Structural and electronic studies in the time domain

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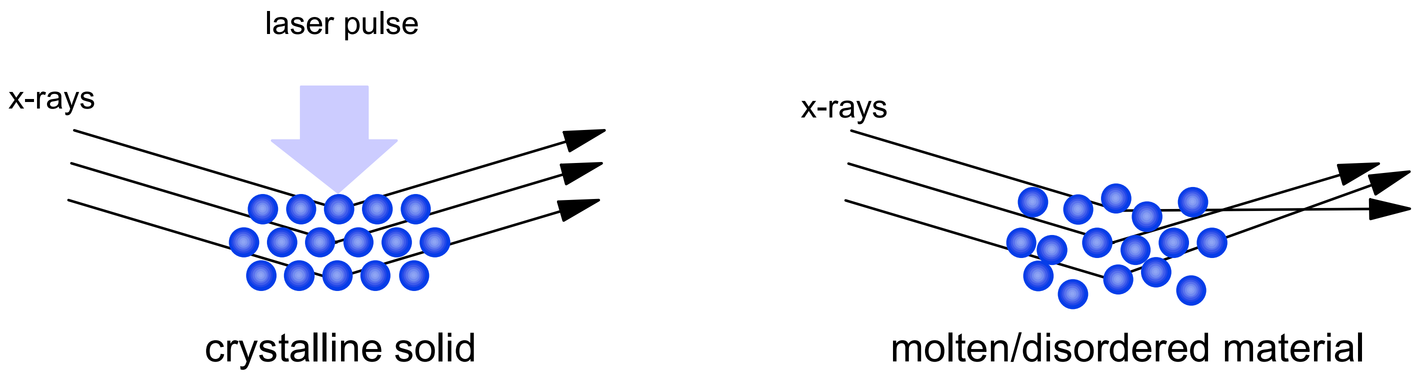
- Time-resolved research using fs laser as pump and SR as probe
- Source requirements
- Racetrack microtron design study at LBNL

fs and ps x-ray research

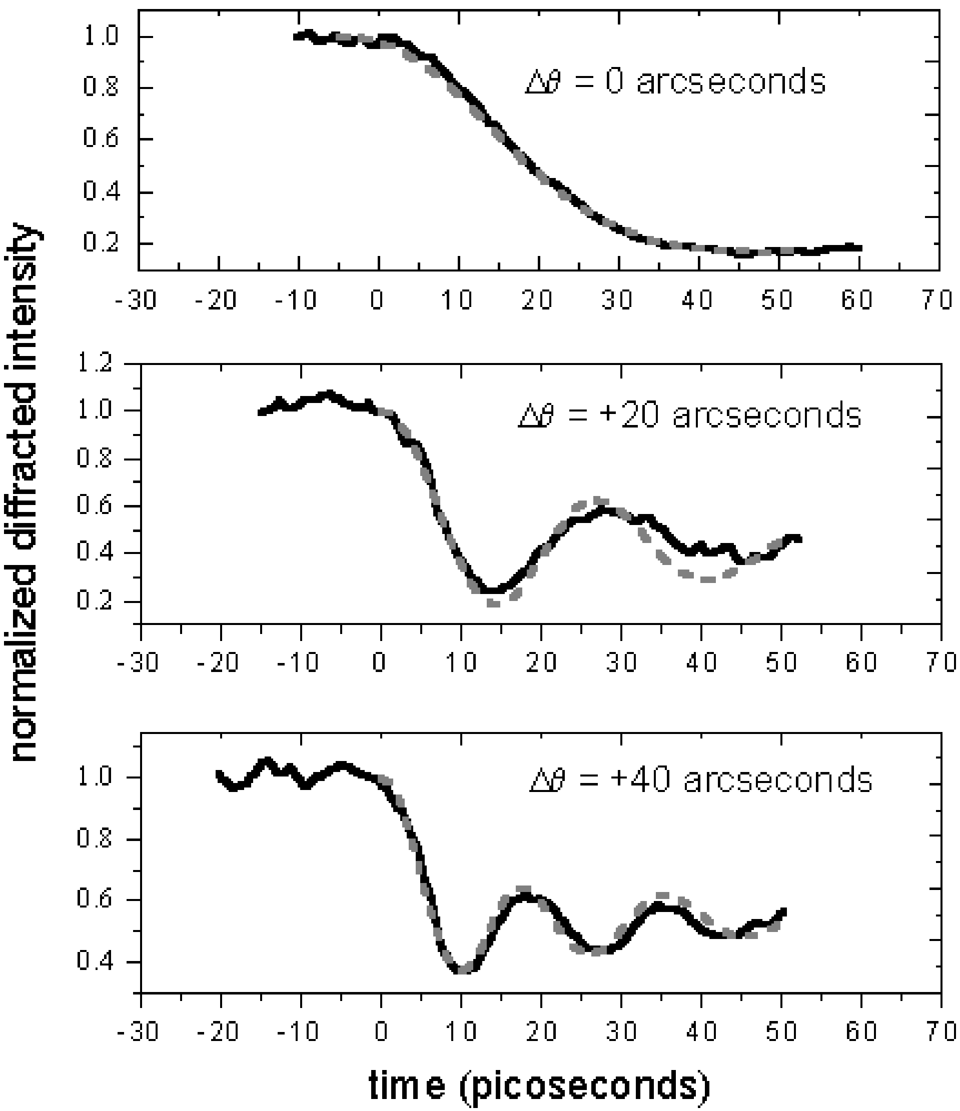
- Non-equilibrium phase transitions: coherent phonons in InSb
- Warm dense matter: Al at high T, solid ρ
- Photogeneration of halogen radicals observed via time-resolved X-ray absoorption spectroscopy - C. Bressler
- Dynamics in complex materials: polarons in $Nd_{1/2}Sr_{1/2}MnO_3$
- Single x-ray pulse x-ray crystallography of CO-myoglobin, photoactive yellow protein, K. Moffat and M. Wolf (ESRF)
- X-ray diffraction of InSb undergoing a phase transition - A. Rousse (ENSTA)
- Research programs at APS, UCSD, proposals at SLS, CLS

