Ultra-fast X-ray Streak Camera Development and application at the ALS

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Outline

1. Introduction

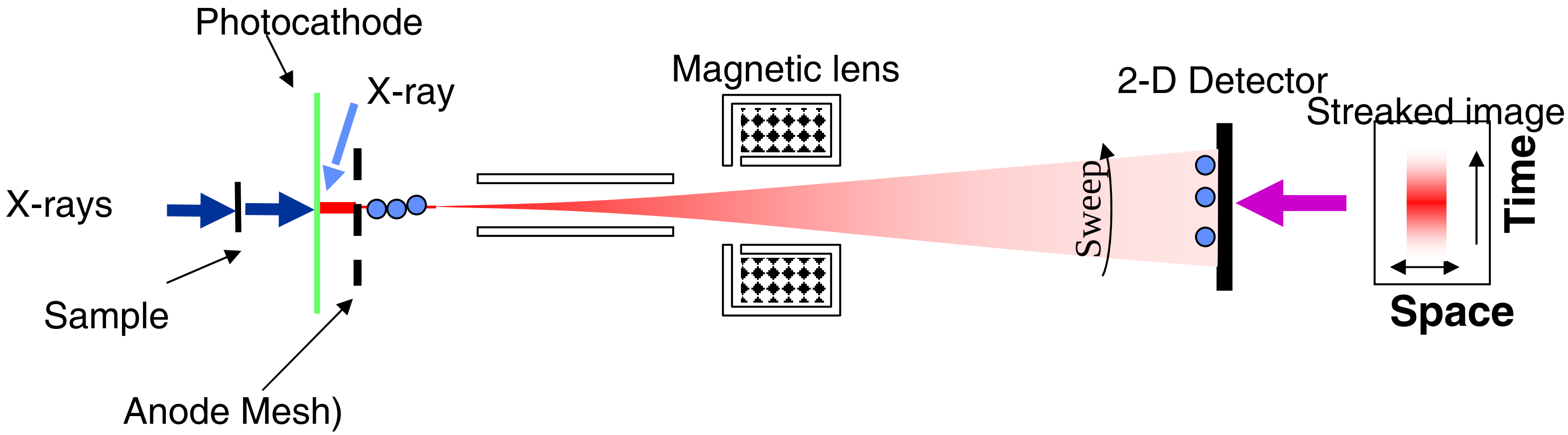
2. Ultra-fast X-ray streak camera program at the ALS

3. Magnetization dynamics application

4. Extending the performance of streak cameras to 100 fsec and beyond

5. conclusion

Introduction: Streak camera principle



Convert fast time information into space information that can be recorded on an area detector

$$\tau = \sqrt{\tau_{ph}^{2} + \tau_{sweep}^{2} + \tau_{jitter}^{2} + \tau_{sc}^{2}}$$

Introduction: X-ray streak camera features and application

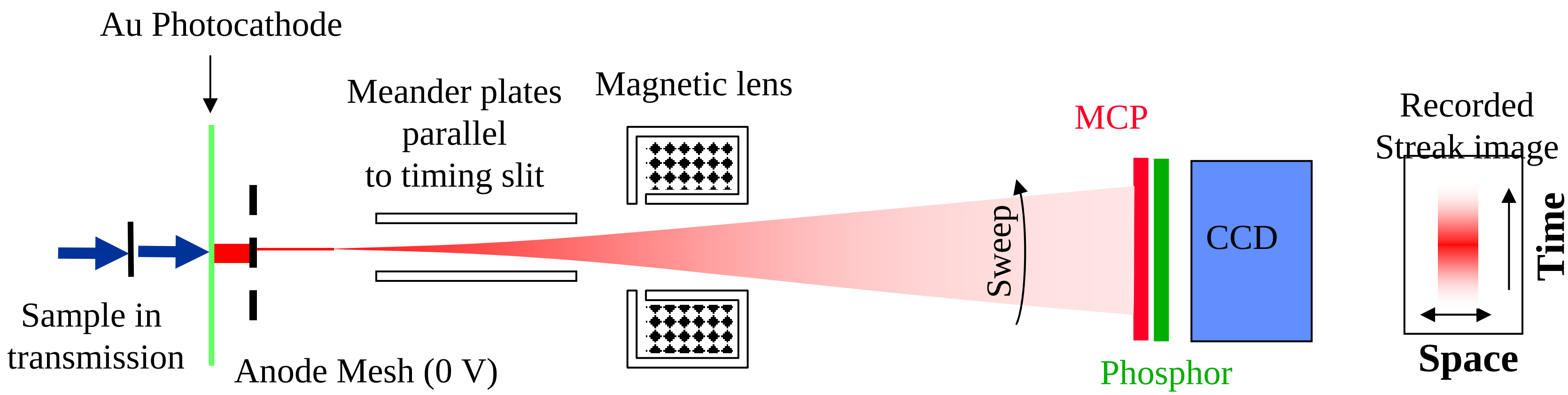
Features

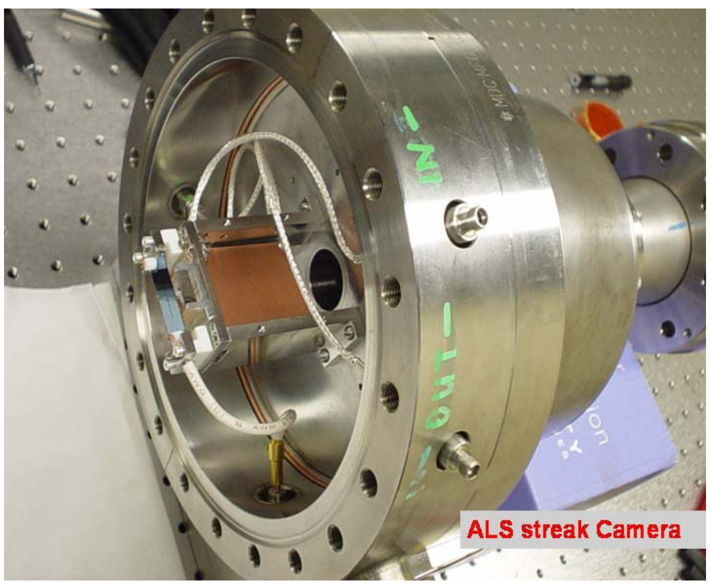
- good temporal resolution (at present psec, could be 100 fsec or better)
- records the whole temporal response (ps-ns)
- wide photon energy range 10ev to 10kev
-simple and inexpensive

Applications

- Dynamics, like ultra-fast magnetization dynamics
- Diagnostics, Sliced X-ray source, XFEL
- plasma physics
- Ultra-fast electron diffraction

