Impact of ERL Pulse-Length and Brilliance on Structure and Evolution Investigations

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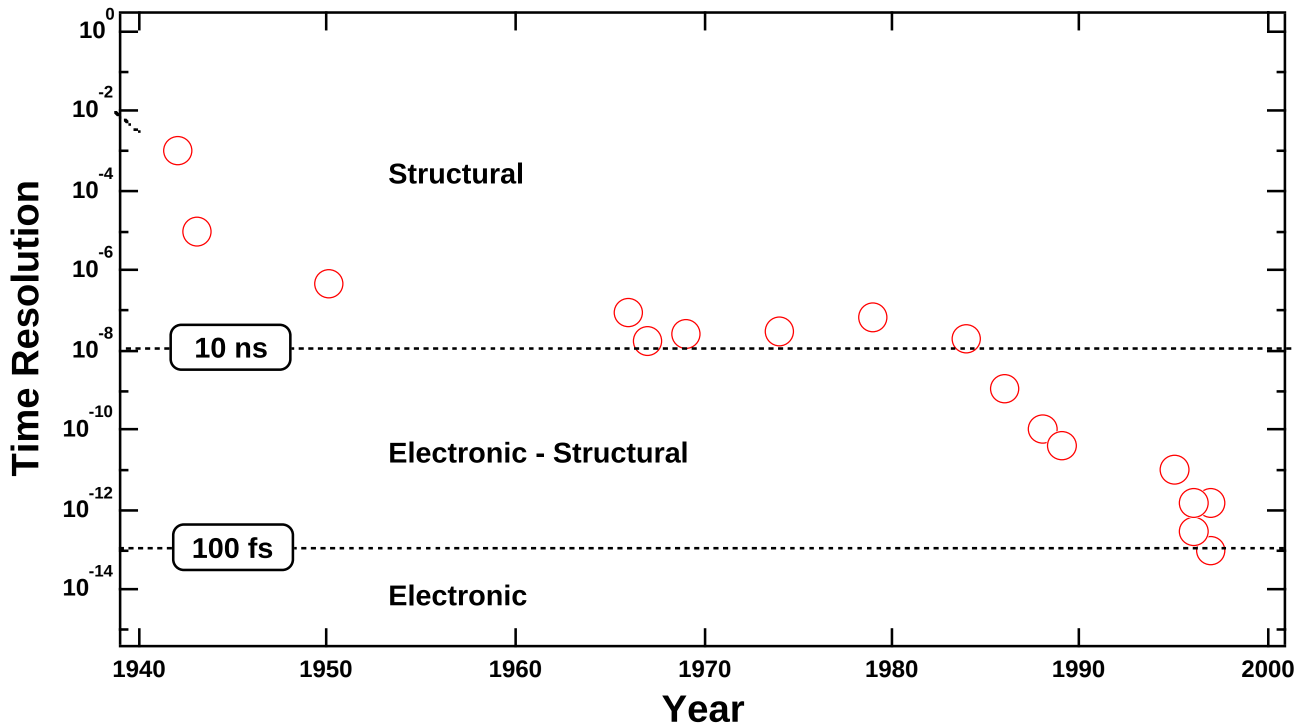
Important Sub-picosecond Threshold for Electronic Effects Reached in Mid-90's



Structural Effects	→	Speed of Sound	~µm/ns
Electronic/Structural Effects		Electron-Phonon Interact.	<10 ps
Electronic Effects		Lattice Vib., Bonding	~100 fs

- Picosecond and Shorter X-Ray Pulses Open Important Areas of Fundamental Physics
- Present Picosecond X-Ray Pulses: Laser-Plasmas or Sliced Synchrotron Pulses
- Projected ERL Brilliance and Fluence Represent Significant Improvements

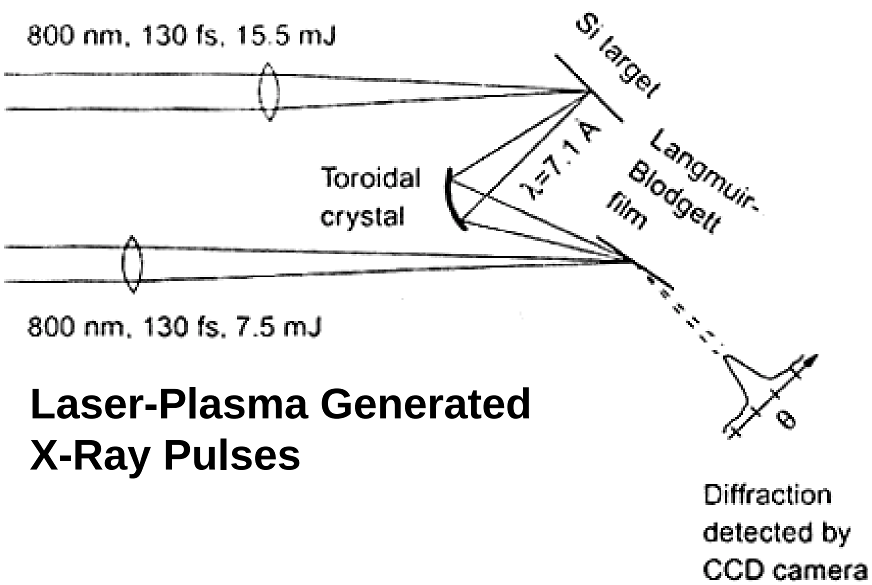
Picosecond and Sub-Picosecond X-Ray Investigations

