Pump-probe thermoreflectance: then and now

Patrick E. Hopkins
Co-Founder, Laser Thermal
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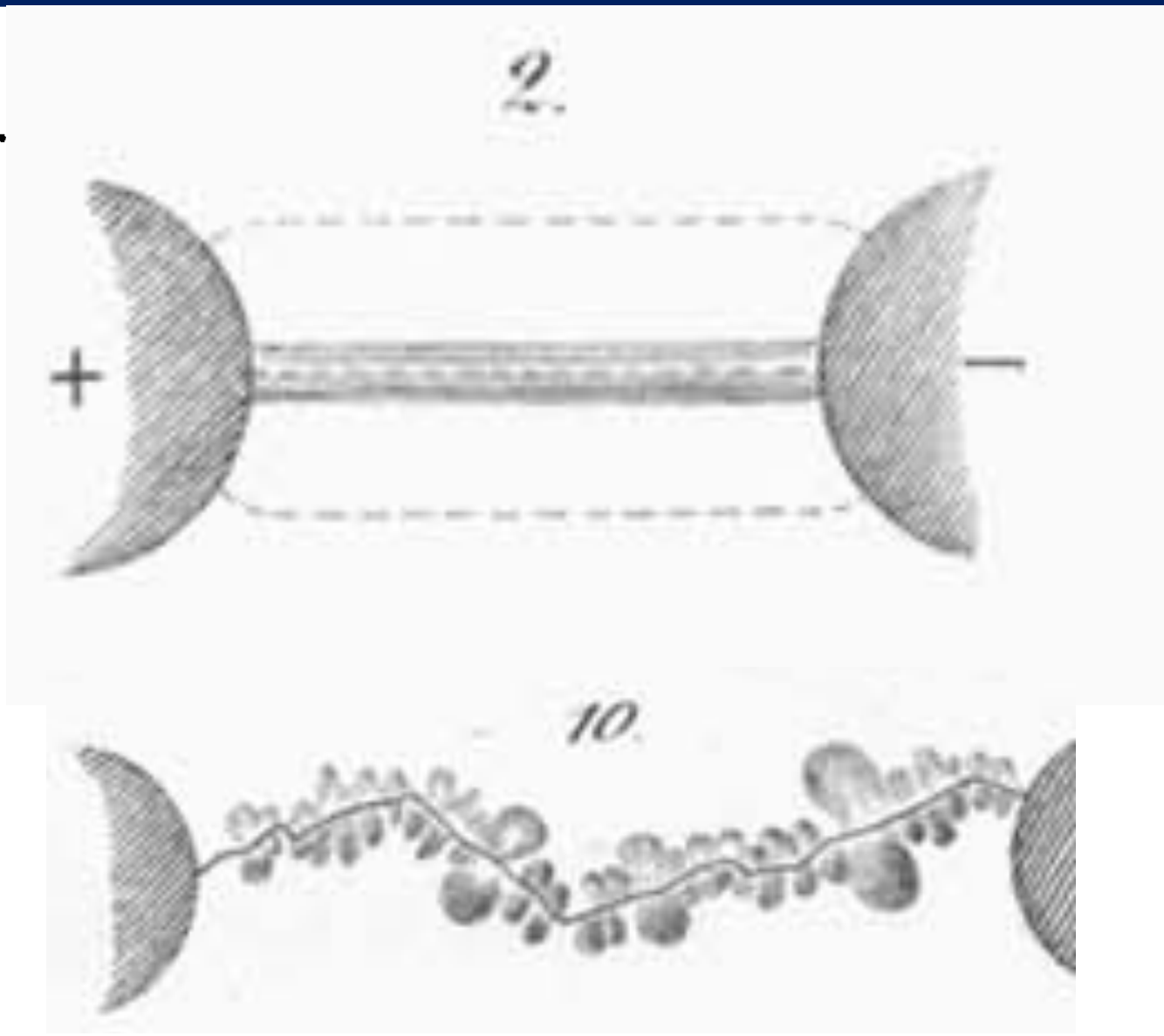
The beginning: Transient light sparks