ALS x-ray streak camera





Photoconductive GaAs switch for triggering

ALS streak camera program

Development area

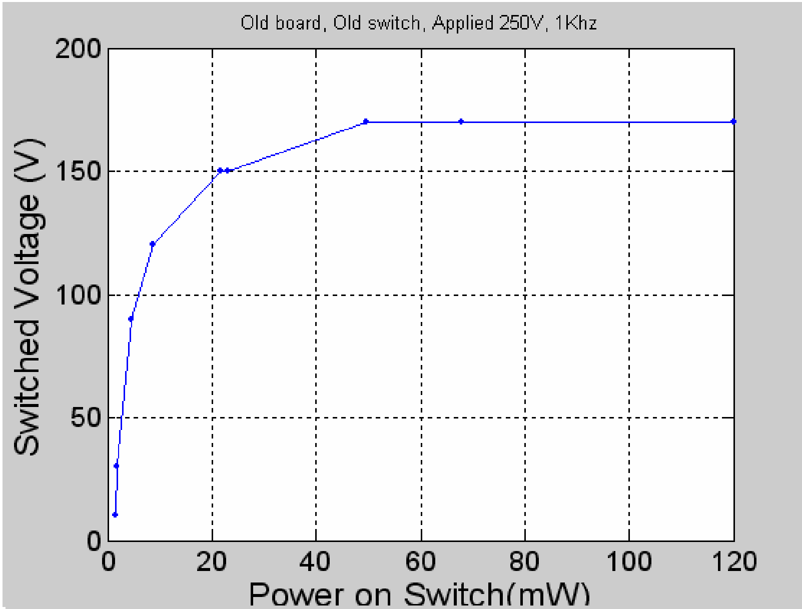
- Photocathode: Increasing photocathode efficiency, reducing radiation damage

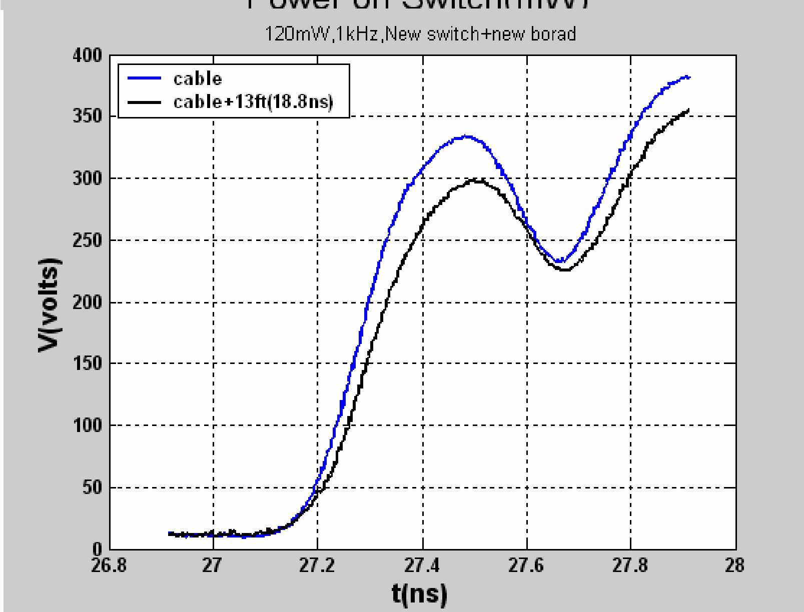
- Photo-conductive switch: efficiency, fast rise-time, Reduction of jitter

