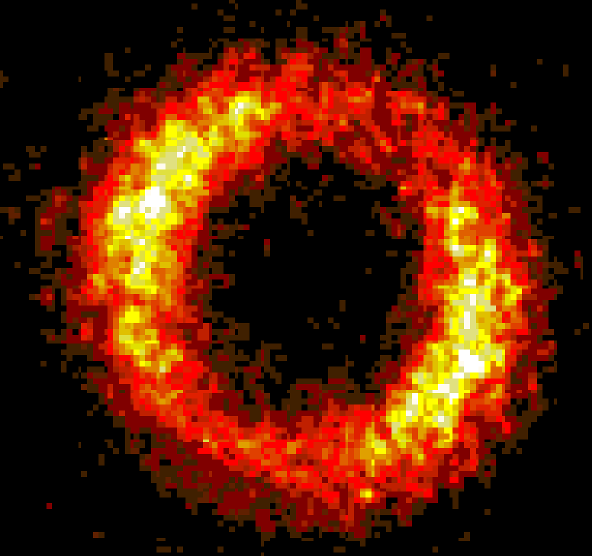
# Fast Compton

*Inverse Compton produced x-rays for structural dynamics*



Oliver Williams

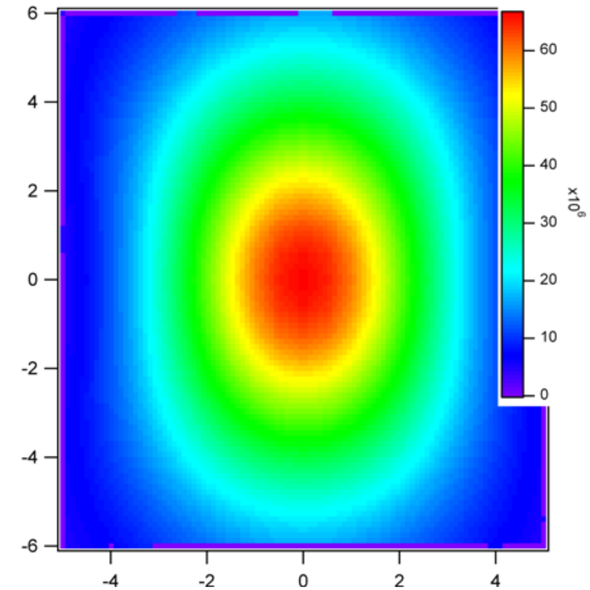
ATF Users Meeting

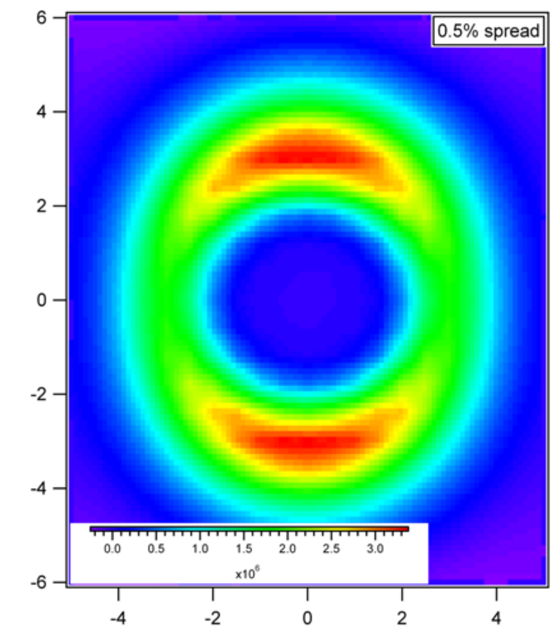
October 2010

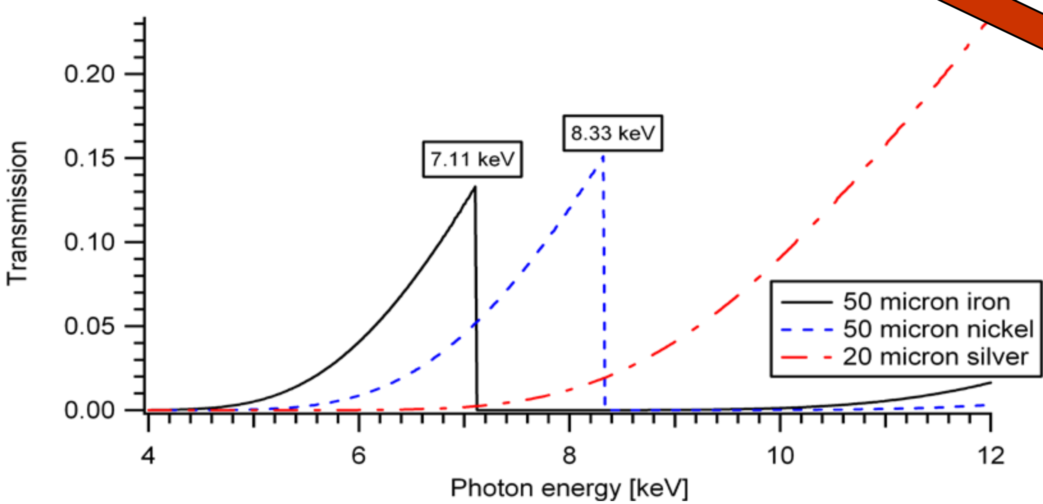
# Energy Measurement Using K-edge

- Characterized x-rays via K-edge foil
- ICS photons have angular-energy relation (undulator eqn.):