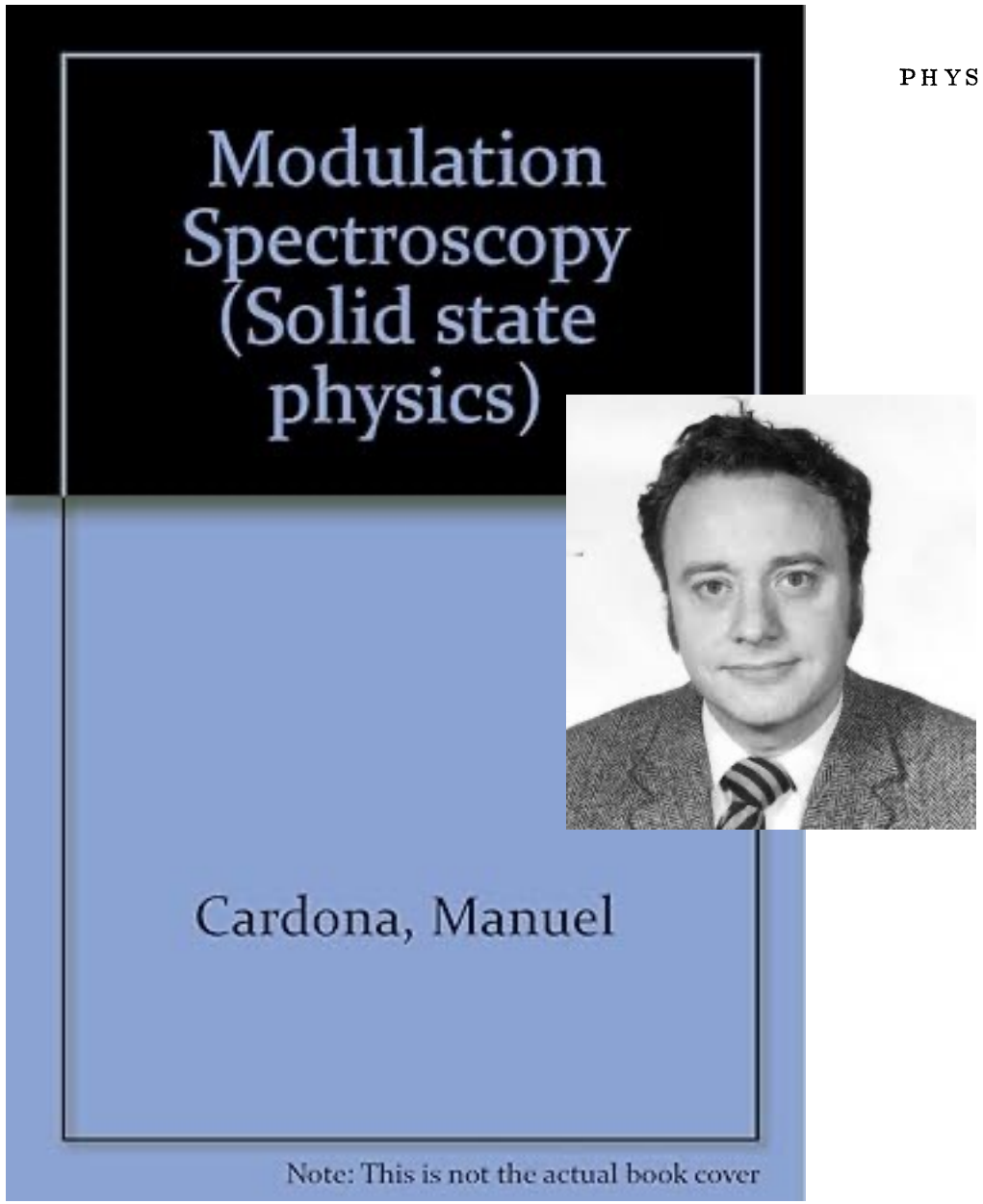
II. *Optische Studien nach der Methode der Schlierenbeobachtung;*
von A. Töpler.

(Fortsetzung von Bd. 131, S. 215.)



- “Pump” light sparks of less than 2 microseconds
- Observe transient changes in refractive index of liquids

Thermomodulation spectroscopy and thermoreflectance



PHYSICAL REVIEW B VOLUME 5, NUMBER 10 15 MAY 1972

Thermomodulation Spectra of Al, Au, and Cu†

R. Rosei* and D. W. Lynch
Institute for Atomic Research and Department of Physics, Iowa State University, Ames, Iowa 50010
(Received 10 January 1972)

