QFI

Quantum Focus
Instruments Corporation

High Resolution Raman Temperature Measurements

Presented by

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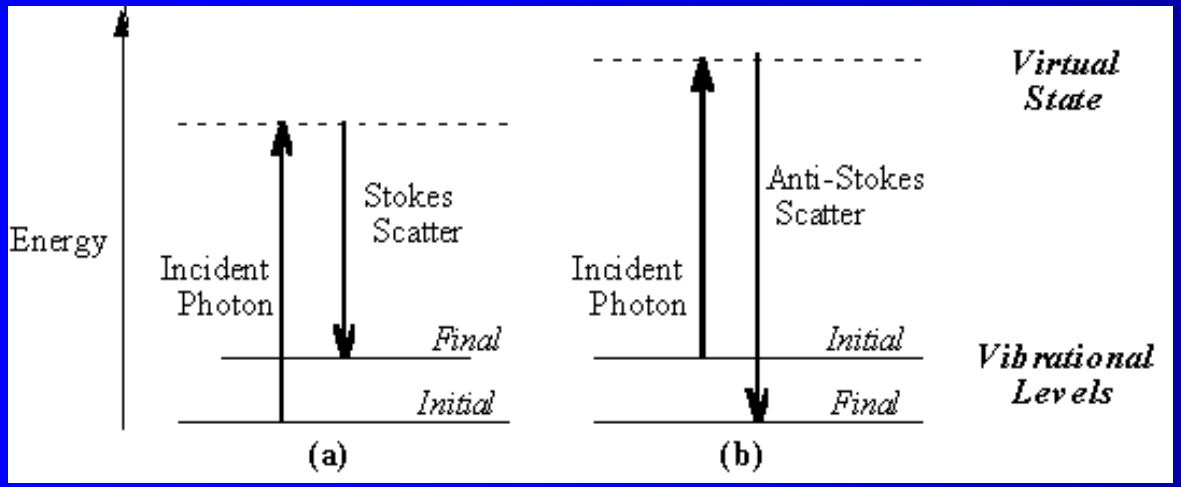
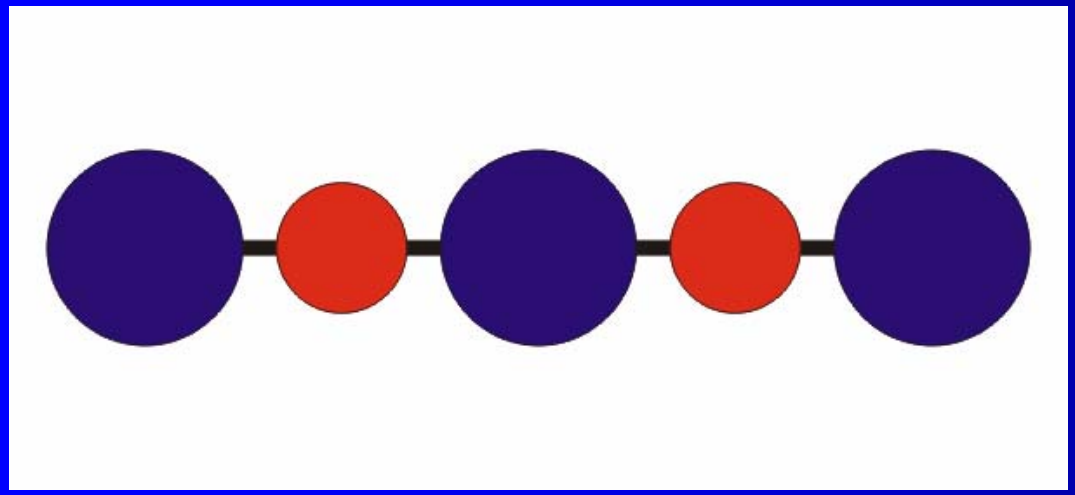
Introduction

- What is Raman Temperature Probe?
- What is Raman Temperature Probe value to IC fabrication?
- QFI Raman Temperature Probe capability

