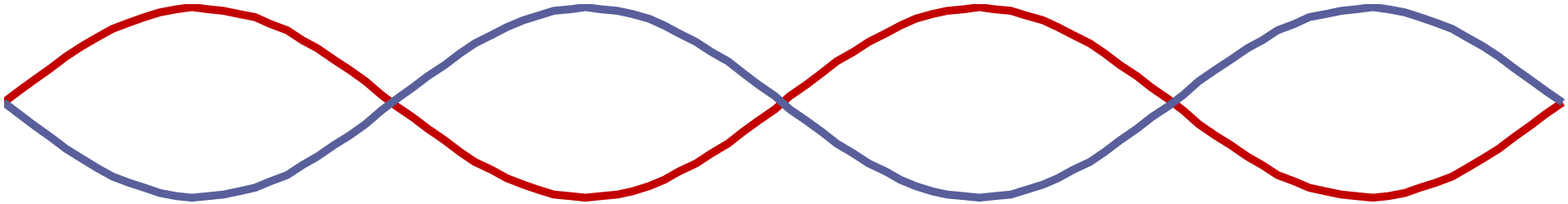
SAND2012-10198C

Measuring Thermal Conductivity with Raman:
Capability, Uncertainty, and Strain Effects

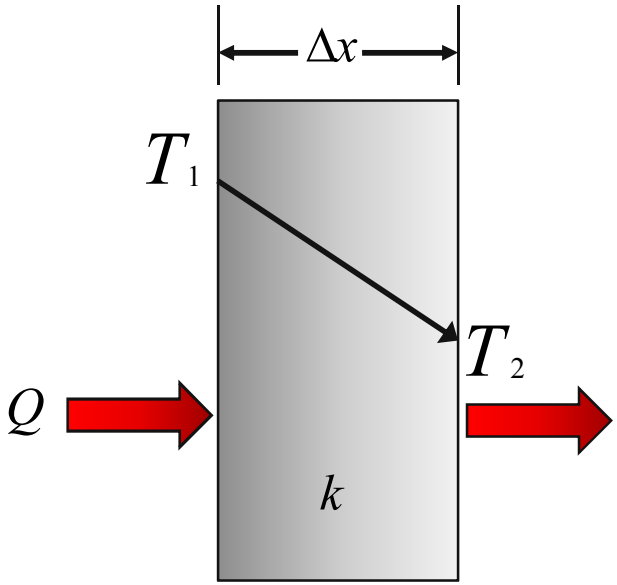


Thomas Beechem and Luke Yates

IMECE 2012

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Quantifying Conductivity

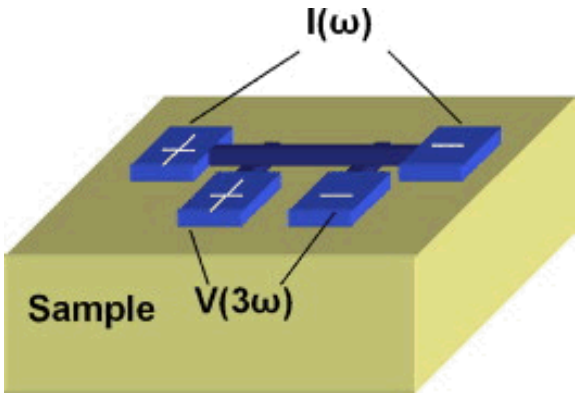


$$k = -Q\left(\frac{\Delta T}{\Delta x}\right)^{-1}$$

Sandia National Laboratories