- Impressive picosecond and sub-picosecond experiments have been performed, but they have been limited by source intensity, resolution, triggering and/or detection capabilities
- Continued development of comprehensive investigations will be needed

Selected Early and Recent Examples

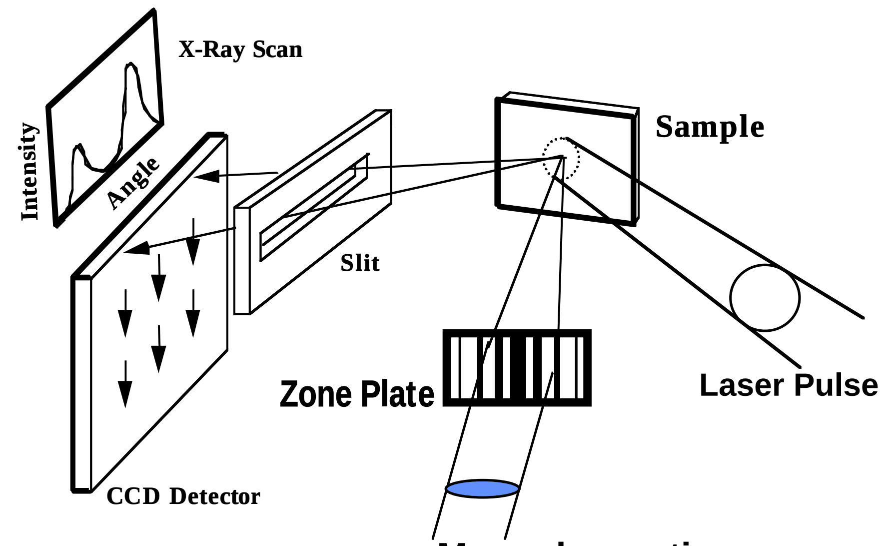
- X-Ray Near Edge Absorption investigation of Laser dissociation of SF_6 Gas (1.5 ps)
  Raksi and Wilson, J. Chem. Phys. 104, 6066 (1996)
- Bragg peak monitoring of laser breakup of metal bonding in Cd arachidate Langmuir-Blodgett Film (~600 fs); Rischel et al., Nature 390, 490 (1997)
- Bragg diffraction study of coherent acoustic phonons; Lindenberg et al., PRL 84,111 (2000)
- Bragg diffraction study of femtosecond laser excitation and anharmonic lattice effects in epitaxial Ge film on Si; Cavalleri et al, Phys. Rev. Lett., 85, 586 (2000)
- Femtosecond X-Ray Science, ALS 2000 Users Meeting Workshop Presentations

Simultaneous Collection of Angular Diffraction Scan Using a Converging Incident X-Ray Beams



Laser-Plasma Generated X-Ray Pulses

Metal Bond Breaking Dynamics During Femtosecond Range Laser Pulse; Rischel et al [Nature, 390, 490 (1997)]