Raman Spectroscopy





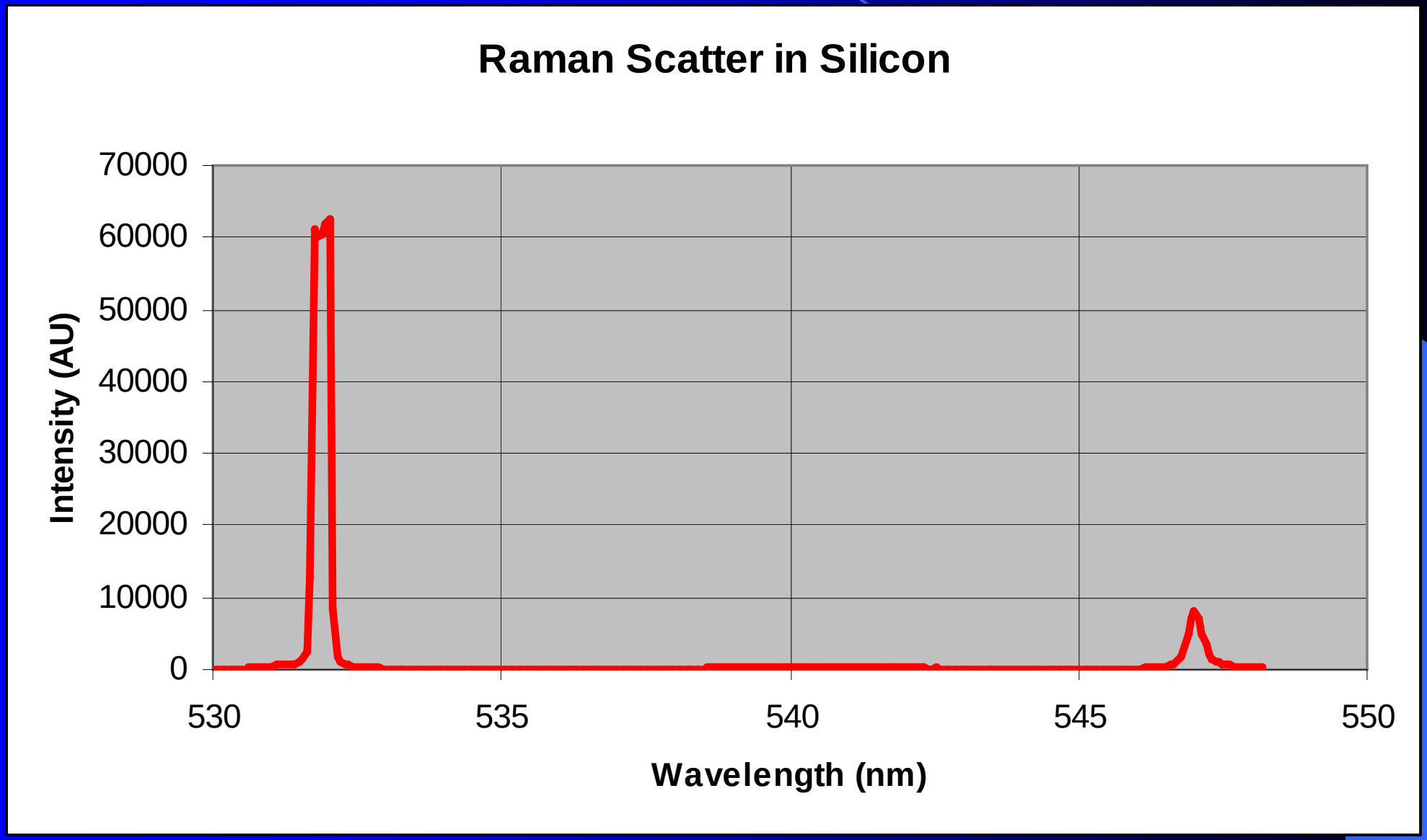
- **Raleigh Scattering**

  Most photons scatter elastically from atoms – no energy change

- **Raman Scattering**

  Less than 1 in a million photons scatter inelastically – gaining or losing energy from vibration states