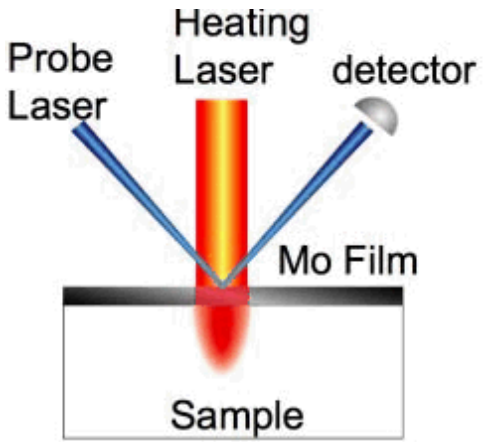
Measuring K in “Small” Materials

3ω Method



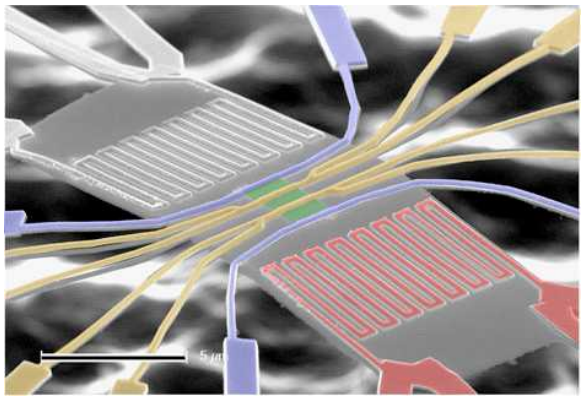
Apanius et al. Sensors & Actuators (140) 168. 2007

TDTR



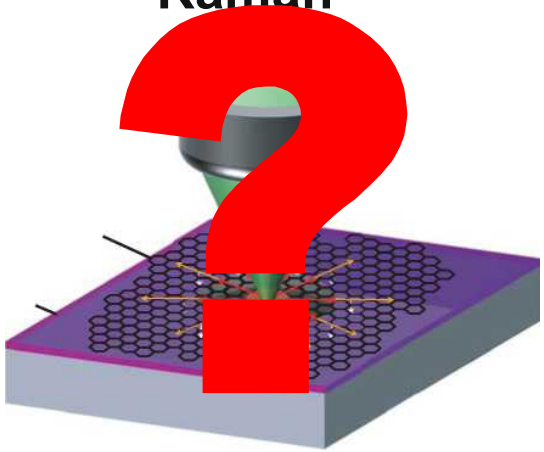
www.nist.gov
(Thermoelectric Measurements)

MEMS Platform



Hochbaum et al. Nature (451) 7175 2008

Raman

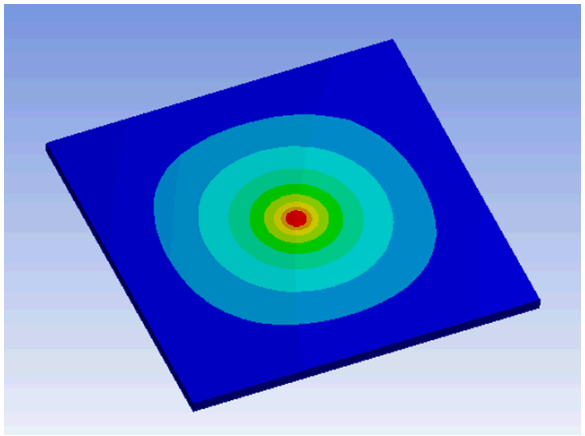


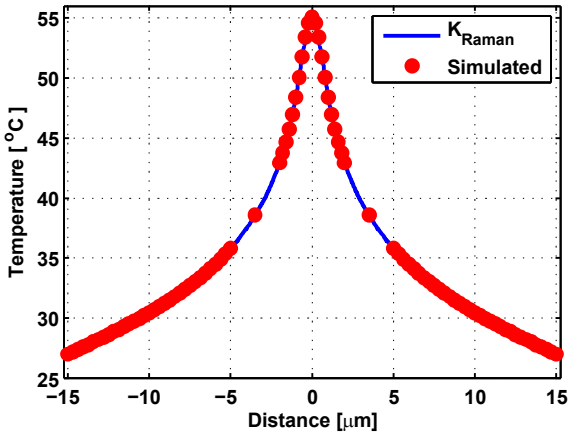
Lee et al. PRB (83) 081419 2011.