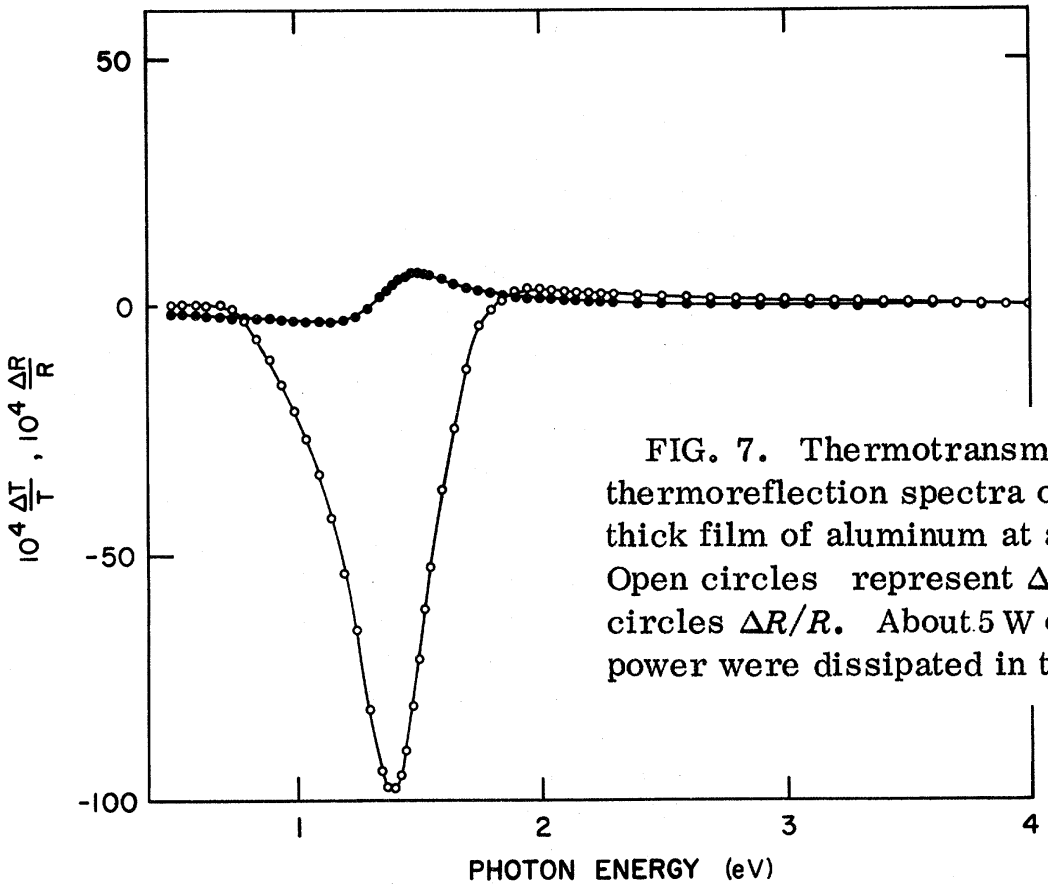


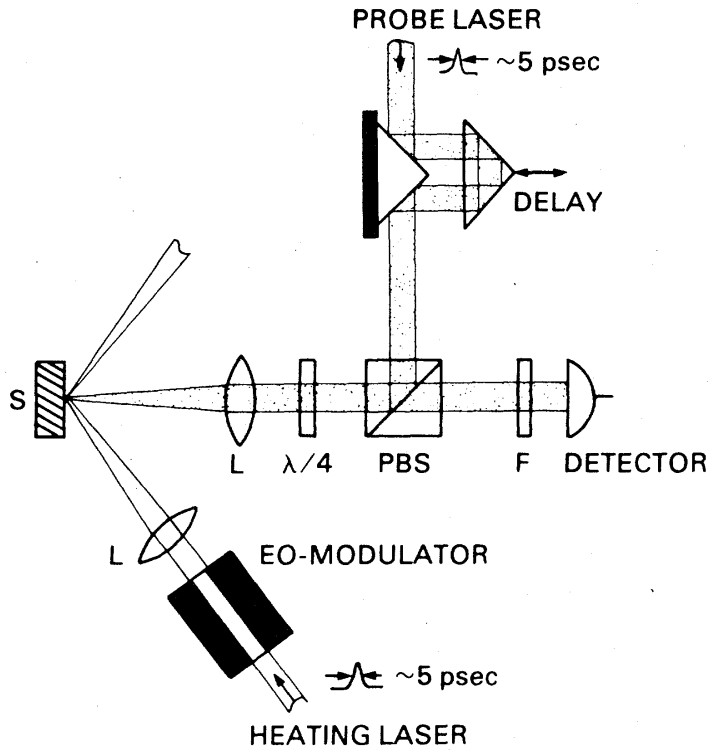
FIG. 7. Thermotransmission and thermoreflection spectra of a 310-Å-thick film of aluminum at about 370 K. Open circles represent $\Delta T/T$ and closed circles $\Delta R/R$. About 5 W of modulating power were dissipated in the sample.

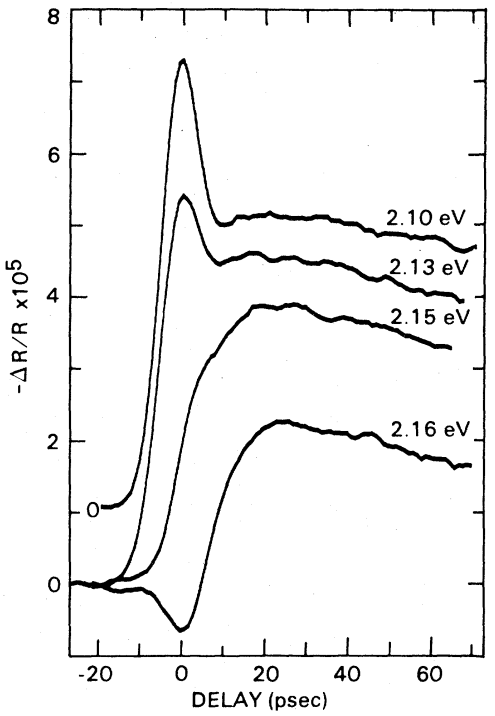
“Modulate power with laser”: Pump-probe

VOLUME 51, NUMBER 23 PHYSICAL REVIEW LETTERS 5 DECEMBER 1983

Observation of Nonequilibrium Electron Heating in Copper

G. L. Eesley
Physics Department, General Motors Research Laboratories, Warren, Michigan 48090
(Received 26 September 1983)

