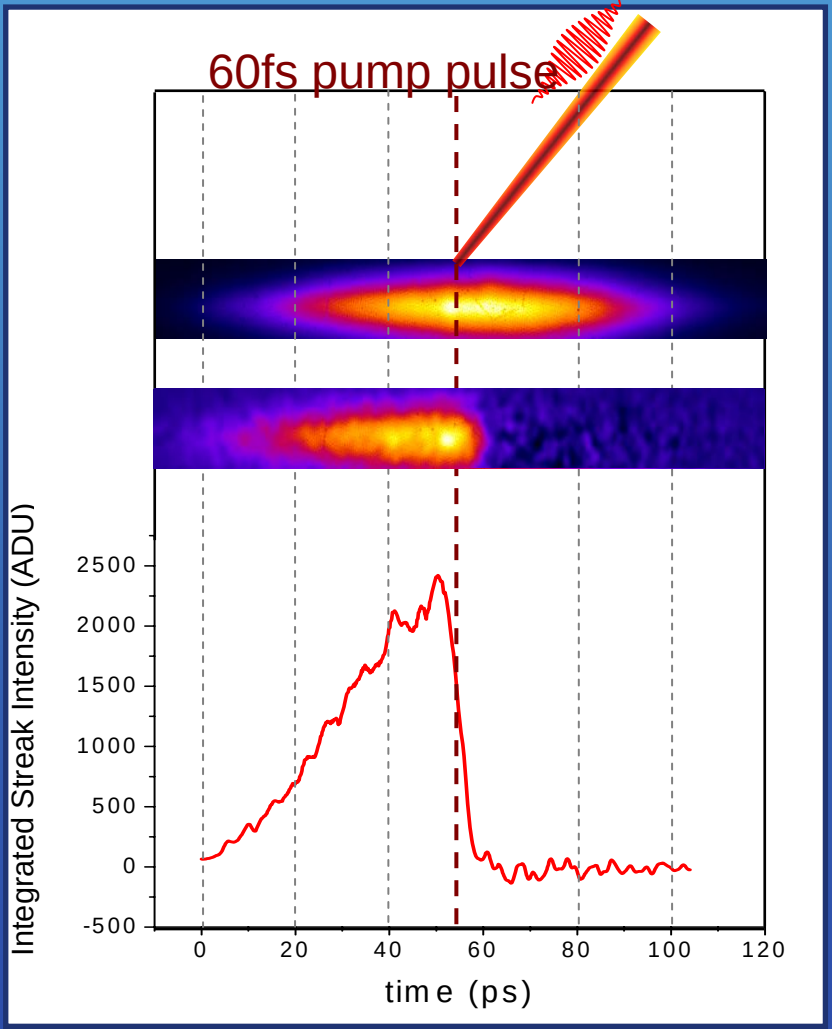
Ultrafast X-ray Streak Camera at the Advanced Light Source

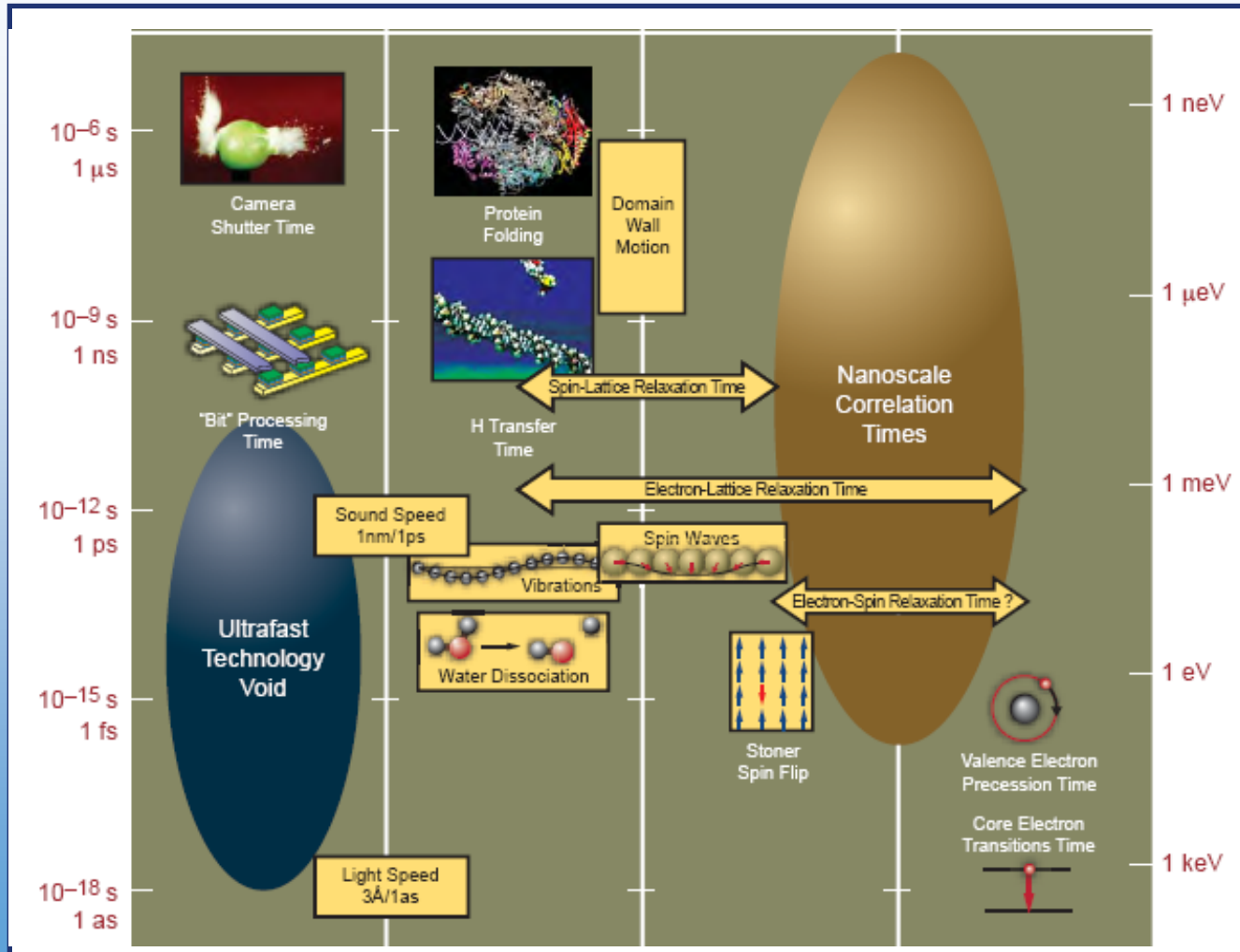


TR_XMCD for Fe L3 edge measured by streak camera

- Introduction and Motivation
- ALS Streak Camera R&D laboratory
- Applications
- Publications
- Future plan
- People and contact information

Introduction and Motivation

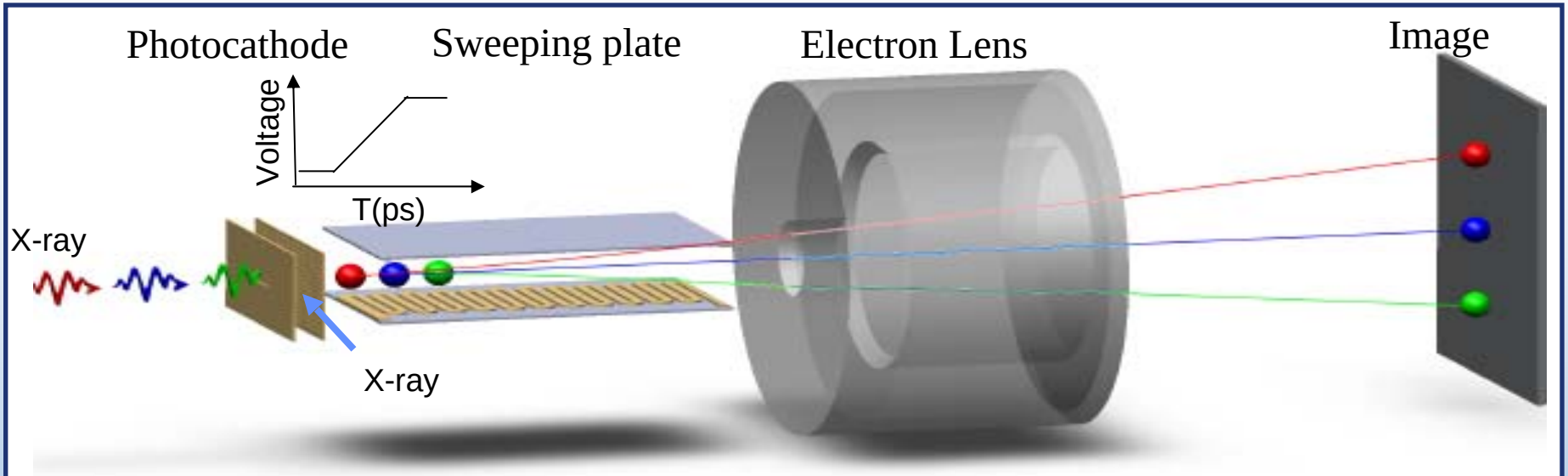
Front field: study the ultra small and ultra fast worlds



