Design, Assembly and Commissioning of a Test Apparatus for Characterizing Thermal Interface Materials

J.R. Culham, P. Teertstra, I. Savija and M.M. Yovanovich

Microelectronics Heat Transfer Laboratory
University of Waterloo
Waterloo, Canada N2L 3G1

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Outline

- Motivation
- Background
- Test Procedure
- Design Alternatives
- Test Apparatus
- Summary

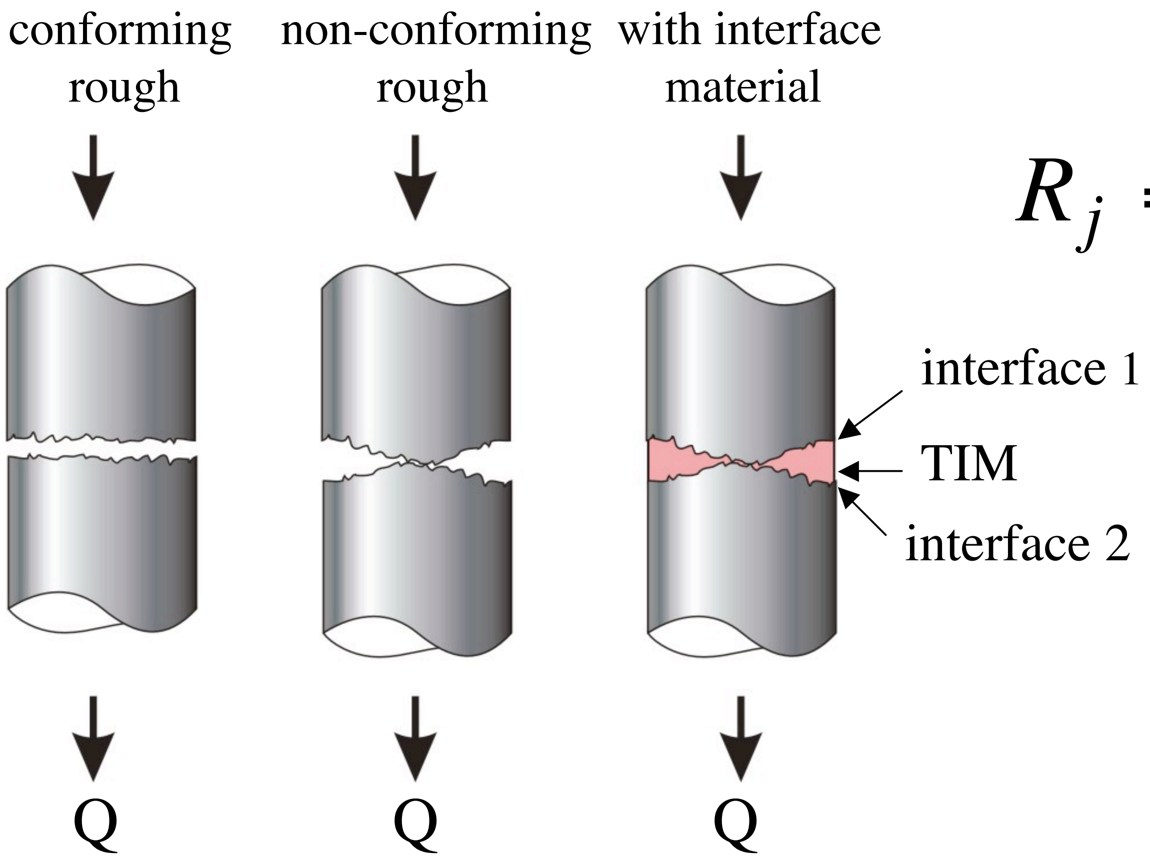
Objectives

- measure resistance and thermal conductivity
  - ✓ grease, compliant polymers, metal foils, graphite, phase change, etc.
  - ✓ interface pressure: 5 - 1000 psi
  - ✓ interface temperature: 0 - 120 ^{o}C
  - ✓ in-situ thickness and resistance versus load