Sandia National Laboratories

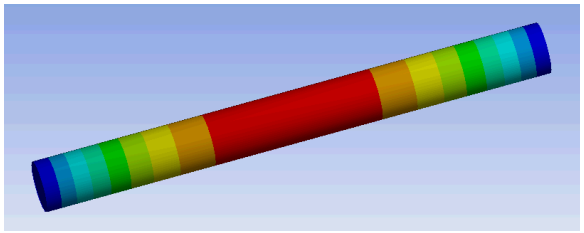
“Measuring” Thermal Conductivity

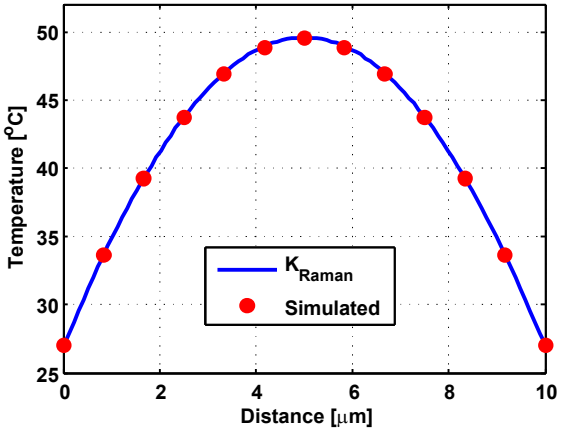
Laser Heating: Chip Geometry





Joule Heating: Rod Geometry





Virtual Experiment (Simulation)

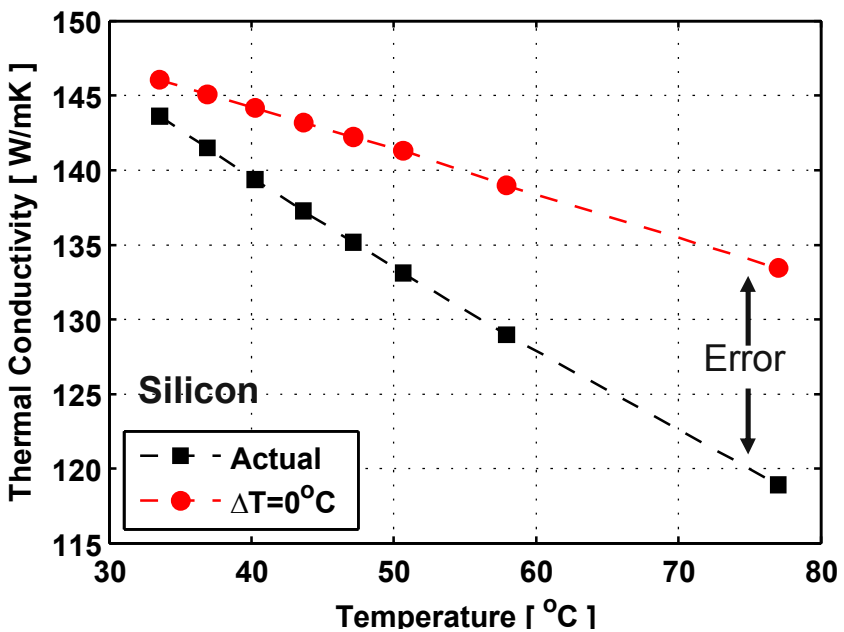
Extract “Measured” Raman Temp. (T_m)