A white paper: Science and tech for future light source

ANL, BNL, LBNL,SLAC Dec.2008

Ultrafast X-ray detector: Streak camera

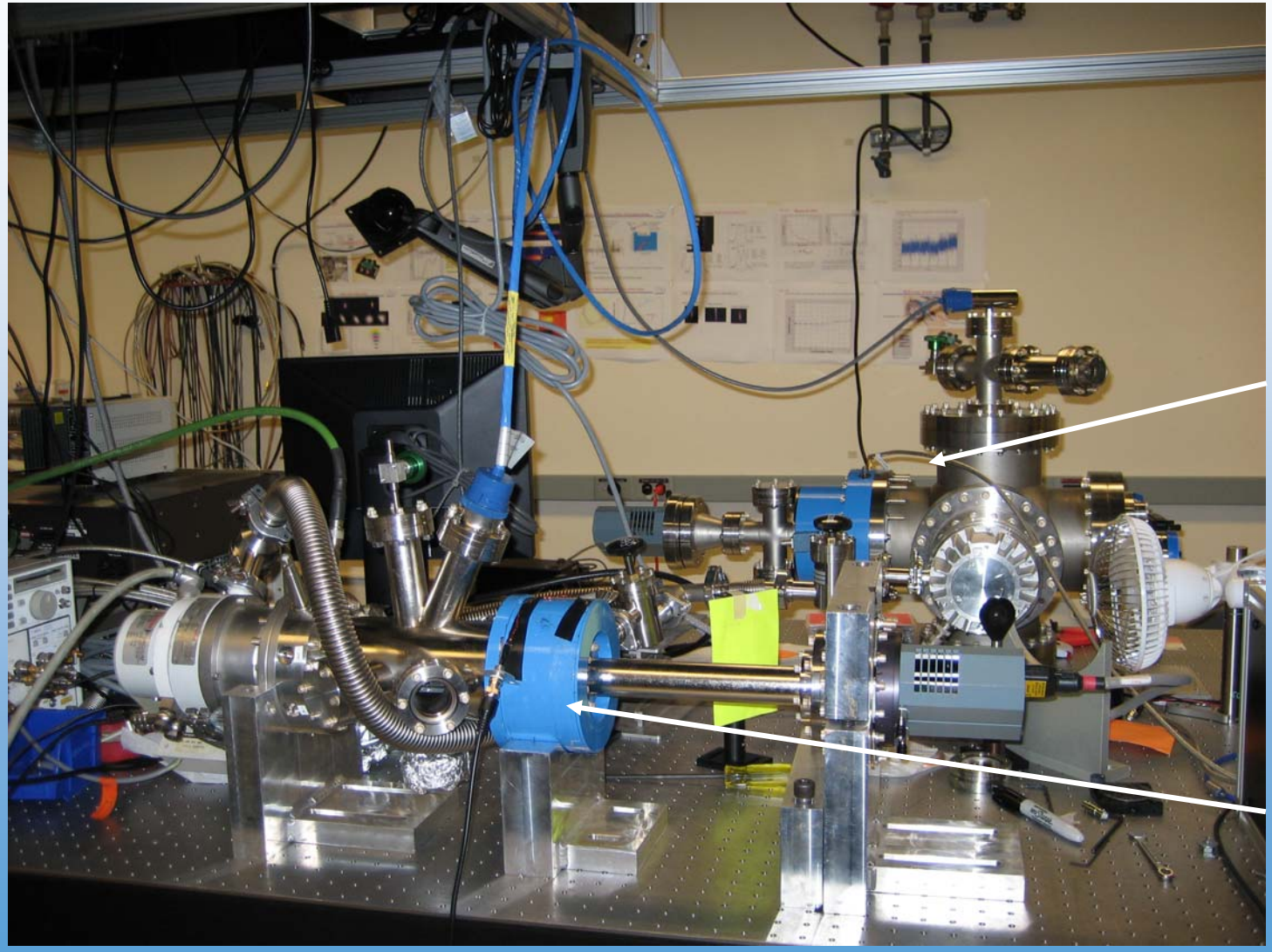


Convert fast time information into space information that can be recorded on an area detector

Features:

- good temporal resolution (230fs with UV achieved)
- records the whole temporal response (fs-ps)
- wide photon energy range 10ev to 10kev
- record the temporal and spectrum simultaneously
- small and compactable

