Revealing thermal transport mechanism in thermoelectric materials

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Thermal conductivity

Figure of merit: **inversely proportional** to thermal conductivity

$$\vec{J} = -\sigma\vec{\nabla}T$$

$$\vec{J} = G\Delta T$$

T_A T_B

T: temperature

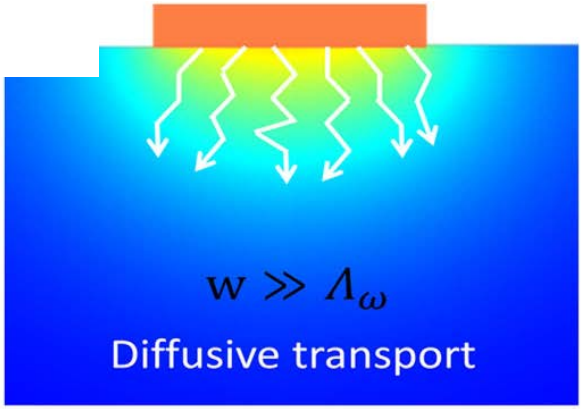
σ: Bulk thermal conductivity

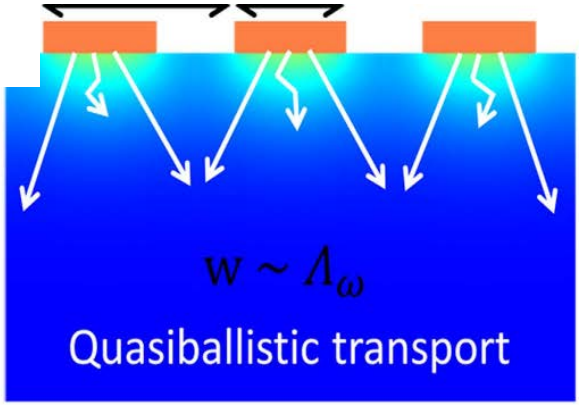
unit: W/m·K

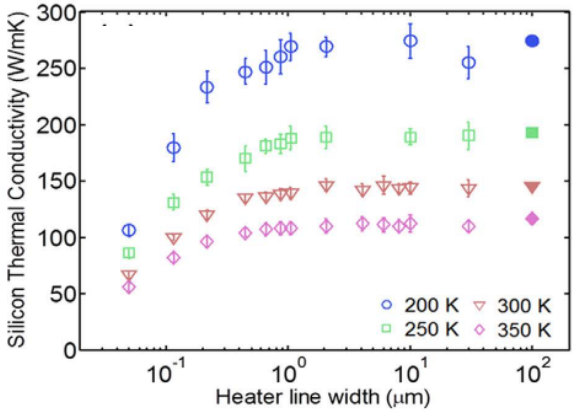
G: Interface thermal conductivity

unit: W/m^2K

Phonon transport at short wavelength







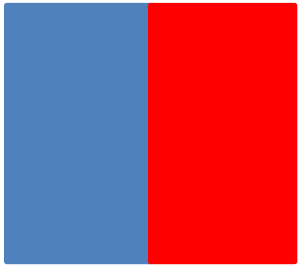
Thermoelectric materials:
MFP is too short

Zeng, L., *Scientific Reports* 5, 17131 (2015)