Motivation

- ASTM D 5470
  - ✓ "thin thermally conductive solid electrical insulation materials"
    - thickness range of 0.02 to 10 mm
    - apparent thermal conductivity based on "as-received" thickness
    - interface pressure - 3.0 MPa
    - interface temperature - 50 ^{o}C
    - surface roughness less than 0.4 μm

Thermal Interface

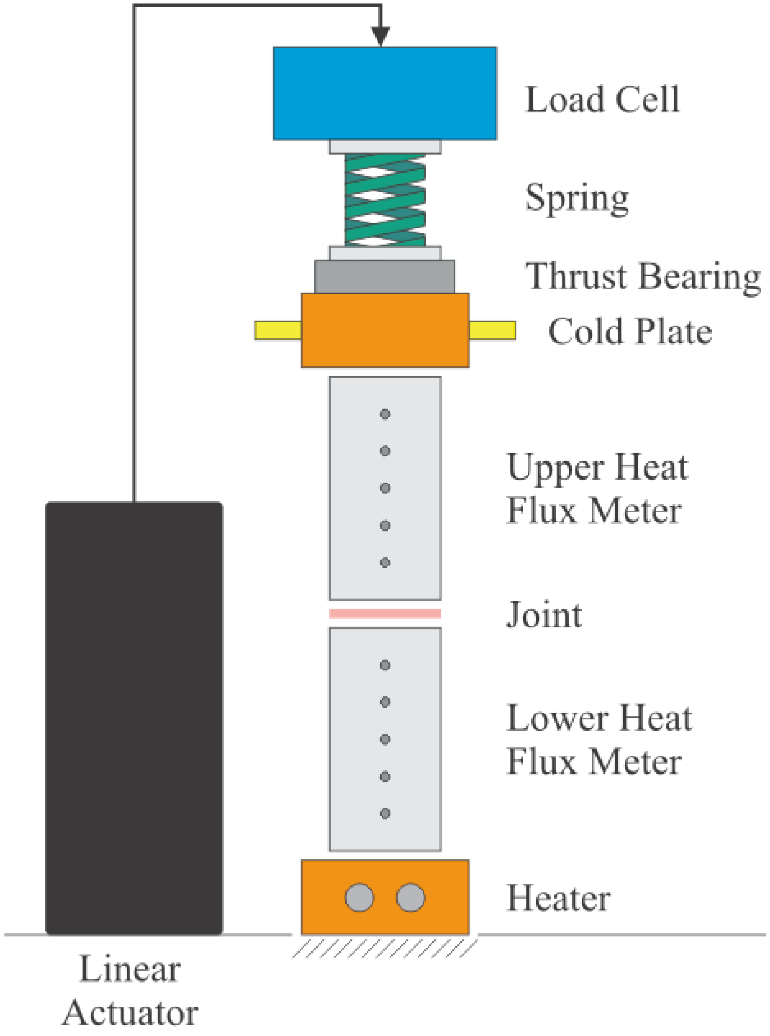


$$R_j = R_{i1} + R_{TIM} + R_{i2}$$

where:

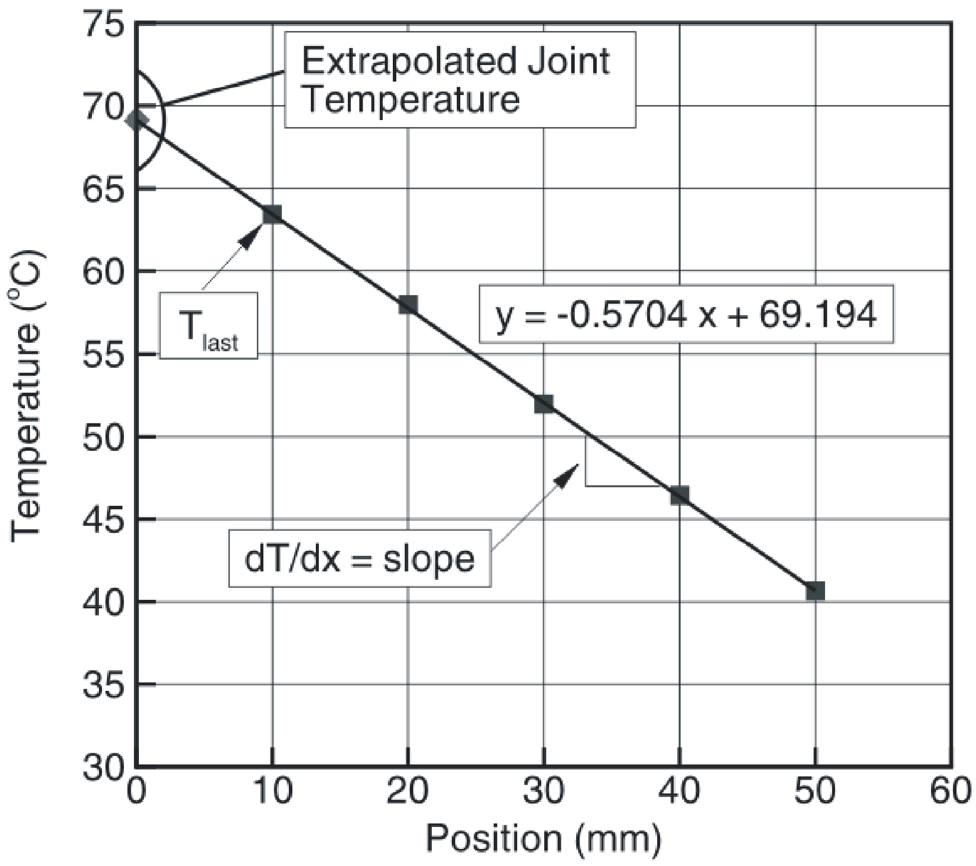
$$R_{TIM} = \left(\frac{t}{k\,A} \right)_{TIM}$$

Test Procedure



- for an applied axial load
  - ✓ establish desired interface temperature with resistance heaters
  - ✓ minimize heat losses using a vacuum environment
  - ✓ establish steady-state in 5 upper & lower temperature sensors
  - ✓ record & reduce temperature data to determine interface temperature rise and heat flow rate

Data Analysis



- Using a linear least squares fit
  - ✓ curve fit temperature data for upper & lower heat flux meter
  - ✓ slope gives temperature gradient
  - ✓ extrapolate to get interface temperatures
  - ✓ knowing the thermal conductivity of the flux meters, calculate heat flow rate
  - ✓ then, $R_i = \Delta T_i / Q$

Temperature Measurement Alternatives

	Thermocouple	**Platinum RTD**	**Semiconductor**	**Thermistor**
Sensor	thermo electric	film resistor	semiconductor	ceramic
Accuracy	0.5 ºC	0.1 ºC	0.5 ºC	0.05 ºC
Stability	prone to aging	0.05 ºC/year	1.0 ºC/year	0.02-0.2 ºC/year
Linearity	non-linear	linear	linear	exponential
Response Time	0.1 – 10 sec.	1 – 50 sec.	5 – 50 sec.	0.5 – 10 sec.
Cost	low	high	moderate	moderate

Thermal Conductivity Measurement

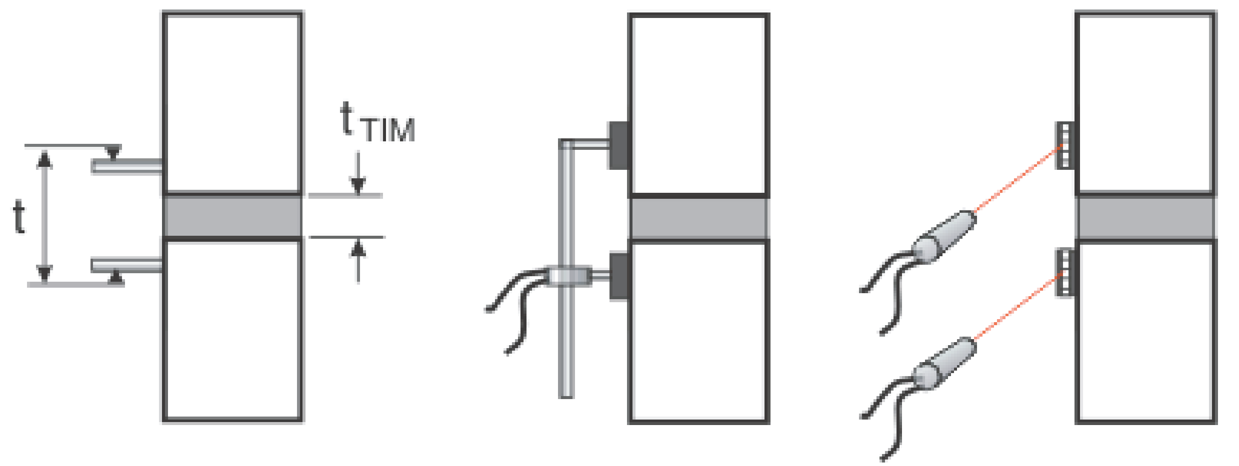
- interface material thermal conductivity:

$$k_{TIM} = \frac{Q}{\Delta T_{TIM}} \frac{t_{TIM}}{A_{TIM}}$$

- ASTM D 5470 recommends using the "as-received" thickness
- material deformation during testing
  - ✓ loading
  - ✓ thermal expansion
- in-situ thickness measurement is required

In-situ Thickness Measurement Alternatives

$t_{TIM} = t - t_{start}$



a) direct measurement

b) LVDT

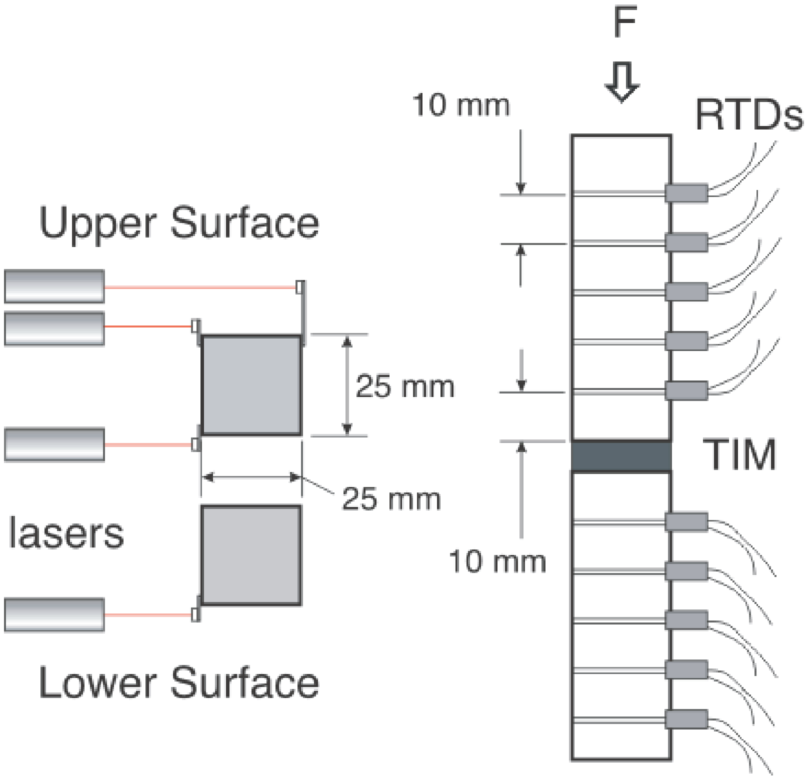
c) laser / detector

-dial gauge or micrometer
-measurement resolution: 100 μm
- cannot be used in vacuum

-linear variable differential transformer
-measurement resolution: 0.5 μm
-physical limitations

