

QFI

Quantum Focus  
Instruments Corporation

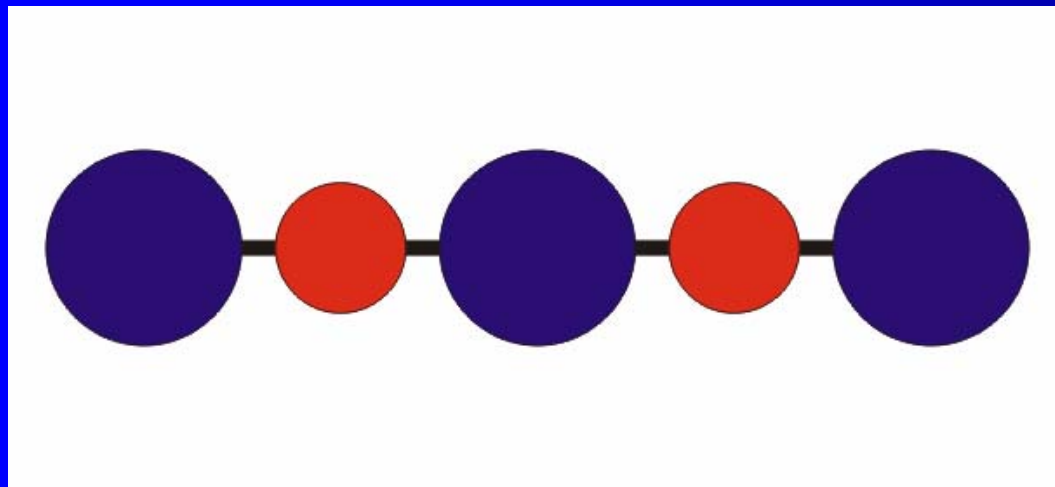
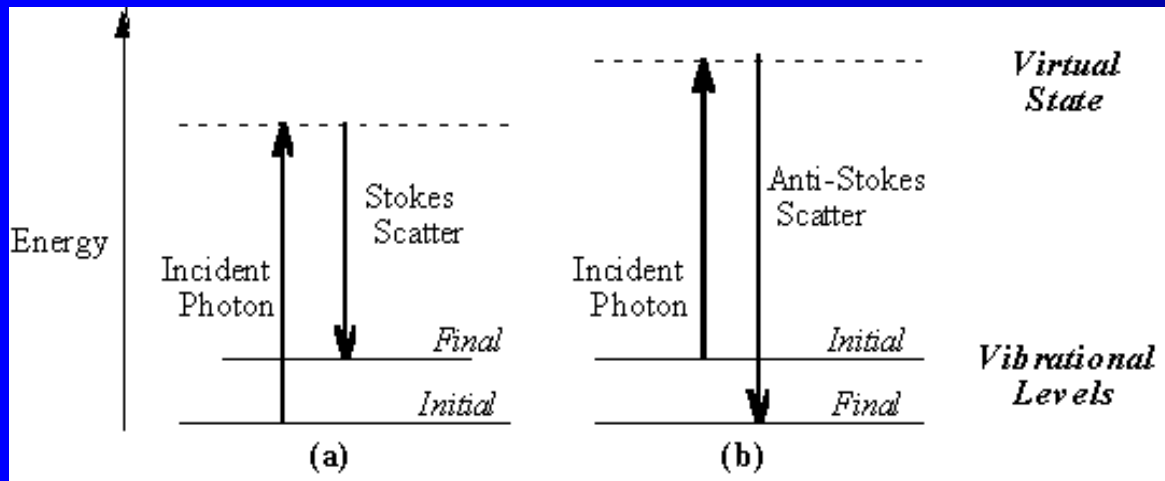
# High Resolution Raman Temperature Measurements

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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