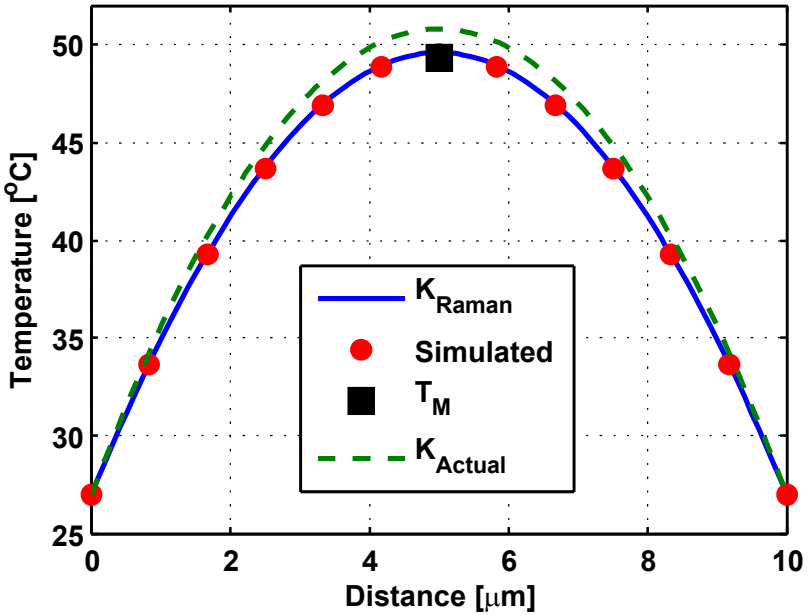
Analytical Model

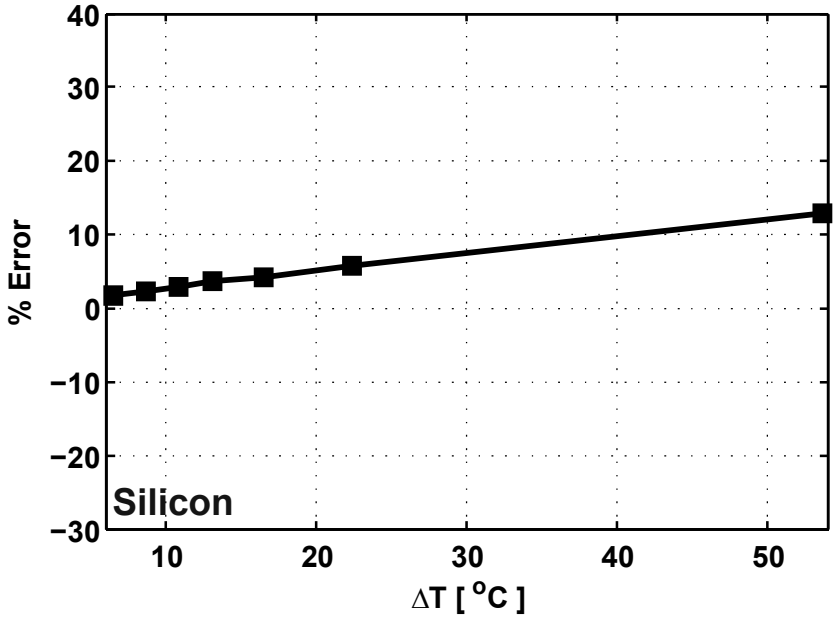
Fit K to get T_m

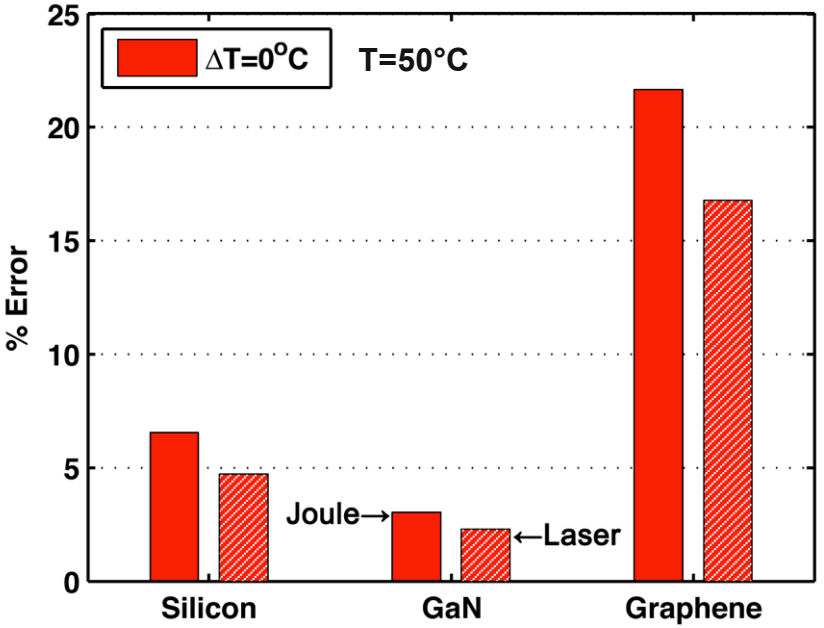
Sandia National Laboratories

How good could it be? Ideal Case

