Fiber-Optic Sensor System Demonstrator for Proba-2

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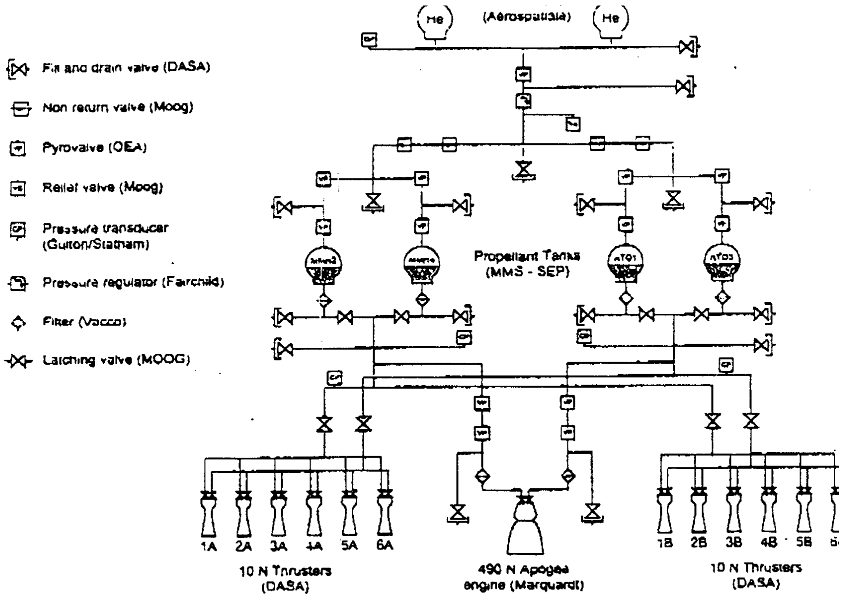
Presentation Outline

- Introduction
- FSD Central Interrogation System
- FSD Fiber-optic Harness
- FSD FBG Sensors
  1. Distributed Temperature
  2. Propellant P/T
  3. Thruster high-T
- Ground Qualification
- Conclusions

Spacecraft Propulsion Systems



Large number of sensors required:

- **Propellant Volume/Pressure**
- **Propellant Flow**
- **Propellant leakage detection**
- **Pipeline temperature distribution**
- **Thruster temperature**
- **Valve position status**
- **Valve temperature**
- **Propellant tank integrity**

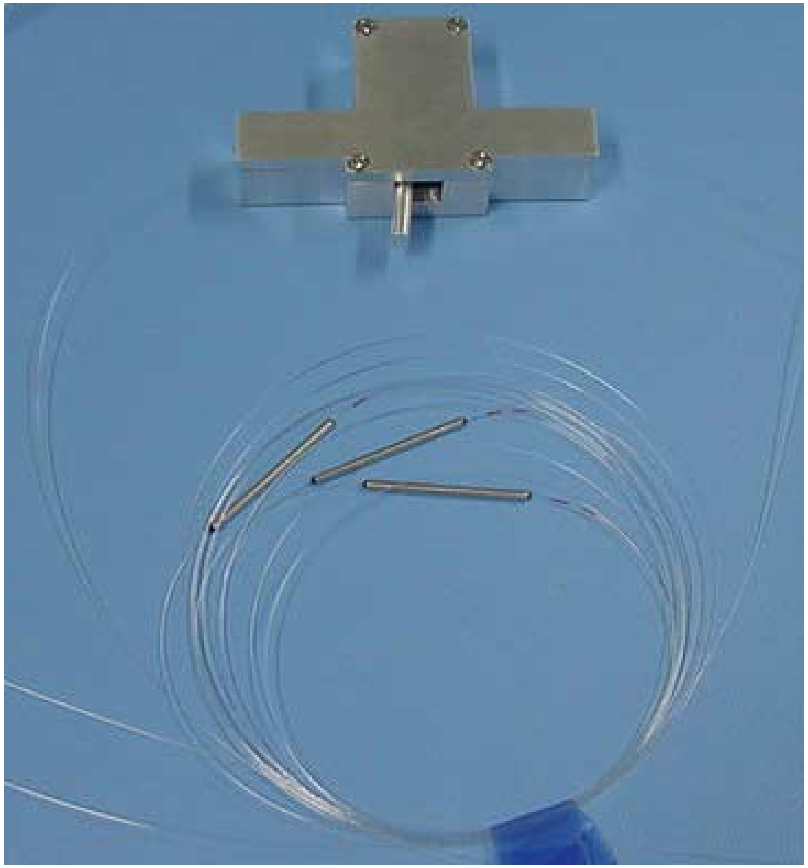
The Problem: Current Electronic Sensors

- **Sensitive to EMI, ESD and sparking -requires heavy shielding for sensors and signal lines**
- **Poor signal integrity - requires close proximity between sensor and the processing electronics**
- **Low sensor capacity: typically one sensor per twisted wire pair**
- **Bulky signal harness (kg/m)**
- **Complex signal routing and ground-loop problems - expensive system integration**

MPB Multi-Channel Fiber-Laser Interrogation System

- 1 to 2 pm spectral resolution
- parallel multi-channel output
- interrogate FBG or F-P sensors
- high sensor capacity per low-power unit (> 250 fiber-optic sensors)

MPB Fiber Sensor Technology



- Single, central tunable Fiber-laser Interrogation System for various sensor types
- Parallel, bidirectional signal distribution to multiple sensor lines
- Serial wavelength-division multiplexing of sensors on single fiber strand
- Preliminary Sensor Types:

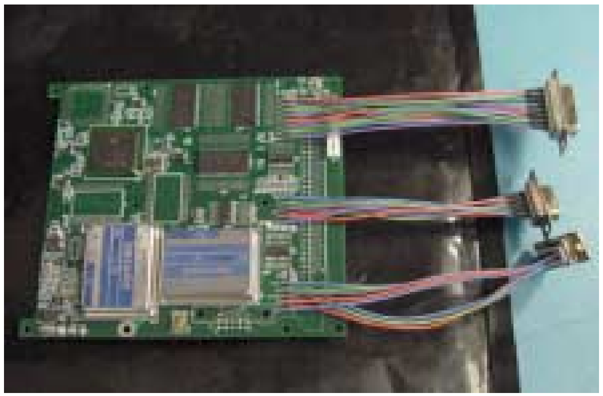
  - FBG Temperature
  - P/T sensor
  - Valve Position Status
  - Hydrazine Gas Leakage
  - High T sensor