Time-resolved x-ray diffraction of laser-excited InSb



- Atomic disordering on a time scale of a vibrational period ?
- Coherent acoustic phonons generation by ultrafast laser pulse (~100 fs)
- Lindenberg et al., Phys. Rev. Lett., **84**, 111, 2000

Coherent acoustic phonons



—— measured

- - - calculated from dynamical diffraction

Fit parameters:

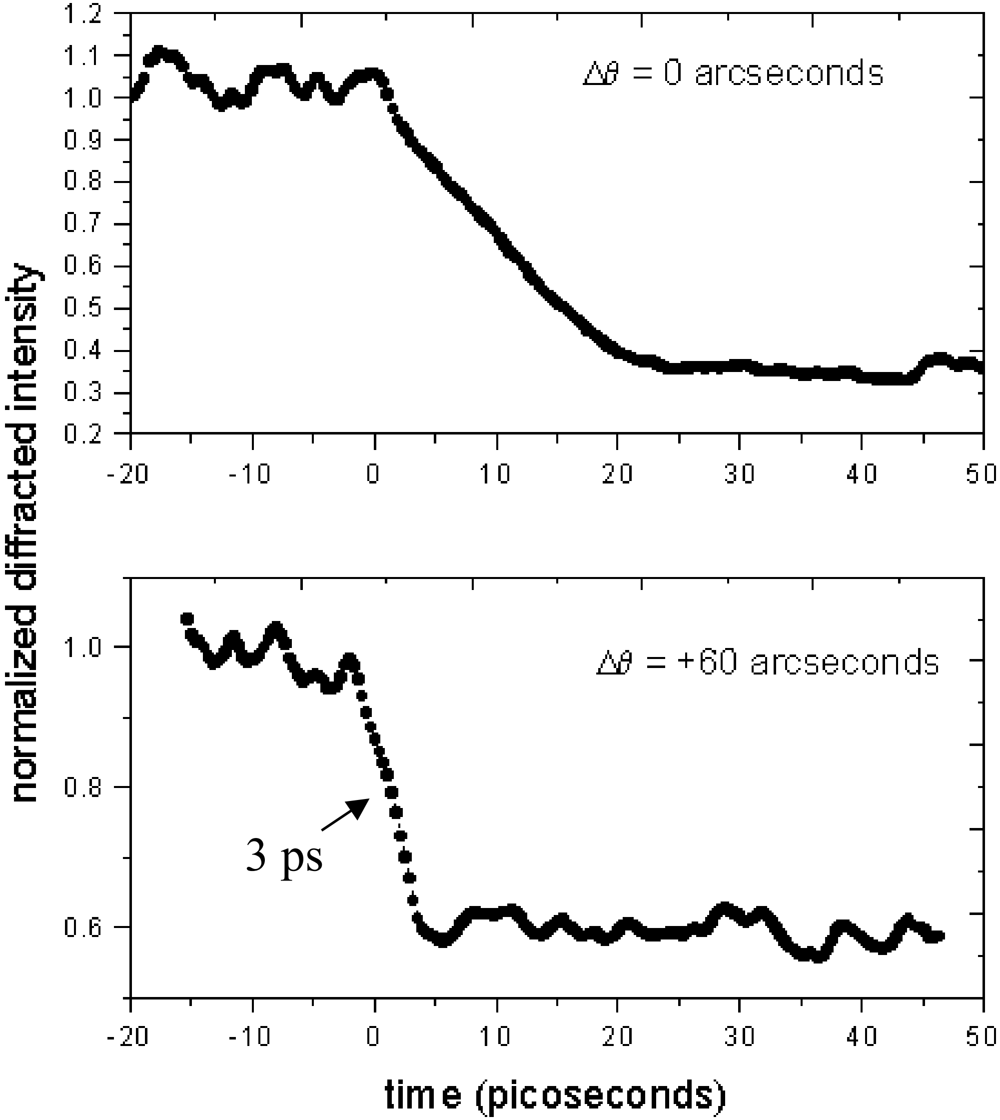
laser attenuation depth: 100 nm

elect.-acoustic coupling time : 12 ps

thermal strain: 0.17% max

instantaneous strain: 0.08% max

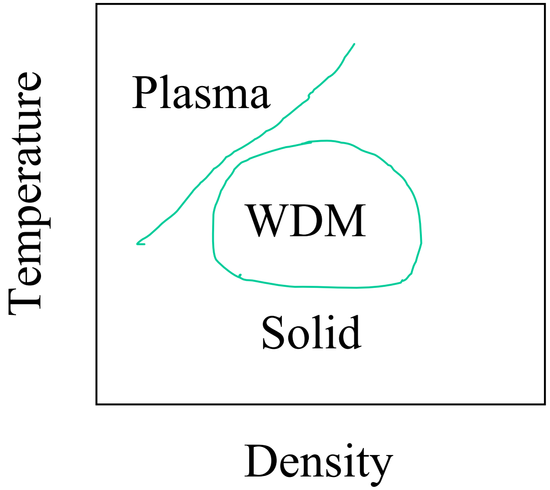
Non-thermal melting



- Just below damage fluence (15 mJ/cm²)
- 3 ps decrease faster than acousto-electric response time (12 ps)
- Bond softening leads to non-thermal melting.