- Electron optics: reduction of aberration, compensation of chromatic aberration

- Modeling of Meander-plate: increase sweep speed

ALS-made PC switch : saturation range





- semi-insulating GaAs

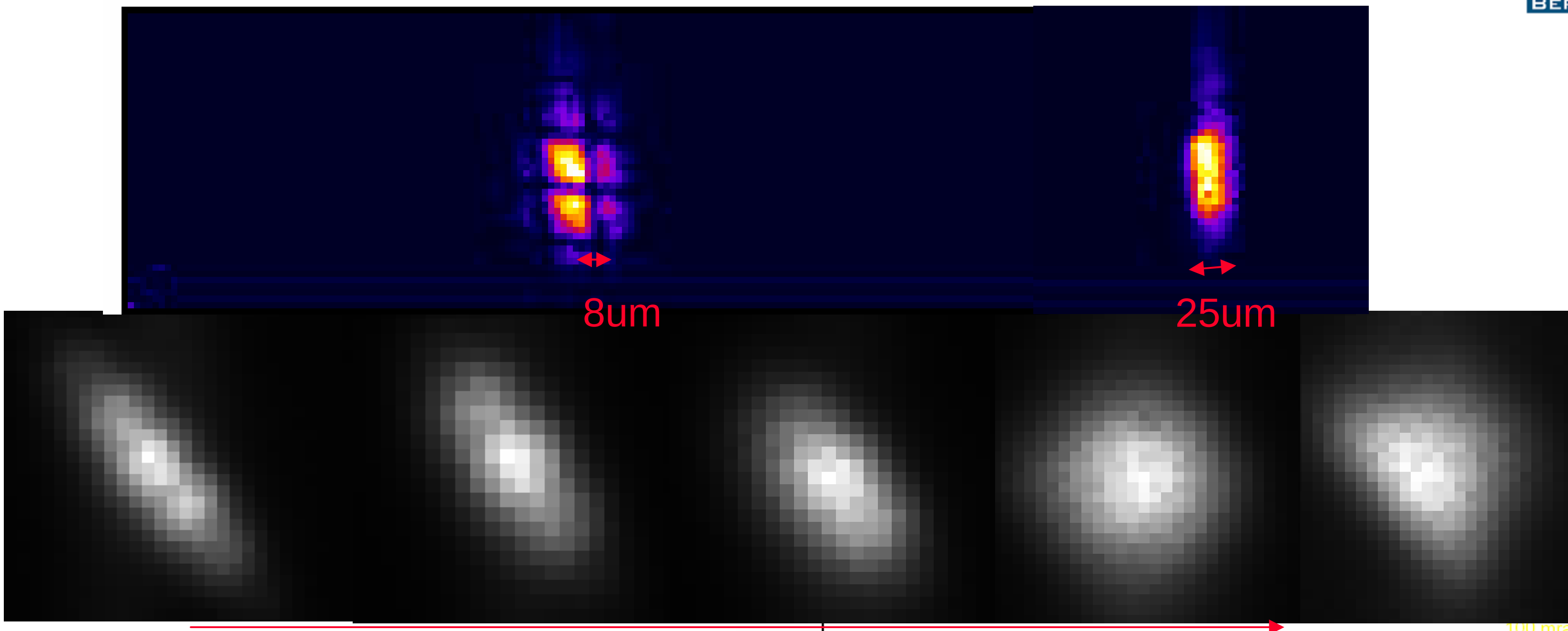
  - fabricated in-house

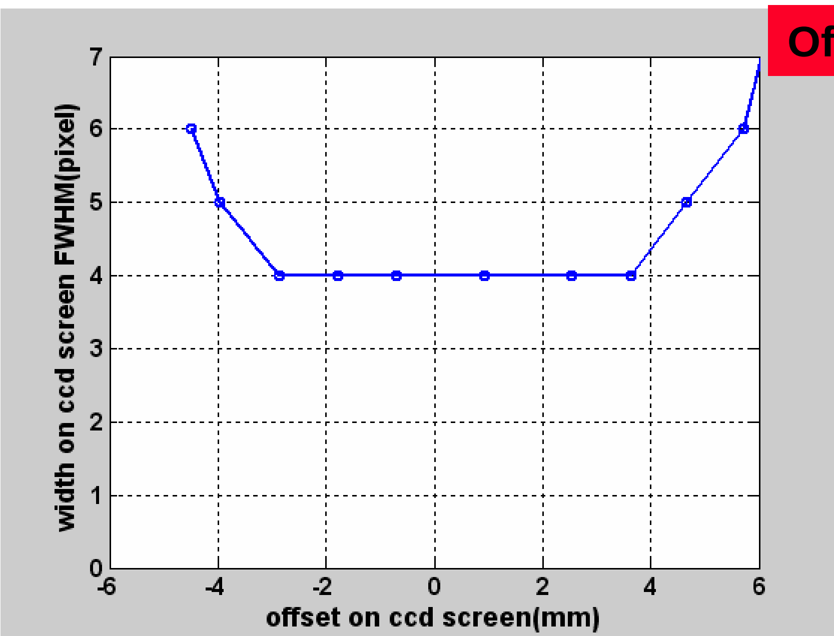
- Reliable 1kHz, 5 KHz operation at 500V

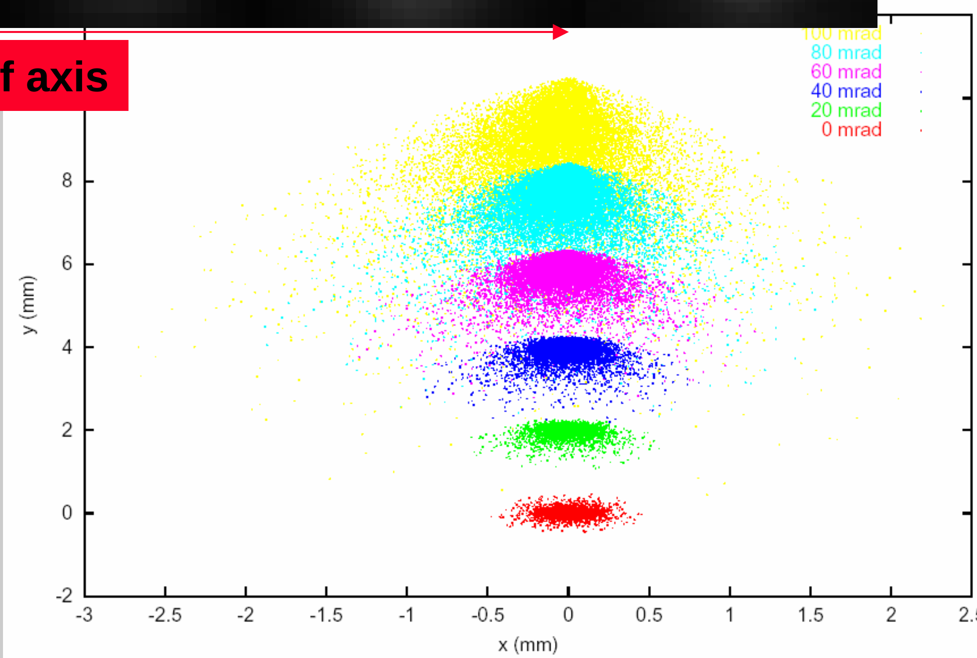
-10-90% ramp ~180 psec determined by the time window of ALS ring (~100ps)