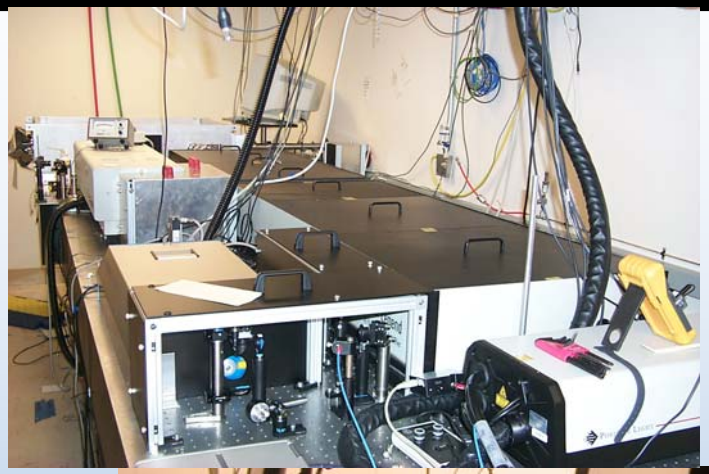
ALS ultrafast streak camera R&D lab

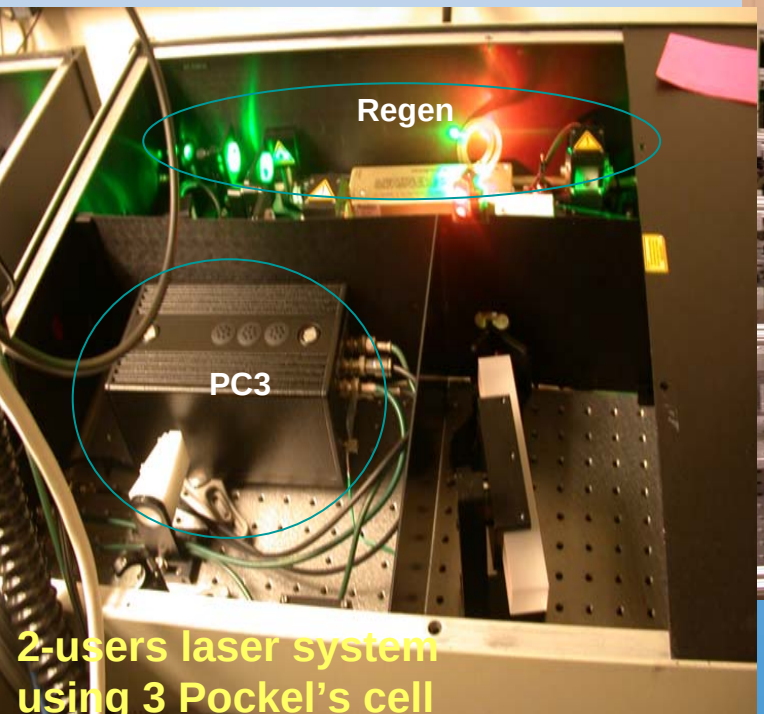


ALS ultrafast streak camera R&D lab: Ti:sapphire fs laser systems

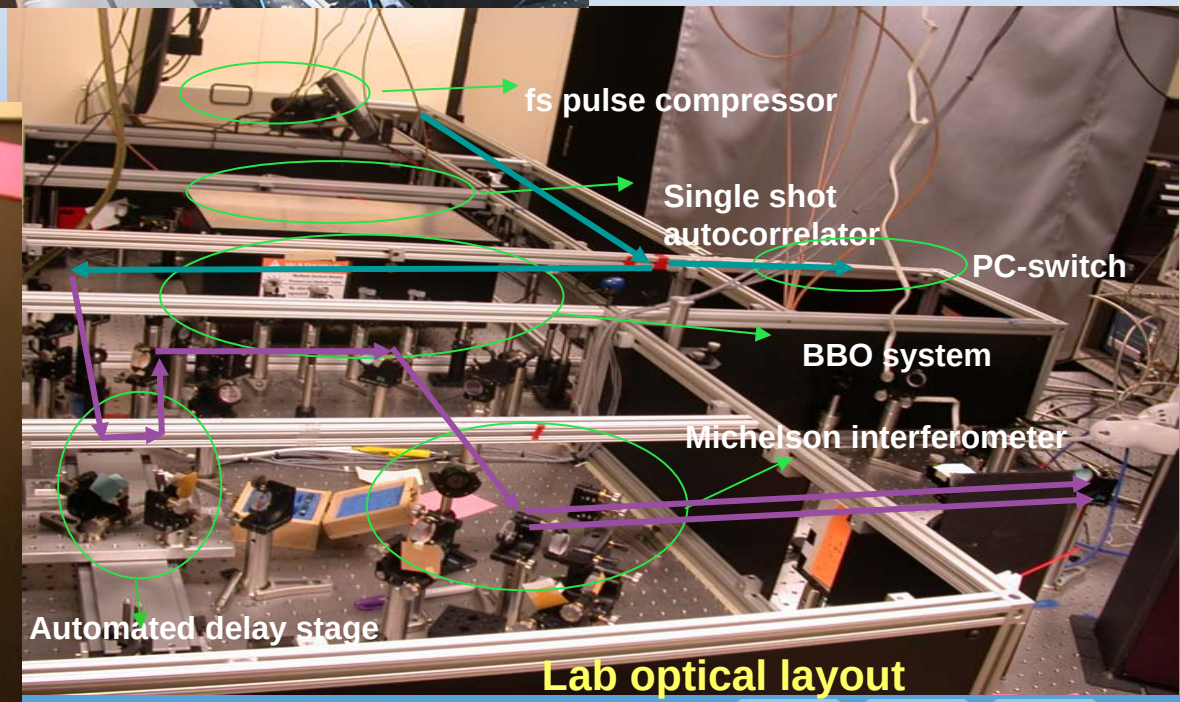
oscillators:
Femto-laser Oscillator
KMlab 62.5Mhz Oscillator

Positive Light Legend Lasers:
30 fsec, 1 mJ / pulse, 1 KHz
30fsec, 0.6mj/pulse, 5kHz





2-users laser system using 3 Pockel's cell



Lab optical layout

ALS streak camera project

Transmission streak camera:

- Providing ultrafast magnetic dynamics study
- improving temporal resolution

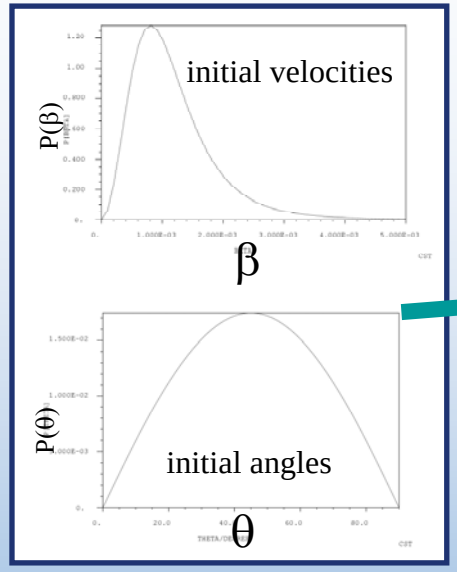
Reflection streak camera:

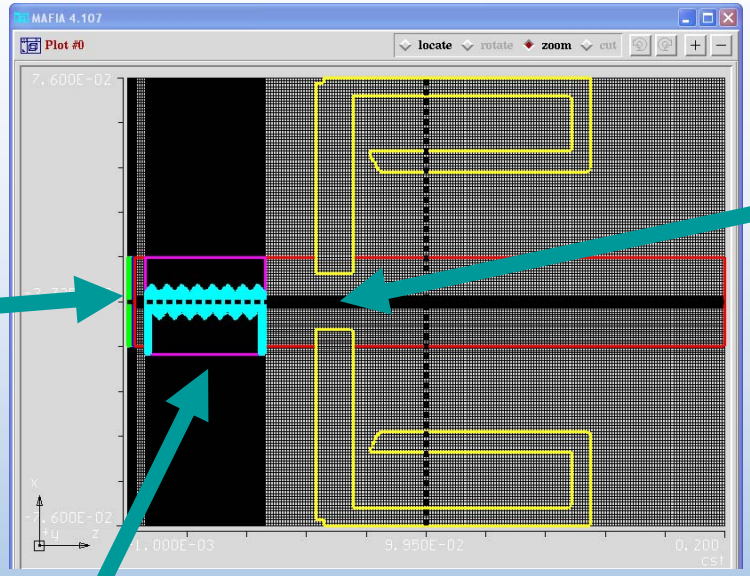
- Slicing diagnostic and related experiment

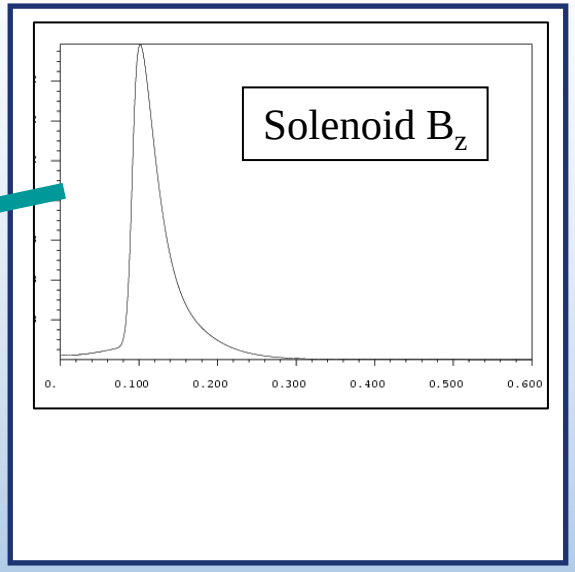
Dual-sweep streak camera

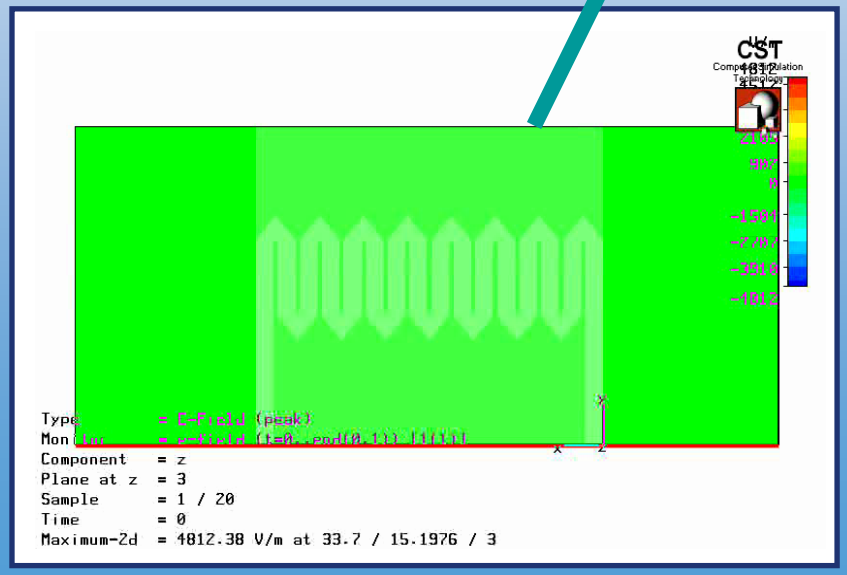
- Photocathode: Radiation-hard, alignment, high voltage, 25μm,10μm
- Photo-conductive switch: fabrication technique, mounting mechanism, fast rise-time,
- Electron optics: large FOV, reducing fringe field
- Meander-plate: increase sweep speed, dv/dt, deflection aberration
- Start-to-end modeling