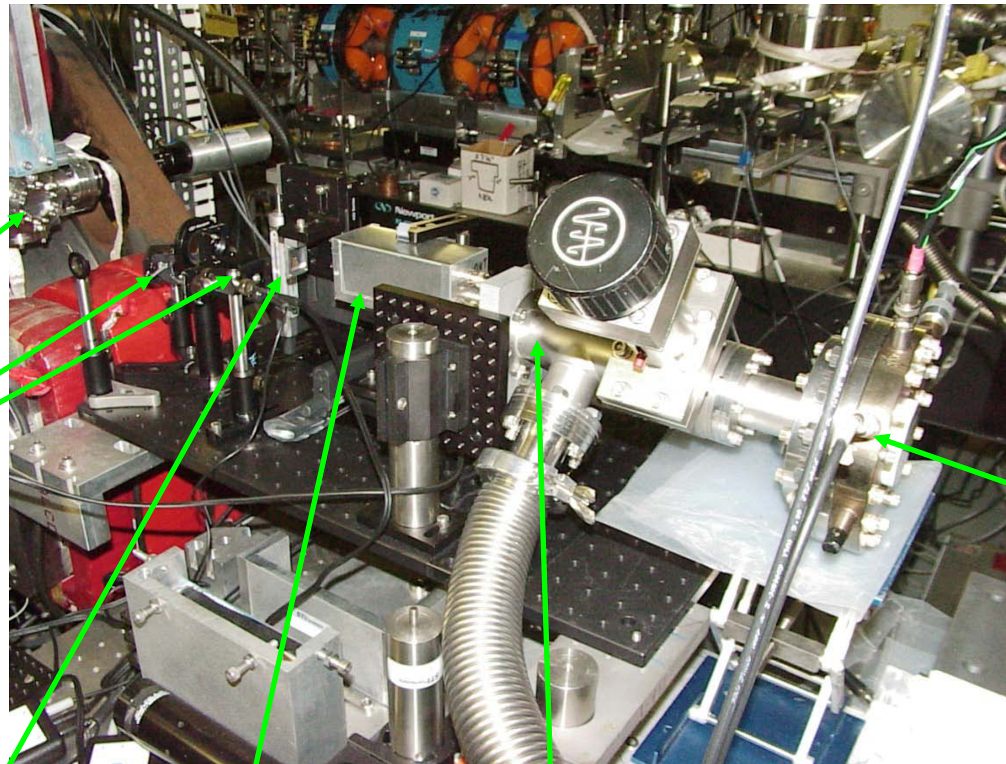
$$E_x = \frac{4\gamma^2}{\left(1 + \frac{a_L^2}{2} + \gamma^2\theta^2\right)} E_L$$