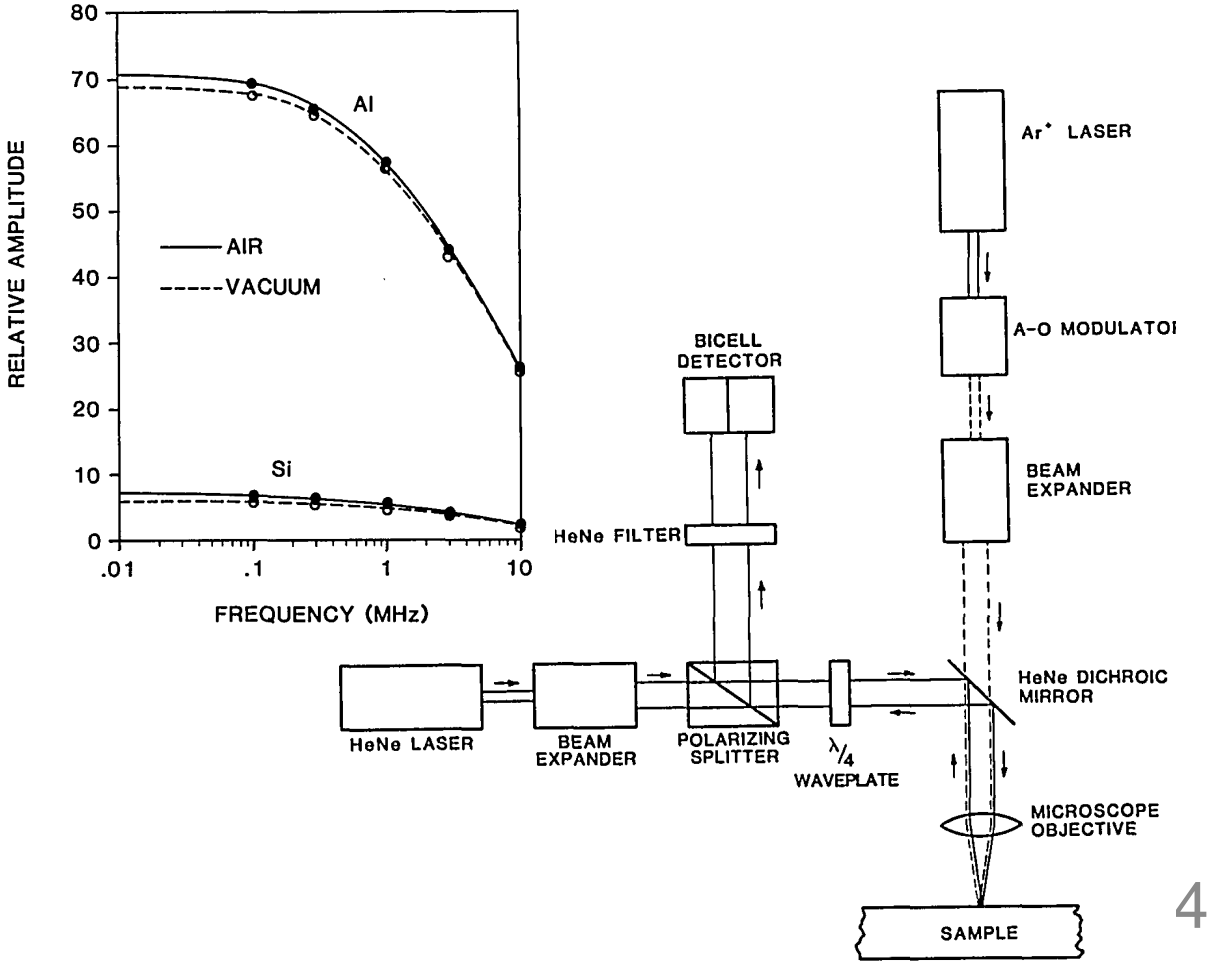




Thermal-wave detection and thin-film thickness measurements with laser beam deflection

15 October 1983 / Vol. 22, No. 20 / APPLIED OPTICS 3169

Jon Opsal, Allan Rosencwaig, and David L. Willenborg



TDTR by Cahill:
Simplifying, standardizing & embracing out of phase signals

Thermometry and Thermal Transport in Micro/Nanoscale Solid-State Devices and Structures

Journal of Heat Transfer

APRIL 2002, Vol. 124 / **223**

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Department of Mechanical Engineering,
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Stanford, CA 94305

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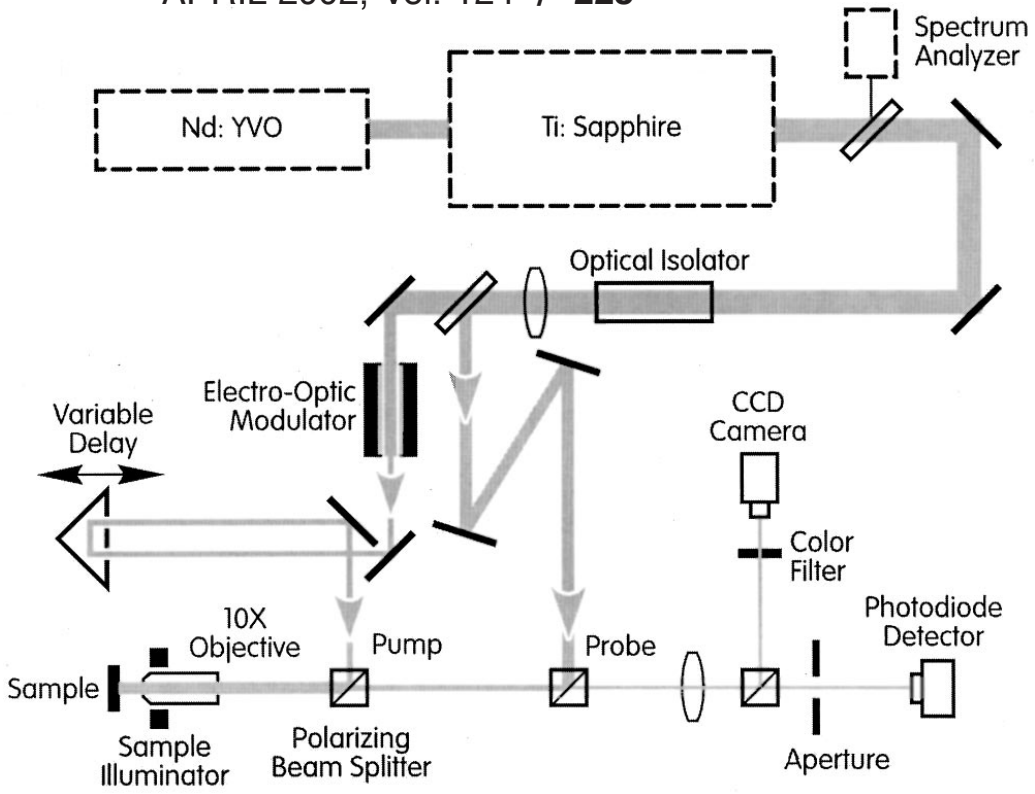
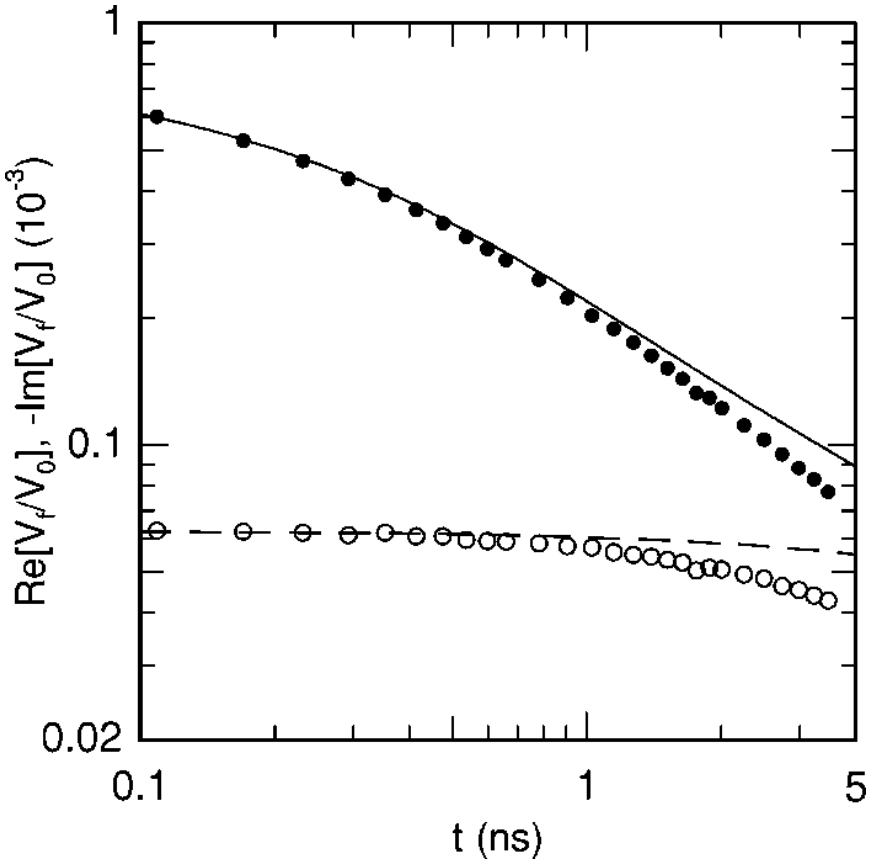
REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 75, NUMBER 12 DECEMBER 2004