3D field modeling: start-to-end





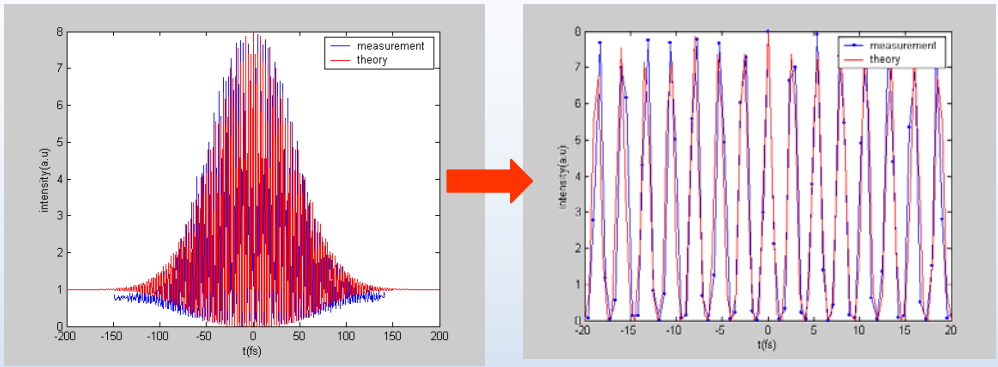




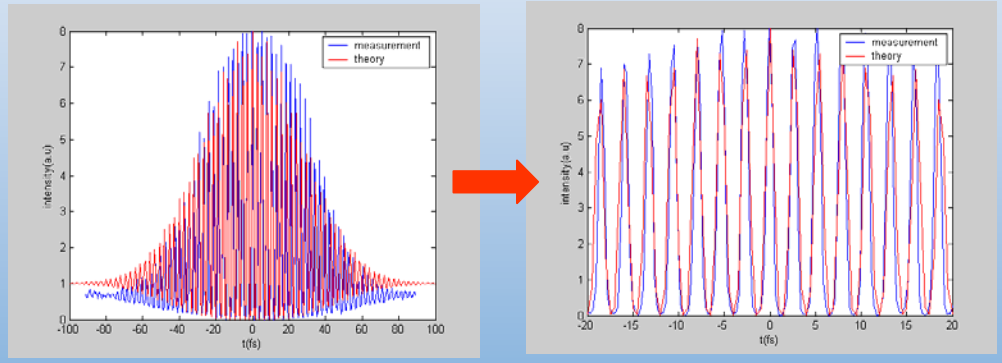
Developed in MAFIA environment

- Photocathode-anode
  - –User-defined initial SE distribution
  - –Velocity dispersion
  - –PIC space charge
- Deflector
  - –Full 3D time-dependent EM field representation
  - –User-defined input pulse
- Focussing system
  - –3D field map for magnetic or electric focussing
  - –Lens aberrations included

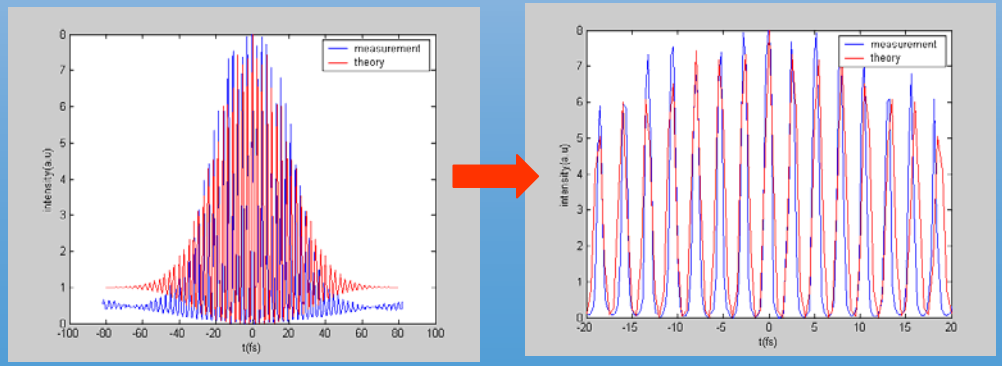
Pulse measurement by home-made Michelson interferometer