- Switched efficiency ~90%

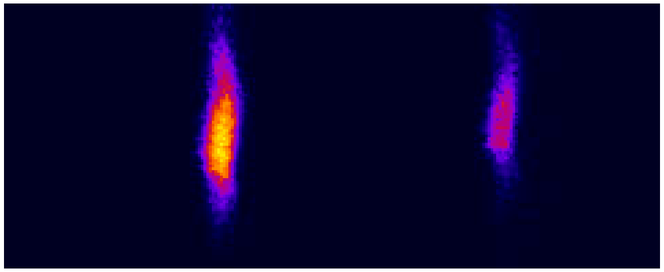
Static mode: image quality



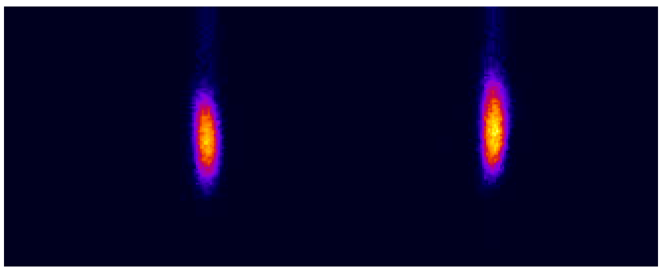




Dynamic mode: UV imaging v. Energy

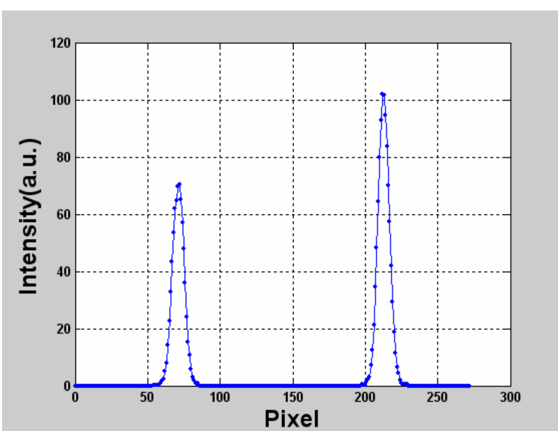


7.5keV, sep: 103px, FWHM:8-9px, 1k shot,1000fs



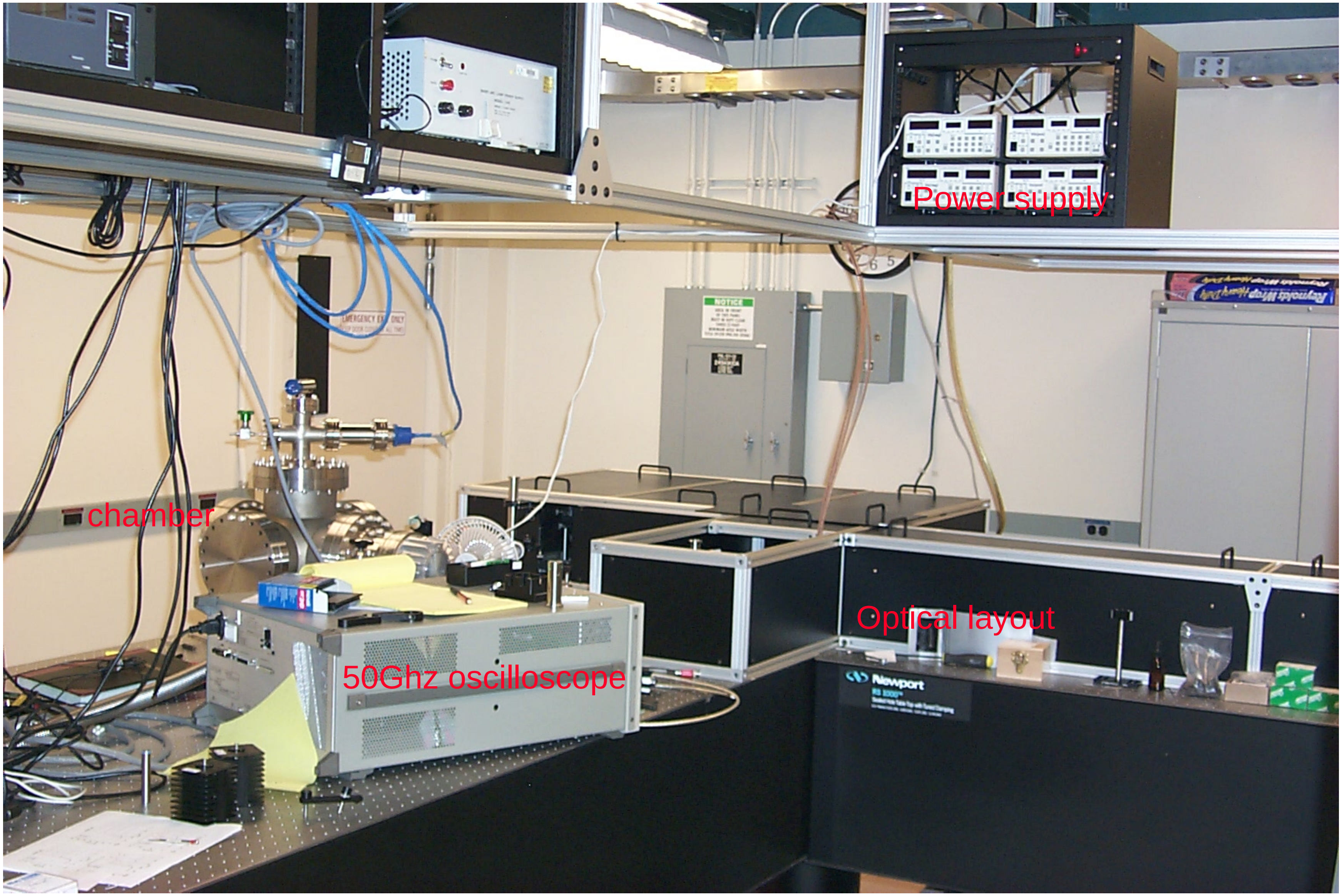
10keV, sep: 144px, FWHM:9px, 1k shots, 800fs

Sweep speed: 90fs/px



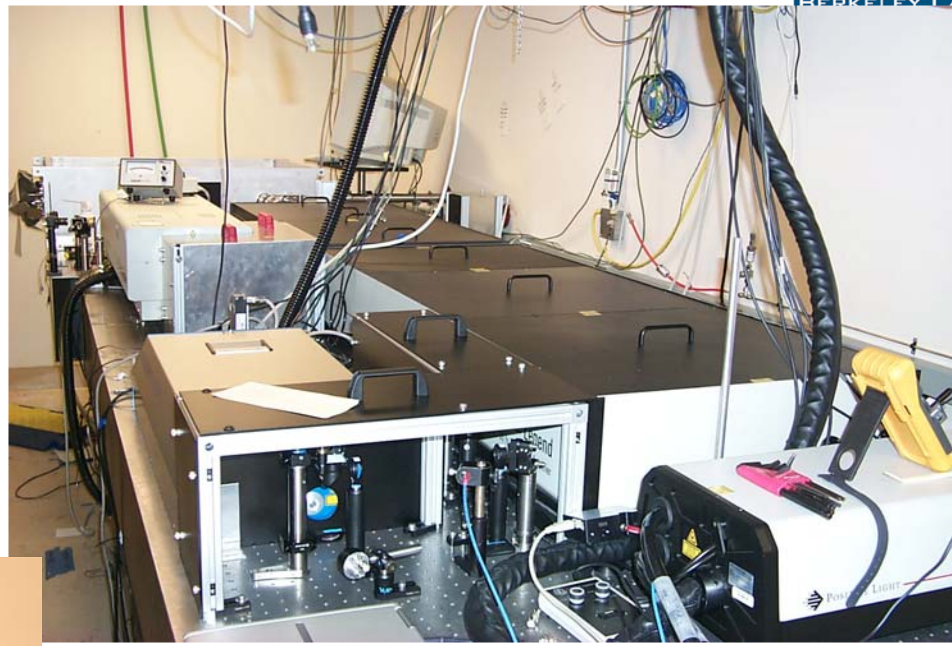
- excellent single shot resolution: 600fs
- photoconductive switch jitter reduction
  - double switch, J.Kineffer, jitter-free
  - Liu, 30fs jitter
  - fast readout CCD

ALS Streak camera R&D lab



Ti: Sapphire Lasers: 1 beamline and 1 lab system

Femto-laser Oscillator
Positive Light Legend Laser:
30 fsec, 1 mJ / pulse, 1 KHz



KMlab 62.5 MHz oscillator
Positive Light Legend Laser:
30 fsec, 0.6 mJ / pulse, 5 KHz

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Motivation

What is the speed limit of magnetic recording?