# Analyzing the photons



250 µm Be-window

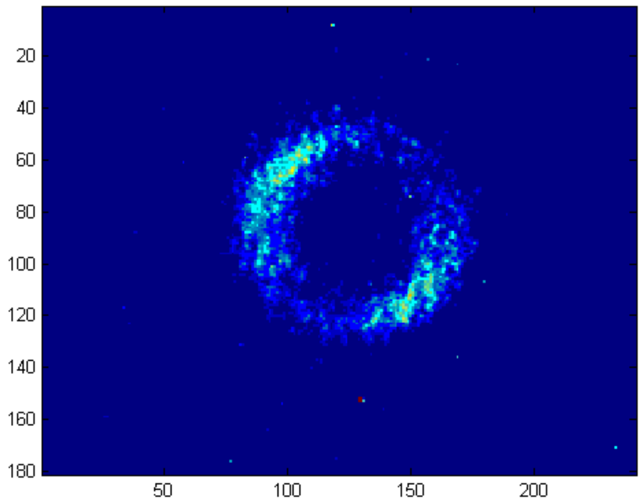
Insertable Ni, Fe, and Ag foils

1 mrad pinhole on remote 2-axis control

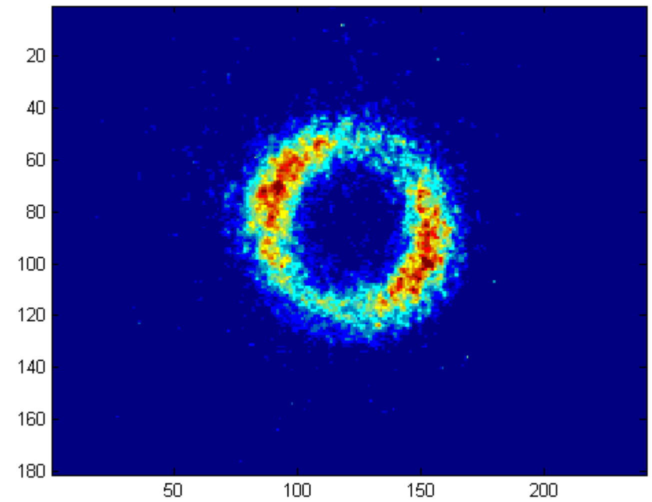
Remotely insertable Si-diode detector

250 µm Be-window

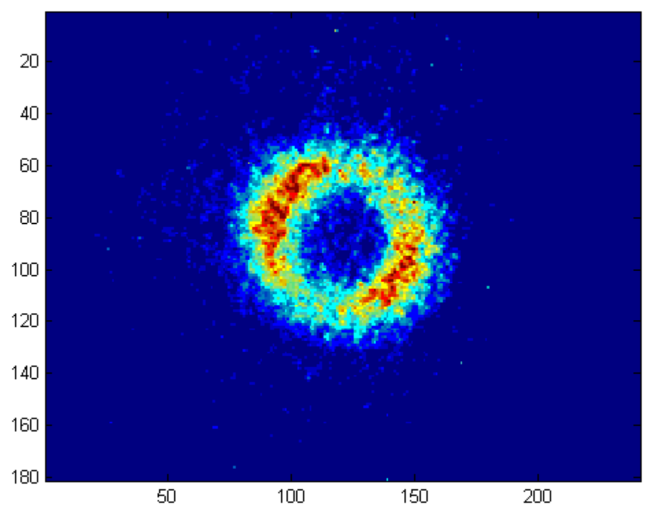
MCP image intensifier (CCD camera not pictured)