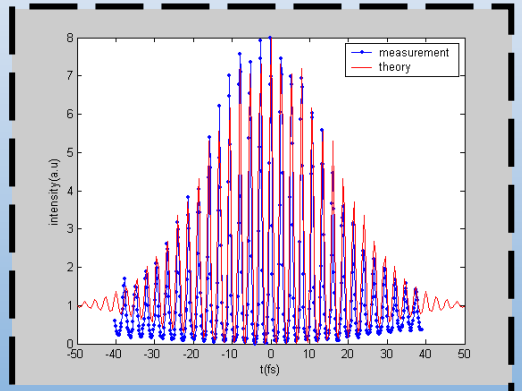
Gaussian: **94fs** in FWHM



Gaussian: **60fs** in FWHM



Gaussian: **42.3fs** in FWHM



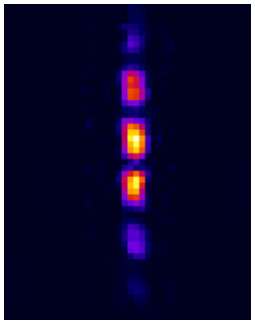
Gaussian: **35fs** in FWHM

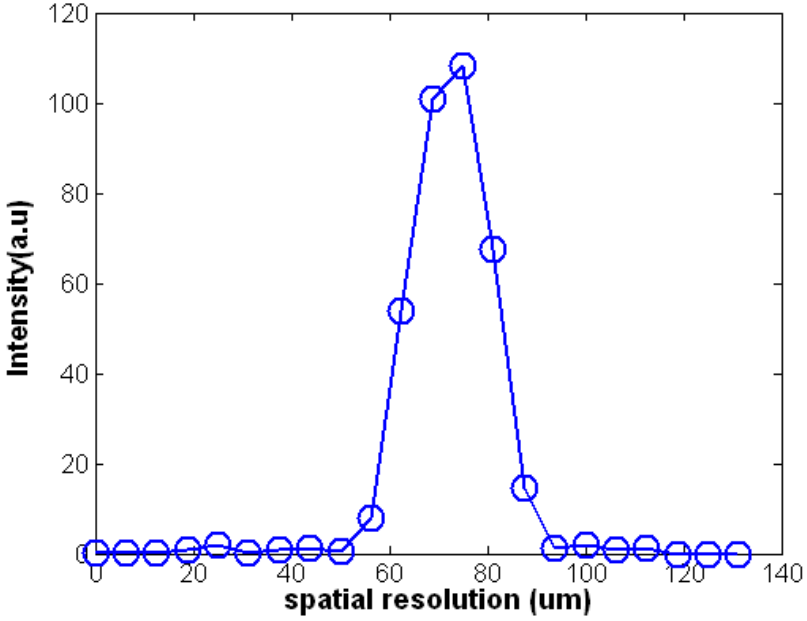
Static mode: basic performance

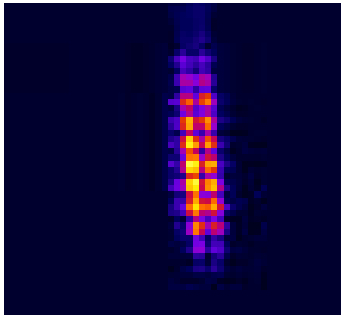
25um Au Cathode

12kev,mesh750lpl

Peroid:25um+8um

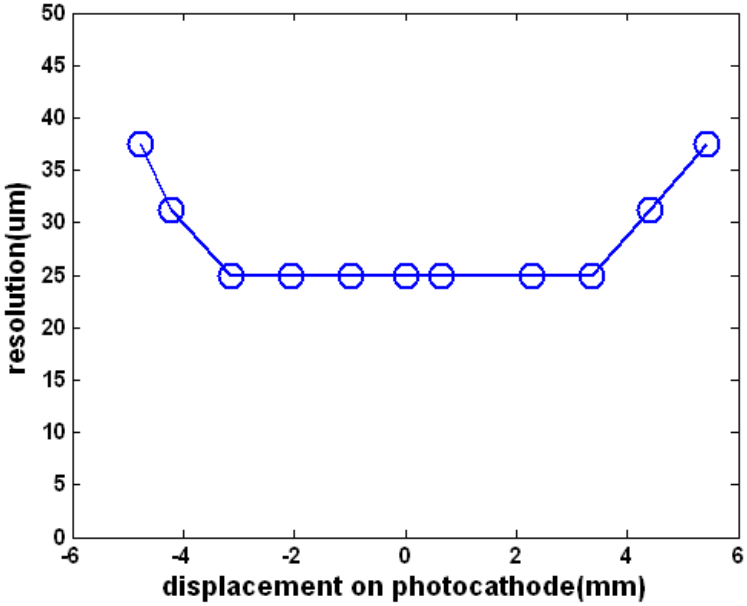




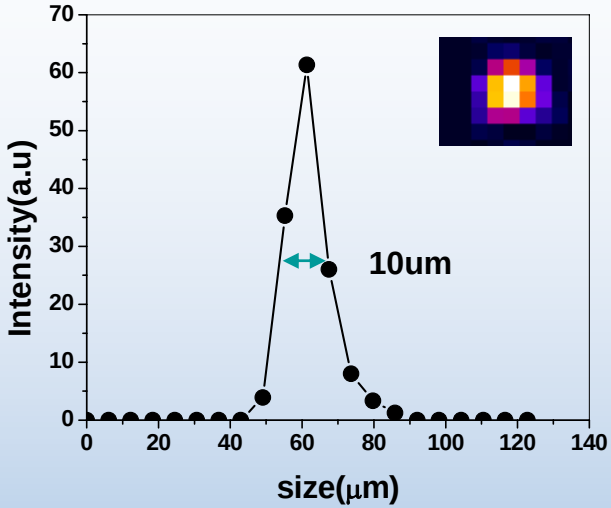


