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Time domain thermoreflectance: From Fundamentals to Operational Details

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What you will learn: Course Map

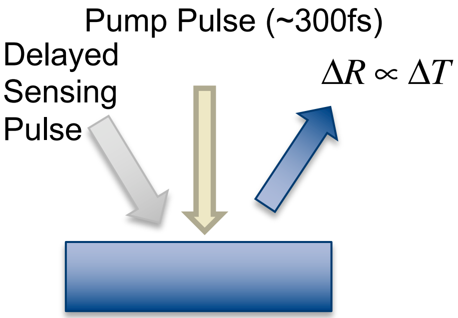
TDTR Hardware → **TDTR Theory** → **TDTR Data Analysis** → **Advanced Topics**

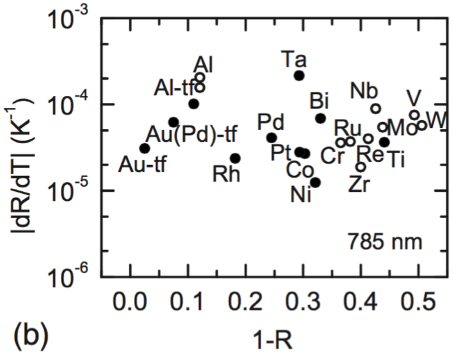
- **TDTR Hardware**
  - Optics
  - Electronics
  - Control
- **TDTR Theory**
  - Thermal Modeling
  - Penetration Depth
  - Pulse Accumulation
- **TDTR Data Analysis**
  - Fitting Data with Models
  - Sensitivity
  - Errorbars
  - Picosecond Acoustics
- **Advanced Topics**
  - Beam-Offset Methods
  - Variable Frequency TDTR
  - Beam-Offset Methods

← Experimental Planning/Setup/Operation →

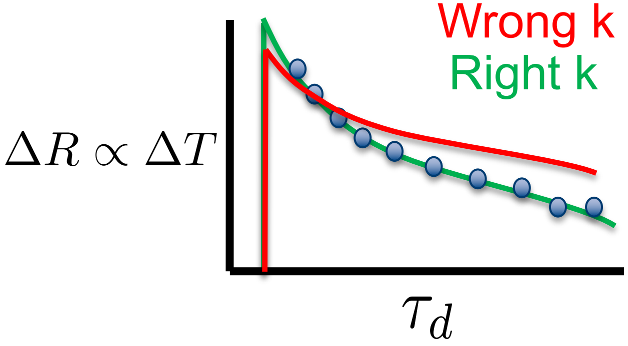
Overview of Time Domain Thermoreflectance

- Use a laser pulse as both "pump" and "probe"
- Pump injects heat, raises temperature
- Probe measures reflectivity, which is a (slight) function of temperature
- Use path length to control arrival times
- Fit thermal model to experimental data by varying thermal property. When model fits, we're done!





Y.X. Wang, JAP, 2010



c = 3×10^{8} m/s -> dx / c = dt , (30×10^{-6} m)/(3×10^{8} m/s) = 100×10^{-15} s

Pro's and Con's of Using TDTR

Pro's

- ✓ It's non-contact, non-destructive
- ✓ Measures only near top surface (~50nm - 2 um)
- ✓ Can measure Kapitza/Interface resistance
- ✓ Fast/simple sample preparation
- ✓ Fast experiments (10 samples/hr)
- ✓ Bonus Acoustic Information

Con's

- ❑ Sample must be smooth/optically reflective (>90% specular typically)
- ❑ Many thermal/geometric properties of sample are required to be known (heat capacity, thickness)
- ❑ Measures only near top surface
- ❑ Capital Expenses are fairly high (~200k$)
- ❑ Analysis/Instrumentation is more involved than for some competing methods.

Open Questions:

- How do we set up the hardware/software to measure change in reflectivity as a function of delay time?
- …accurately enough see parts per million changes in reflectivity?!
  - $dR/dT \sim 1 \times 10^{-4}$ /K
  - So for $dT \sim 1K \rightarrow dR \sim 1 \times 10^{-4}$
  - But I don't *just* want to be able to *detect* it, I need to *measure with it*!
    - actually need to detect $dR \sim 1 \times 10^{-4} / 100 \sim 1 \times 10^{-6}$!!!
- How do we model thermal problem? What physical properties does transport depend on?
- How accurate are the thermal properties extracted from this method?