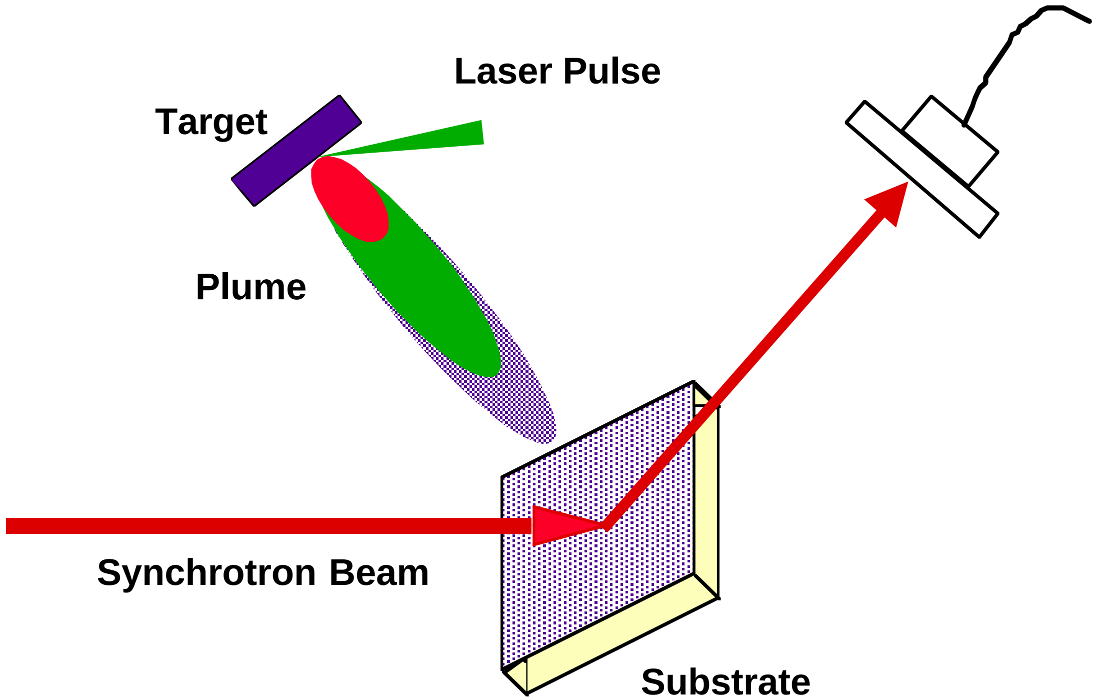


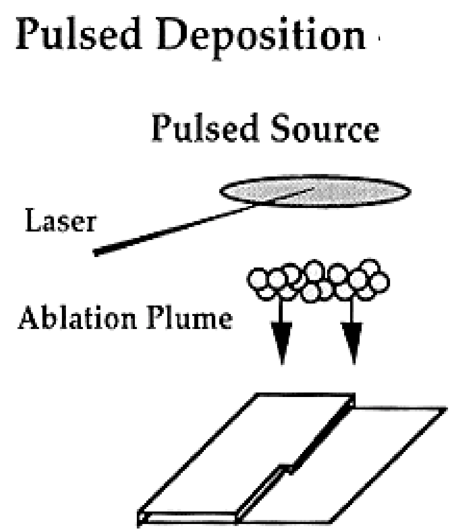
Angle-Dispersive Scattering Using Linear Zone Plate or K-B Mirror Converging Optics With High Brilliance ERL Pulses

Capability for Angular Scans with Individual ERL X-Ray Pulses
or
Full Laue Pattern from Single White ERL Pulse

Pulsed-Deposition and Non-Equilibrium Film-Growth on Surfaces

Pulsed-Laser Deposition (PLD) and Film Growth



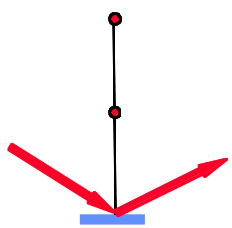


PLD Deposition Phase Beyond Present Time-Resolved Intensity Capabilities
PLD Crystallization Phase Not Yet Resolved in Diffraction Studies

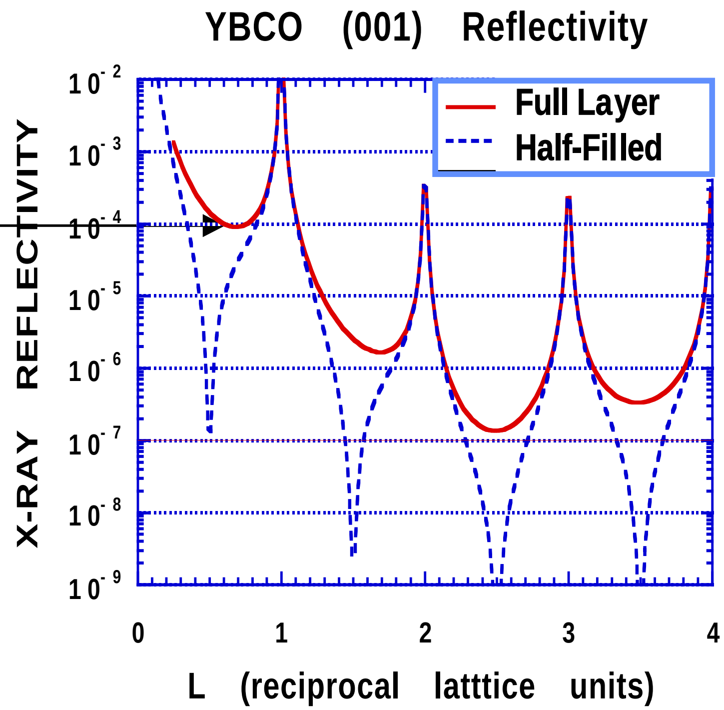
Time-Resolved Crystal Truncation Rod Measurements