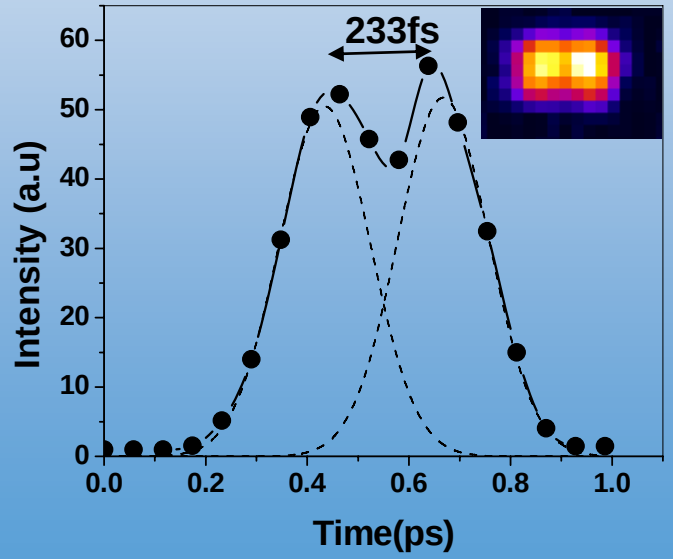
12kev,mesh1500lpl

11um+5.6um



Ultra-fast x-ray streak camera





Streak camera in transmission geometry

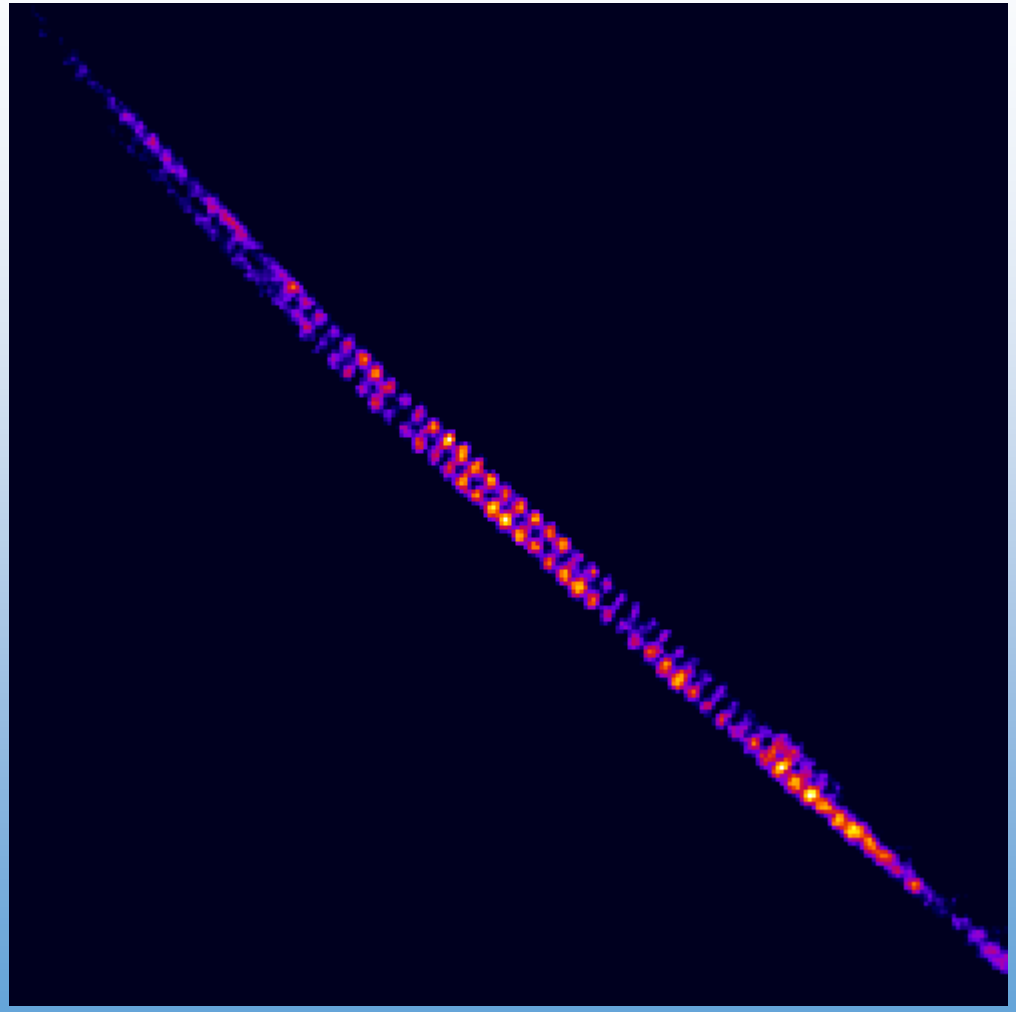
Fast temporal resolution

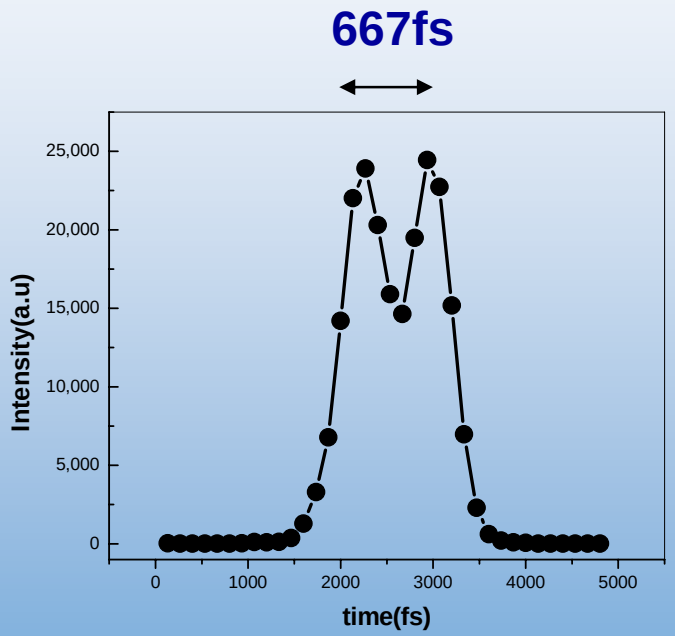
High spatial resolution

large linear range

Jun Feng, et al App.Phys.Lett., 91(2007)134102

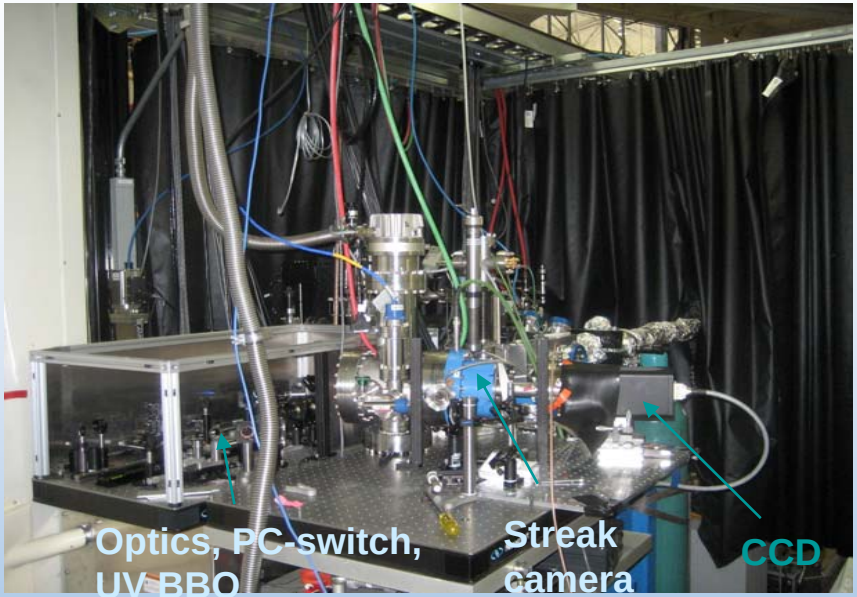
Reflection streak camera with 100um x 6mm slit