Interface heat transport

- Acoustic-mismatch (AM) model

$$t_{AB} = \frac{4 Z_A Z_B}{(Z_A + Z_B)^2} \qquad Z = \rho c$$



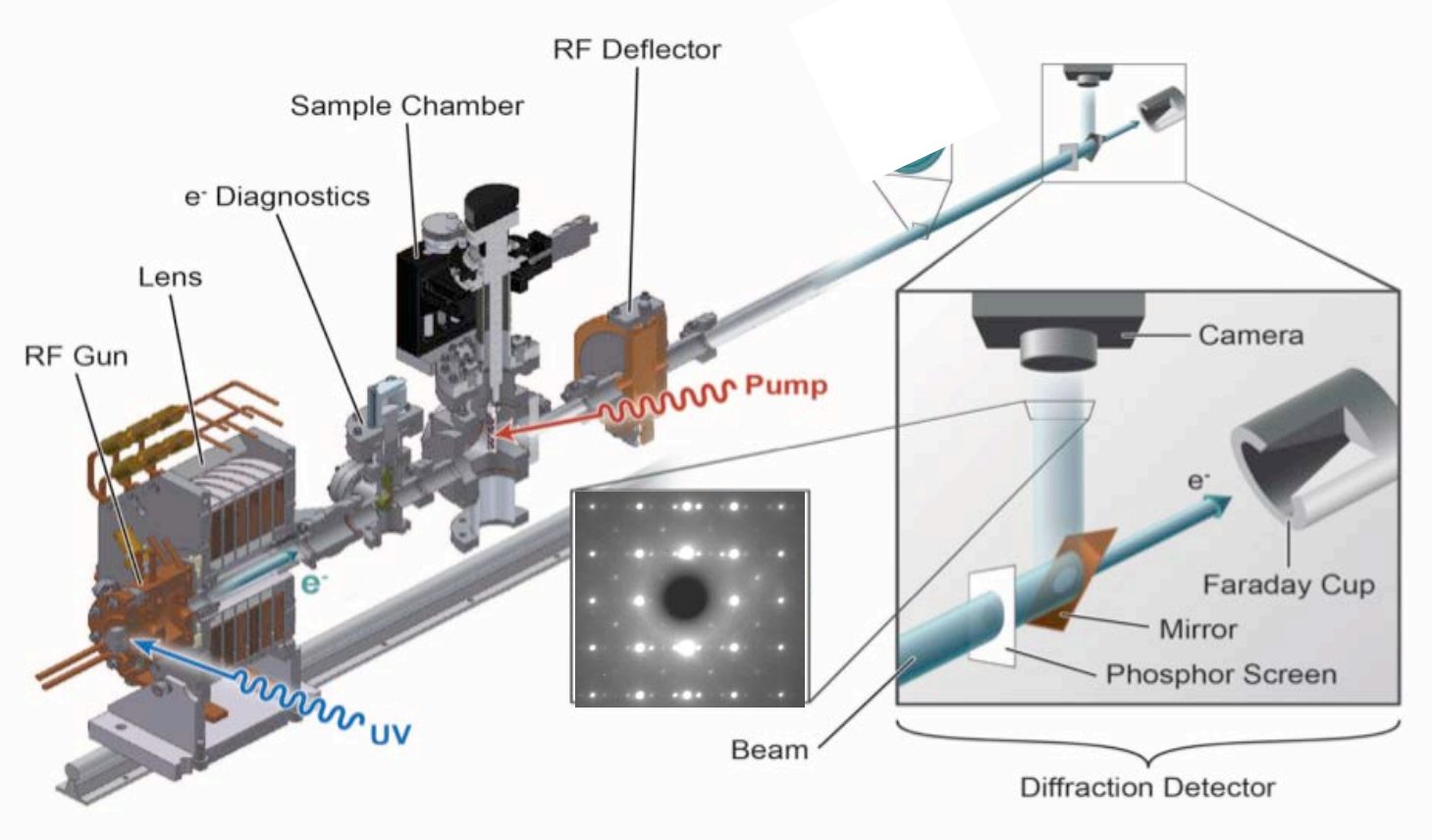
- diffuse mismatch (DM)model

the probability of being scattered to one side is simply proportional to the phonon density of states

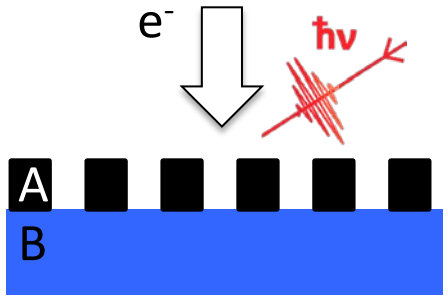
Nanometer scale materials:
theory and regular measurement method don't work

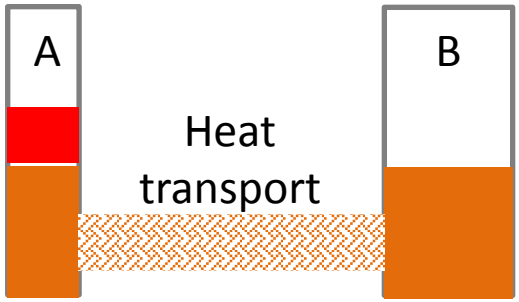
Cahill, D. G., *J. App. Phys.* 93, 793 (2003)