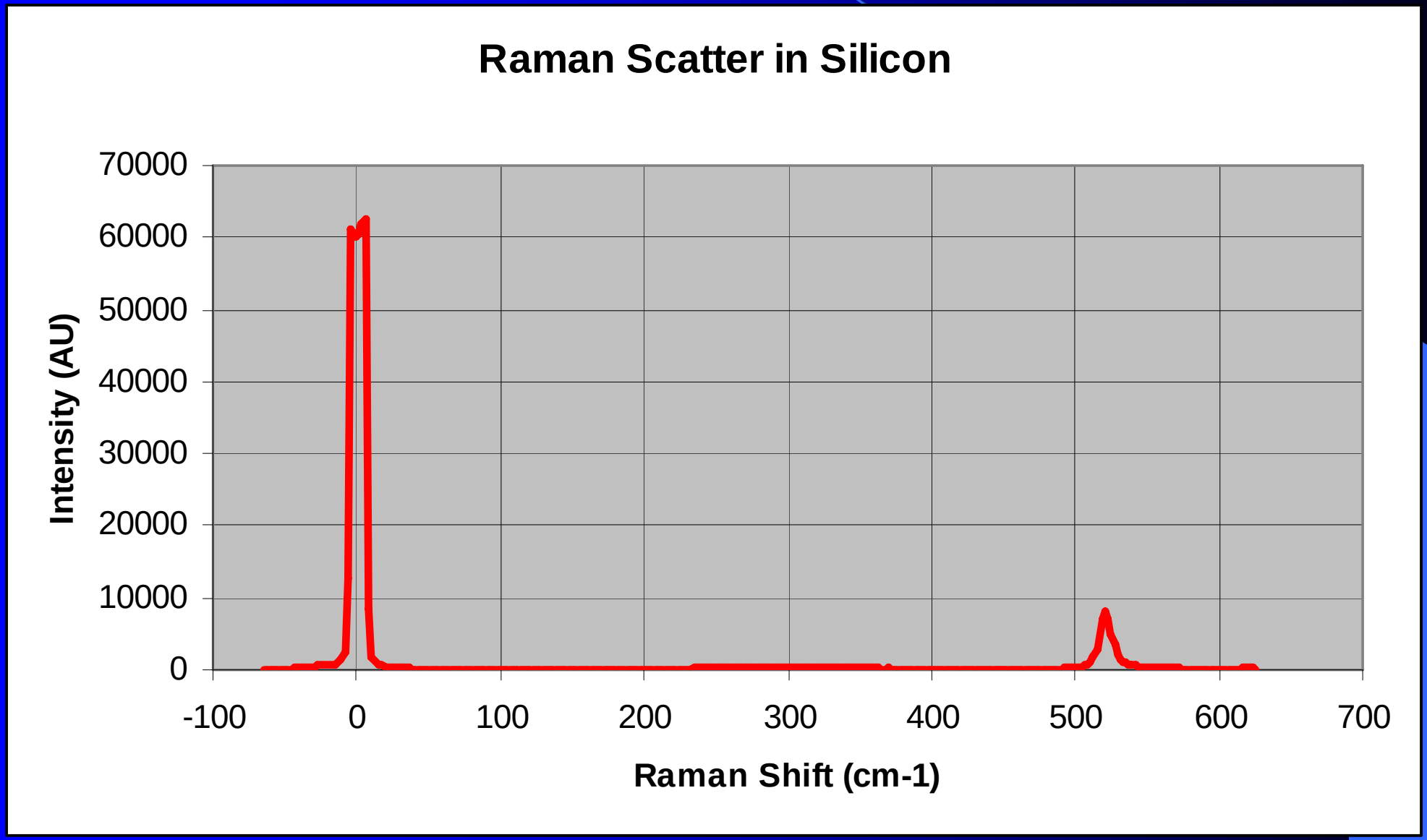
Typical Raman Spectrum



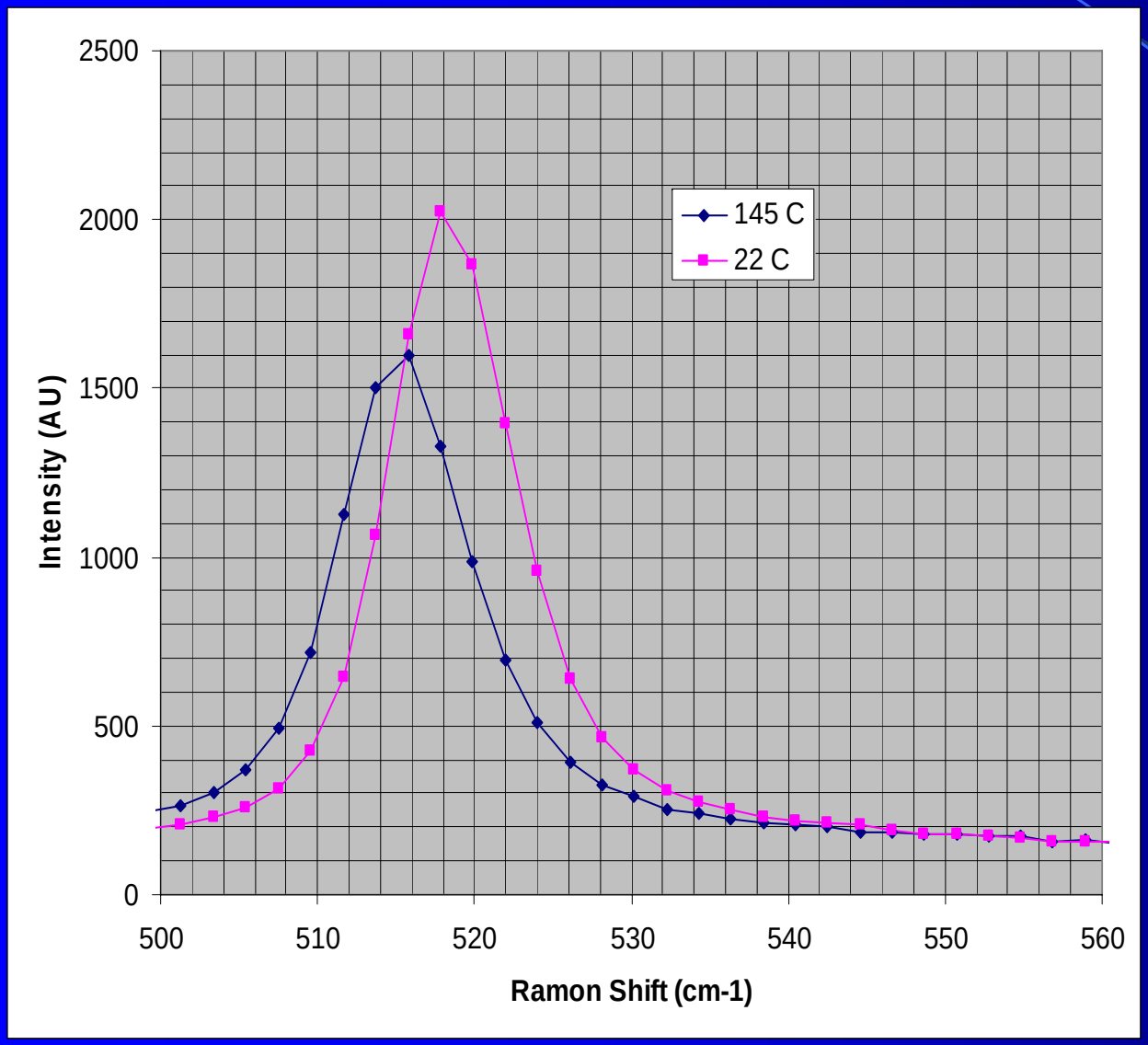
Raman Properties

- Energy shift or wavenumbers (cm^{-1})
  $\nu = 1/\lambda_{inc} - 1/\lambda_{scat}$, produces unique material signature
- Energy shift varies slightly dependent on several parameters
  - Stress
  - Material stoichiometry
  - **Temperature**