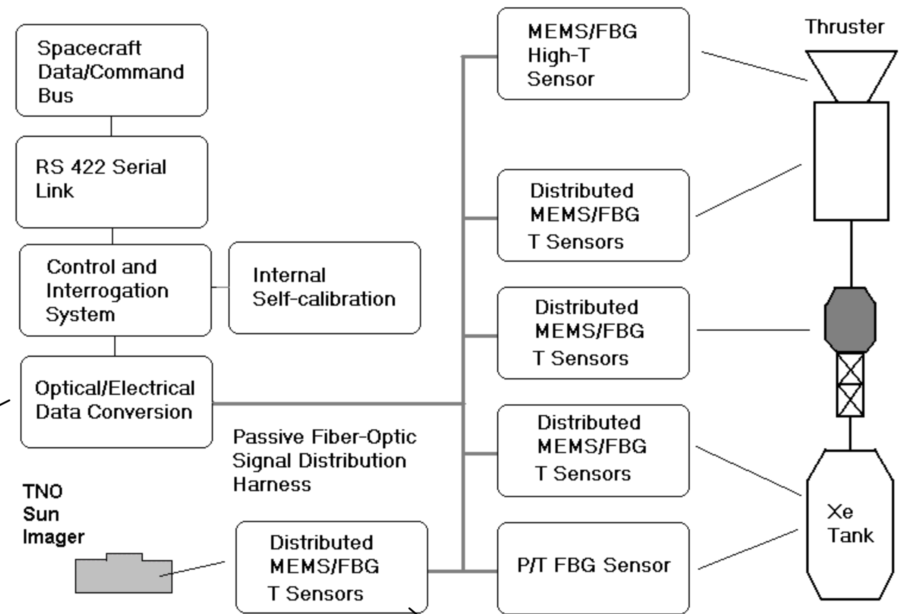
FSD for Proba 2

- **Demonstrate the advantages of a low-power multi-channel network of lightweight fiber-optic sensors for the "in situ"monitoring of space subsystems.**
- **Selection and adaptation of terrestrial fiber-optic technologies to facilitate operation in space**
- **Provide new sensors that meet specific requirements for space:**
  - **P/T sensor for propellant tank**
  - **High-T sensor for thruster measurements**
- **Employ a central, remotely positioned interrogation system for the sensor network.**
- **Incorporate critical redundancy into the FSD system for reliability in space**

Fiber *S*ensor Demonstrator (*FSD*) for ESA's Proba-2:

1. Central Interrogation System
2. Distributed FBG sensors





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Monolithic Interrogation System with
Al PCB board stiffener
Integral Optical Tray

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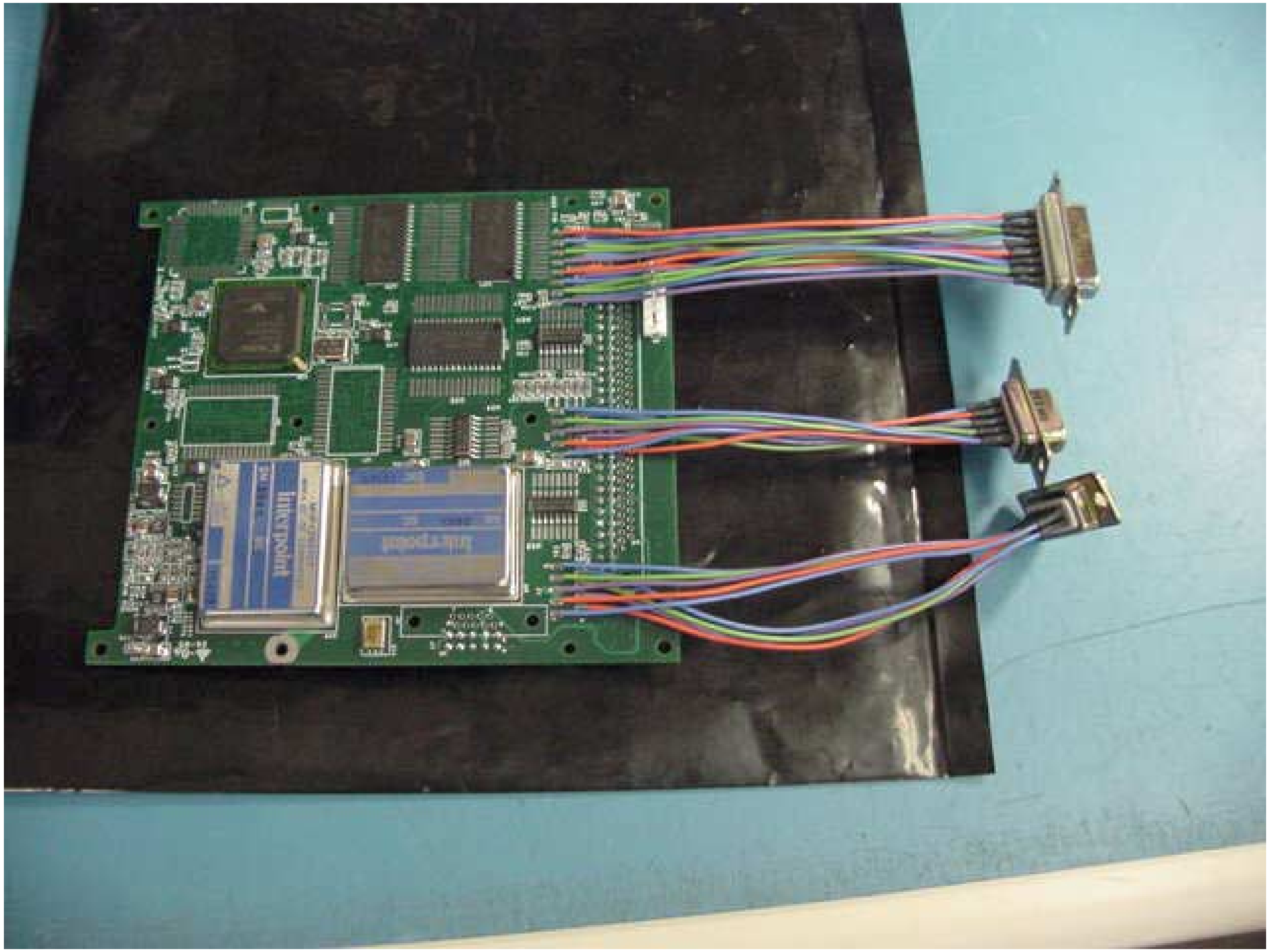
Representative Unit CPU Board