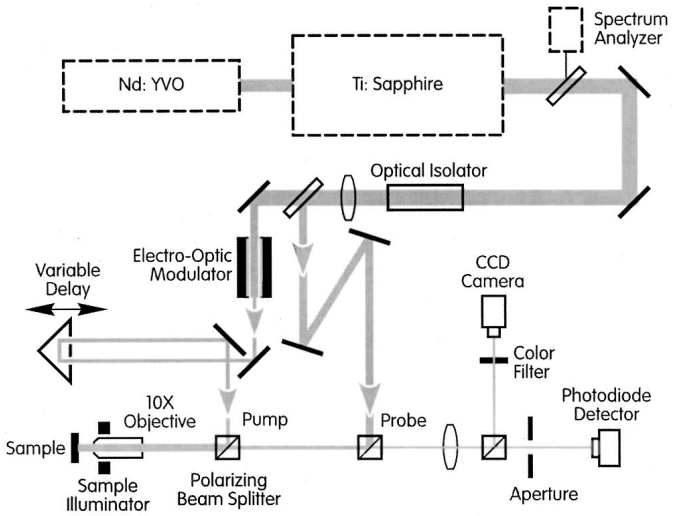
Analysis of heat flow in layered structures for time-domain thermoreflectance

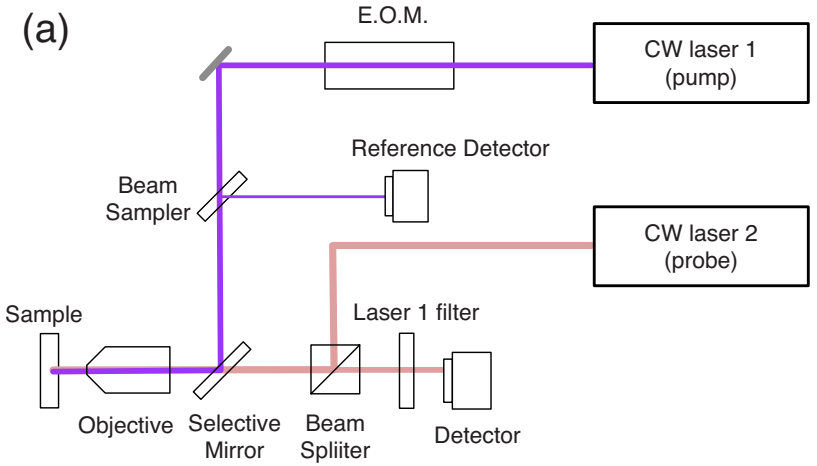
David G. Cahill[a)]
Department of Materials Science and Engineering and Frederick Seitz Materials Research Laboratory, University of Illinois, Urbana, Illinois 61801