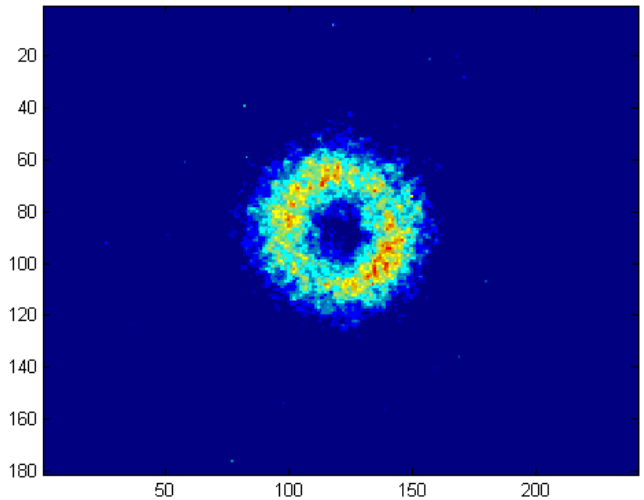

72 MeV



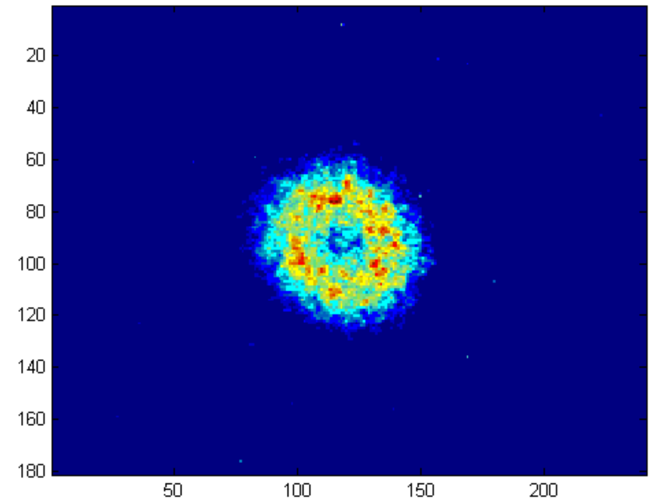

70 MeV



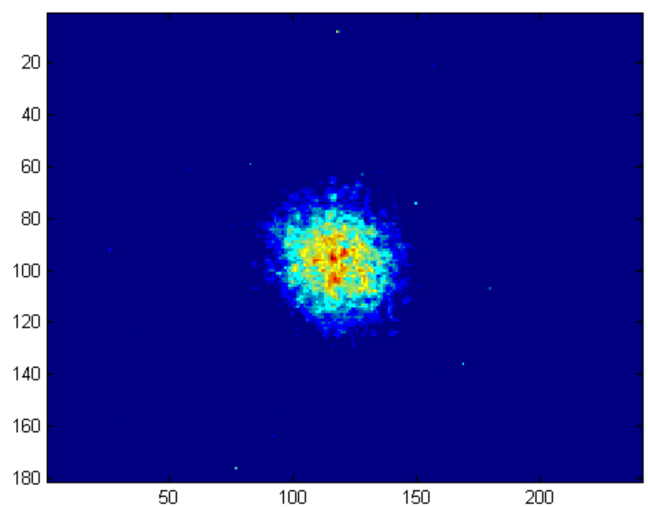

68 MeV




66 MeV

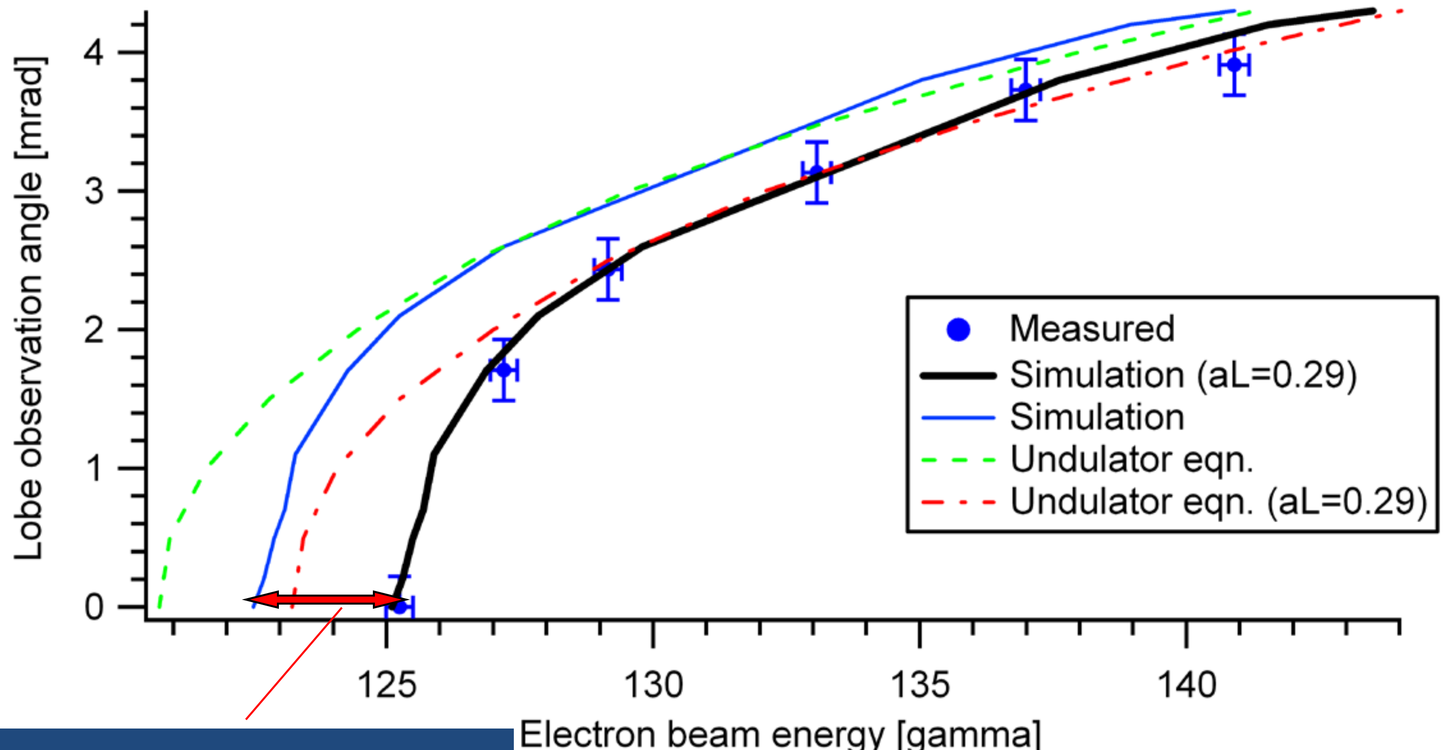



65 MeV




64 MeV

# Lobe observation angle



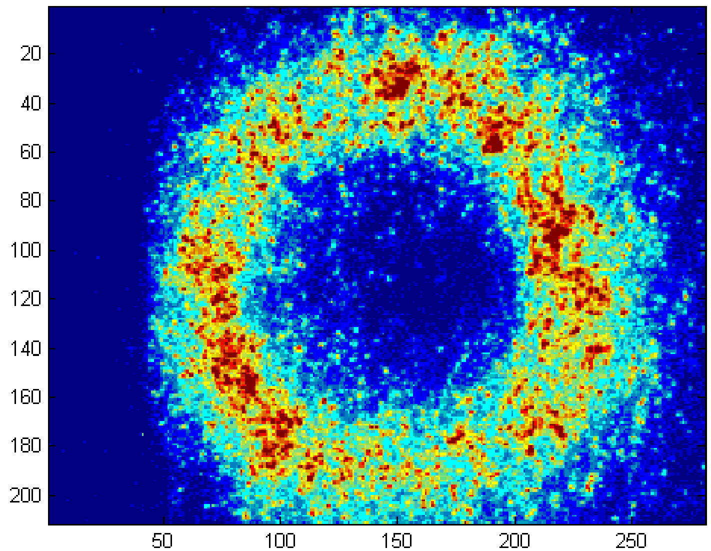

$\Delta E_e$=1.3 MeV => $\Delta E_x$= 290 eV

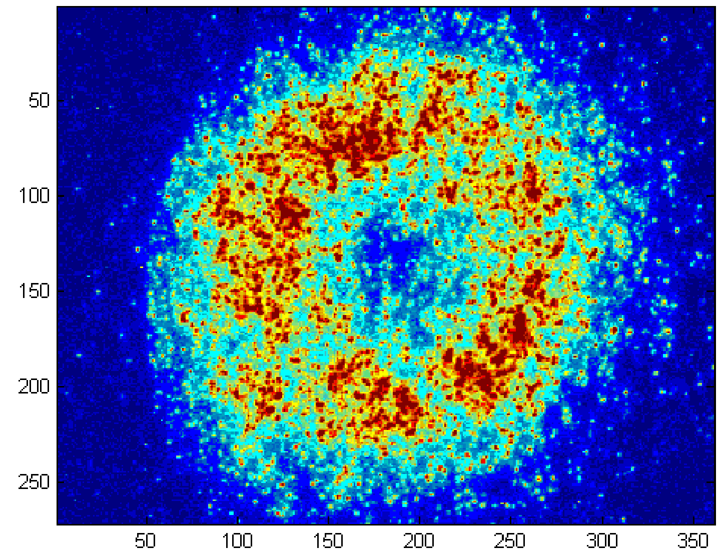
Fit simulation curve to data by adding energy offset (~290 eV)

-Energy offset could be due to absolute e-beam energy calibration or nonlinear induced red-shifting ($a_L$>0) (more likely)

-Nonlinear effects would then dominate bandwidth: 4%

# Circular polarization and sub-ps pulses




68 MeV, 4 ps FWHM e-beam