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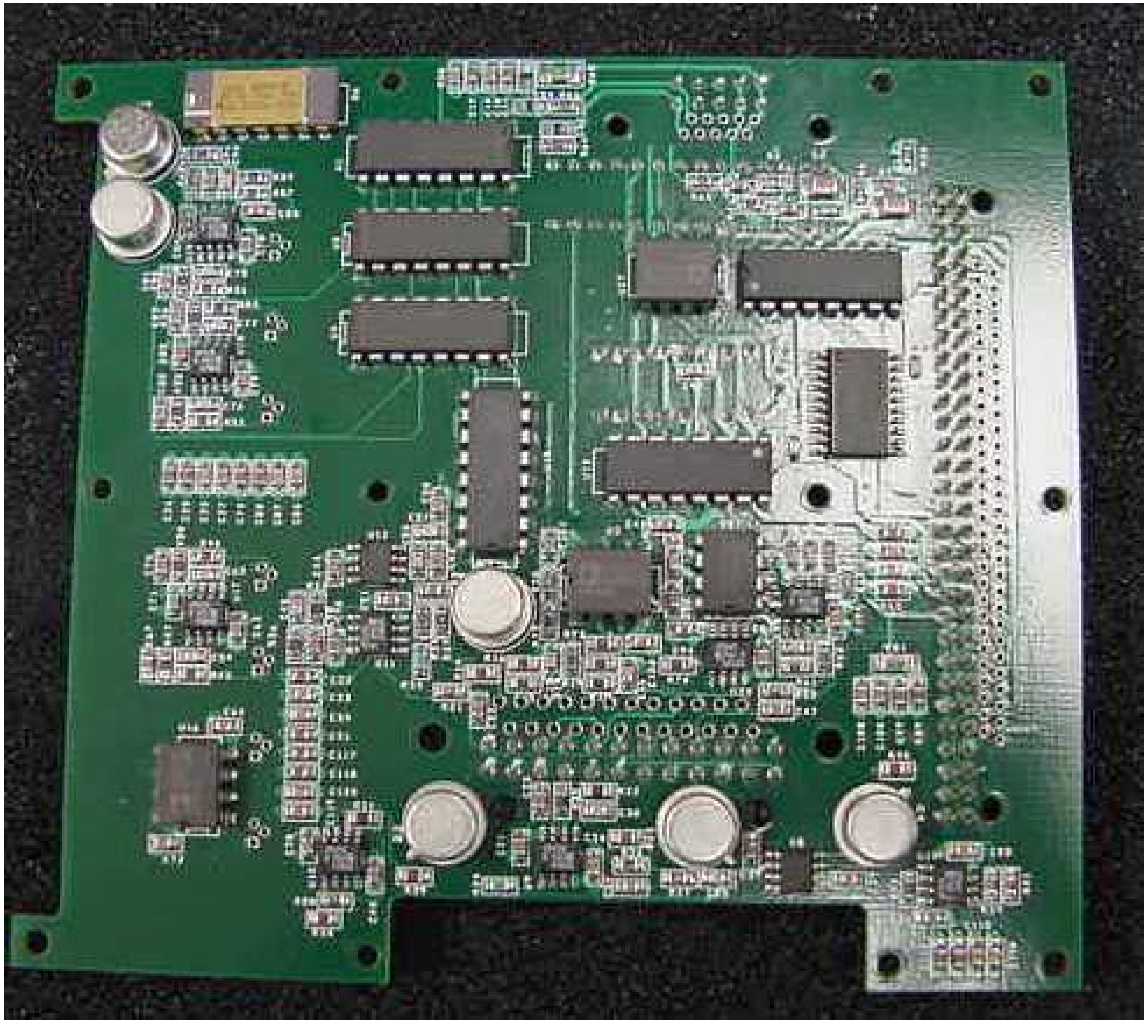
Representative Unit DAQ/EO Board



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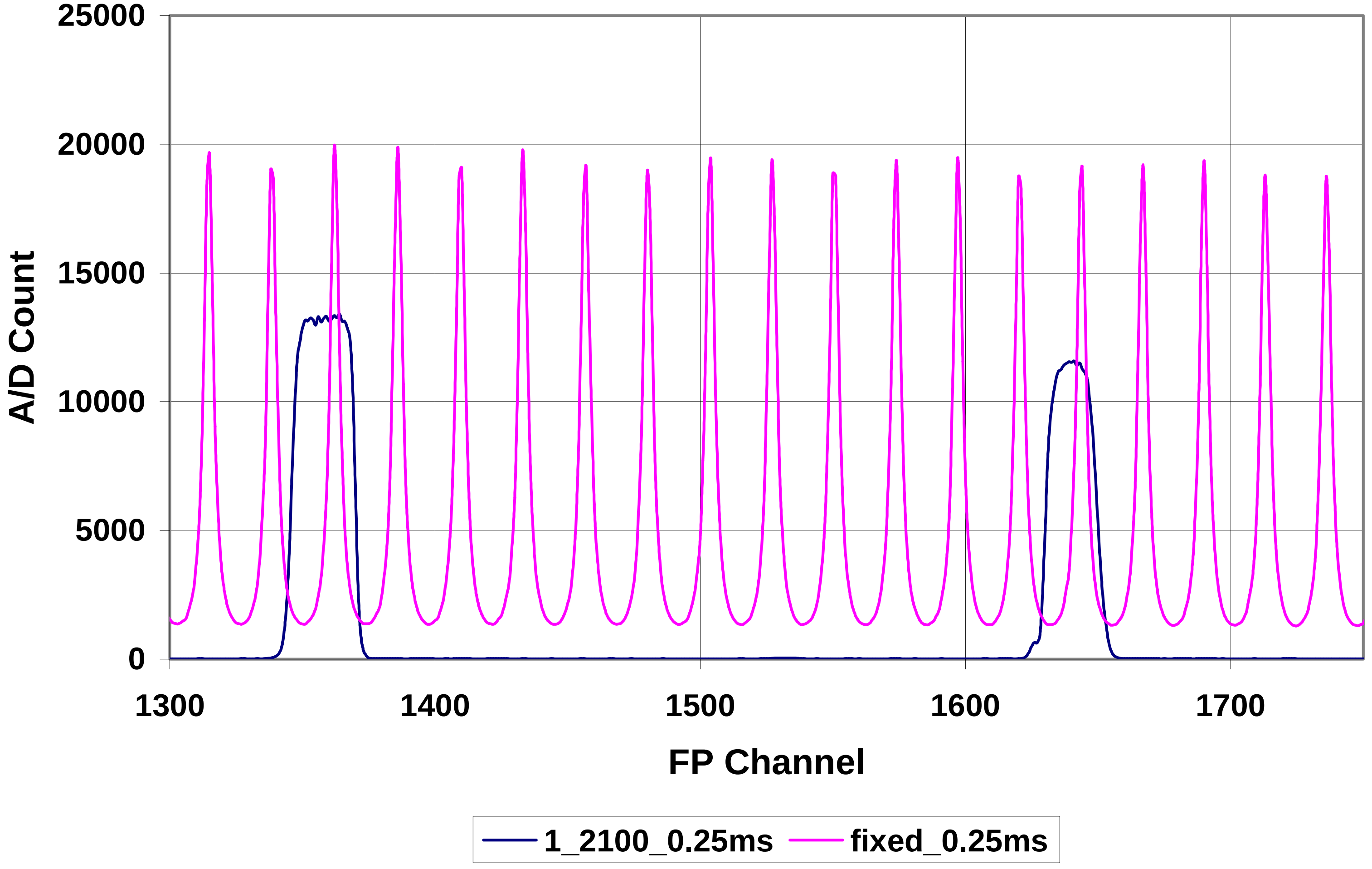
Interrogation System Optical Tray