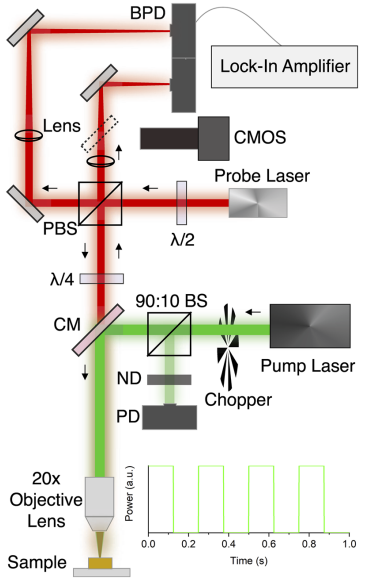


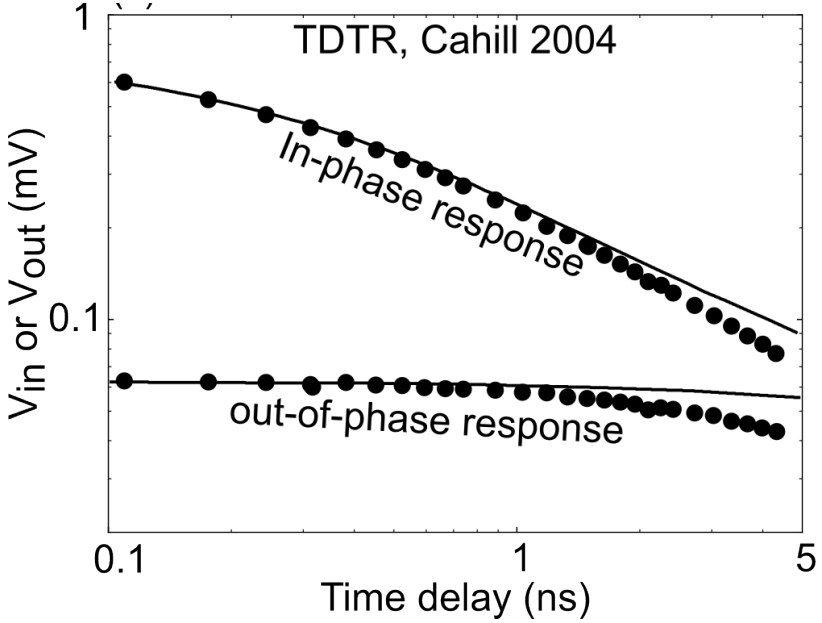


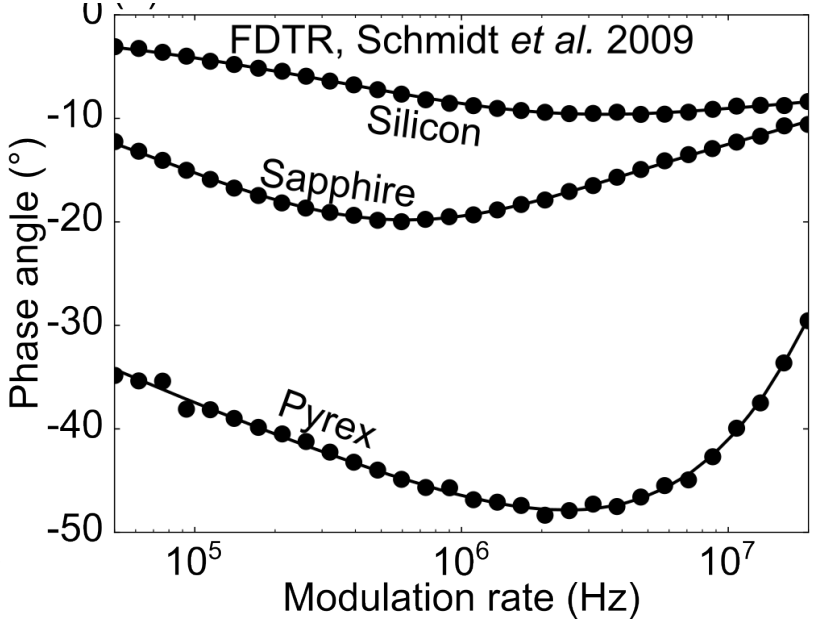
The “basic flavors” of thermoreflectance

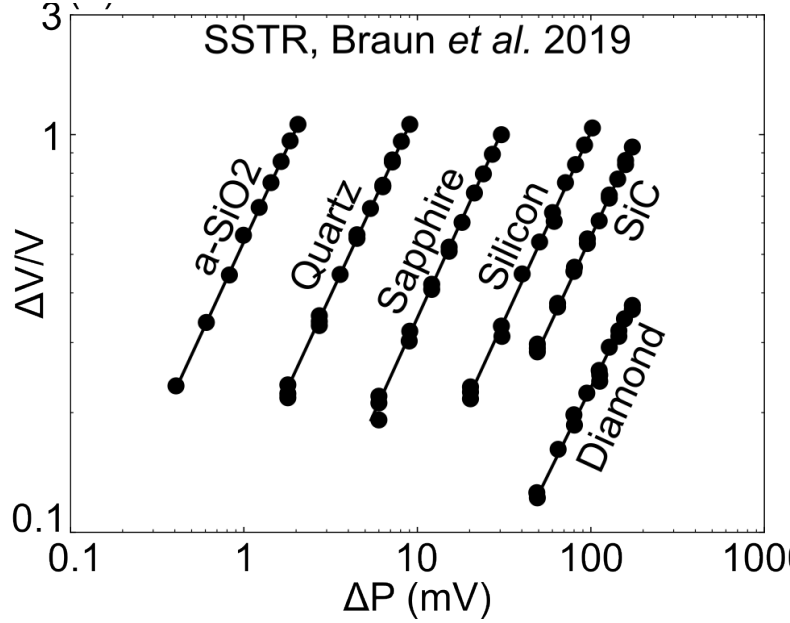












Some “how to” papers

TDTR

JOURNAL OF APPLIED PHYSICS **124**, 161103 (2018)

Tutorial: Time-domain thermoreflectance (TDTR) for thermal property characterization of bulk and thin film materials

Puqing Jiang, Xin Qian, and Ronggui Yang[a)]
Department of Mechanical Engineering, University of Colorado, Boulder, Colorado 80309, USA

nature reviews methods primers
https://doi.org/10.1038/s43586-025-00425-8

Primer

Check for updates

Time-domain thermoreflectance

Ramya Mohan[1,6], Samreen Khan[2,6], Richard B. Wilson[2,3] & Patrick E. Hopkins[1,4,5]

FDTR

An instrumentation guide to measuring thermal conductivity using frequency domain thermoreflectance (FDTR)

Cite as: Rev. Sci. Instrum. **95**, 103006 (2024); doi: 10.1063/5.0213738
Submitted: 12 April 2024 • Accepted: 19 September 2024 •
Published Online: 14 October 2024

View Online Export Citation CrossMark

Dylan J. Kirsch,[1,2,a)] Joshua Martin,[1,b)] Ronald Warzoha,[3,c)] Mark McLean,[1,d)] Donald Windover,[1,e)] and Ichiro Takeuchi[2,f)]