Typical Raman Spectrum



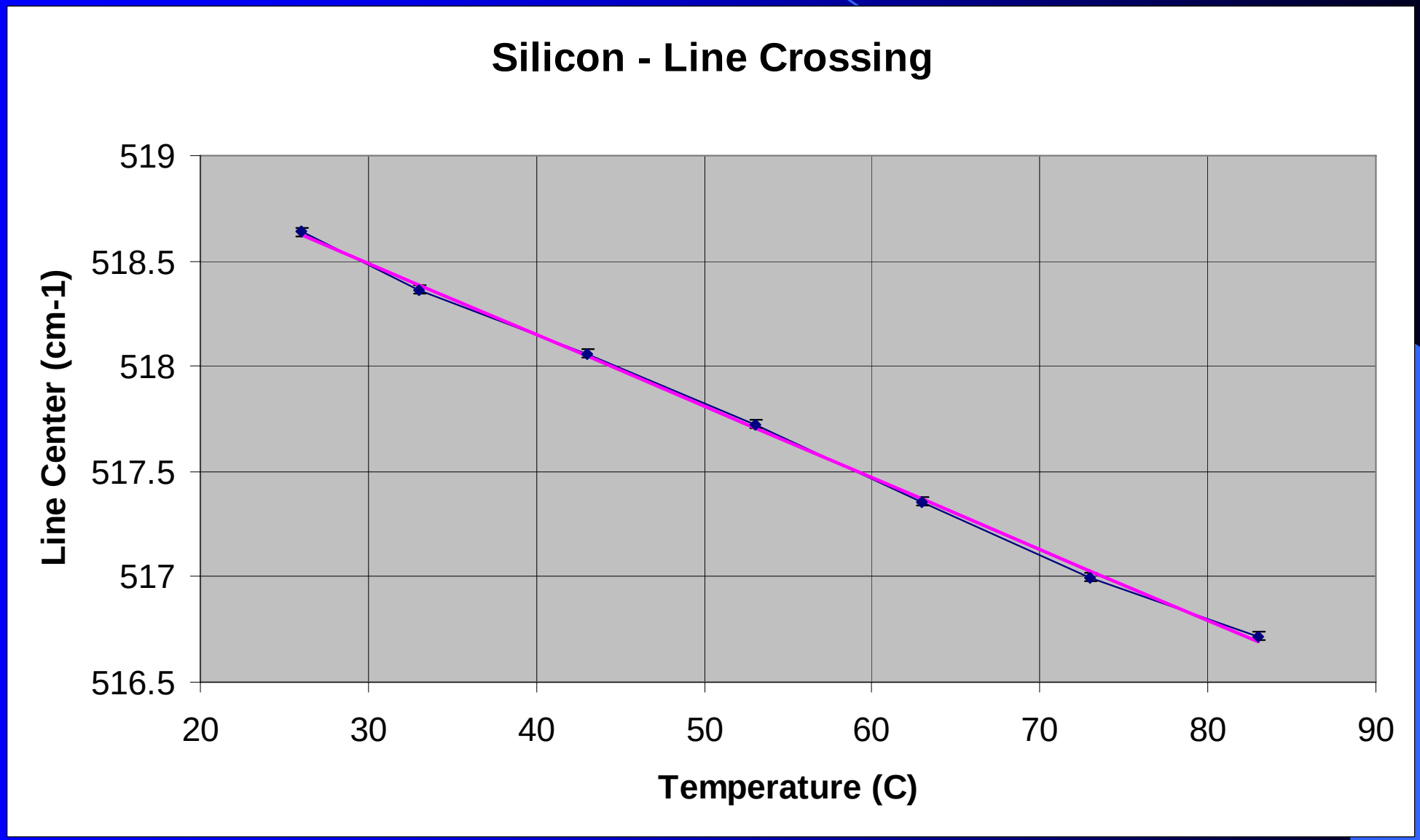
Temperature Dependence



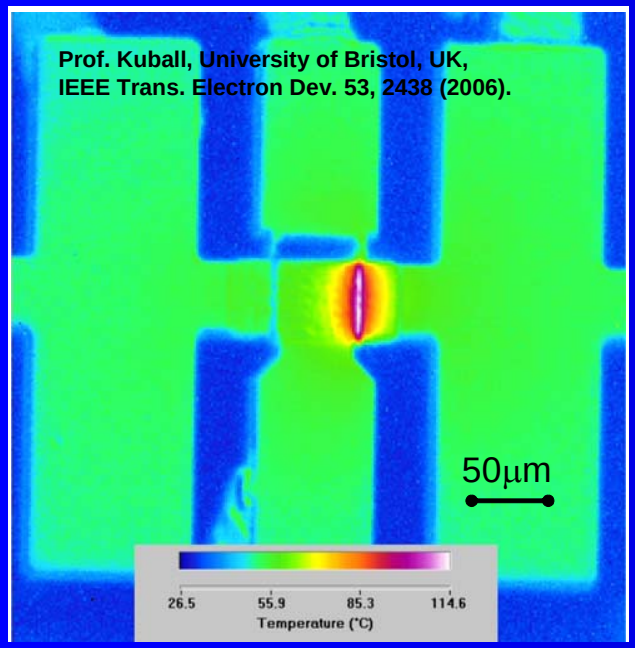
Raman line in Silicon

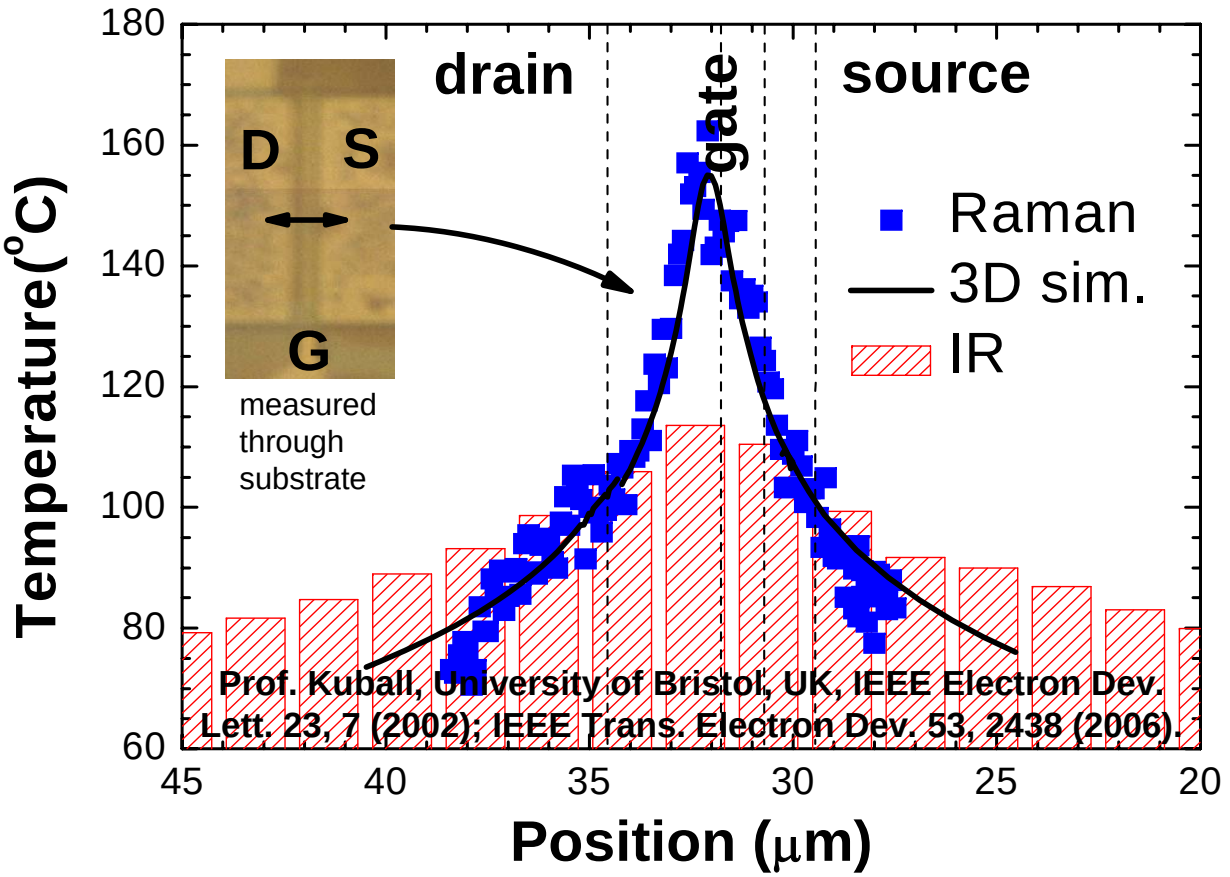
- Crystalline semiconductors typically have one strong Raman line at a shift of 300 – 1000 cm^{-1}
- Line center shifts of 0.01 to 0.03 cm^{-1} per degree centigrade occur
- Line width and intensity also shift with temperature – but are typically not as reliable/accurate of an indicator.