- **Unit power-on Mode "0" safe state for electro-optic components**
- **Critical optics and electro-optics positioning for maximum radiation shielding.**
- **Parallel architecture to provide redundant tunable fiber-laser system - can sustain two critical active component failures.**
- **Laser diode (LD) pumps biased at 50% of power ratings to maximize lifetime**
- **Internal monitoring of LD power and temperature with T control.**
- **Internal fiber-optic component mounting with some vibration/shock damping.**
- **Internal reference FBG for each external fiber-optic sensor line for independent operation.**

Rep. Unit spectral scans of 0.4 nm-spaced reference fixed FP and a FBG test line with internal/external sensor.



Interrogation System: Component/PCB Level Testing

Component	Test Purpose	Test Condition	Equipment	Location
FBG-stabilized Laser Diode Pump	Validate optical power output, bias current set-point, thermal control requirements.	-30 C to +40C	Dry, N2-purged Environmental Control Chamber.	MPBC
Tunable FP Filter	Validate Operation with Temperature	-30 C to+40C	Dry, N2-purged Environmental Control Chamber.	MPBC
Micro/DAQ Protoflight PCBs	Check inrush current, power consumption, operation.	-40 C to +60 C	Vacuum thermal chamber, PCB depowered during pump down/vent.	CSA
Optical tray assembly	Validate component mounting using RTV2943 for vibration damping during operation.	Low-level random sine at 20 C.	CSA shaker	CSA

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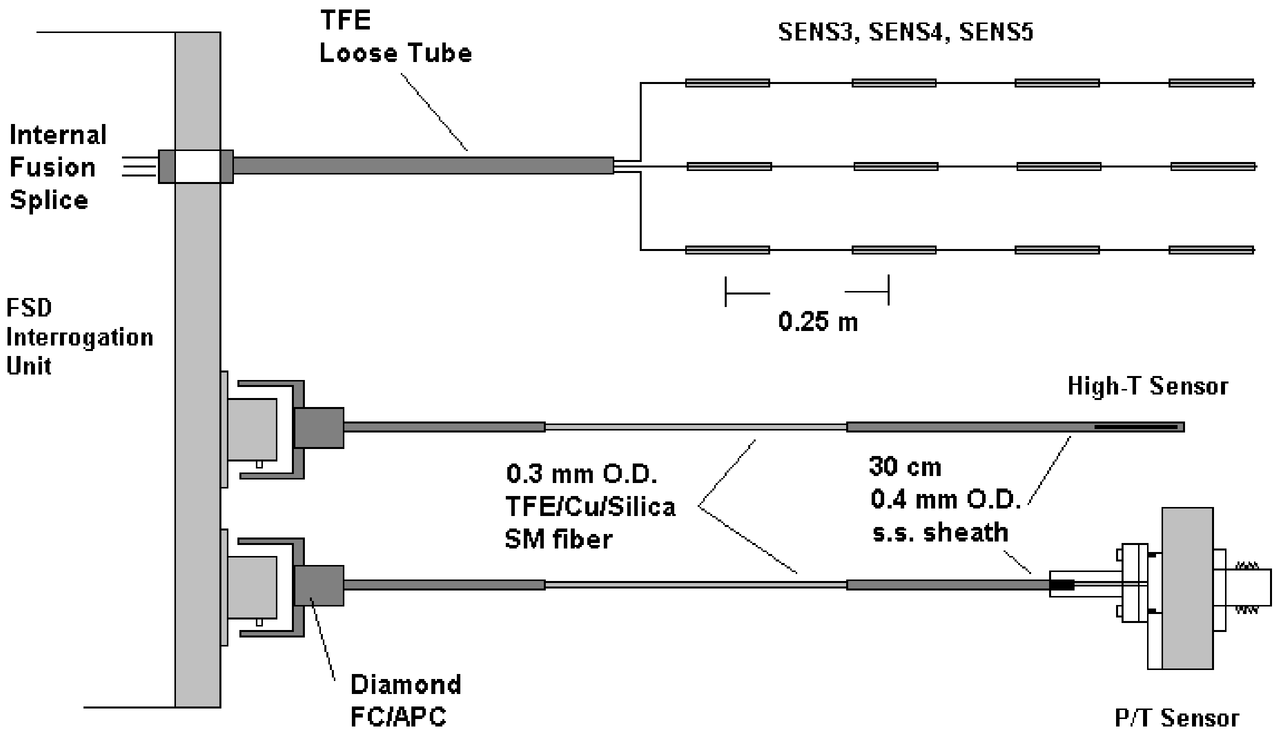
FSD Optical Fiber

- **Vacuum-compatible, high-temperature Cu-coated silica fiber (Cu melting point of 1080^{o}C).**
- **Additional Teflon FEP (to 260^{o}C) or polyimide (to 400^{o}C) protective protective coating/sleeve.**
- **Protected, fusion-spliced internal joints to minimize mechanical optical interconnections.**