SSTR

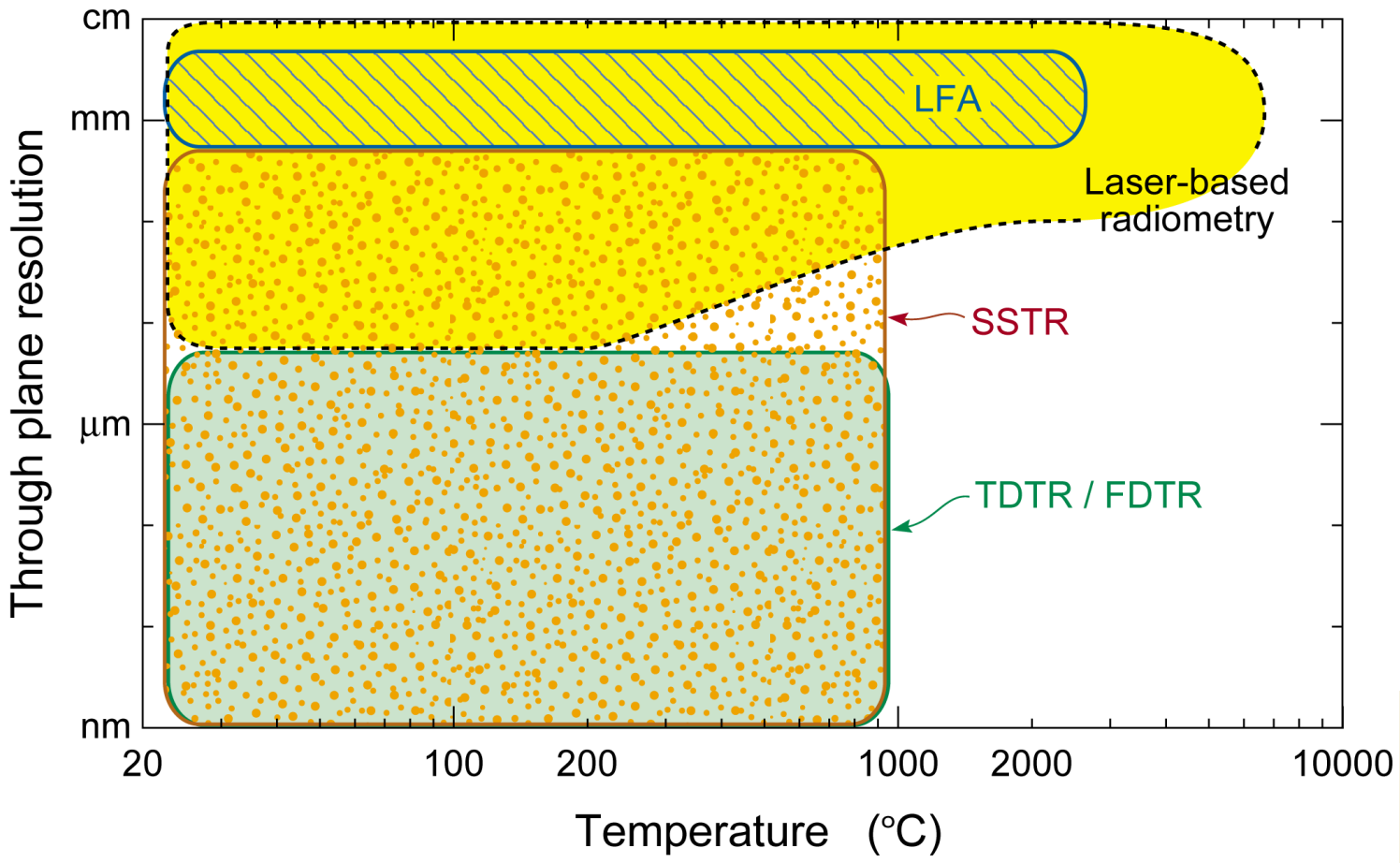
the transducer. A commercial fiber-based SSTR (SSTR-F) has now been developed while turnkey FDTR or TDTR instruments do not yet exist.

Quote from paper

LASER THERMAL

COI Statement: Hopkins’ co-founder of LT

But what about the limitations? And tips and tricks?



ANNUAL REVIEWS

Annual Review of Materials Research

Limitations and Advances in Optical Thermal Transport Measurements: Extremes in Properties, Length Scales, and Temperature

Thomas W. Pfeifer,[1,*] Hunter B. Schonfeld,[1,*] Ethan A. Scott,[1] Henry T. Aller,[2] John T. Gaskins,[3] David H. Olson,[3] Jeffrey L. Braun,[3] Samuel Graham,[2] and Patrick E. Hopkins[1,3,4,5]

[1]Department of Mechanical and Aerospace Engineering, University of Virginia, Charlottesville, Virginia, USA

[2]Department of Mechanical Engineering, University of Maryland, College Park, Maryland, USA

[3]Laser Thermal, Charlottesville, Virginia, USA

[4]Department of Physics, University of Virginia, Charlottesville, Virginia, USA

[5]Department of Materials Science and Engineering, University of Virginia, Charlottesville, Virginia, USA; email: phopkins@virginia.edu

Annu. Rev. Mater. Res. 2025. 55:37–70

First published as a Review in Advance on April 21, 2025

The *Annual Review of Materials Research* is online at matsci.annualreviews.org

https://doi.org/10.1146/annurev-matsci-080423-010435

Keywords

thermoreflectance, pyrometry, thermal transport, thermal measurements, high temperature, ultrahigh temperature, challenges, thermal conductivity, radiative transport, thermal boundary resistance

Abstract

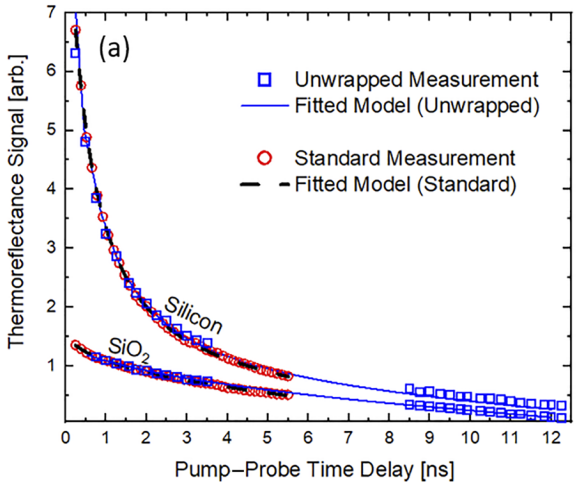
But what about the limitations? And tips and tricks?