State-of-art storage: long range interaction, low density, ns switching

future storage: local interaction, high density, ps switching

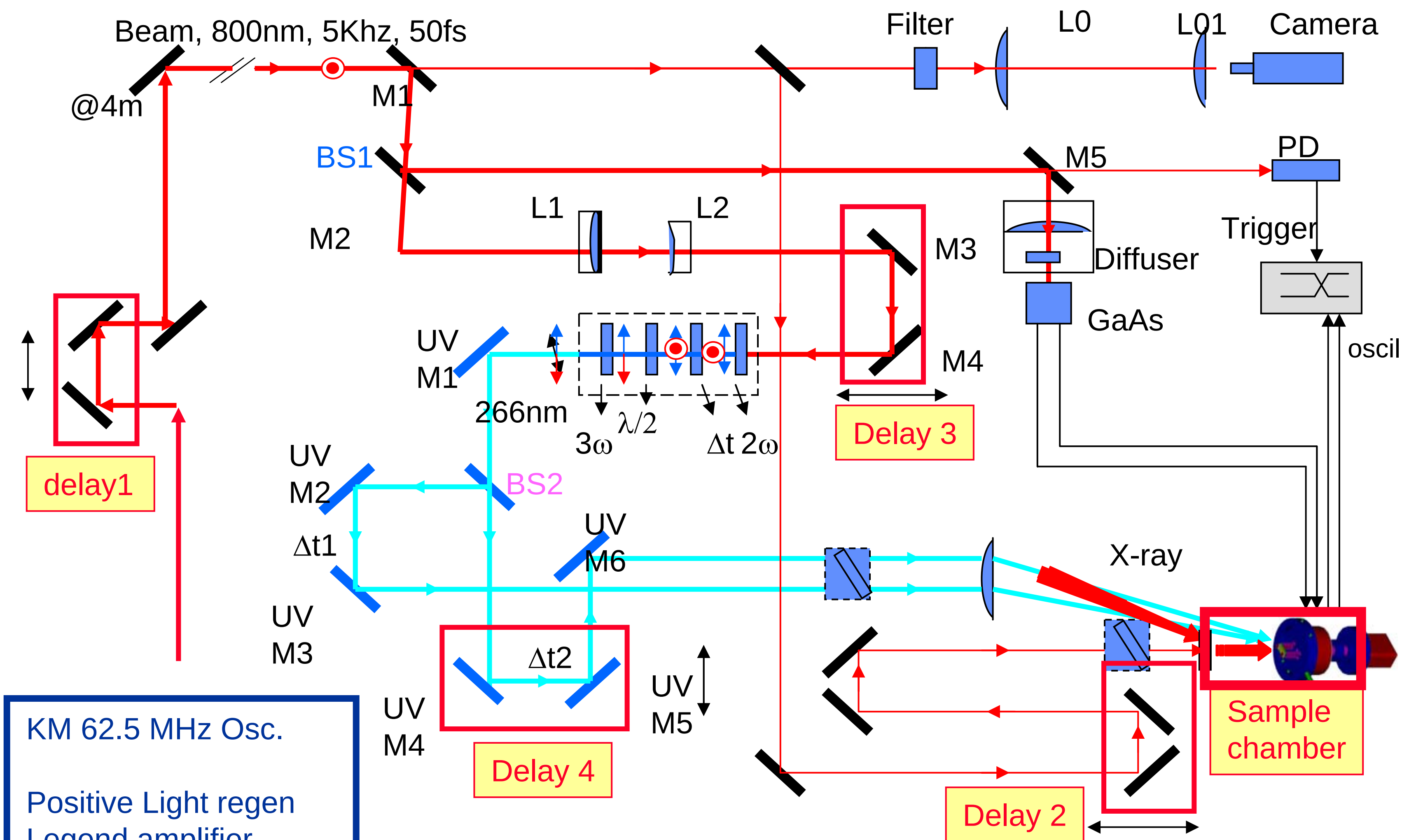
Is the early optical experiment accurate ?

TR-Kerr measurements show different results

How does energy flow in a magnetic system when changing the magnetization?

- electron, spin, lattice, spin-orbit coupling

Laser System Setup

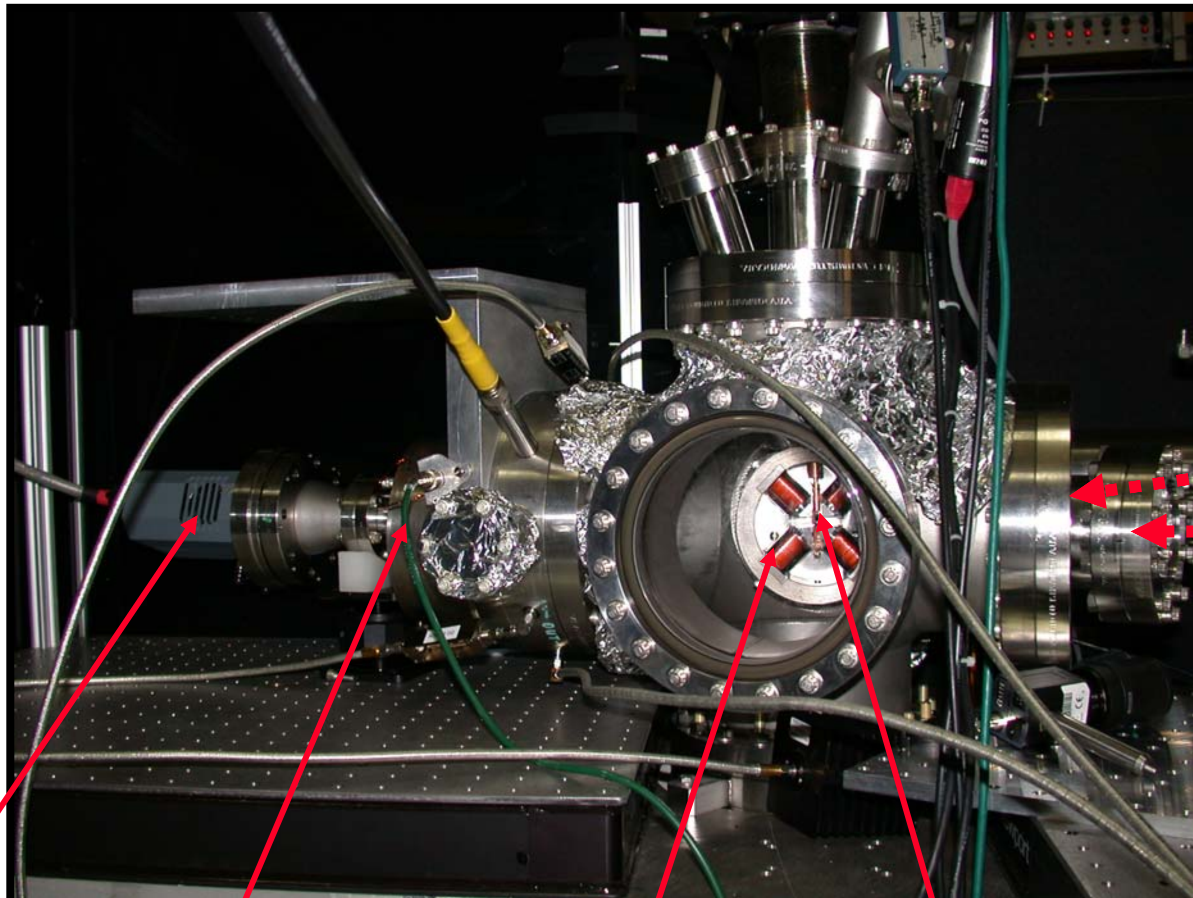


KM 62.5 MHz Osc.