FSD Fiber-Optic Harness

1. **Cu-clad, Ge-doped optical fiber with additional TFE coating.**
2. **Additional s.s. flexible sheathing at interface points for mechanical protection - based on preliminary mechanical vibration test results.**



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MPB Computer-Controlled FBG Fabrication Facility

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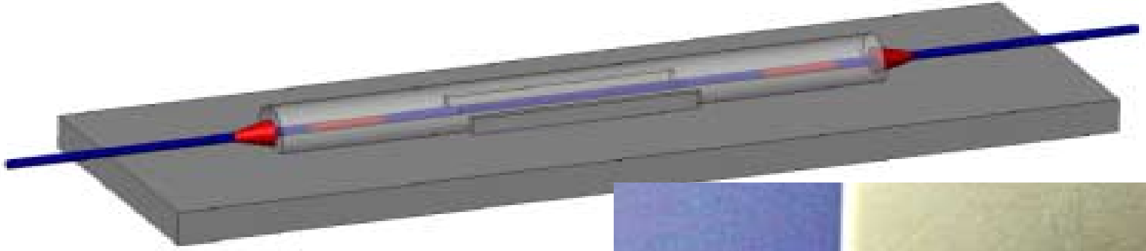
Development of methodology to integrate FBG T-sensors with spacecraft:

Maintain Temperature Calibration
Selection of Adhesive
Repeated Thermal Cycling (-40 to +75 C)
Vibration/Shock Dampening



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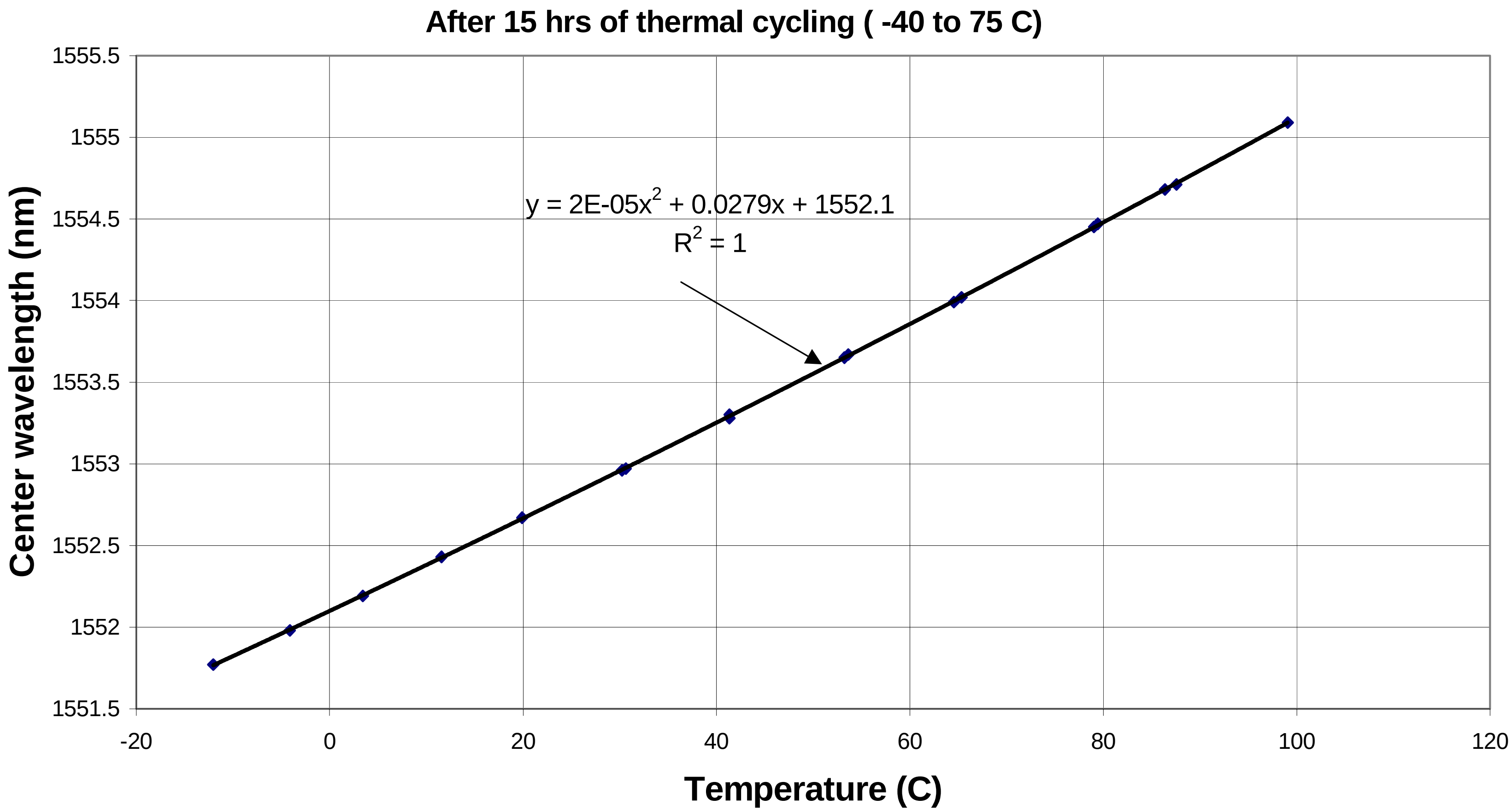
Testing of FSD FBG Temperature Sensors



