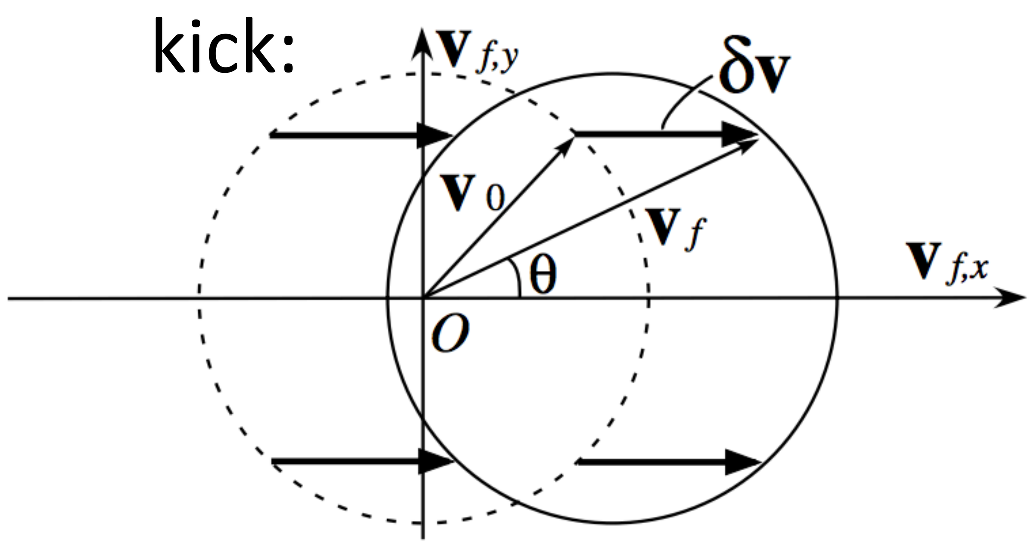

Fig. 1: illustration of angular momentum streak
Itatani, J., et al. "Attosecond streak camera." Physical Review Letters 88.17 (2002): 173903.

