Determination of Directional Atomic Displacement from Femtosecond Laser Excited Bismuth in Time Resolved Electron Diffraction


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UESDM December 14, 2012, UCLA
Electron diffraction from Bismuth

**Laser:** Ti:Sapphire-CPA
- \( \lambda = 800 \text{ nm} \)
- Rep. rate = 1 kHz

- e\(^-\) pulse duration < 700 fs @ 3000 e\(^-\)
- e\(^-\) - focus < 100 \( \mu \text{m} \)
- stability < 3 \%

**Diagram:**
- THG 267 nm
- Photo cathode
- Anode
- Magnetic lens
- Bi-membrane on Ni-mesh
- Pump 800 nm
- MCP + Phosphor
- Diffraction pattern
Anisotropic excitation in Bi
- directional atomic displacement
- preferential direction depends on the laser polarization
- relaxation of anisotropy: ~ 100 ps

Excitation of transverse acoustic phonon by photo-elastic effect

Driving force

Photo-elastic effect

Electrostriction: the quadratic coupling between strain and electric field

Strain:

\[ \sigma_{ij} = \sum Q_{ijkl} E_k E_l \]

Elastic wave equation

\[ \frac{\partial^2}{\partial t^2} U_{TA} - \nu_{TA}^2 \frac{\partial^2}{\partial z^2} U_{TA} = F_{TA} \]

\[ \frac{\partial^2}{\partial t^2} U_{LA} - \nu_{LA}^2 \frac{\partial^2}{\partial z^2} U_{LA} = F_{LA} \]
Disordered displacement

Debye-Waller factor

Laser heating

$G(h,k,l)$

$k_{in}-k_d$
Transverse distortion

Rocking-curve

Only sensitive to the lattice deformation in the surface plane
Vertical distortion

Include the lattice deformation normal to the surface plane
Excitation of elastic wave

Unpublished results indicate a contribution of an oscillation from the lattice deformation normal to the surface plane.
Conclusion

UED to study the laser induced structure dynamics

- Electronic-phonon coupling
  - High pressure
  - Coherent optic and acoustic phonon
  - Phase transition

Optical excitation

Direct coupling of the laser to the lattice

- Stimulated scattering: Raman, Brillouin

“Hot” electron

Electron-phonon coupling

- High pressure
- Coherent optic and acoustic phonon
- Phase transition

“nl. optics”
Conclusion

Experiment observation in Bismuth:

Anisotropic intensity change of the diffraction pattern

Excitation of transverse acoustic phonon

Propagating of elastic wave

Excitation of longitudinal acoustic phonon

Polarization dependence

Pulse duration (intensity) dependence

Direct excitation of the lattice by laser pulse
Acknowledgement

Klaus Sokolowski-Tinten
Uwe Bovensiepen

Roberto D. Merlin
from the University of Michigan for the helpful discussions

R.J. Dwayne Miller and his group from the University of Toronto for their assistance to build up the electron diffraction setup

Financial support by the Deutsche Forschungsgemeinschaft through SFB 616 “Energy dissipation at Surfaces”