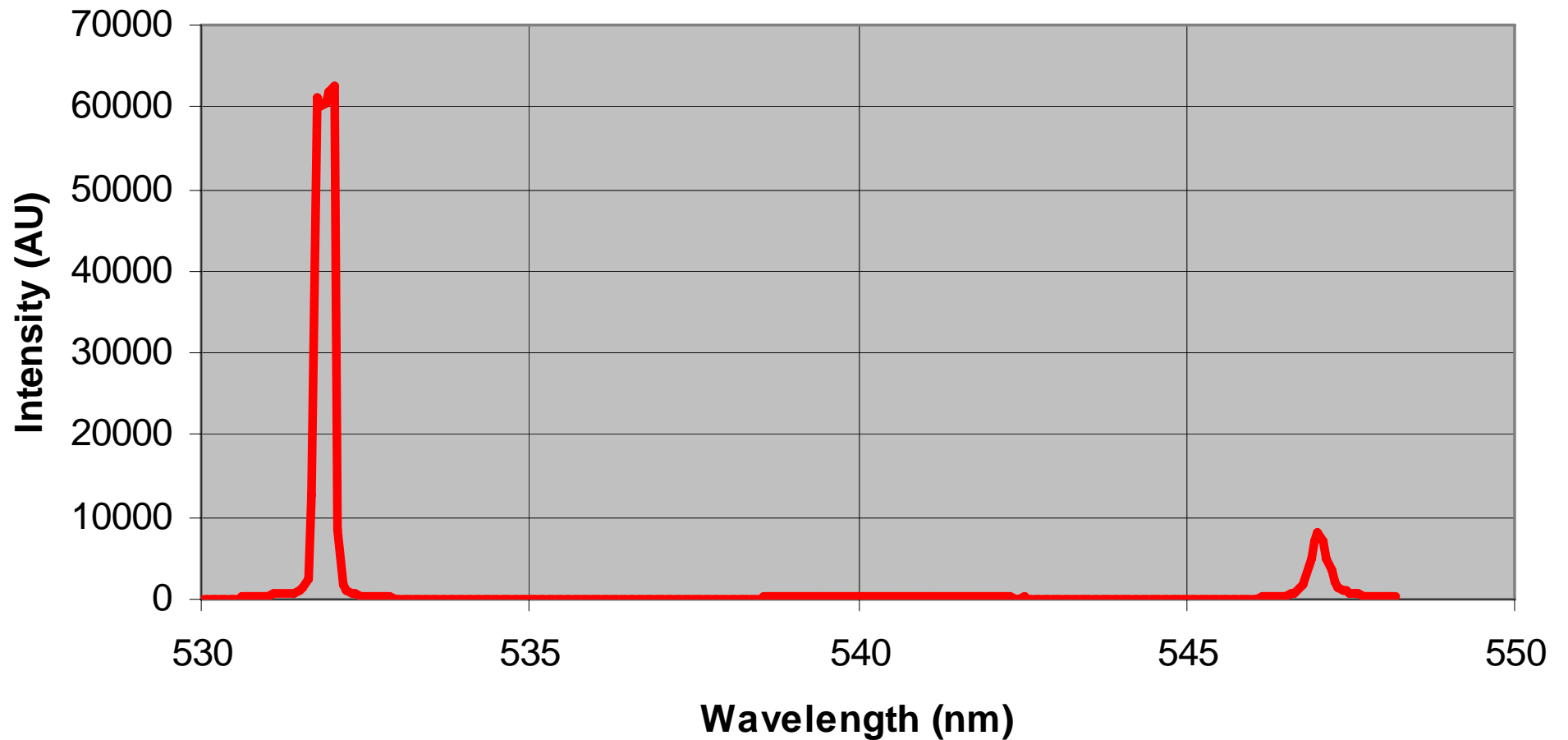
Most photons scatter elastically from atoms – no energy change