-5 mW laser
-6x1 mm detector (1 gram)
-Measurement resolution: 0.75 μm

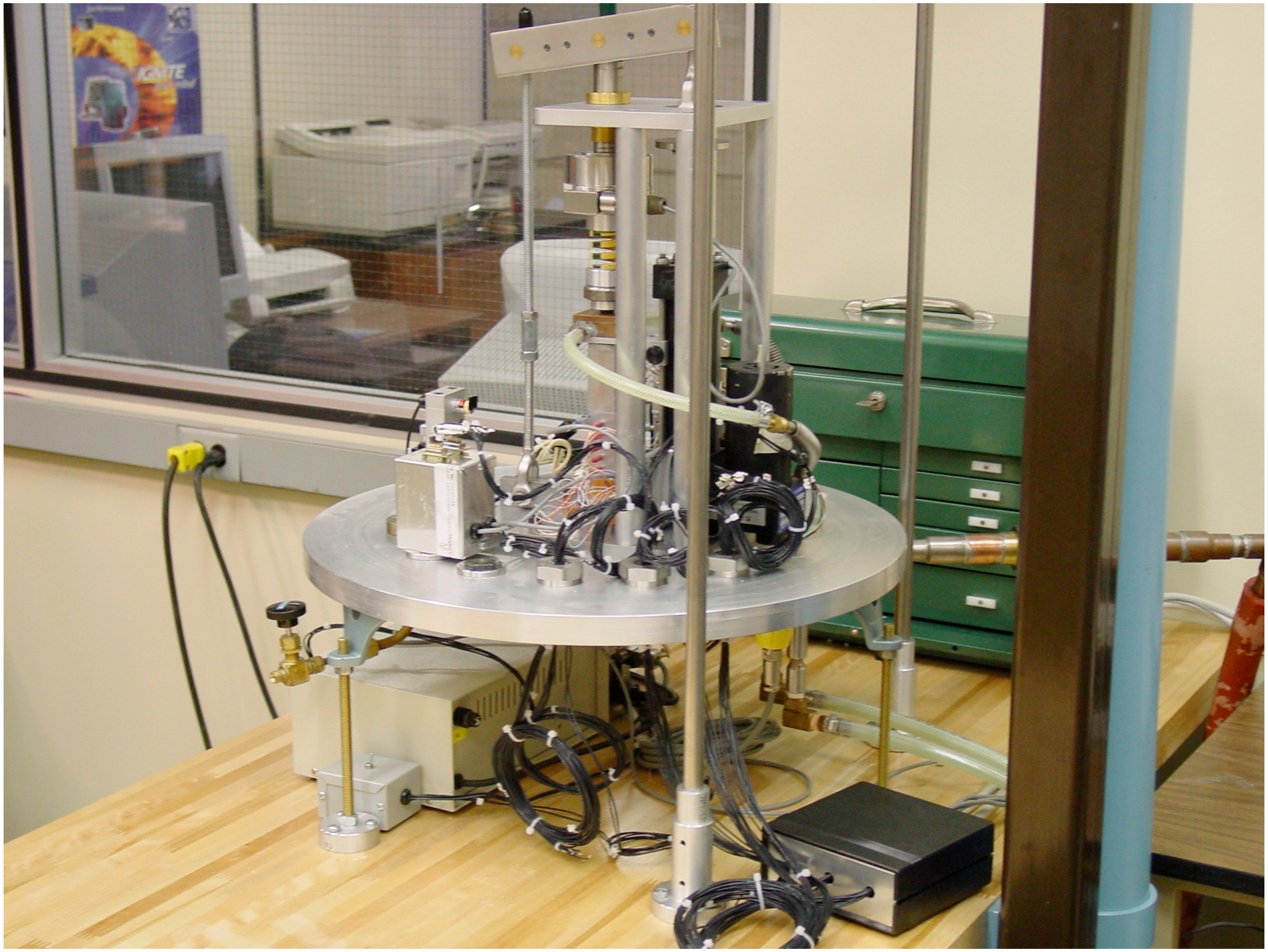
In-situ Thickness Measurement Alternatives