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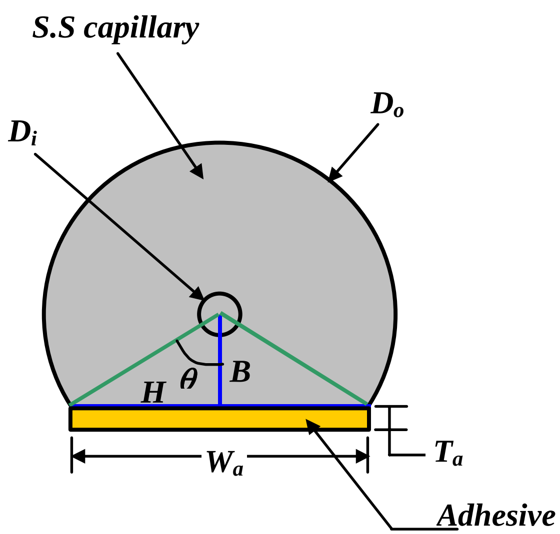
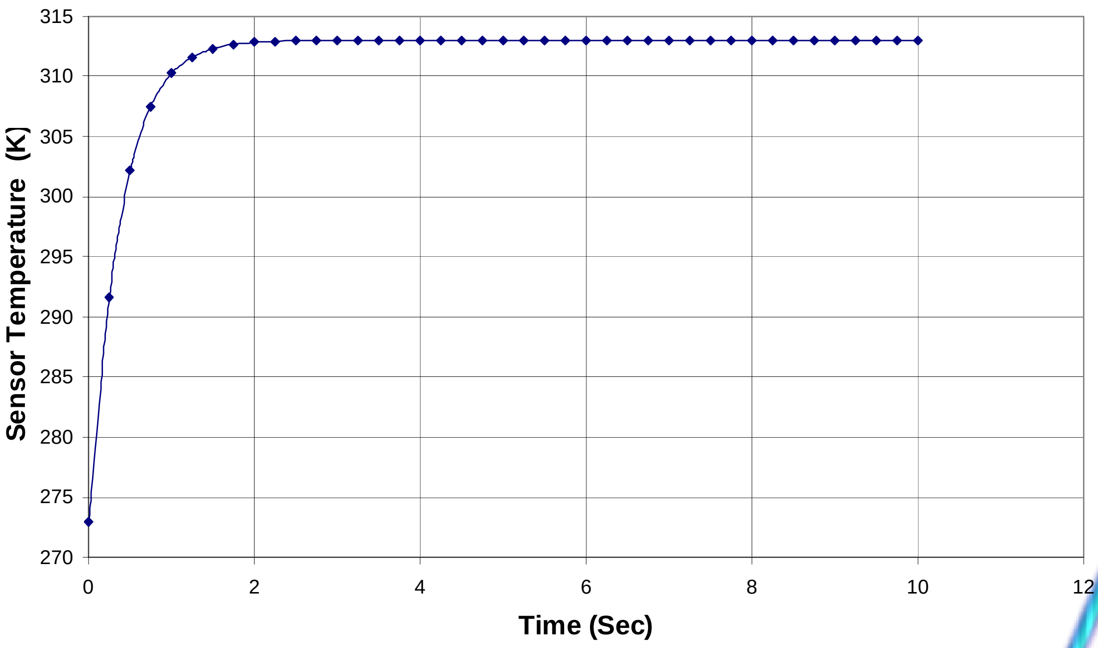
Ansys simulations of FBG T-sensor Transient Response of 1.6 mm O.D. packaged sensor using Selected Adhesive (Rated to 1400°C) for sensor attachment.





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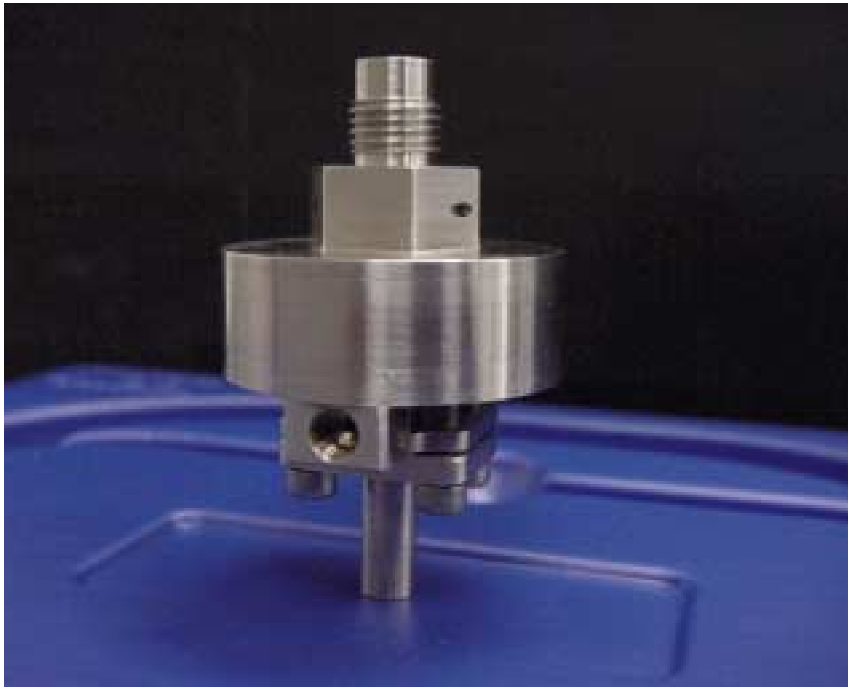
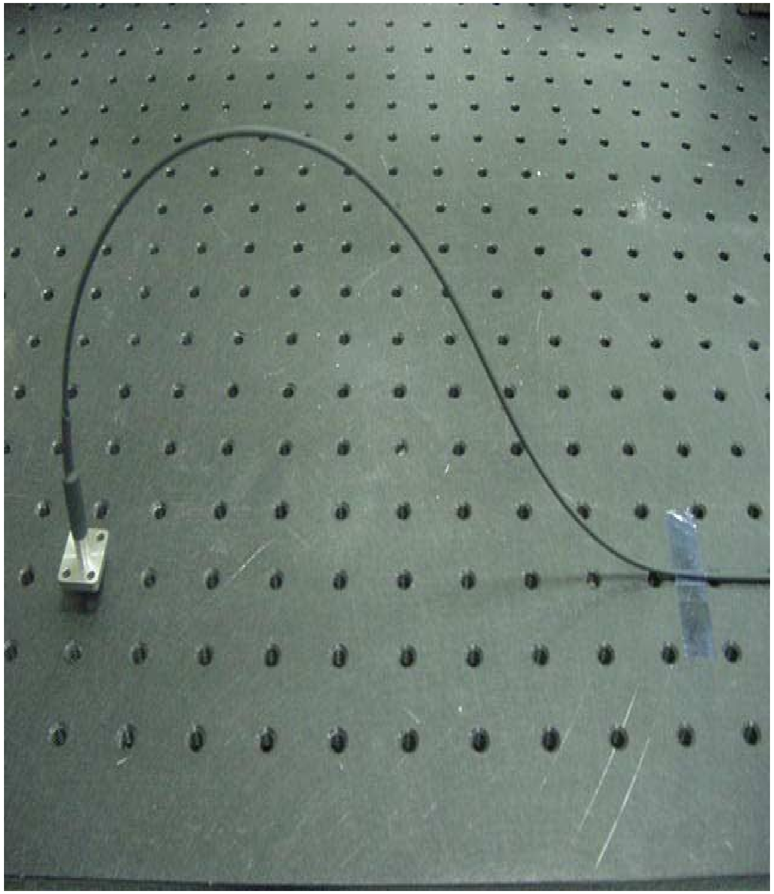
Advanced P/T Sensor and Protective Cabling