($2\Delta\gamma/\gamma=\Delta E/E=1\%$)

*X-rays are e-beam bunch length*

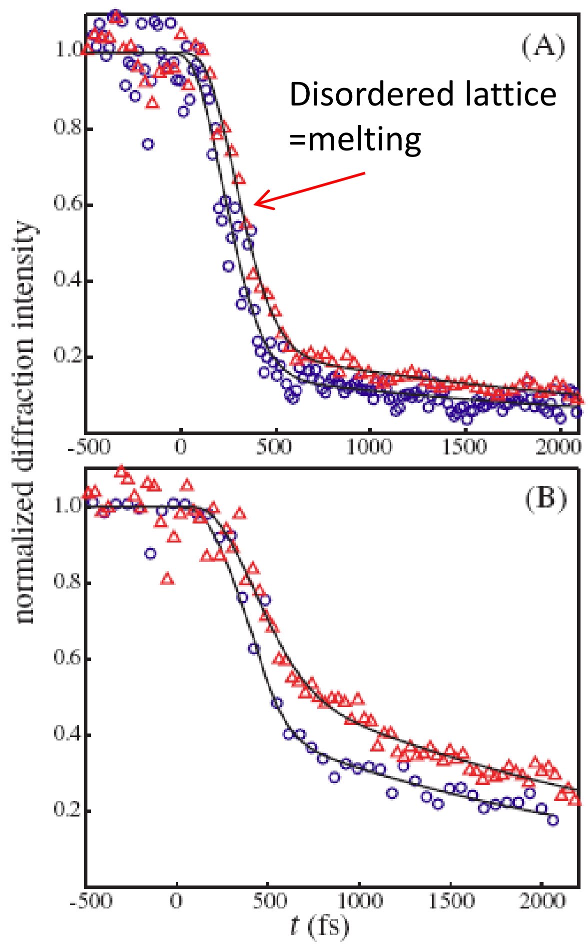
68 MeV, 300 fs FWHM e-beam
($2\Delta\gamma/\gamma=\Delta E/E=2\%$)

Measured BNL ICS source:

~$2\text{x}10^6$ photons over 1 mrad ($1\text{x}10^8$ full angle) in a modest 300 fs pulse

# Dynamics: Where ICS shines…

- Pump-probe and living samples require data in a single shot
- Can't compete with avg. brightness of synchrotrons, but…
- ICS capable of delivering high flux in single sub-ps pulse
- Tunability of energy and polarization allows for range of ultra-fast applications: lattice changes, magnetic materials dynamics, chemical processes, etc.