- Raman Scattering

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

# Typical Raman Spectrum

**Raman Scatter in Silicon**

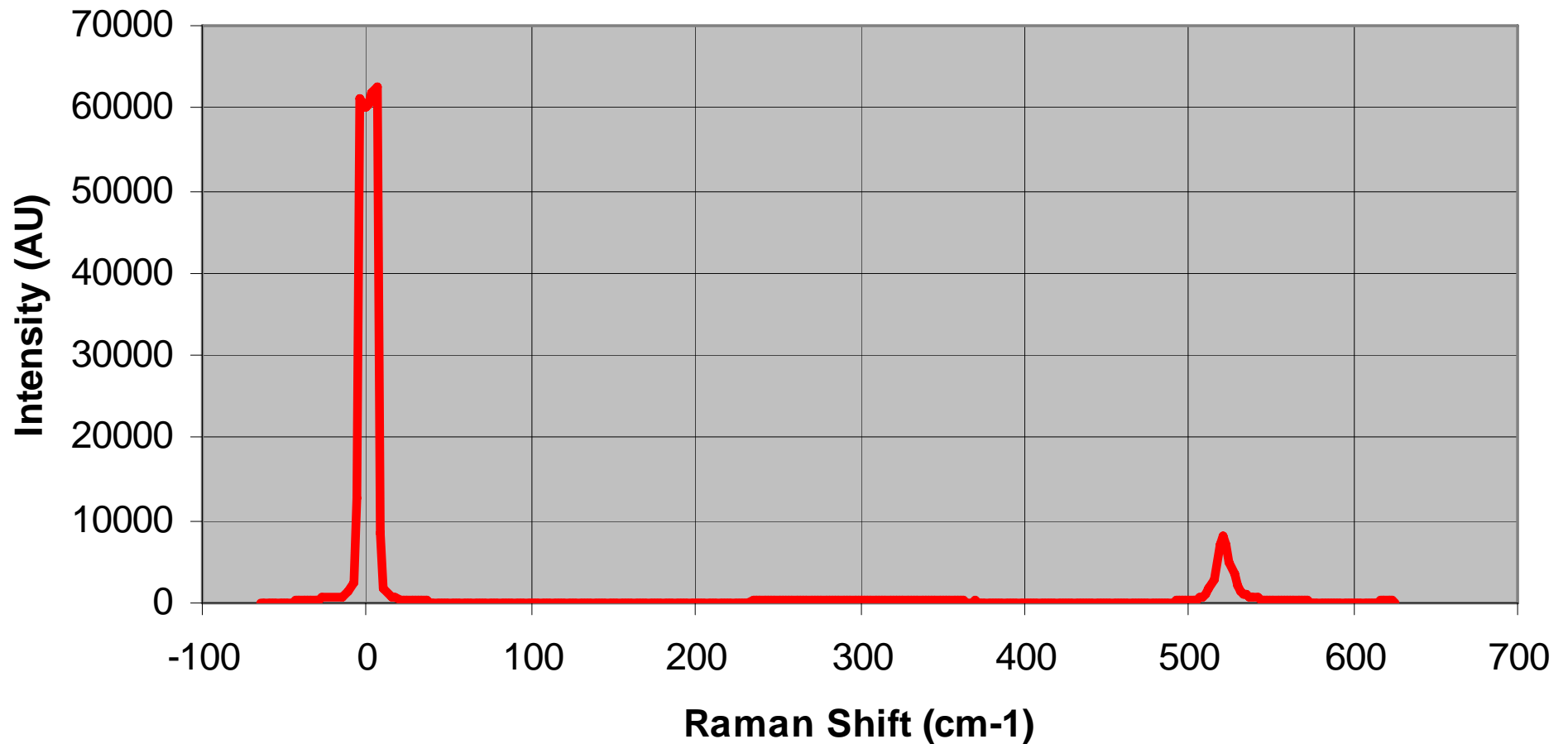


# Raman Properties

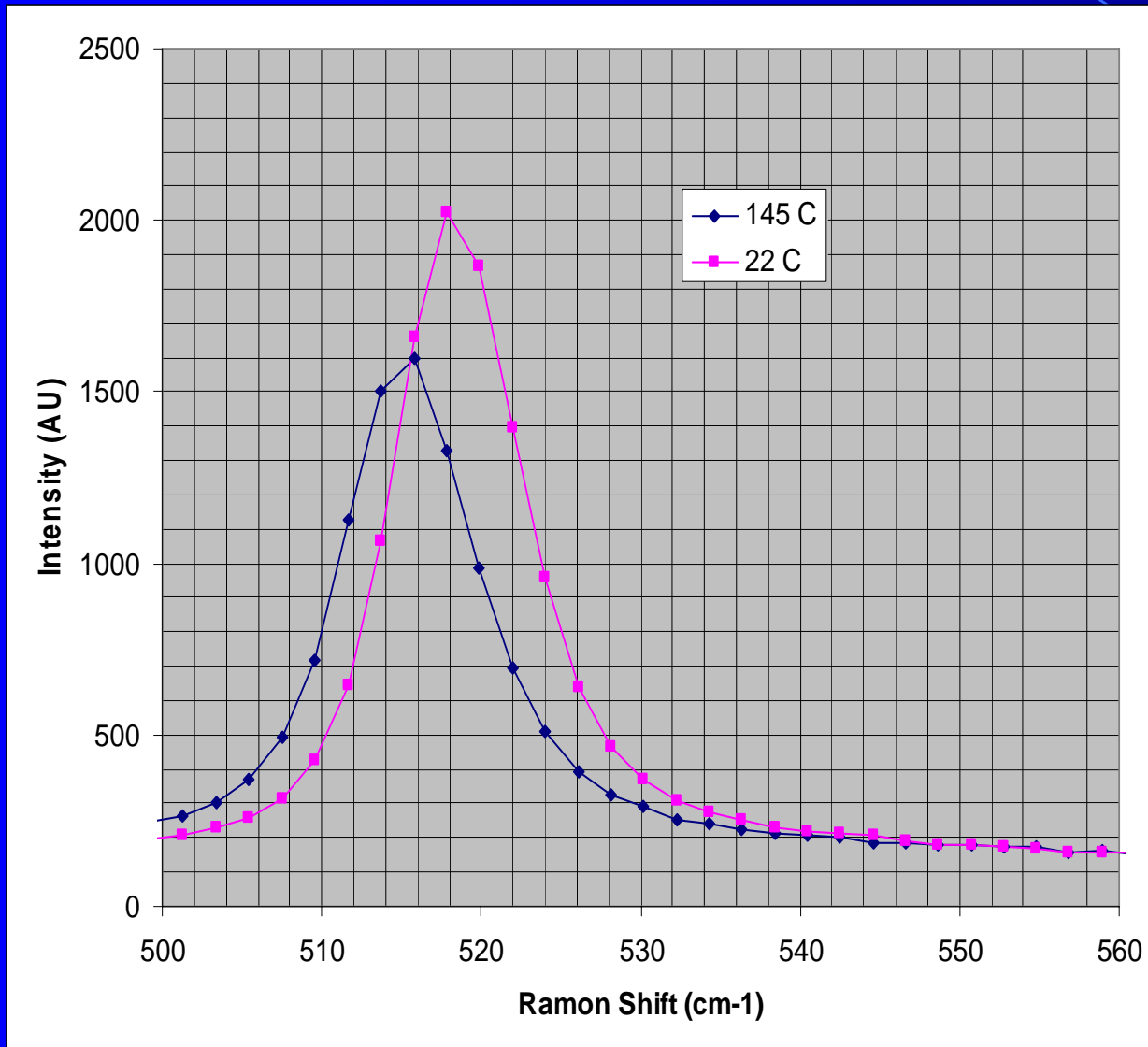
- Energy shift or wavenumbers ( $\text{cm}^{-1}$ )  
 $\nu = 1/\lambda_{\text{inc}} - 1/\lambda_{\text{scat}}$ , produces unique material signature
- Energy shift varies slightly dependent on several parameters
  - Stress
  - Material stoichiometry
  - Temperature