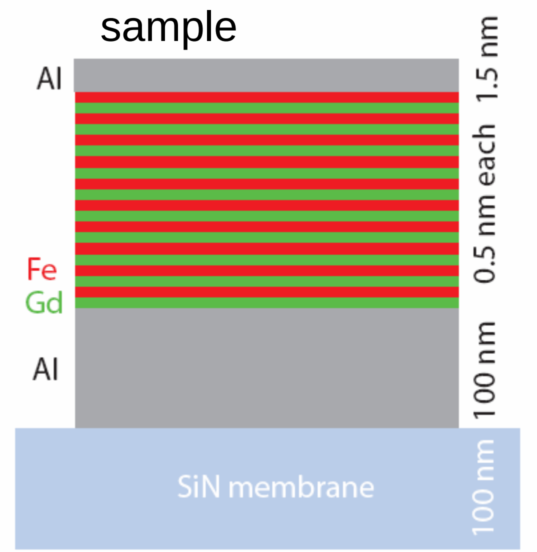
Positive Light regen
Legend amplifier
0.6 mJ, 5 kHz, 50 fsec

4 beams with 4 delays (0.6 mJ total)
- **IR pump beam**
- **IR to streak camera PC switch trigger**
- **uv for temporal fiducial to photocathode**
- **uv for timescale calibration to photocathode**

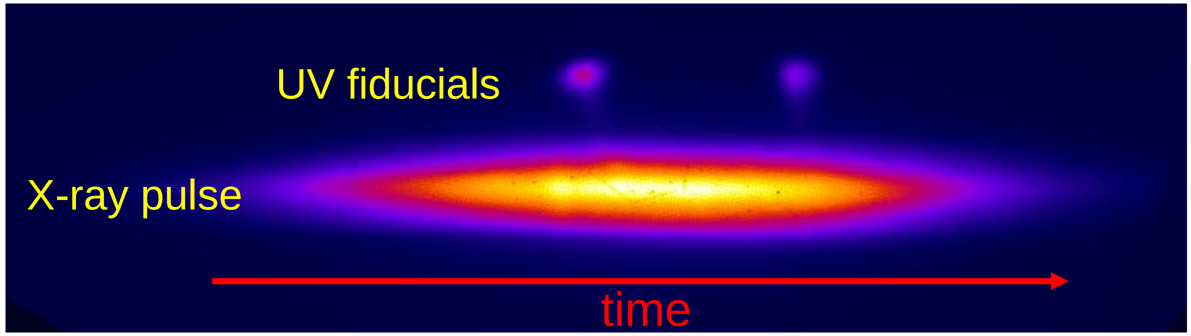
Streak camera on ALS EPU BL 4



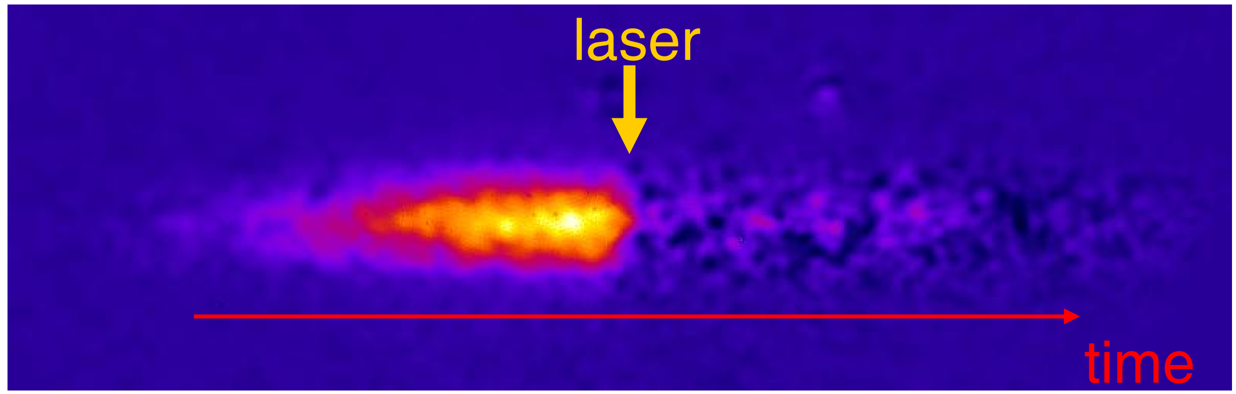
It works: demagnetization happens within picoseconds



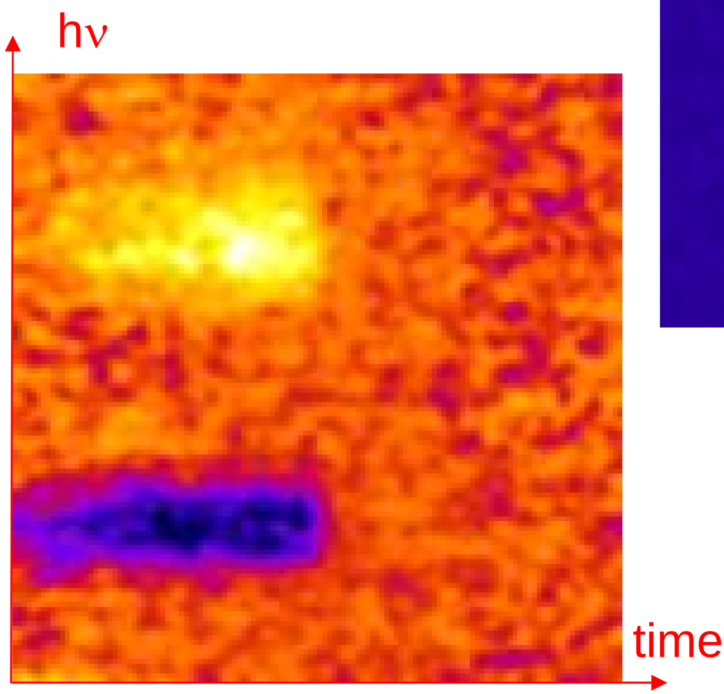
Streaked x-ray pulse and UV fiducials



XMCD streak at "time zero"



Full demagnetization **is observed**



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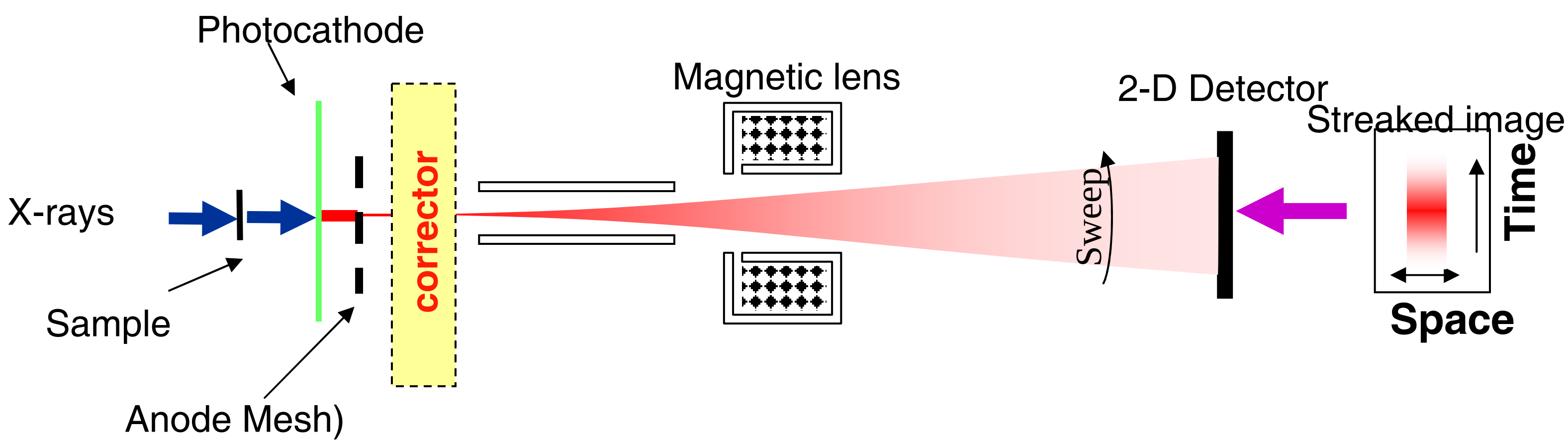
Corrector needed