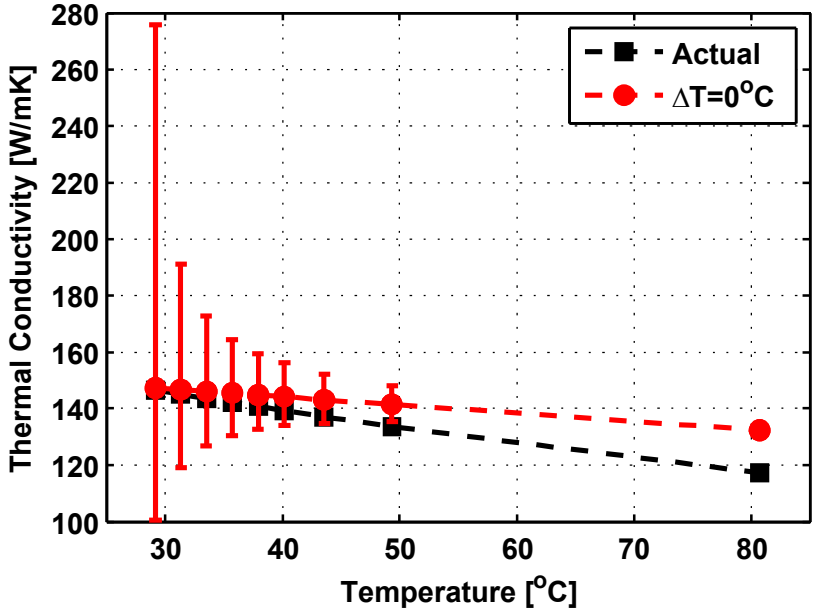


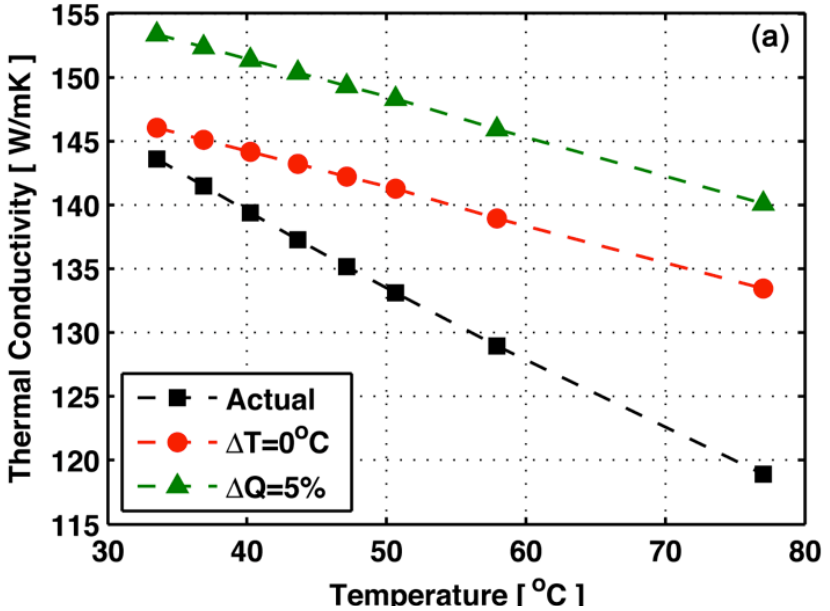


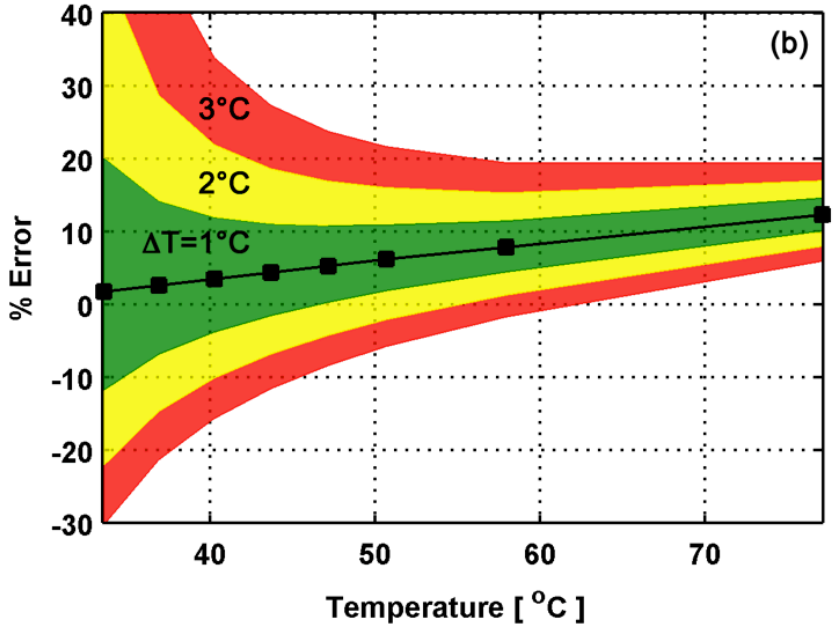


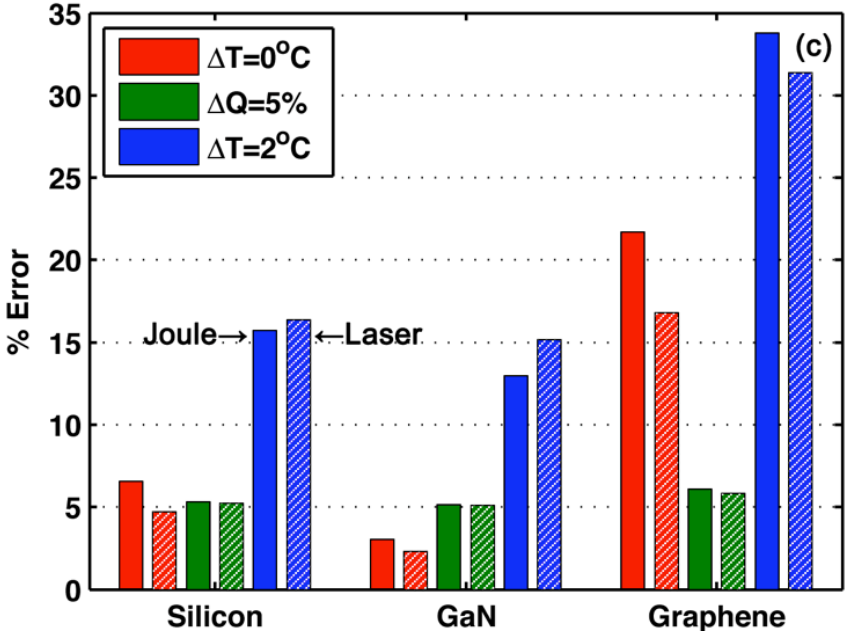


How good is it really? Uncertainty