# Typical Raman Spectrum

**Raman Scatter in Silicon**



# Temperature Dependence

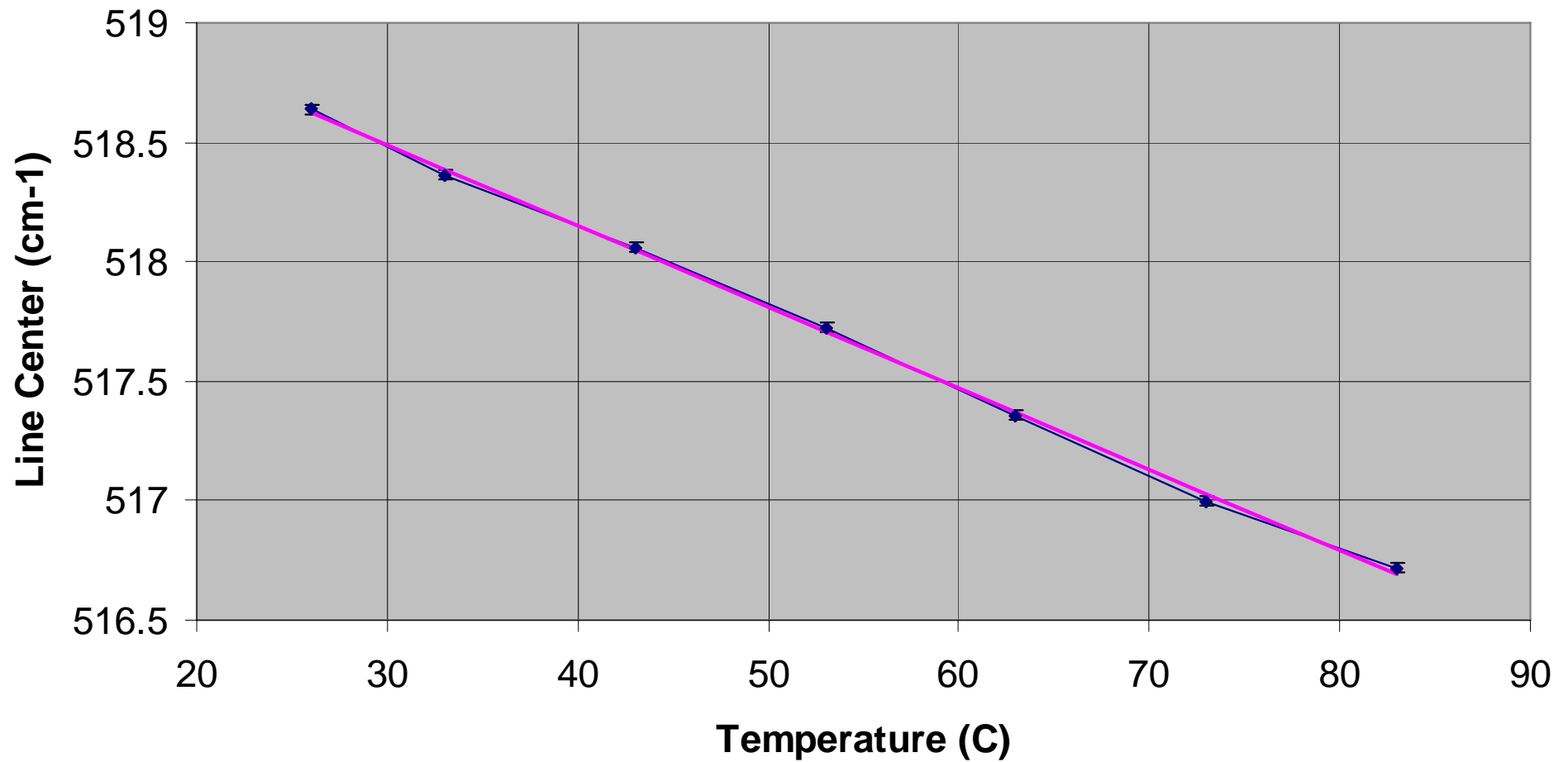


*Raman line in Silicon*