- Photocathode has negative time dispersion Dt/DE=-k
  - ie. low energy electrons take the longest time

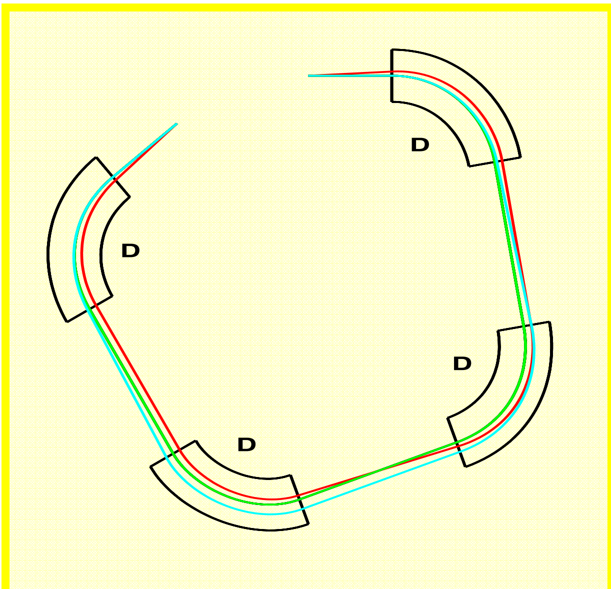
- fundamental resolution limit set by energy spread from photocathode

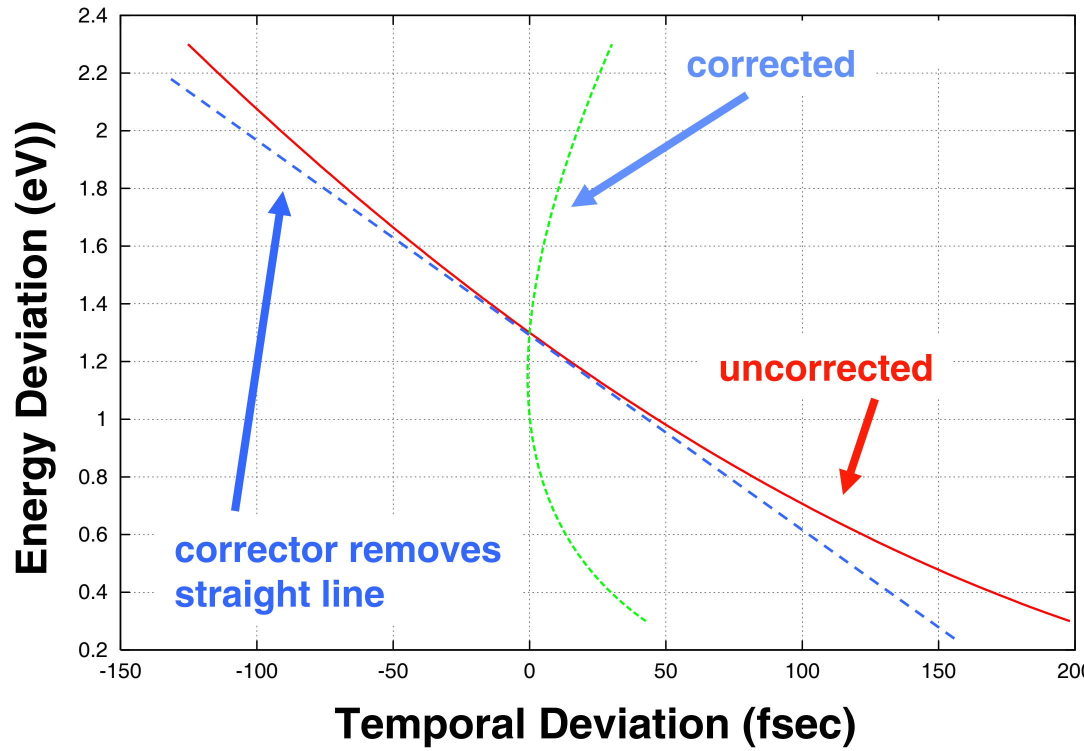
Au,Wf=4.6ev, FWHM=3.8ev, 10kV/mm field, ~500fs

CsI Wf=1.9ev, FWHM=1.5ev, 10kV/mm field, ~350fs

- need an additional element to produce positive energy dependent time of flight
- corrector gives positive energy dependent time of flight dispersion
  - low energy electrons take the shortest path and therefore take the shortest time