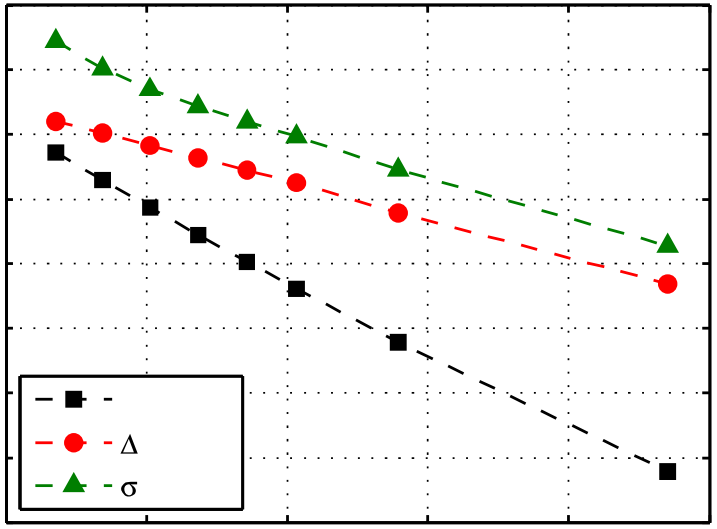


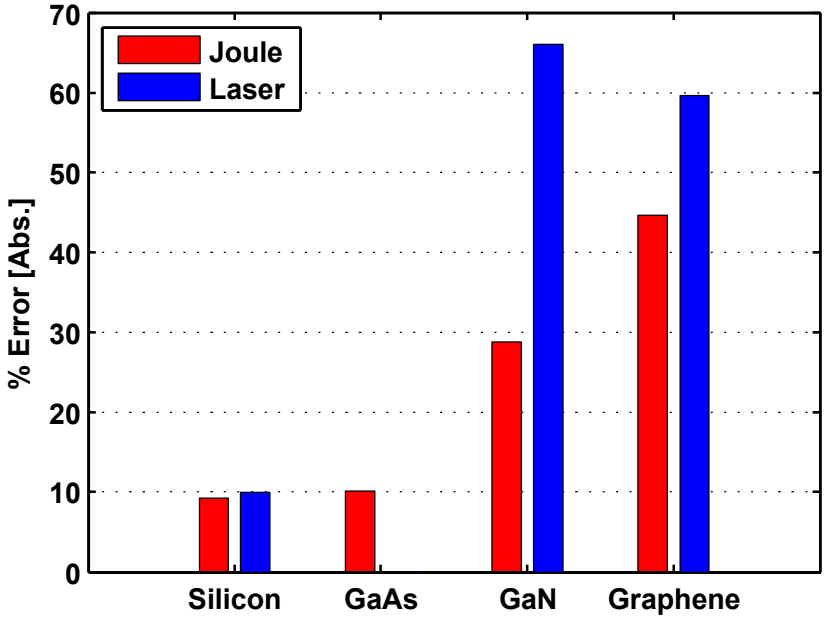




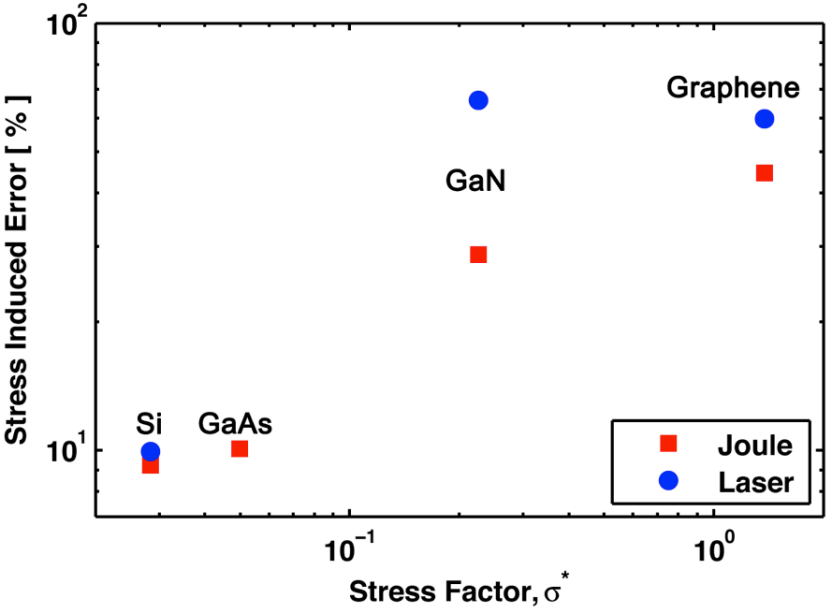


Can we “break” it? Stress

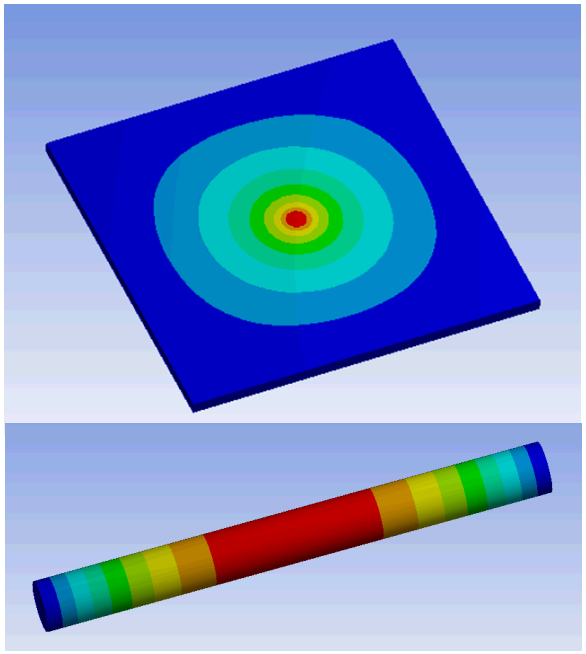