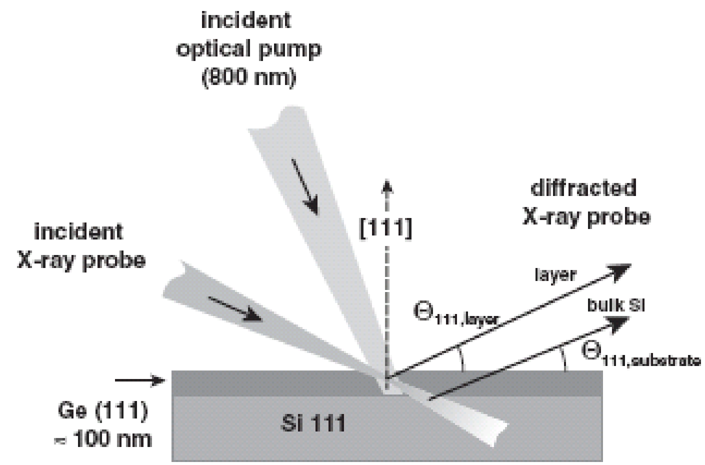


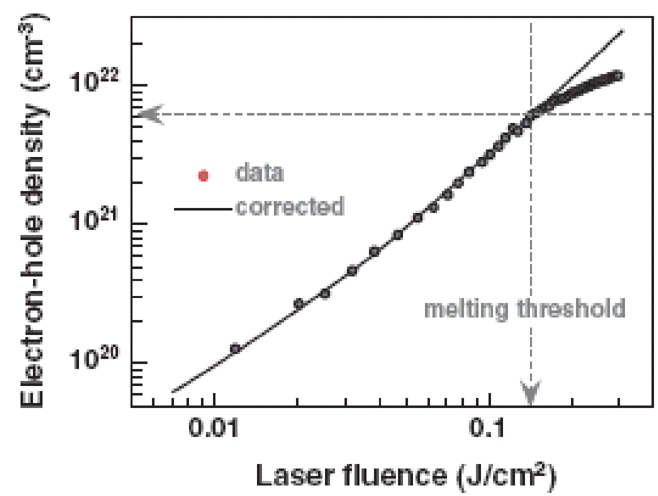

Melting of InSb

K.J. Gaffney, et al., PRL 95, 125701 (2005)

# Is “Fast Compton” Possible?

- Need to show feasibility of Compton as ultra-fast x-ray source
- Requires a “basic” study to understand pump-probe synchronization
- Will watch non-thermal melting of Ge-layer on Si-substrate (bulk crystal won’t reveal melted surface by diffracted x-rays)
- Preferential absorption of 800 nm pump by x-ray probed Ge layer
- 1st: Static Diffraction
- 2nd: Time stamp e-beam (x-ray) arrival time = Electro-optic sampling (EOS)

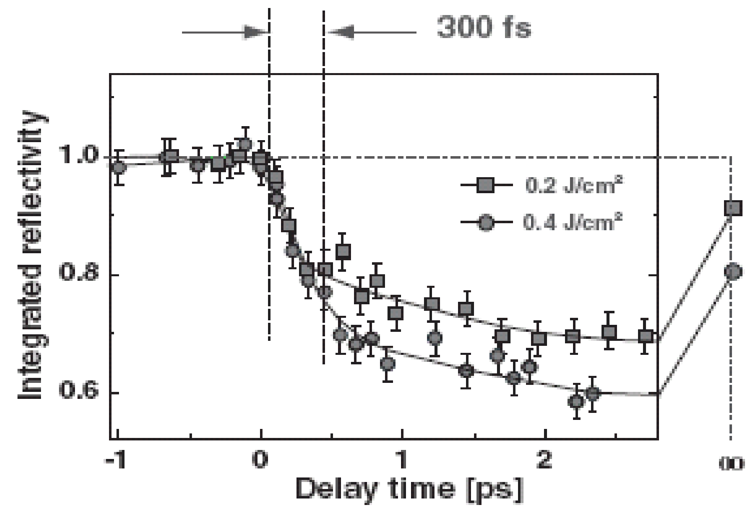


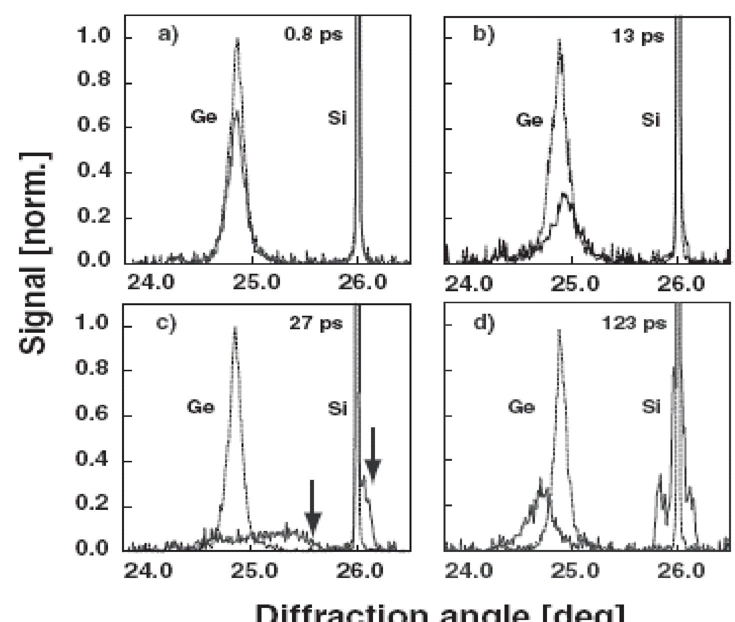




Linde, et al., J. Phys. Cond. Matter 16 (2004)