Line Center vs. Temp



Resolution is important

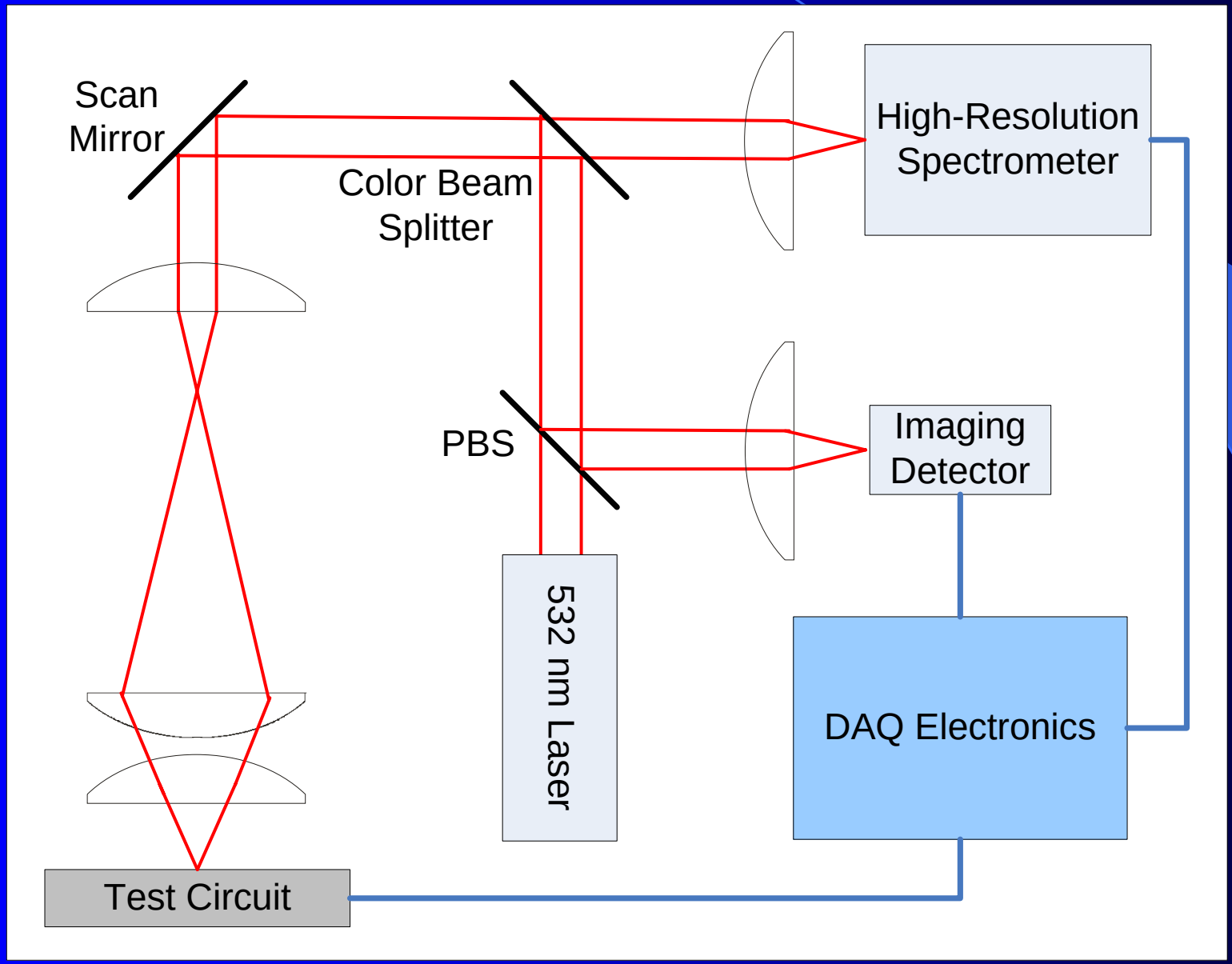




Development History

- 2000-Present – Developed and proven at University of Bristol by Dr. Martin Kuball
- 2005 – QFI worked Dr. Kuball to integrate temperature mapping sensor into Raman system
- 2006 – Exclusive licensing agreement with UB, followed by commercialization program
- 2007 – Commercial product demonstrated