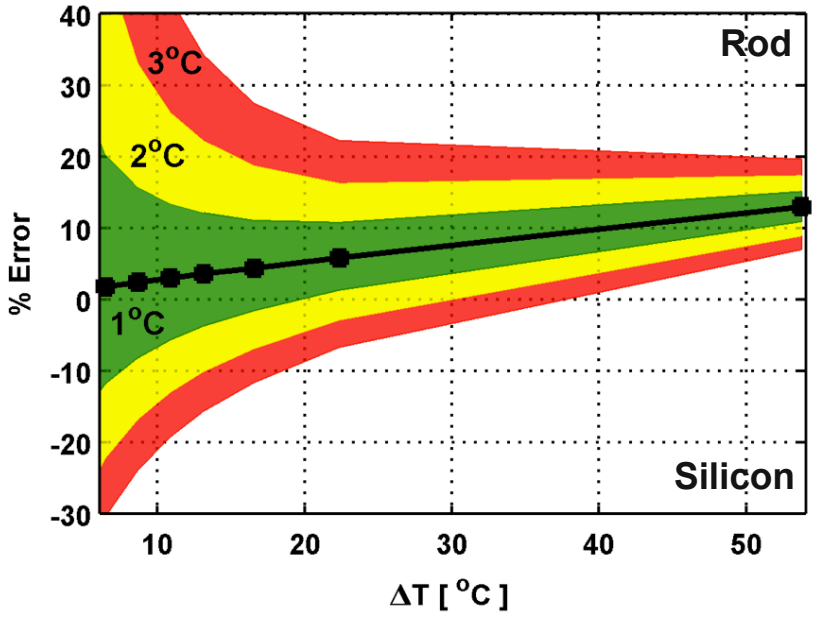


$$\sigma^{*} = \alpha\left[\frac{\varepsilon}{^{\circ}C}\right] E\left[\frac{GPa}{\varepsilon}\right] \bullet \frac{B_{Raman}\left[\frac{cm^{-1}}{GPa}\right]}{A_{Raman}\left[\frac{cm^{-1}}{^{\circ}C}\right]}$$



Takeaways





Bottom Line

Raman is a viable method to measure thermal conductivity.
BUT uncertainty and stress effects require alternative approaches.