"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

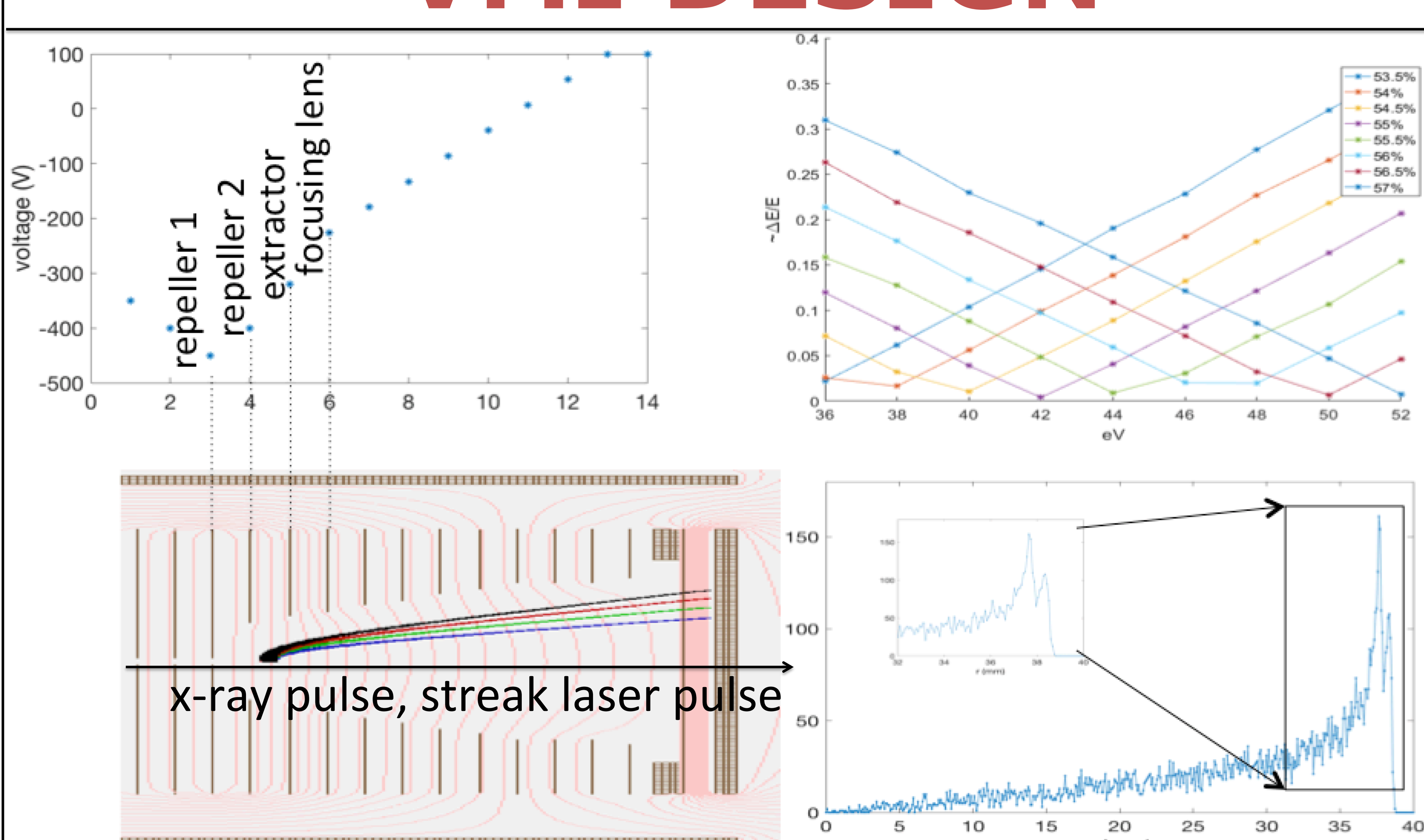

Fig. 2: details of VMI design.

STREAKING SIMULATION

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

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

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

$$B(p_x,p_y) = \int dp_z \left| b(p_x,p_y,p_z)b^*(p_x,p_y,p_z)\right|$$

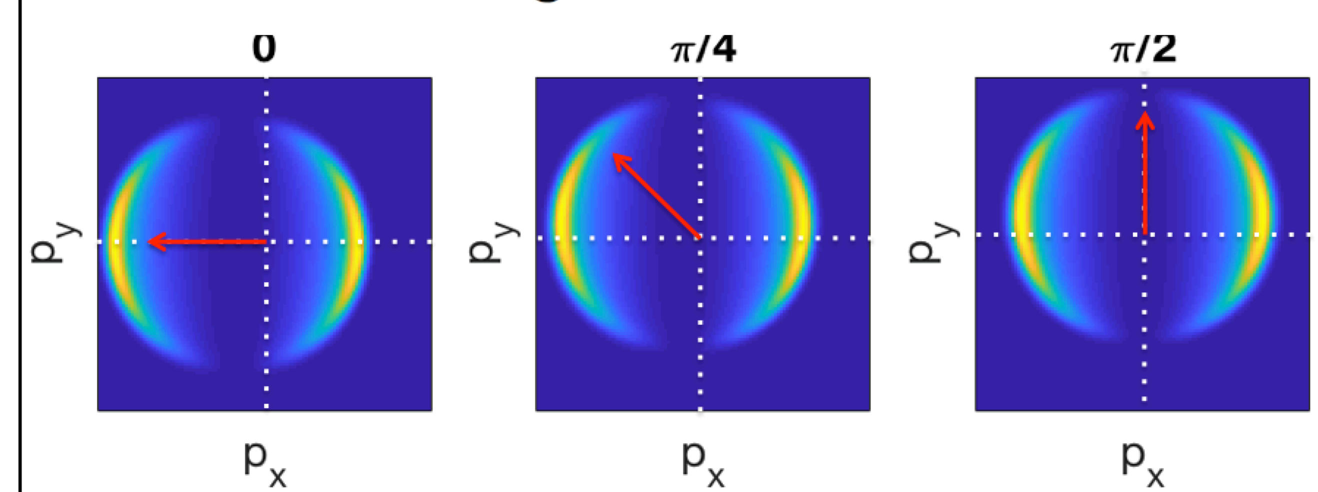

Fig. 3: simulated VMI image varying relative phase between x-ray pulse and streak pulse