# Lattice Dynamics

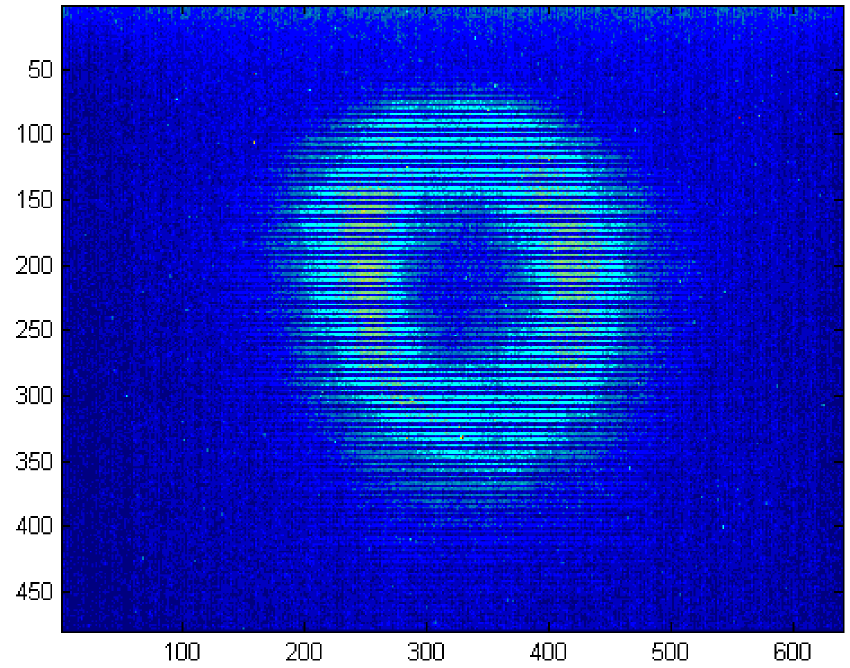
- Compressed e-beam can (presumably) produce 100 fs x-rays
- Allows sub-ps probe of lattice changes in non-thermal melting of Ge
- Look for decrease in diffracted signal
- Recreating known experiment can put upper bounds on x-ray pulse length = temporal diagnostic



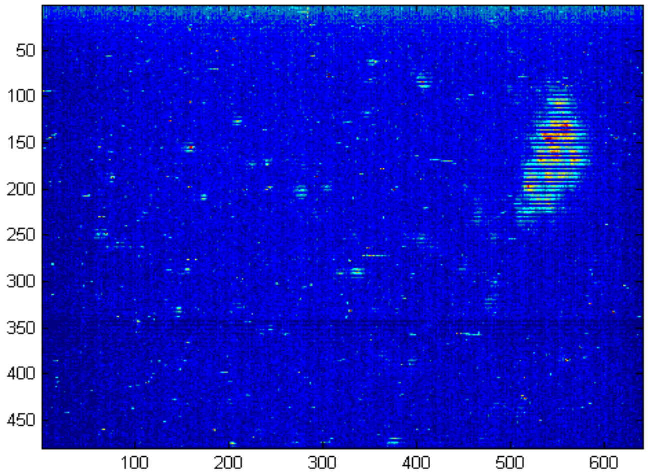



# Chapter 1: Static Diffraction (Bragg Condition : $\lambda=2d\sin\theta$)

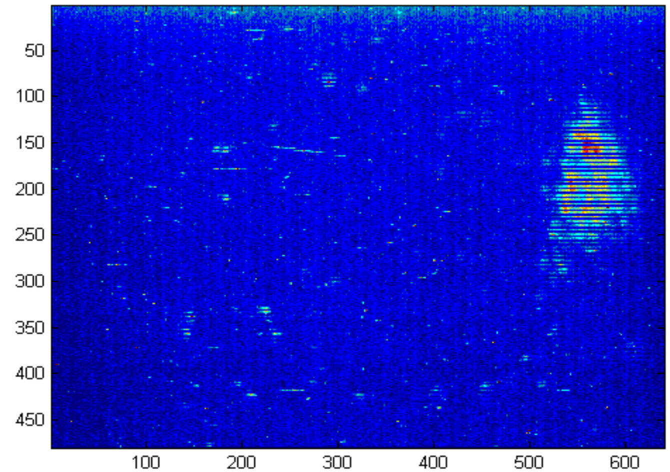
- Measurement of central photon energy made using Ni-foil method
- Shows ~8.6 keV photons on axis
- Start with Si-crystal: cheap, Bragg angle near our energy, part of exp!
- Given Si lattice spacing of 2d=6.28, have θ=13.3 deg.