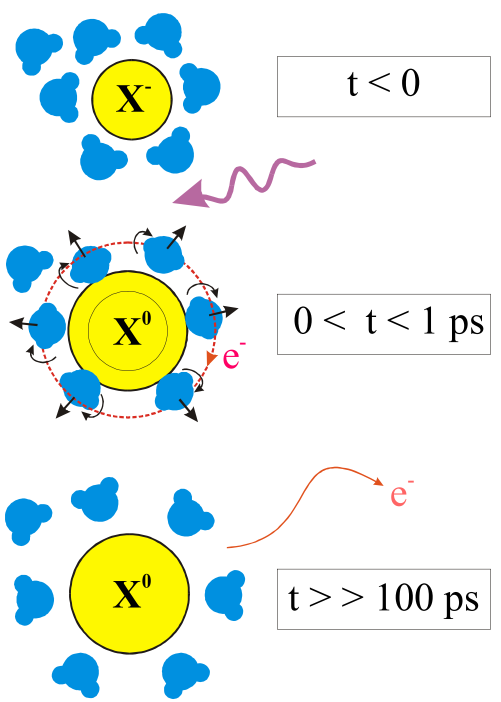
Warm dense matter

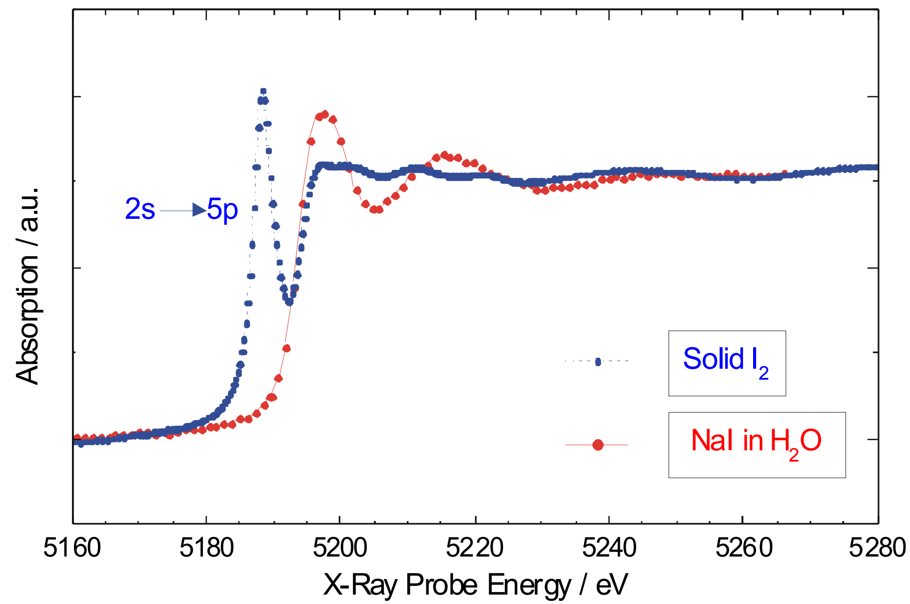
- Warm dense matter is at high T (~10,000 K) and solid ρ, at interface between solid state and plasma physics, these conditions exist in planets
- Measure Near-Edge X-ray Absorption (XANES) as probe of electronic structure
- Comparison and test of calculations being done at LLNL
- First system: aluminum, hydrodynamic properties well studied at high T



Structural evolution of simple photochemical reaction: I^- photodetachment

- Reaction: $I^- + h\nu \rightarrow I + e_{sol}$ in H_2O.
- Solvated electron has been extensively studied by femtosecond optical spectroscopy. Evolving structure of solute and solvent cage cannot easily be derived.
- Use x-ray absorption fine structure (XAFS) to determine time-resolved structure of solvent cage.



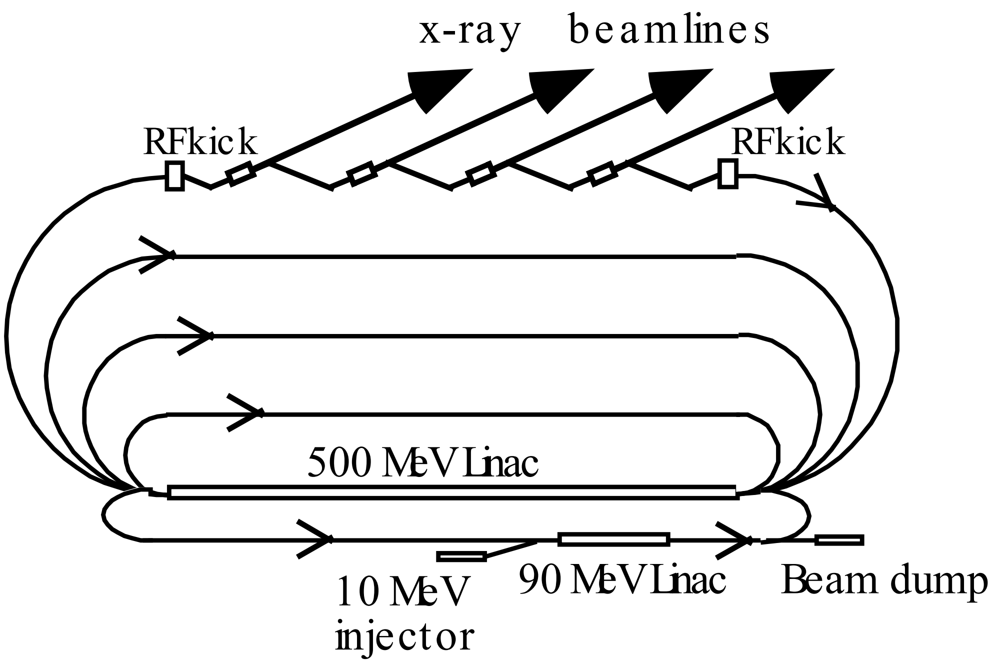


- Steady-state measurement.