X-RAY RECONSTRUCTION

$$b(\vec{p}) \propto \vec{E_X}(t) \qquad b(\vec{p}) = \sum_n c_n b_n(\vec{p})$$

$$B(p_x,p_y) = \sum_n\sum_m \int dp_z c_n^* c_m b_n^*(\vec{p}) b_m(\vec{p}) = \sum_n\sum_m c_n^* c_m B_{nm}(p_x,p_y),$$

Electric field basis function:

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

(Fechner, Susanne, et al. Optics express 15.23 (2007): 15387-15401.)

$$\vec{E}recon = \sum_{i,j} Q_{i,j}\,\alpha_{\omega_i t_j} \qquad n = ij$$

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:

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

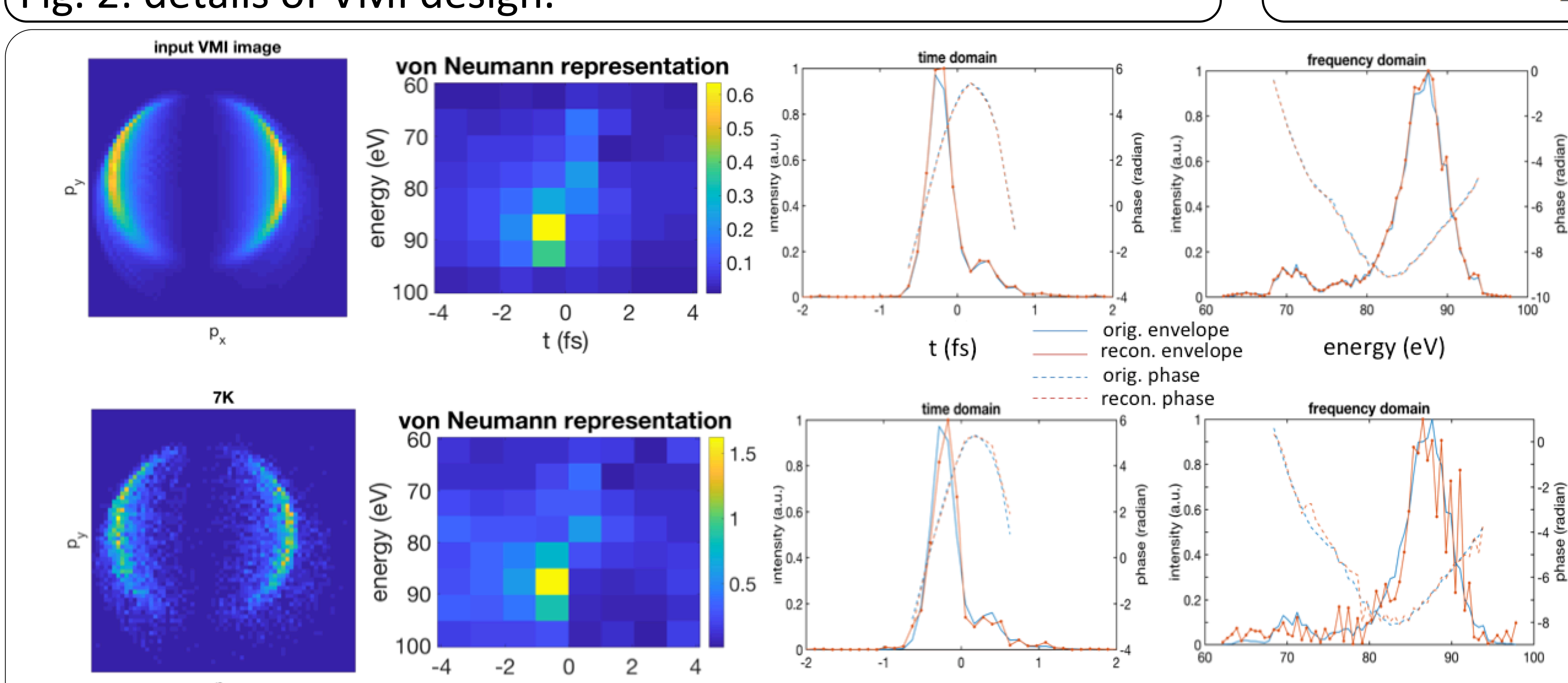

Fig. 4: example of x-ray time and frequency domain reconstruction from a simulated VMI image of an x-ray pulses, generated by FEL code GENESIS. Pulse duration is ~ 300as. The effect of counting noise is shown on second row.

More information in paper WEP060