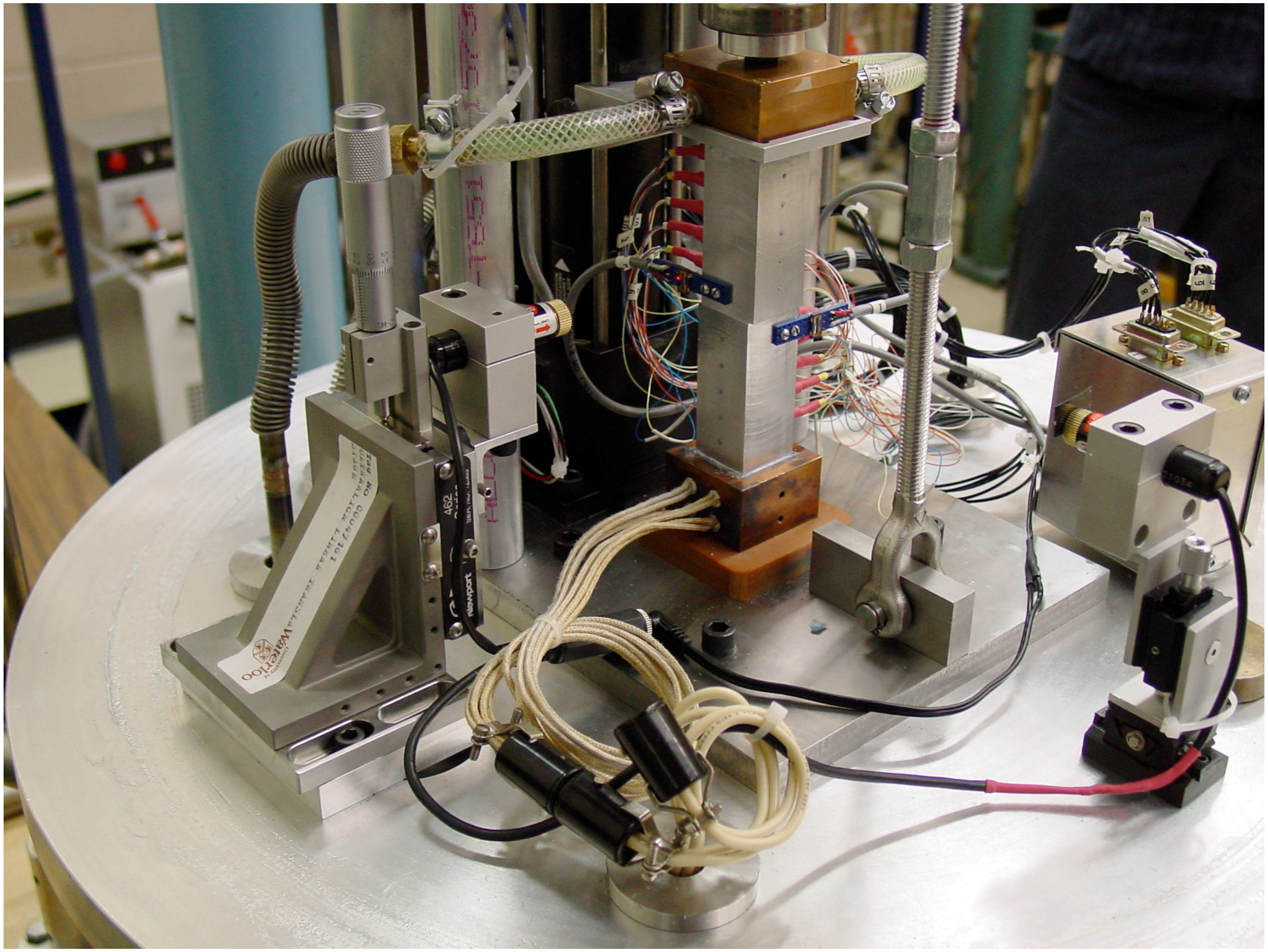


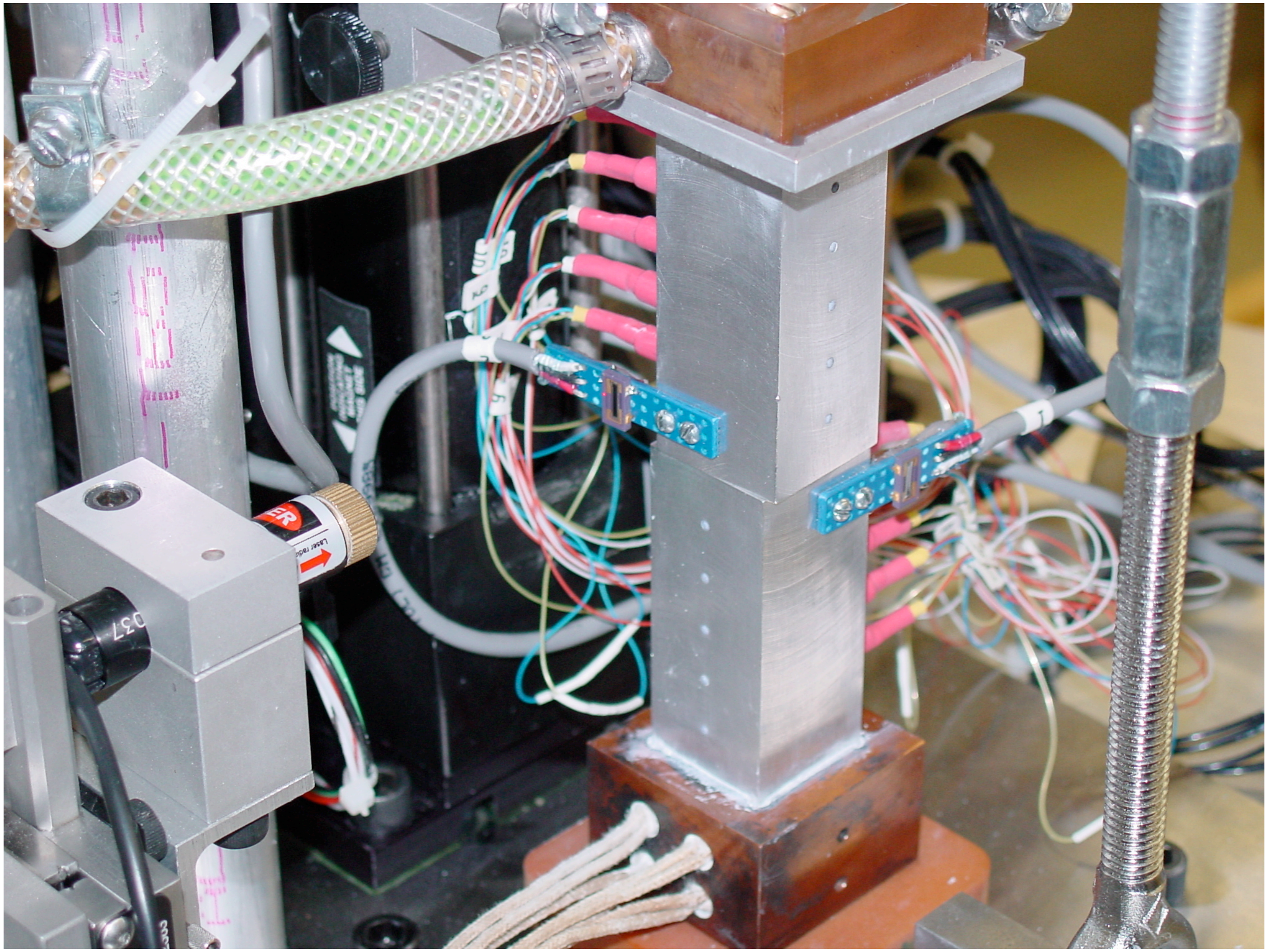
- 2 laser system
  - ✓ relative displacement
- 4 laser system
  - ✓ relative displacement
  - ✓ out-of-flatness