Source requirements of fs and ps x-ray research

- Photon energy range: 100 eV to 10 keV
  - laser penetration depth ~ 0.1 μm while x-ray penetration depth increases with photon energy
- Repetition rate: 10 kHz
  - present state-of-art fs laser with mJ pulse energy
  - sample recovery, for semiconductor ~ 100 ns
- Flux: $\sim 10^{10}$ 1/s 0.1% bw, Brightness: $\sim 10^{14}$ 1/s 0.1% bw
- Pulse duration: 100 fs, synchronized to a laser with same accuracy
  - period of typical molecular vibration
  - pulse duration of commercially available fs laser
- Tunable

Dedicated facility for an ultra-fast x-ray spectroscopy

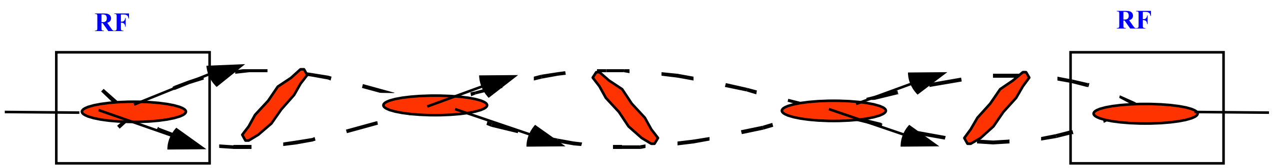


- A. Zholents

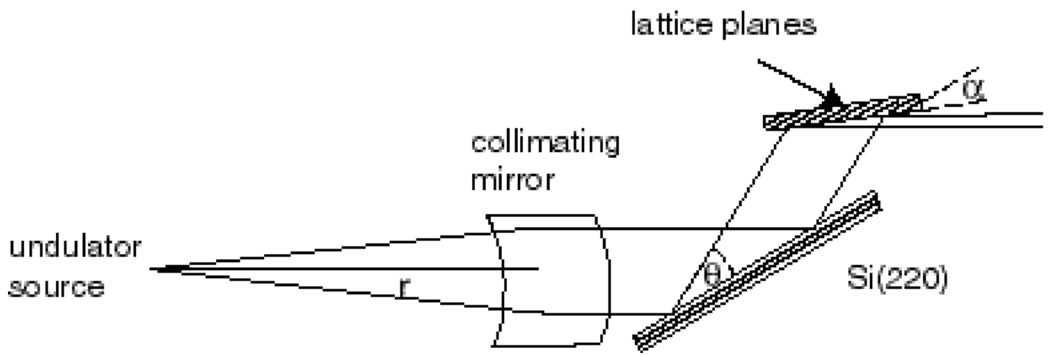
- Racetrack microtron suits above defined goals at a relatively modest cost
- Electron bunch length is compressed from ~10 ps to ~ 1 ps before entering the last straight
- X-ray pulse is compressed from ~ 1 ps to ~ 0.1 ps in the beamline

Pulse compression

X-ray pulse compression is due to a correlation between the longitudinal and transverse positions of electrons inside the electron bunch created by the RF orbit deflection in a cavity in the beginning of the final straight.



An optical scheme for pulse compression with a collimating mirror and a double asymmetrically cut crystal monochromator



Racetrack microtron characteristics

Undulator:
period = 14 mm,
peak magnetic field = 1.5 T
gap = 5 mm
number of periods = 100

X-ray flux and brightness corresponding
to the spontaneous undulator radiation at 9-th harmonics.

Beam energy, GeV	2
X-ray wavelength, Å	1.5
Flux, x-rays/sec/0.1% bw	2 $x10^{10}$
Brightness, (usual units)	$2x10^{14}$
Pulse length (FWHM), fs	100