Higher Brilliance and Higher Flux Will Provide The Capability to Accept Full Beam with Sample At Very Low Angles

Scattering ~ 10^4 Hz/μ–sec



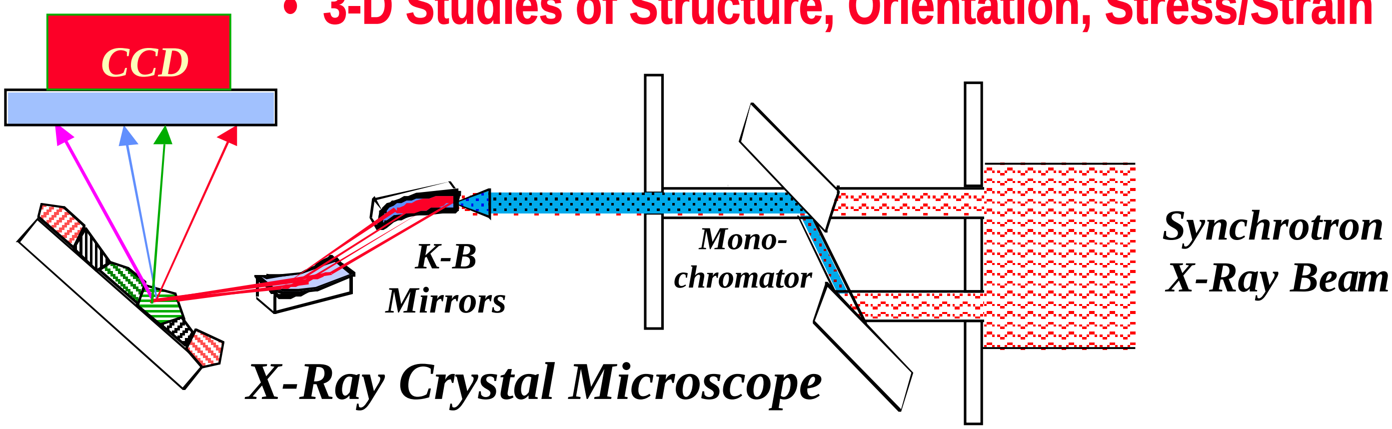
X-Ray Surface Scattering



- **ERL Brilliance Will Provide Capability to Study ~μ–sec Deposition Phase as Well As Aggregation Phase of Pulsed Thin-Film Growth**
- **Microbeam Focusing With ERL Brilliance Will Provide Intensity for Single-Terrace Surface Studies**

X-Ray Microbeams Provide A Revolutionary New Technique for Mesoscale Materials Physics

- 3-D Studies of Structure, Orientation, Stress/Strain



Fundamentally Important Development for Materials Physics

- New Directions for The Investigation of The Microstructure, Phase, Orientation, Strain, Dynamics, and Structural Evolution of Materials
- Includes Virtually All Areas of Materials Research and Technology:
  - Poly- & Single-Crystal Materials, Thin-Films, Buried Interfaces
  - Deformation, Grain Growth, Fracture, Combinatorial Studies
- New Linkage to Theory, Simulation, Multi-Scale Modeling

- Present White Microbeam Resolution is ~0.5 x 0.5 μm^2
- ERL With ~ 10-50 Times Higher Brilliance Will Provide for ~0.05 x 0.05 μm^2 Resolution
- 3D Nanoscale Materials Structure and Evolution Investigations Will Become Possible

Conclusions

- Time-Resolved Measurements in Femtosecond Range Are in Progress
  - Applications Range from Structural to Structural/Electronic to Electronic
  - Intensity, Selective Sample Pumping, Triggering, and Detection Limit Present Studies

- Synchrotron X-Ray Sources with High-Brilliance Sub-Picosecond Pulses Are Crucial for Time-Resolved X-Ray Scattering Studies in the Regime of Electronic Dynamics

- Projected ERL X-Ray Time-Structure and Brilliance Will be Complementary to Laser-Plasma and Projected Free-Electron Laser X-Ray Sources

- Brilliance of ERL Source Will Enable Pulsed-Growth Time-Resolution ~ 1 Microsecond to Resolve Deposition and Crystallization Phases of Pulsed-Laser Film-Growth

- Brilliance of ERL Source Will Enable White Microbeam Resolutions to ~0.05 μm
  - 3D Orientation, Size, and Stress/Strain Measurements in Materials
  - 3D Nanoscale Structural Investigations Will Become Possible

- Continued Detection Development is Critical to All X-Ray Scattering Investigations