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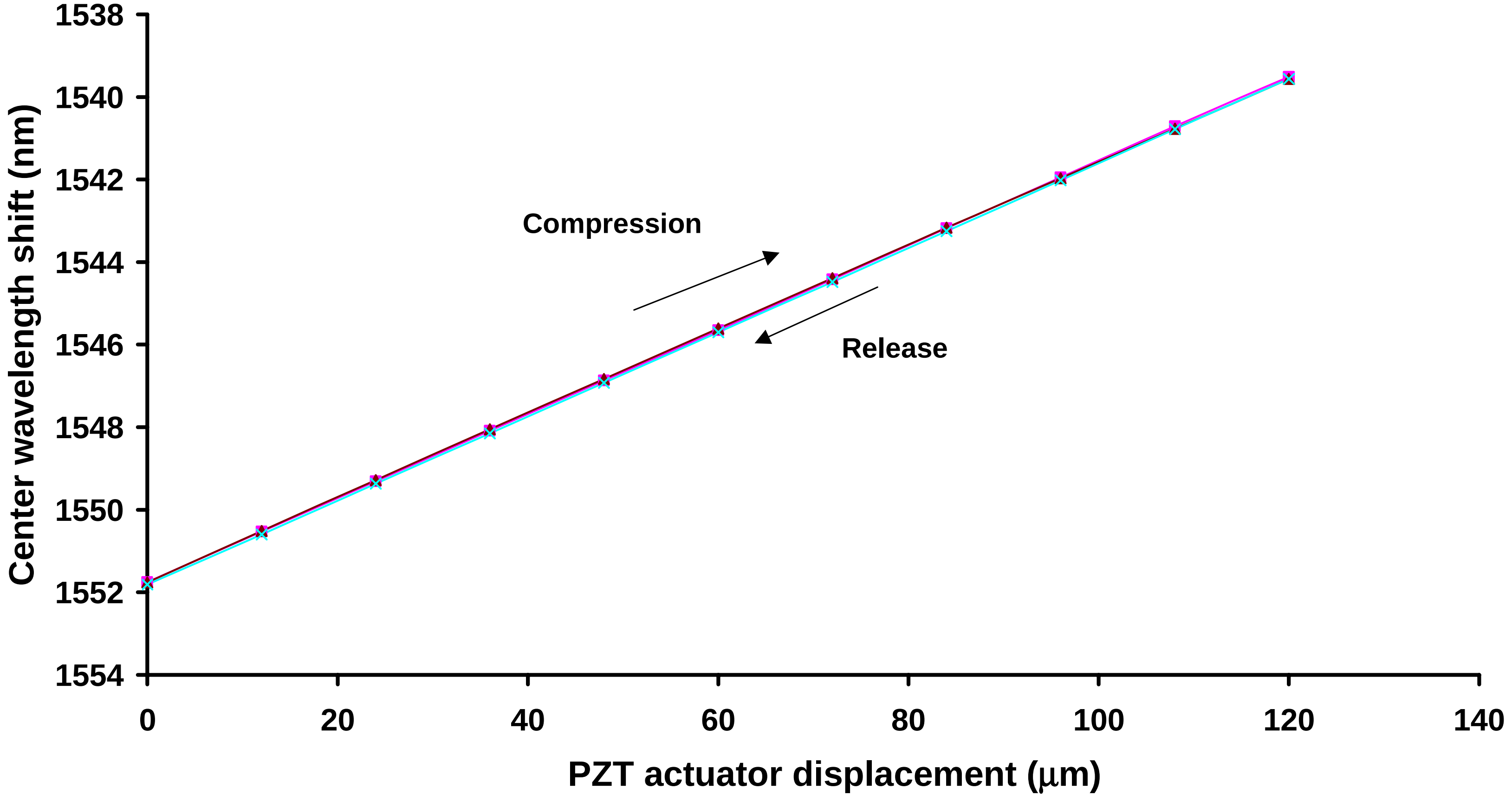
P/T FBG Hysteresis obtained for Compression/Release of Sensor Membrane



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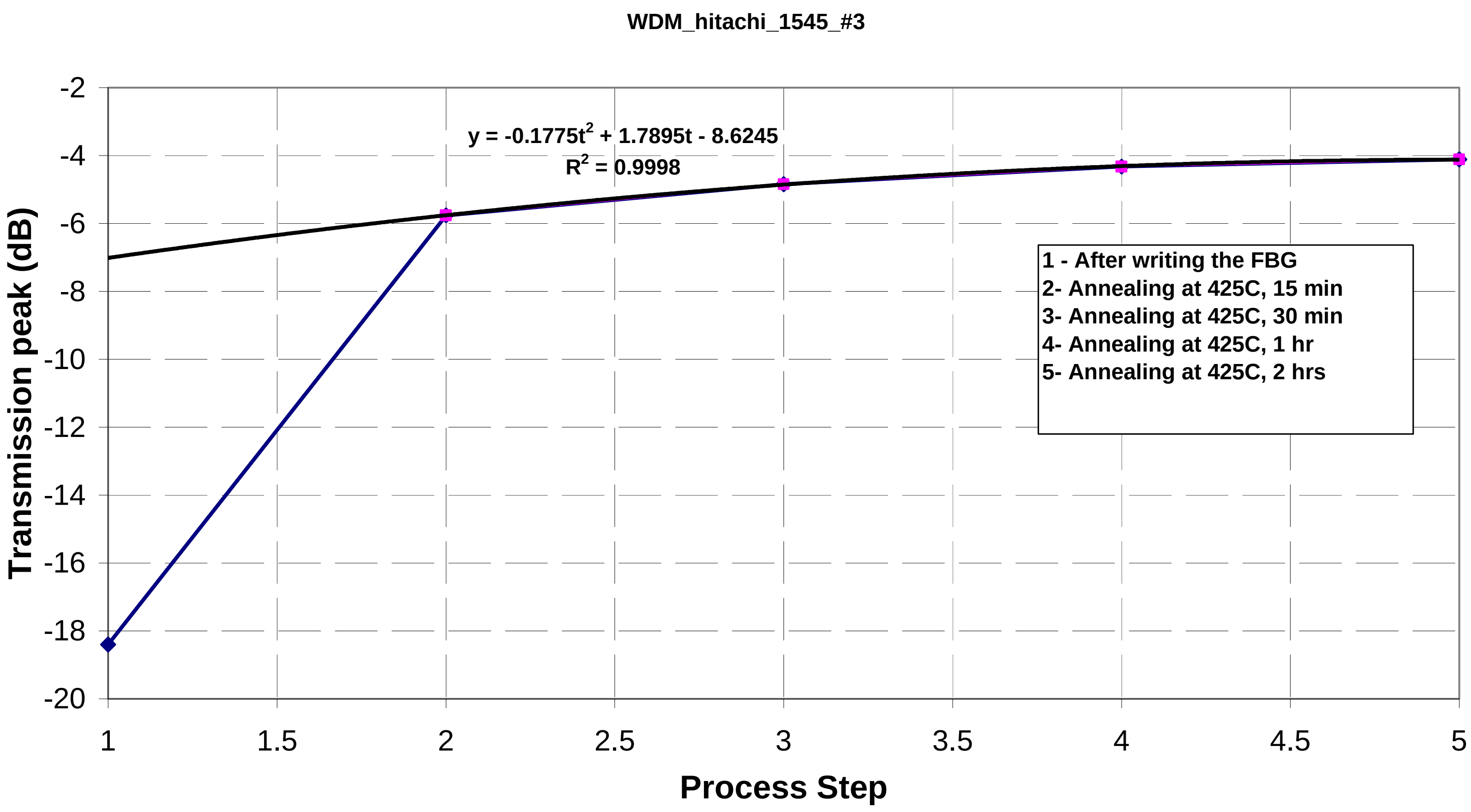
FBG Peak Transmission Variation with High Temperature Annealing