Raman Temperature Probe Layout

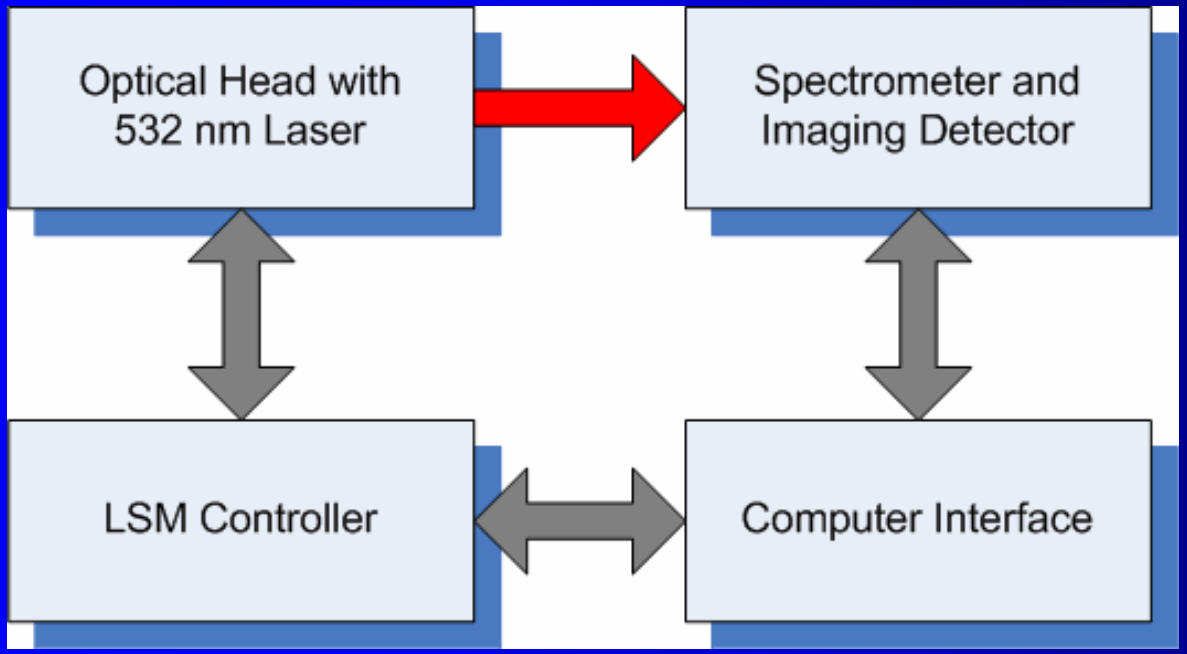


Raman Specs

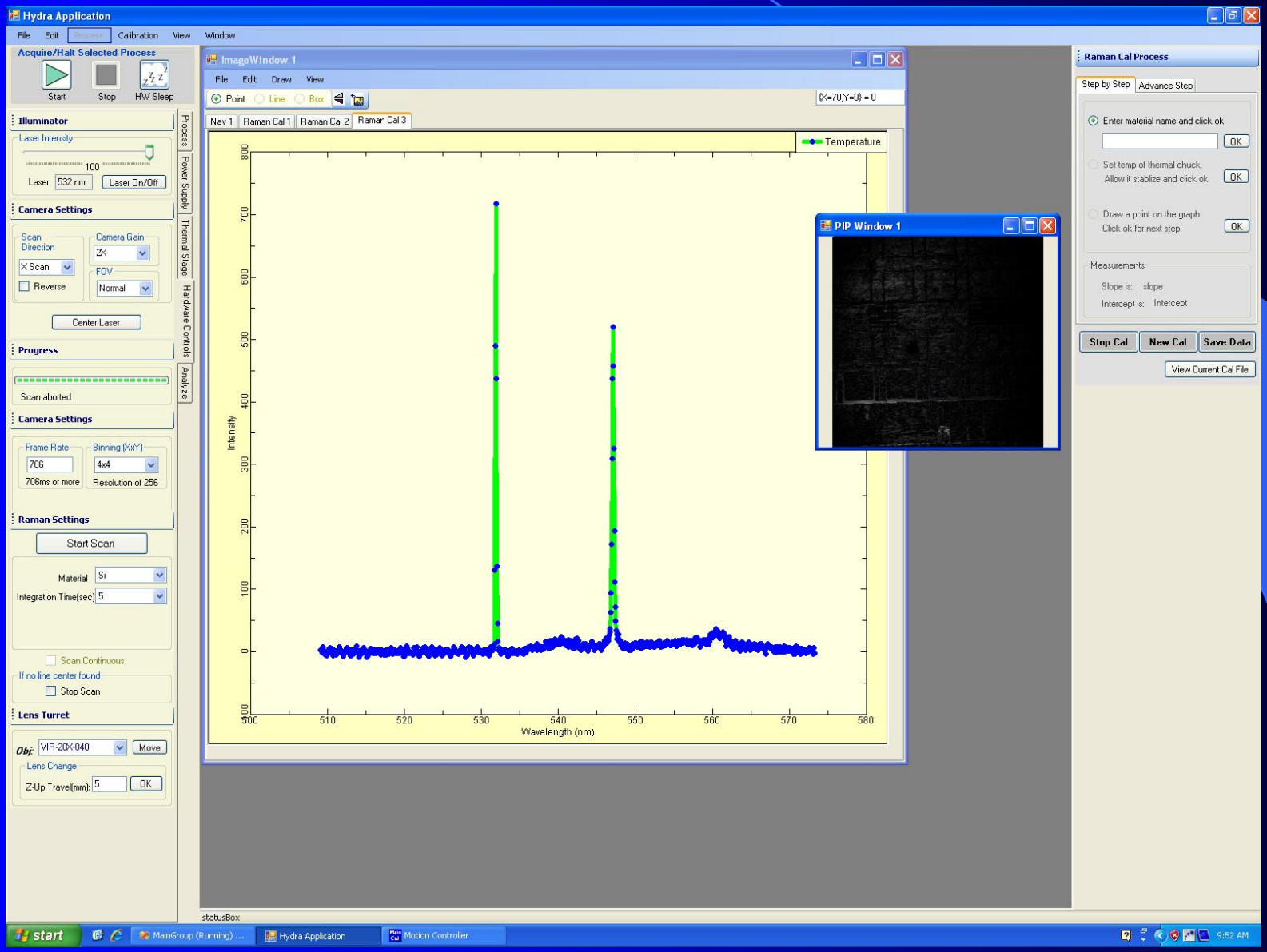
Detector	High resolution spectrometer
Stimulator	532 nm DPSS laser
Spatial Resolution	~ 0.5 um @ 0.55 NA ~ 0.1 um @ 2.3 NA
Temperature Resolution	~ 1 ^{0}C (silicon, 10 sec ave.)
Temperature Range	No limits
Data Acquisition Modes	Single Point, Line Scan, Area
Material Calibration	Built in
Imaging Source	Laser Scanning Microscope