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

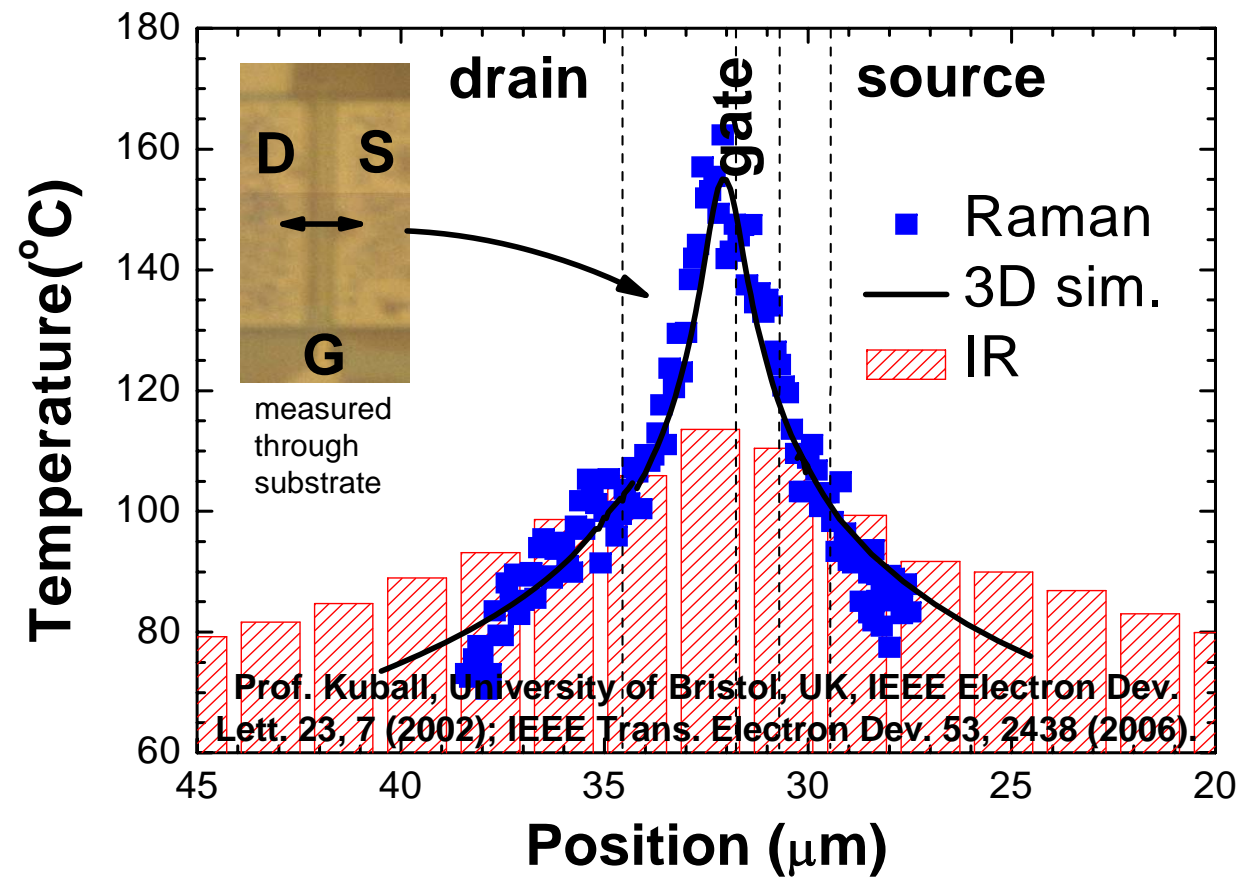
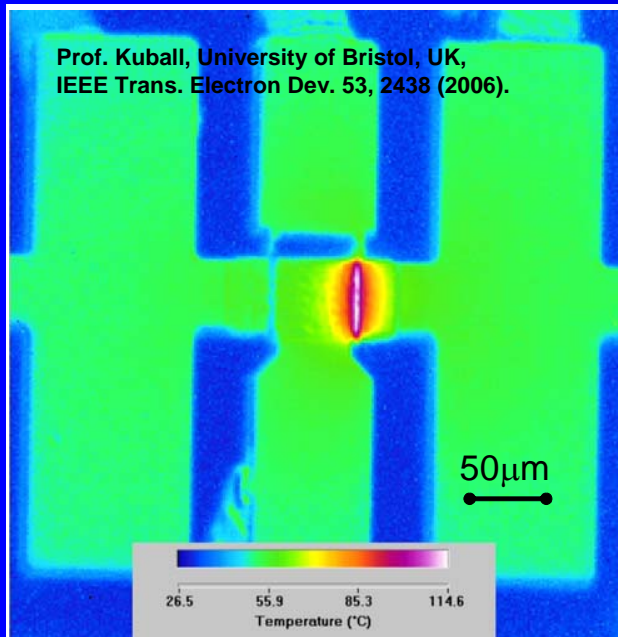
# Line Center vs. Temp