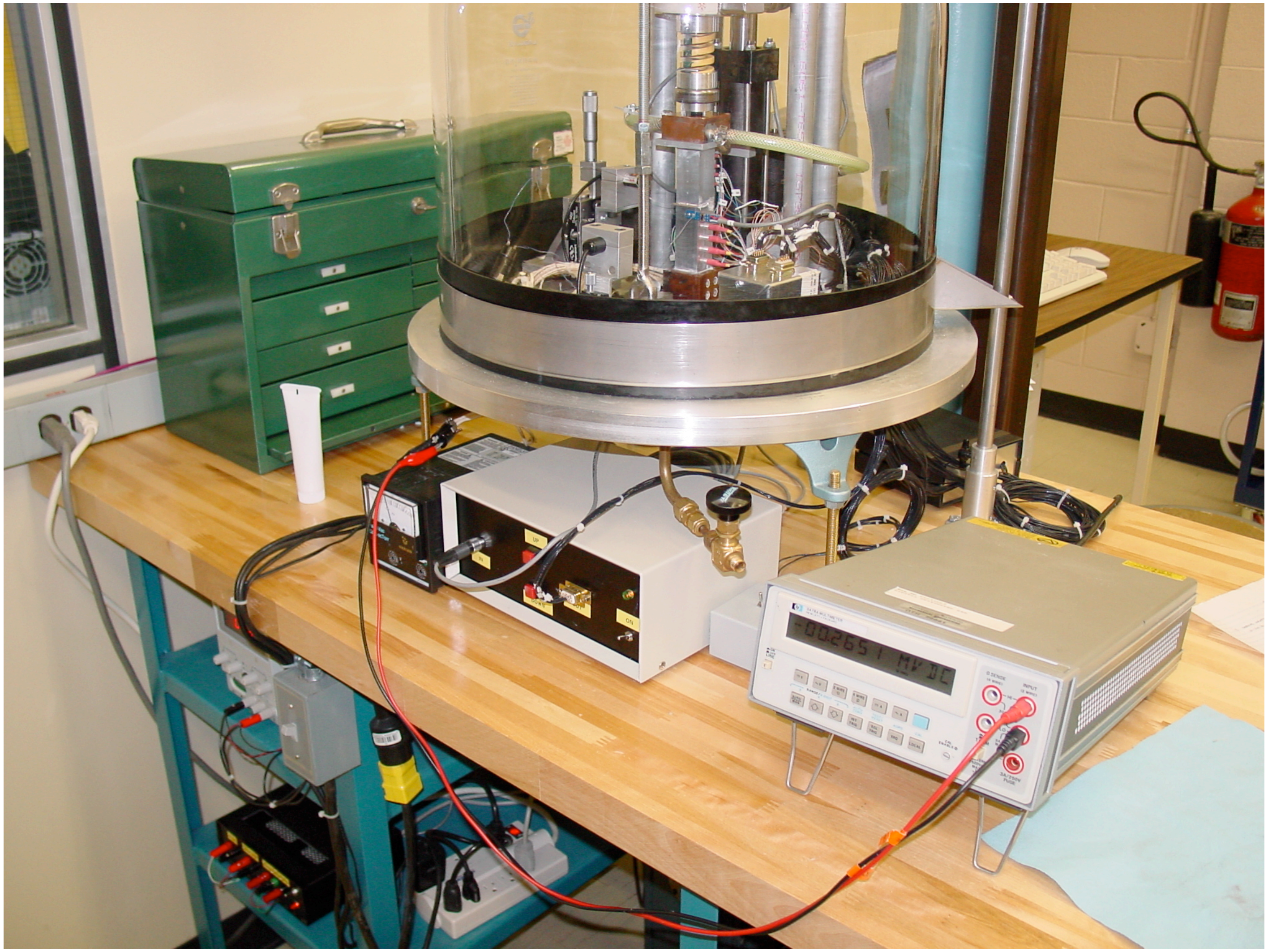
Test Apparatus

- load range: up to 1000 psi (7 MPa)
- interface temperature: -10 °C to 150 °C
- vacuum pressure: 10^{-4} torr
- data collection rate: 0.1 seconds









Cost

- Test Column - $3,700
- Vacuum System - $5,400
- Data Acquisition - $3,800
- In-situ Thickness Measurement - $3,800
- Miscellaneous - $7,100
- Total - $23,800

Summary

- Thermal interface test apparatus designed and built:
    - ✓ in-situ thickness measurement with sub-micron precision
    - ✓ overall energy balance to within ±2%
    - ✓ thermal resistance and thermal conductivity measurements to within ±3%

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