LabWalker System

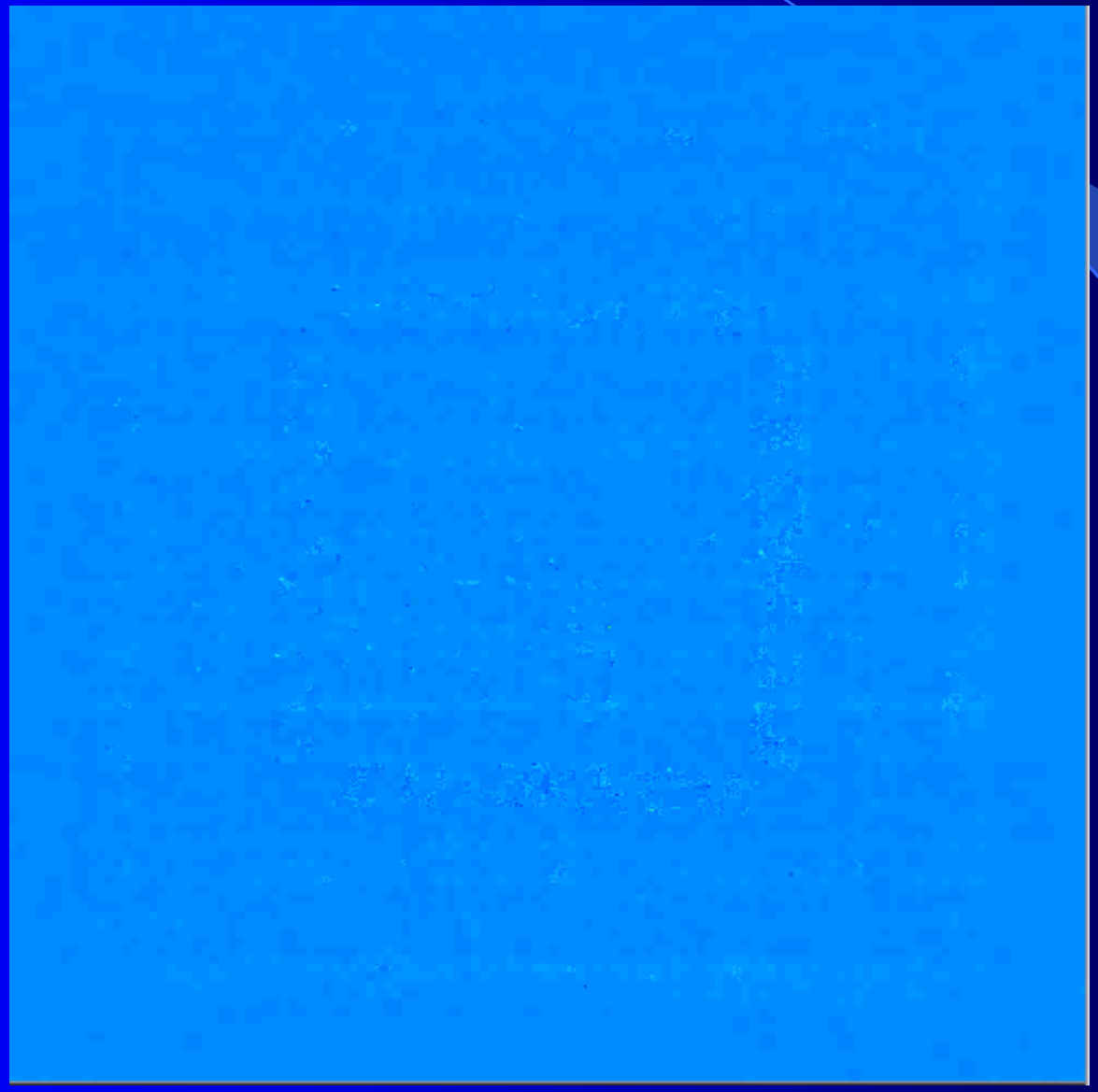
Raman Components



Software Interface



Importance for “Non-Power” Devices



Silicon Tool Development

- 532 nm works well for top-side silicon and wide bandgap semiconductors (GaN, SiC) power devices
- 1340 nm unit under development for silicon backside measurements
  - Signal scaling
  - InGaAs spectrometer
  - Air – Solid interface

Conclusions

- Raman Micro-Probe represents a breakthrough in micro-thermal measurements
  - High spatial resolution, < 500 nm
  - Temperature resolution, ~ 1 ^{0}C
  - Critical to extracting true peak temperature with small feature size