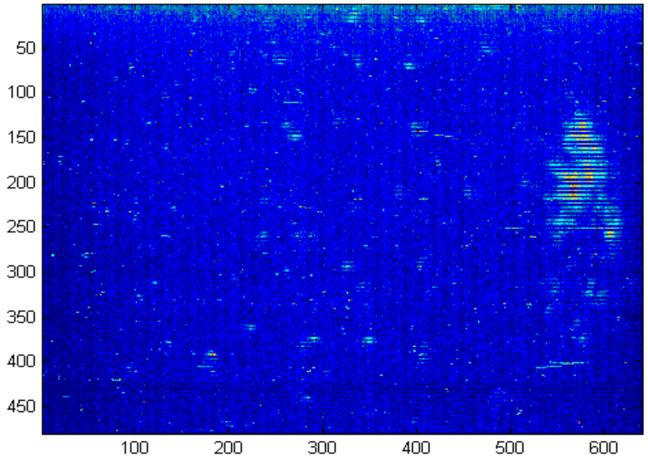
# Single-shot Static Diffraction



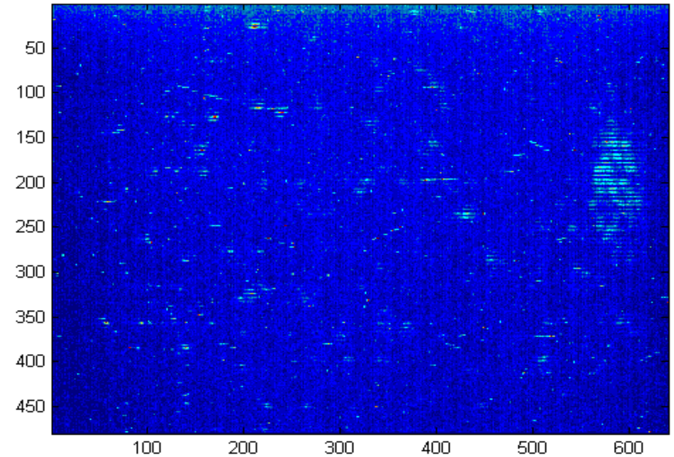

Θ=13.4 degrees (“8.53 keV”)




Θ=13.5 degrees




Θ=13.7 degrees



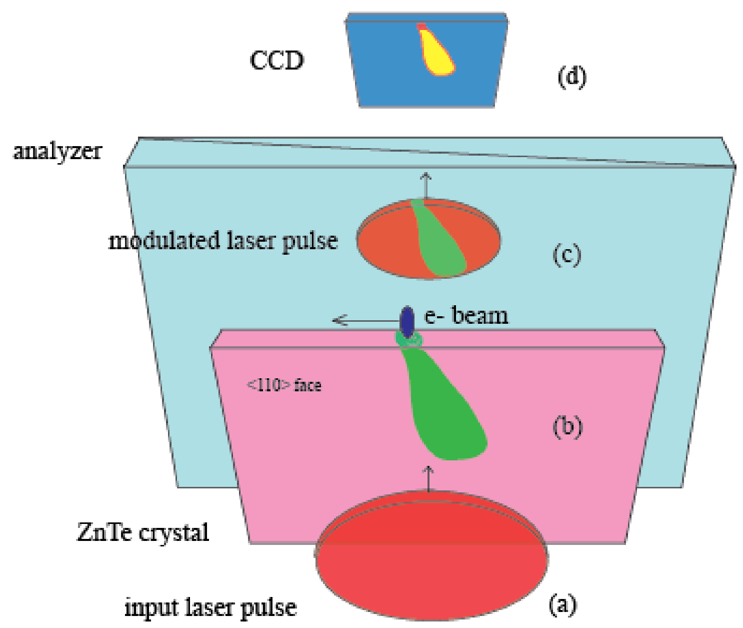

Θ=13.8 degrees (“8.28 keV”)

# Diffraction lessons learned

- Observed diffraction signal in 250 eV window (as dictated by Bragg angle)
- Corresponds to expected bandwidth given in simulation and K-edge measurements
- Central energy not exactly right: very possibly due to non-normal incidence angle on crystal
- Higher resolution detector/camera may be needed for melting experiments

# Electro-optic sampling

- Use nonlinear crystal (e.g. ZnTe <110>)
- E-field of electron bunch imprinted on crystal
- Acts as polarization gate
- resolution: probe laser pulse length and crystal thickness
- Time window: crystal width and laser spot size
- Provocation based on measurements done at UCLA Pegasus Lab




C. M. Scoby, et al., PRSTAB 13, 022801 (2010)

# Summary

- Fairly good confidence in deliverable x-ray energy using two different diagnostics
- To our knowledge, 1st observation of single shot static diffraction from a Compton source
- Use new Ti:Sa laser for pump AND time-stamping of x-ray arrival time due to system jitter
- Experience with EOS will carry to other experiments requiring tight synchronization requirements
- Will demonstrate feasibility of ATF Compton source for ultra-fast science