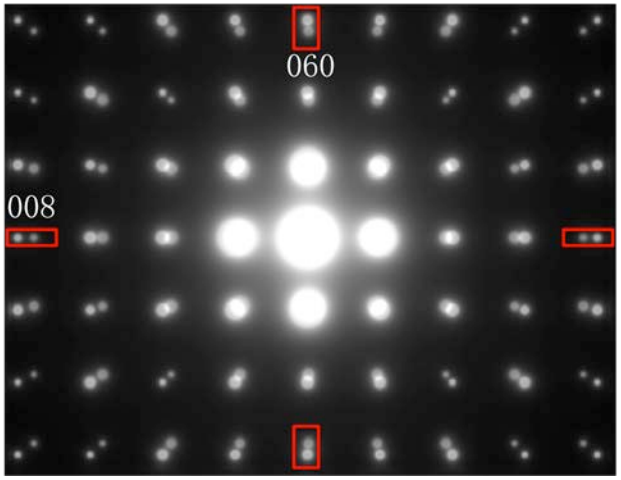
MeV-Ultrafast Electron Diffraction

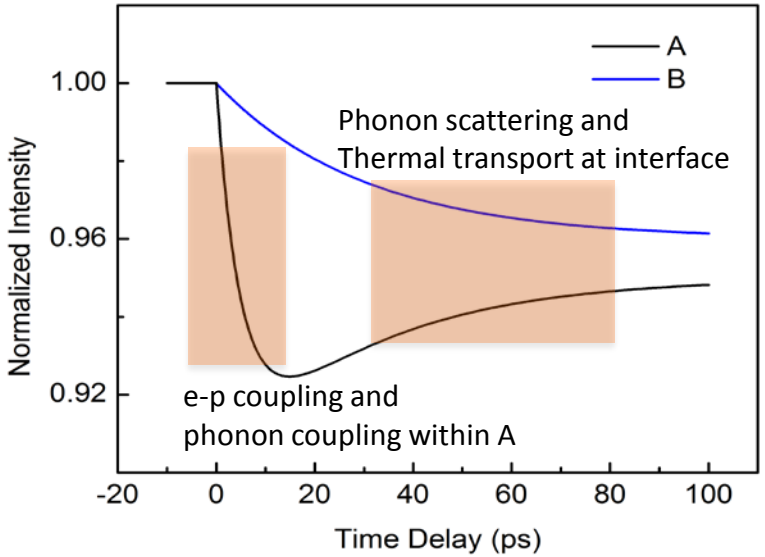


Time resolved method with UED



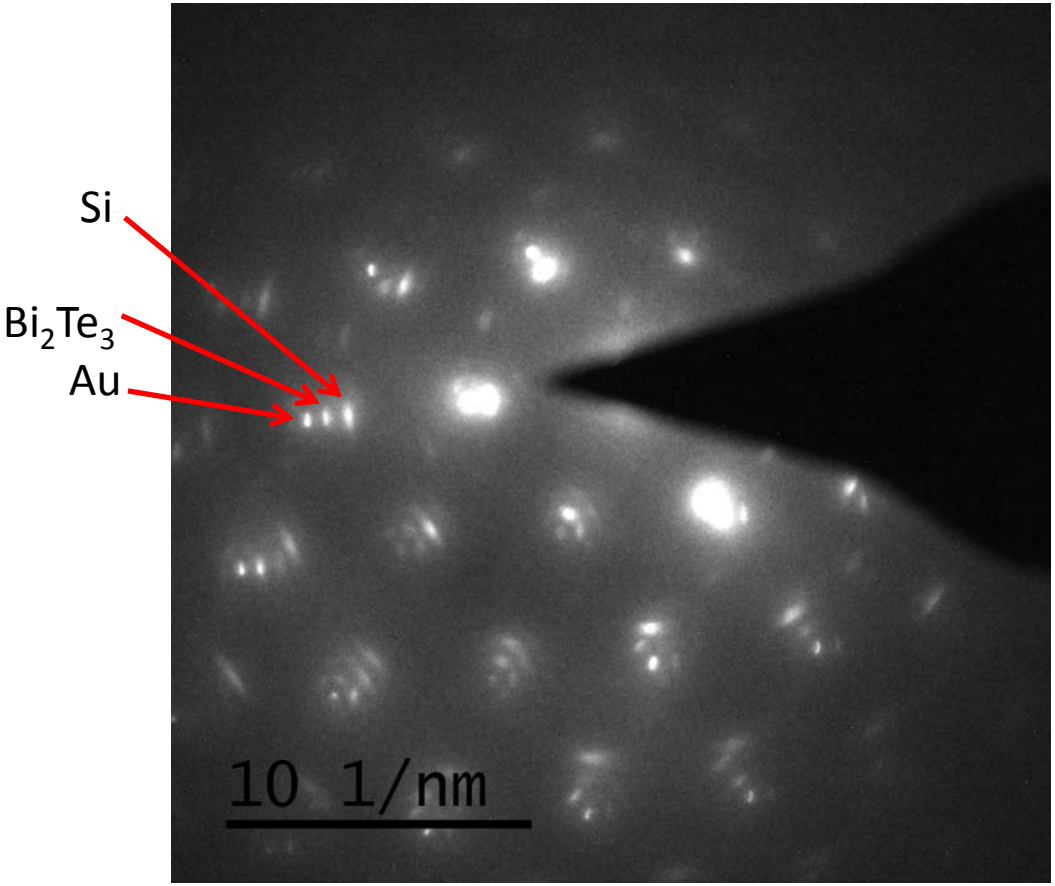






$$I_{hk0}(\Delta t) = I^0_{hk0} \cdot e^{-\frac{1}{2}G^2_{hk0}\Delta\langle u^2_\perp\rangle(\Delta t)} \qquad \Delta\langle u^2_\perp\rangle \sim T$$

Electron diffraction test on $Au/Bi_2Te_3/Si$



Summary

- Difficult to measure heat transport at nanometer scale
- UED present a unique method to scale temperature and measure thermal conductivity.
- Preliminary test shows promising result

Thank You!