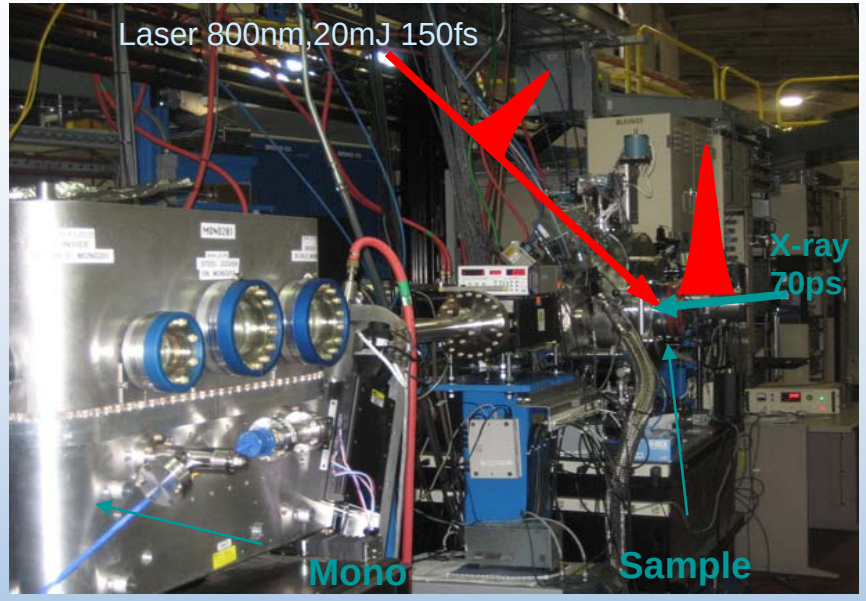


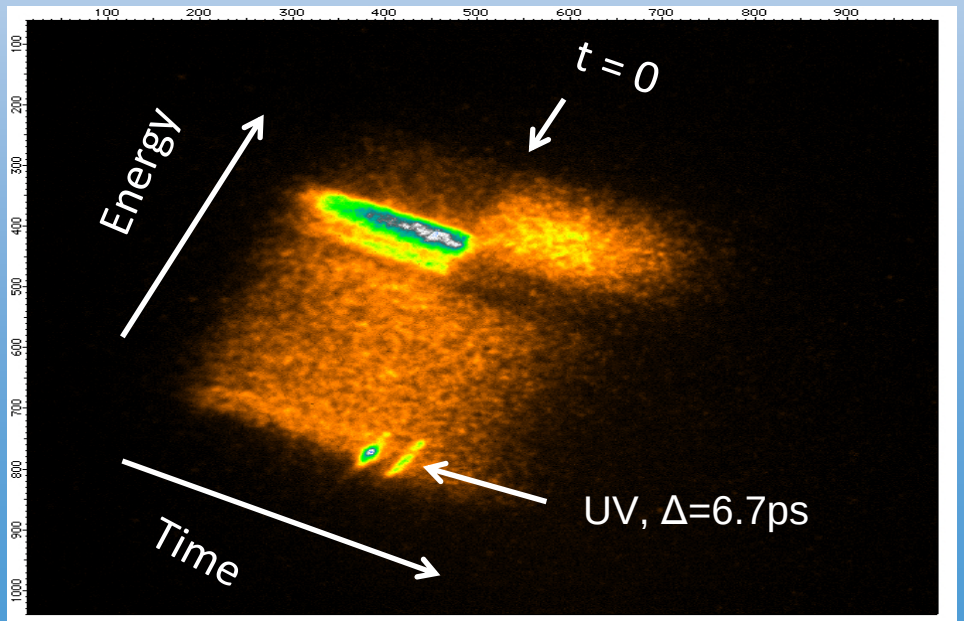


Two UV pulses separated by 0.1mm

Streak camera application at BL6.0.2: WDM study



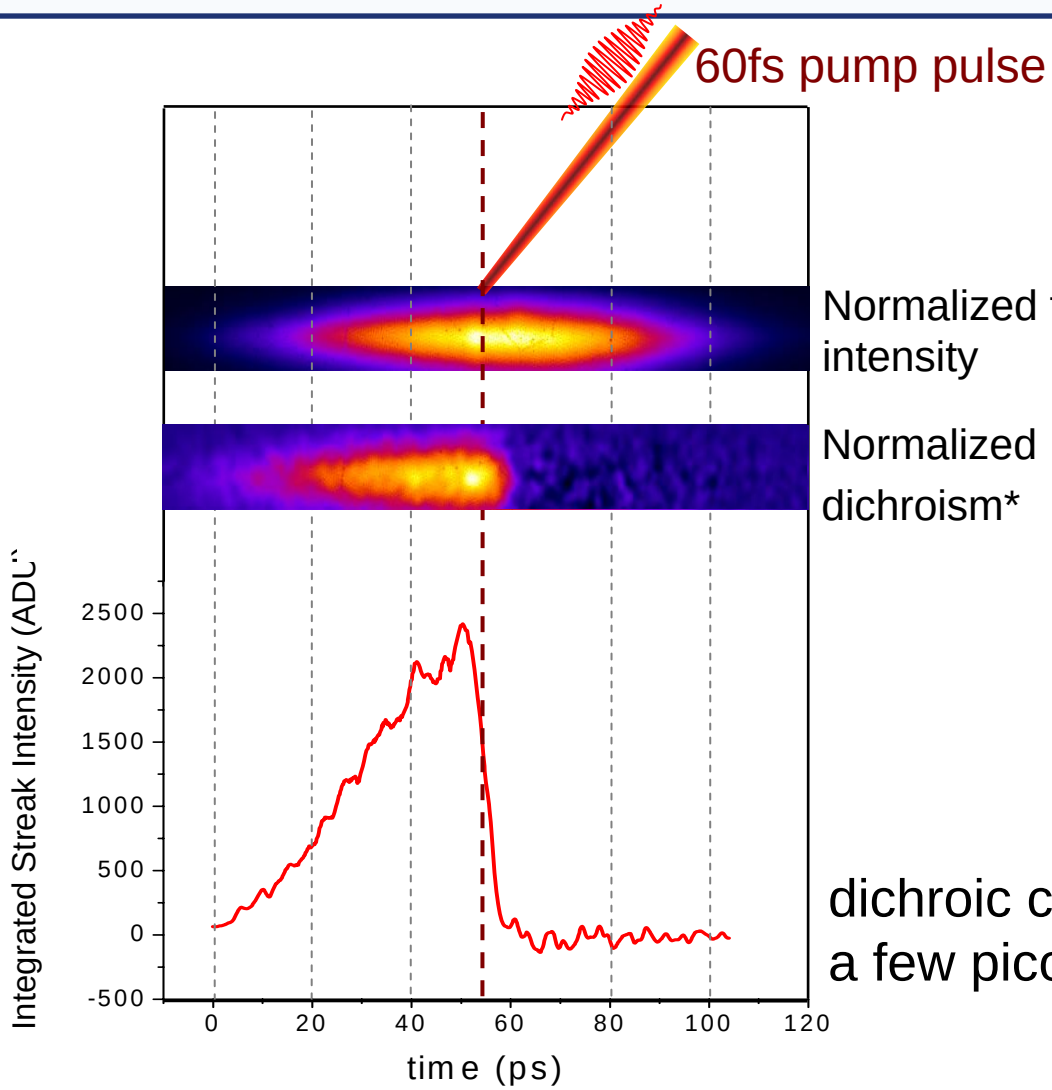


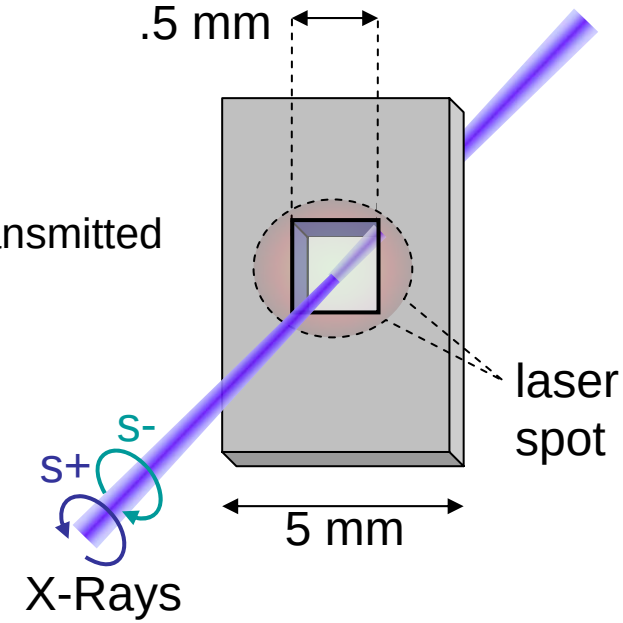


A-C samle melted by laser and phase change measured by streak camera

Single shot data

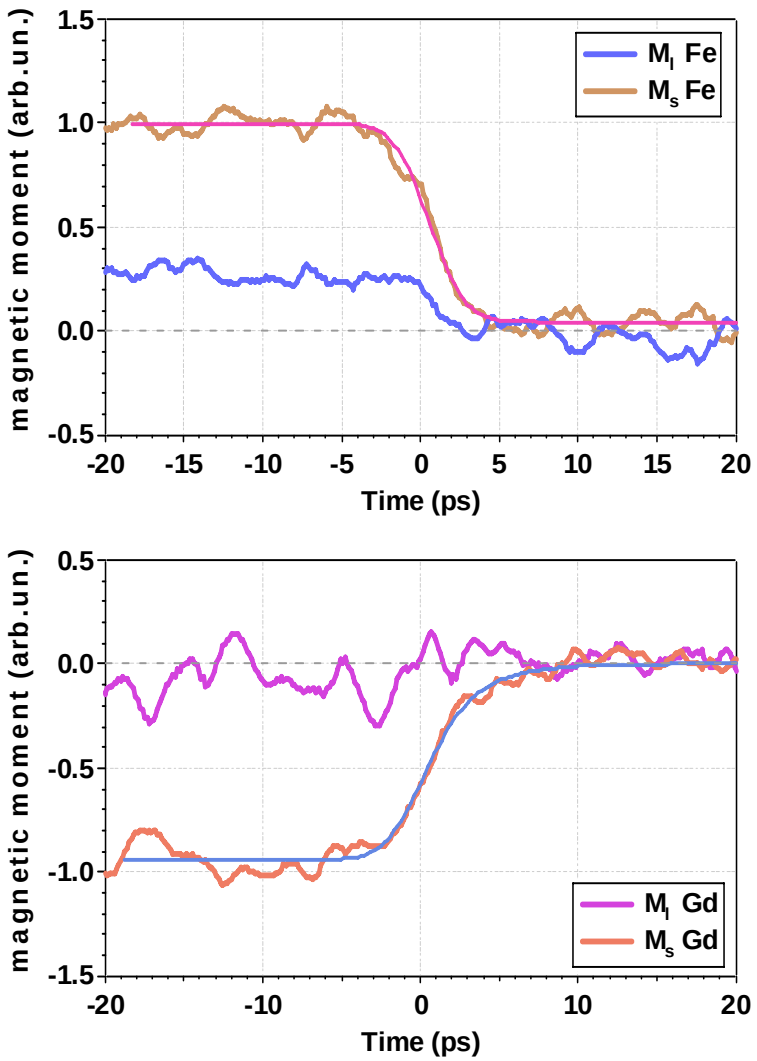
Streak camera application at BL11.0.2: ultrafast magnetism dynamics study





dichroic contrast is lost in a few pico-seconds

Streak camera application at BL11.0.2: ultrafast magnetism dynamics study



Simplified Sum Rules:

$m_s(Fe) \sim 3/2\ (L_3\text{-}2L_2)$

$m_l(Fe) \sim 2\ (L_3+L_2)$

$m_s(Gd) \sim 3/2\ (M_5\ \text{-}3/2\ M_4)$

$m_l(Gd) \sim 3\ (M_5+M_4)$

Gd orbital moment vanishes for all delay

no transient increase of orbital momentum

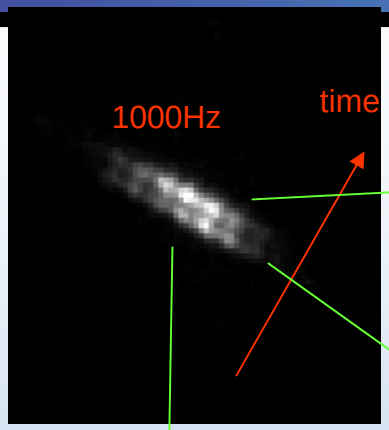
After Deconvolution:

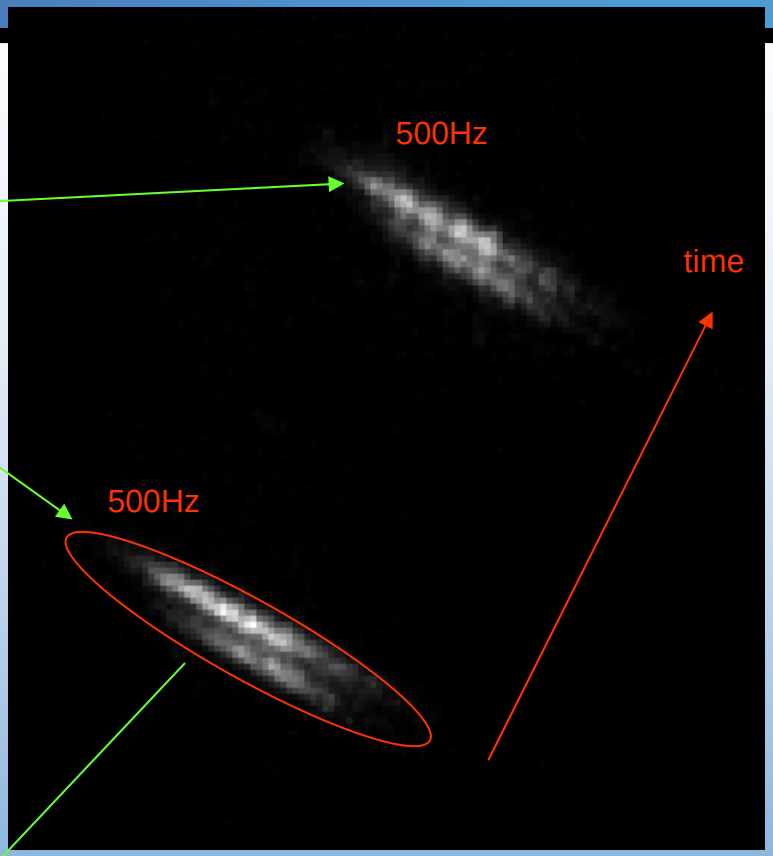
Fe: $\tau = 1.1 \pm 0.7$ ps

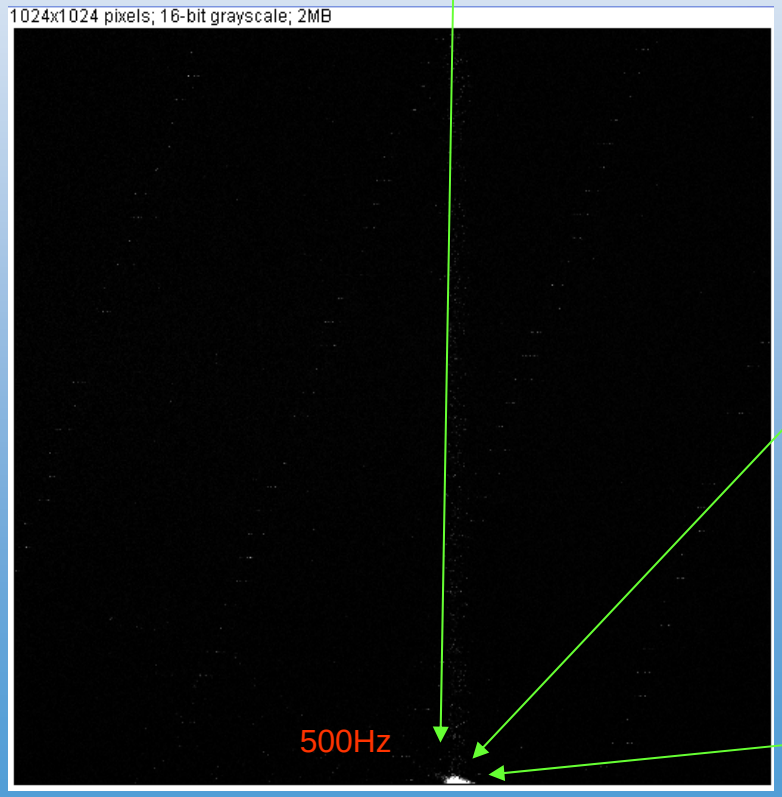
Gd: $\tau = 2.4 \pm 0.3$ ps

A.Bartel, et al App.Phys.Lett., 90(2007)162503

Dual-sweep streak camera







Slow ramp+fast ramp

Gated beam by slow bias pulse, can be blocked by Faraday cup in front of CCD

Future Plan

- Short term
  - Pulsed high accelerating voltage
  - Robust photocathode
  - Faster switch and circuit
  - Slow sweep
  - Laboratory 6-9ev source
  - RSC optimization
- Long term

  New generation of ultrafast x-ray streak camera

  -correction of time chirp in accelerating area
  - Ultimate temporal resolution in the X-ray range

Publications

X-ray streak camera temporal resolution improvement using a longitudinal time-dependent field
J. Qiang, J.M.Byrd, J.feng, G.Huang, Nuclear Instruments and Methods, A598(2009)465

An x-ray streak camera with high spatio-temporal resolution
J. Feng, H.J.Shin, J.Nasiatka, W.Wan, A.Young, G.Huang, A.Comin, J.Byrd and H.PAdmore, *Appl. Phys. Lett.* **91** (2007) 134102.

An ultrafast x-ray detector system at an elliptically polarizing undulator beamline
J.Feng, A.Comin, A.F.Bartelt, H.J.Shin, J.Nasiatka, H.PAdmore, A.Young, A.Scholl, Nucl.Instr.Method, A582 (2007) 248

Element-specific spin and orbital moment dynamics of Fe/Gd multilayers
A. Bartelt, A. Comin, J. Feng, J. R. Nasiatka, T. Eimüller, B. Ludescher, G. Schütz, H. A. Padmore, A .T.Young, A. Scholl, Appl.Phys.Lett. , 90, 162503(2007)

Streak camera temporal resolution improvement using a time-dependent field
Ji Qiang, John Byrd, Jun Feng, Gang Huang, Proceedings of Particle accelerator conference 2007, P3973

Progress on modeling of ultrafast x-ray streak cameras
G.Huang, J.Byrd, J.Feng, J.Qiang, W.Wan, Proceedings of Particle accelerator conference 2007, P3961

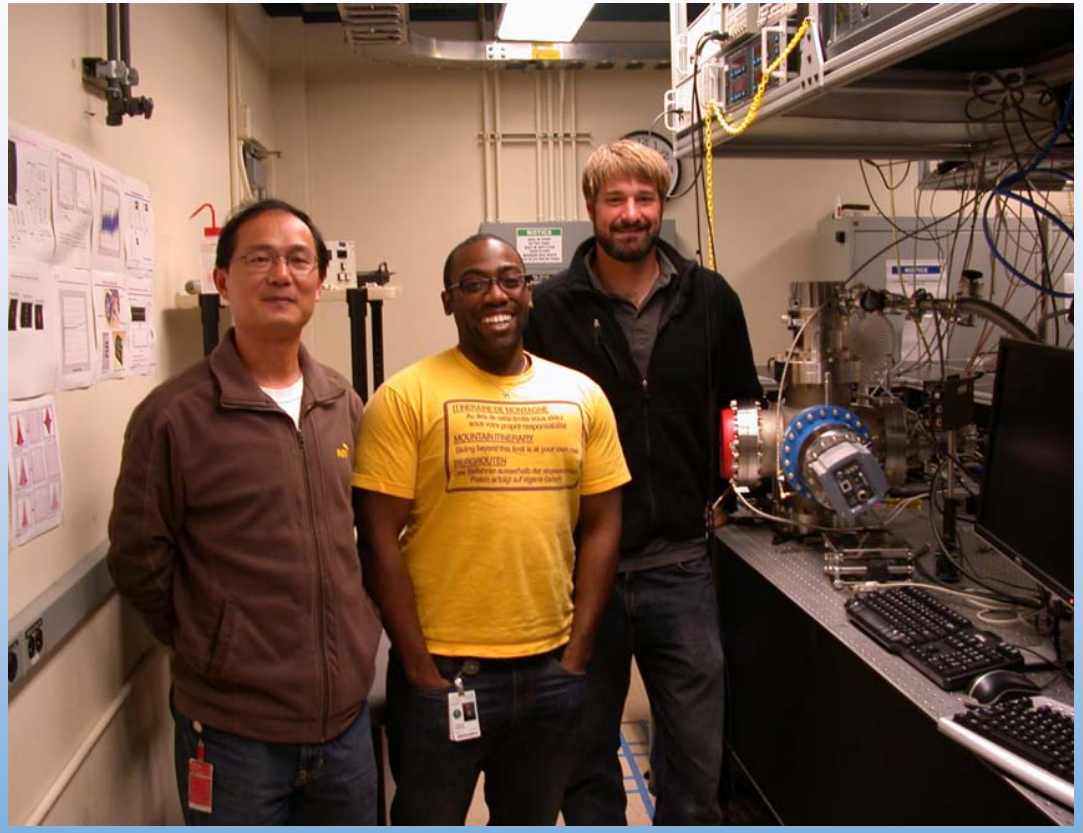
Modeling of ultrafast streak cameras
G. Huang, J.M. Byrd, J. Feng, H. A. Padmore, J. Qiang, W. Wan
Proceeding of tenth European Particle Accelerator conference 2006, P1250

An Ultrafast X-ray Detection System for the Study of Magnetization Dynamics
T. Young, A. Bartelt, J.Byrd, A. Comin, J.Feng,G.Huang, J.Nasiatka,J.Qiang, A. Scholl, Hyun-Joon Shin, H.A.Padmore, AIP conference proceedings, Vol.879, P1206,2006, 9th international conference on synchrotron radiation instrumentation

An ultrafast x-ray streak camera for the study of magnetization dynamics
J.Feng, W.Wan, J.Qiang, A.Bartelt, A.Comin, A>Scholl, J.Byrd, R.Falcone, G.Huang, A.MachPhee, J.Nasiatka, K.Opachich, D.Weintein, T.Young, H.Padmore, Pro. SPIE 5920, 592009 (2005)

Ultrafast magnetization dynamics studies using x-ray streak camera
A.Bartelt, A.Comin, J.Feng, J.Nasiatka, H.PAdmore, A.Scholl, A.Young, Pro. SPIE 5920, 592019 (2005)

People and contact information



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Research Assistant: K.Engelhorn
Ph.D student: M.Greaves
Email: **fjun@lbl.gov**, phone: 510-495-2471

Funded by:
Office of Science, Office of Basic Energy Sciences,
U.S. Department of Energy

LBL Laboratory Directed Research and Development Program

Picture

First row from left: J. Qiang, T.Young, H.J.Shin, J.Feng K.Opachich

Second row from left: G.Huang, M.Greaves, A.Comin, A.Bartelt

Third row from left: Christopher, W.Wan