**Silicon - Line Crossing**





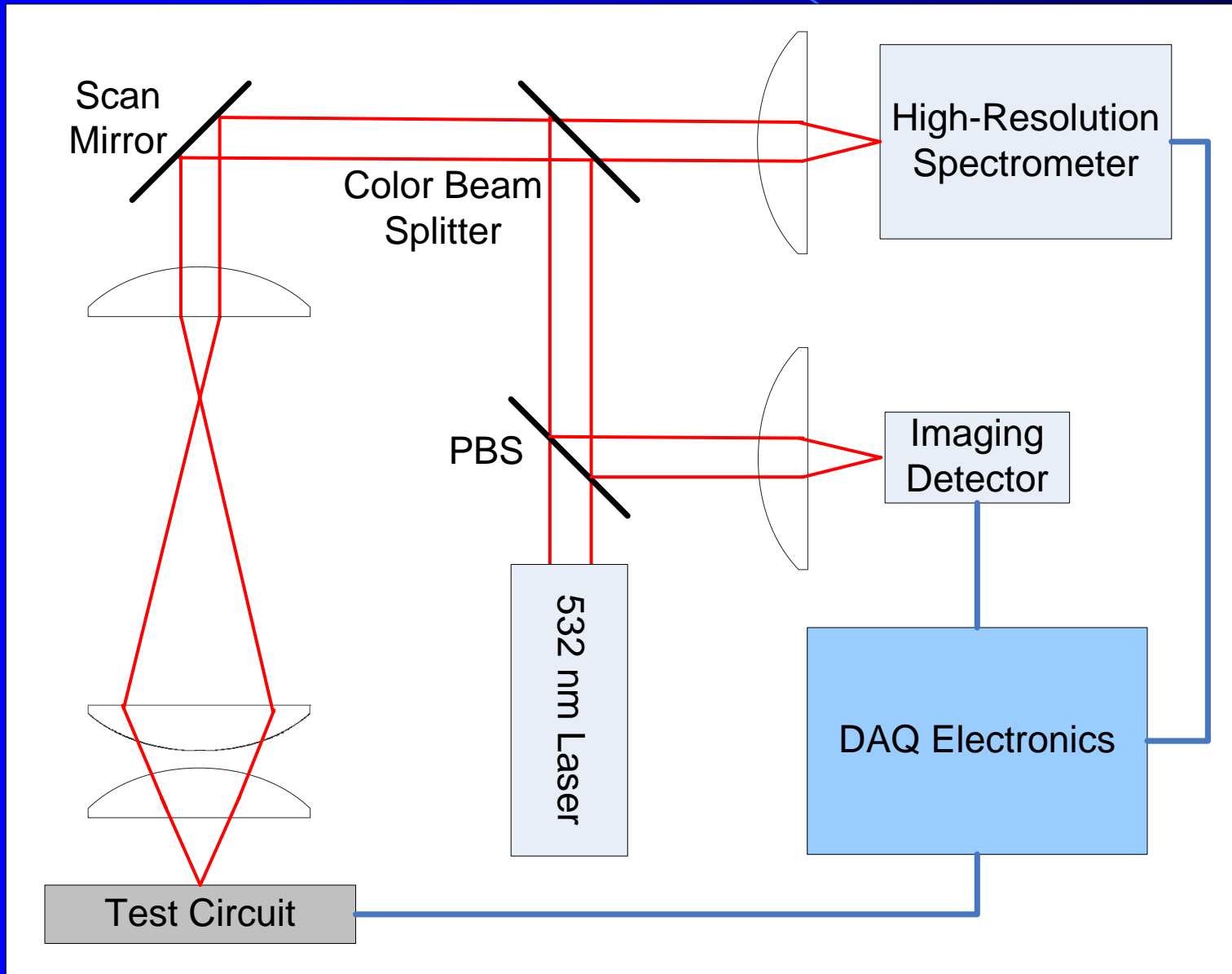
# Resolution is important



# 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

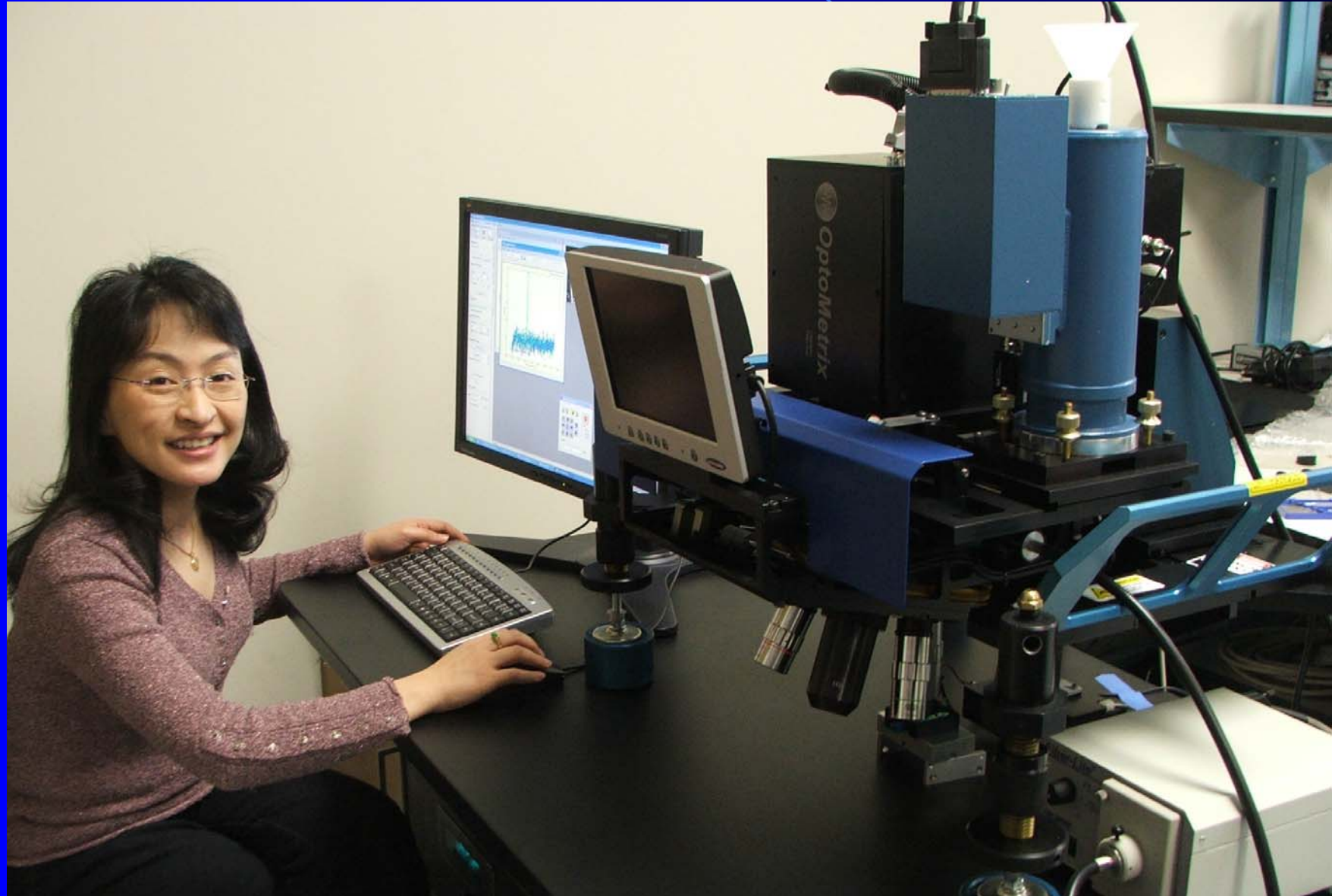
# Raman Temperature Probe Layout



# Raman Specs

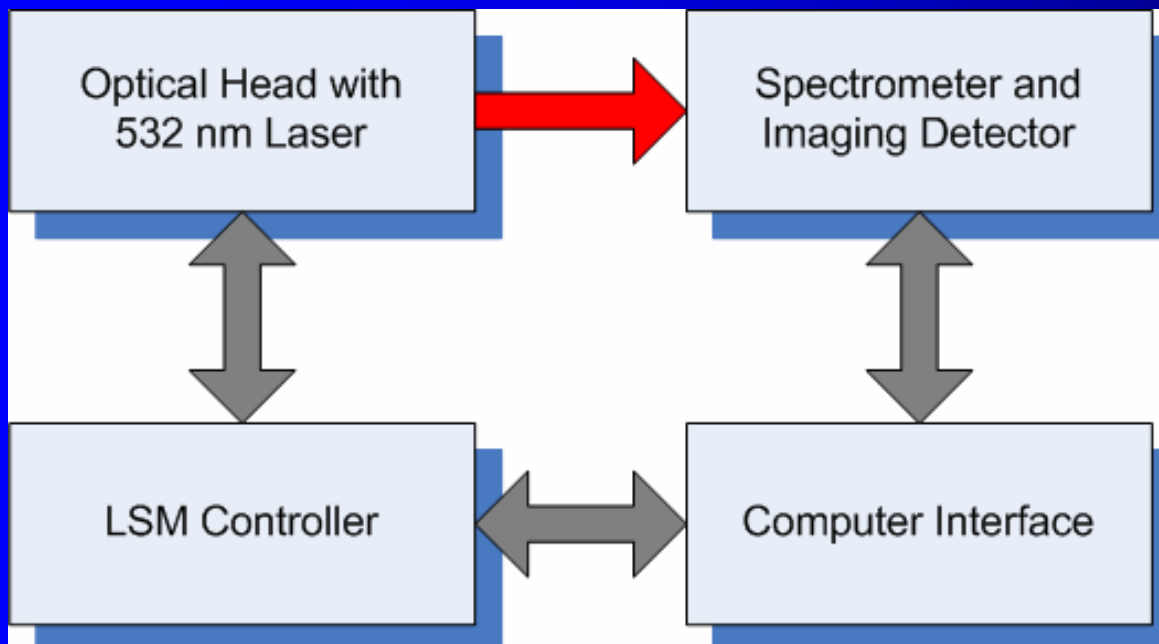
<b>Detector</b>	High resolution spectrometer
<b>Stimulator</b>	532 nm DPSS laser
<b>Spatial Resolution</b>	~ 0.5 $\mu\text{m}$ @ 0.55 NA ~ 0.1 $\mu\text{m}$ @ 2.3 NA
<b>Temperature Resolution</b>	~ 1 $^{\circ}\text{C}$ (silicon, 10 sec ave.)
<b>Temperature Range</b>	No limits
<b>Data Acquisition Modes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

# LabWalker System





# Raman Components



# Software Interface

The screenshot displays the Hydra Application software interface, which is used for Raman spectroscopy. The main window, titled "Hydra Application", contains several panels and a central plot area.

**Left Panel (Control and Settings):**

- Acquire/Halt Selected Process:** Includes Start, Stop, and HW Sleep buttons.
- Illuminator:** Shows Laser Intensity (100) and Laser (532 nm) with a Laser On/Off button.
- Camera Settings:** Includes Scan Direction (Z), Camera Gain (2X), X Scan, Reverse, FDV, and Normal options, along with a Center Laser button.
- Progress:** Shows a progress bar and "Scan aborted" status.
- Camera Settings (Secondary):** Includes Frame Rate (706), Binning (4x4), and Resolution (256).
- Raman Settings:** Includes Start Scan, Material (Si), and Integration Time (5). It also has checkboxes for Scan Continuous and Stop Scan.
- Lens Turret:** Includes Obj (VIR-20X-040) and Z-Up Travel (5) settings.