Unwrapping a full temporal cycle in time domain thermoreflectance for enhanced measurement sensitivity in thermally insulating materials

Cite as: Rev. Sci. Instrum. 93, 084904 (2022); doi: 10.1063/5.0089075
Submitted: 22 February 2022 • Accepted: 14 July 2022 •
Published Online: 19 August 2022

View Online Export Citation CrossMark

Brian F. Donovan,[1] Taylor L. Gray,[1] Adam A. Wilson,[2] and Ronald J. Warzoha[3]

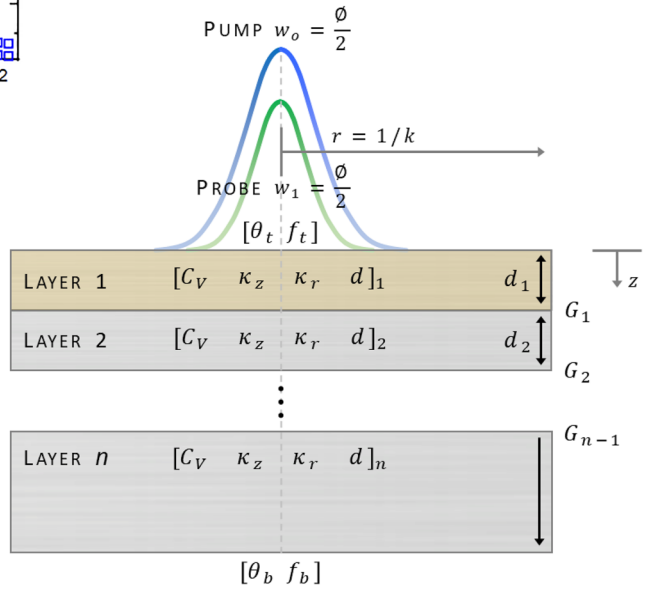


An instrumentation guide to measuring thermal conductivity using frequency domain thermoreflectance (FDTR)

Cite as: Rev. Sci. Instrum. 95, 103006 (2024); doi: 10.1063/5.0213738
Submitted: 12 April 2024 • Accepted: 19 September 2024 •
Published Online: 14 October 2024

View Online Export Citation CrossMark

Dylan J. Kirsch,[1,2,a)] Joshua Martin,[1,b)] Ronald Warzoha,[3,c)] Mark McLean,[1,d)] Donald Windover,[1,e)] and Ichiro Takeuchi[2,f)]

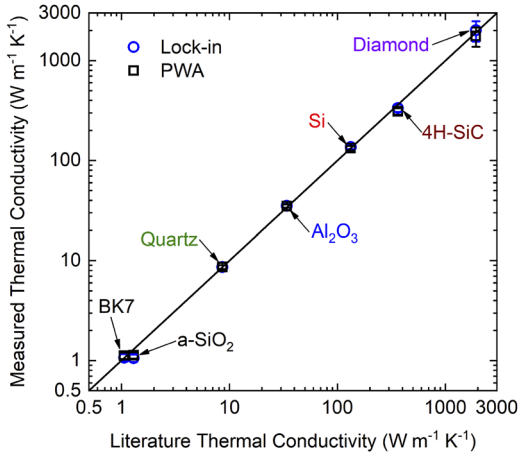


A steady-state thermoreflectance method to measure thermal conductivity

Cite as: Rev. Sci. Instrum. 90, 024905 (2019); doi: 10.1063/1.5056182
Submitted: 12 September 2018 • Accepted: 9 February 2019 •
Published Online: 28 February 2019

View Online

Jeffrey L. Braun,[1] David H. Olson,[1] John T. Gaskins,[1] and Patrick E. Hopkins[1,2,3,a)]



But what about the limitations? And tips and tricks?

ACS APPLIED MATERIALS & INTERFACES

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Research Article

Measurements of Thermal Resistance Across Buried Interfaces with Frequency-Domain Thermoreflectance and Microscale Confinement

Ronald J. Warzoha,* Adam A. Wilson, Brian F. Donovan, Andy Clark, Xuemei Cheng, Lu An, and Gang Feng

Cite This: https://doi.org/10.1021/acsami.4c05258

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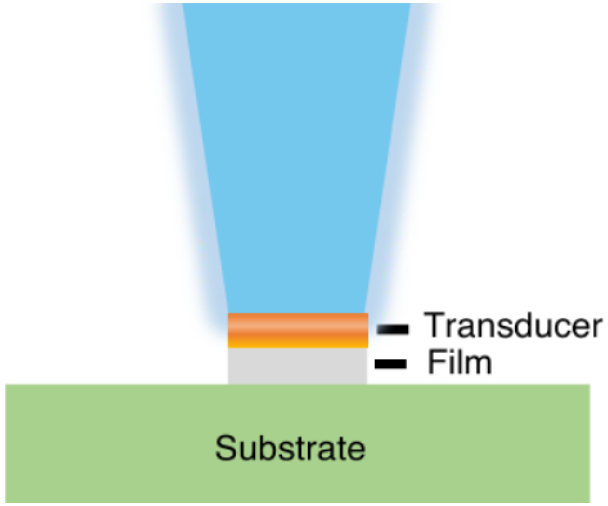

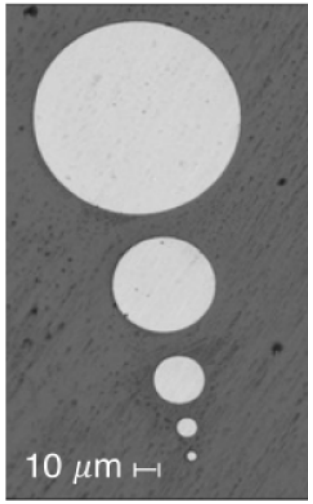

THE JOURNAL OF PHYSICAL CHEMISTRY Letters

Letter

pubs.acs.org/JPCL

Time-Resolved Magneto-Optical Kerr Effect of Magnetic Thin Films for Ultrafast Thermal Characterization

Jun-Yang Chen,† Jie Zhu,‡,§ Delin Zhang,† Dustin M. Lattery,‡ Mo Li,† Jian-Ping Wang,† and Xiaojia Wang*,‡