Chromatic time of flight correction in a streak camera



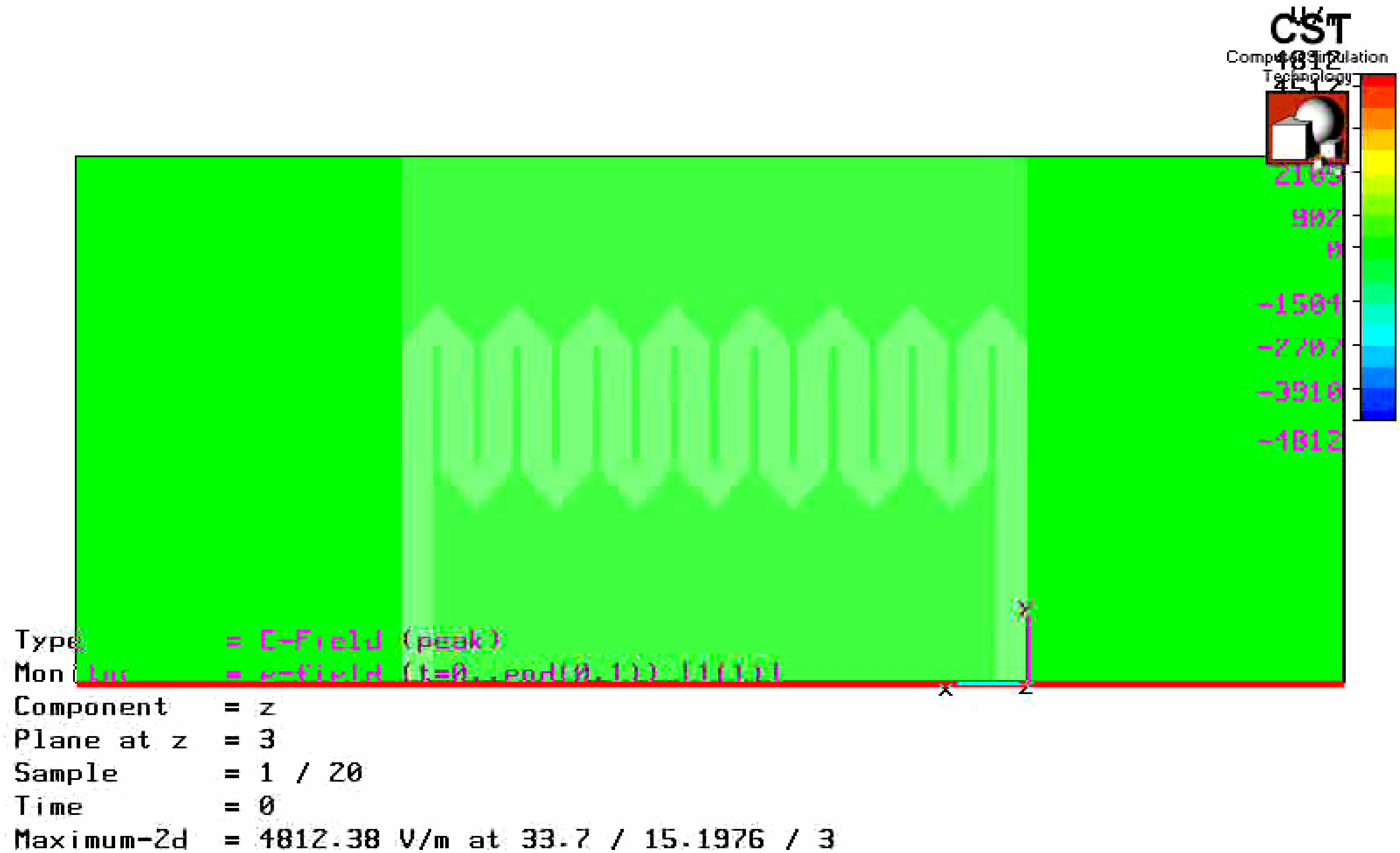


- 4 dipoles can be arranged to be double focusing, achromatic, zero angular time of flight dispersion and with defined dT/dE for correction

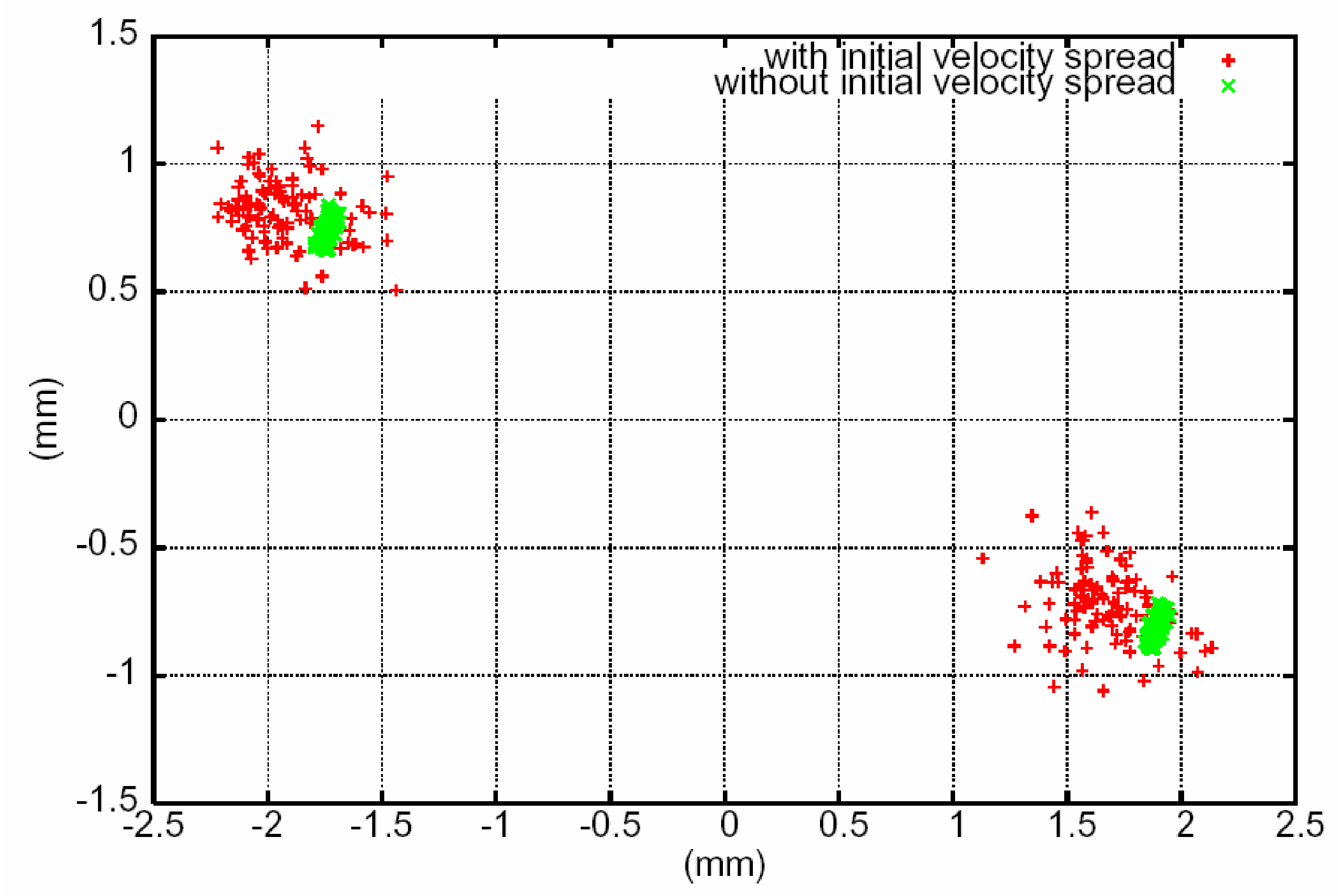
- < 50 fsec resolution from initial simulation!

Time-dependent 3D field in meander plate

BERKELEY LAB



End-to-end modeling



Using 3D time – varying field, end to end modeling is developed, full simulation can be done

Conclusion

• sub-psec 5 KHz streak camera has been developed at ALS

• psec magnetization dynamics program underway at ALS

• 50 fsec resolution appears possible using dispersion compensation

Acknowledgement

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