**Central Plot Area (ImageWindow 1):**

- Shows a Raman spectrum plot with Intensity on the y-axis (0 to 800) and Wavelength (nm) on the x-axis (500 to 580).
- Two prominent peaks are visible at approximately 532 nm and 547 nm, both highlighted with green vertical lines.
- The plot is titled "Raman Cal 1", "Raman Cal 2", and "Raman Cal 3".
- A "PIP Window 1" is overlaid on the plot, showing a dark image of the sample.

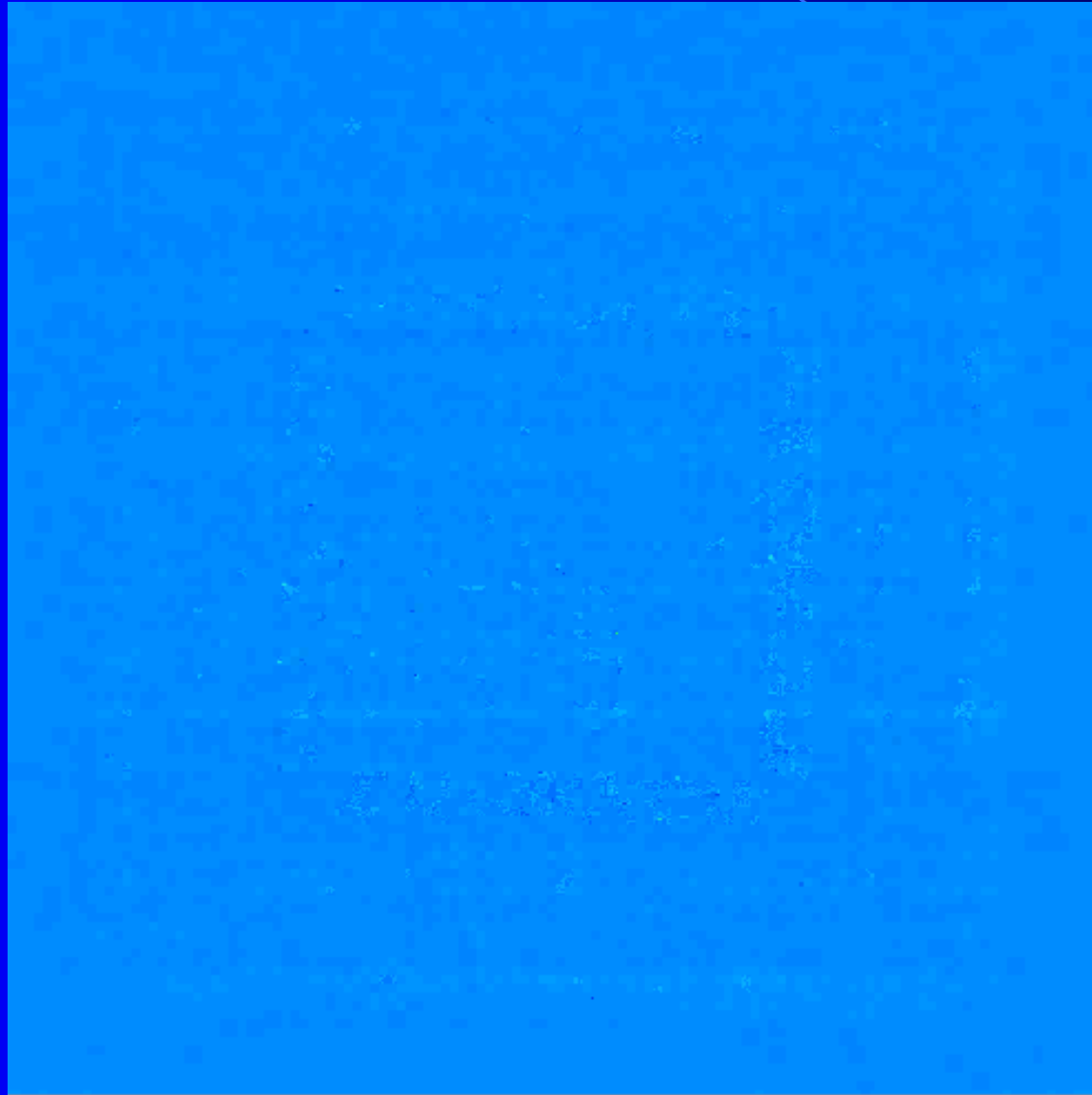
**Right Panel (Raman Cal Process):**

- Includes "Step by Step" and "Advance Step" buttons.
- Options for "Enter material name and click ok", "Set temp of thermal chuck", and "Draw a point on the graph".
- Measurement fields for "Slope is: slope" and "Intercept is: Intercept".
- Buttons for "Stop Cal", "New Cal", "Save Data", and "View Current Cal File".

**Bottom Panel (Windows and Taskbar):**

- Windows: start, MainGroup (Running) ..., Hydra Application, Motion Controller.
- Taskbar: Shows the system clock at 9:52 AM.

# 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,  $\sim 1$  °C
  - Critical to extracting true peak temperature with small feature size