# Time domain thermoreflectance: 

From Fundamentals to Operational Details


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## 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!

Pump Pulse (~300fs)

(b)

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\text { Y.X. Wang, JAP, } 2010
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$$
\mathrm{c}=3 \times 10^{8} \mathrm{~m} / \mathrm{s}->\quad \mathrm{dx} / \mathrm{c}=\mathrm{dt} \quad, \quad\left(30 \times 10^{-6} \mathrm{~m}\right) /\left(3 \times 10^{8} \mathrm{~m} / \mathrm{s}\right)=100 \times 10^{-15} \mathrm{~s}
$$

## Pro's and Con's of Using TDTR

## Pro's

$\checkmark$ It's non-contact, non-destructive
$\checkmark$ Measures only near top surface ( $\sim 50 \mathrm{~nm}-2$ um)
$\checkmark \quad$ Can measure Kapitza/Interface resistance
$\checkmark$ Fast/simple sample preparation
$\checkmark$ Fast experiments (10 samples/hr)
$\checkmark$ 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)
$\square$ Measures only near top surface
- Capital Expenses are fairly high ( $\sim 200 \mathrm{k} \$$ )
$\square$ 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~1×10-4 $/ \mathrm{K}$
- So for $\mathrm{dT}^{\sim} 1 \mathrm{~K} \rightarrow \mathrm{dR} \sim 1 \times 10^{-4}$
- But I don't just want to be able to detect it, I need to measure with it
- actually need to detect $\mathrm{dR} \sim 1 \times 10^{-4} / 100 \sim 1 \times 10^{-6}$ !!!
- How do we model thermal problem? What physical properties does transport depend on?
- How accurate are the thermal properties extracted from this method?