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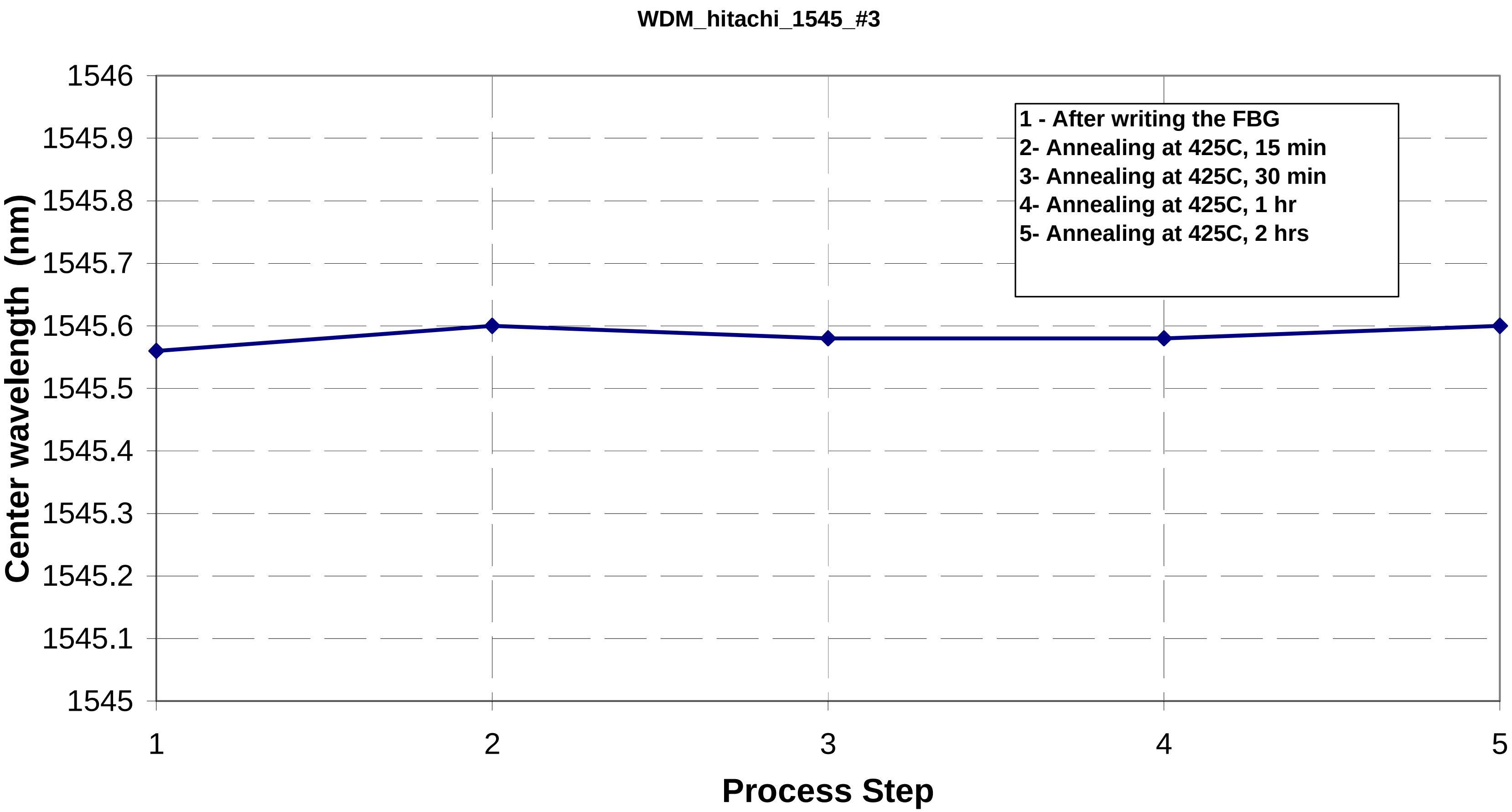
Change in FBG Center Wavelength with High Temperature Annealing.



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FSD Benefits

Space demonstration of key MPB fiber-optic technologies:

- Tunable Fiber Laser
- Fiber-optic signal harness
- FBG temperature sensor
- High-T sensor
- Fiber-optic pressure sensor
- WDM signal multiplexing

Additional development:

- Compact, low-power (2.0 W) microprocessor and data acquisition system for microsat applications

Preliminary Specifications

Sensor	Description	Range	Wavelength Span	Resolution
MEMS/FBG Temperature	Pipeline temperature of propulsion system	-40 to 70 ^oC	5 nm per sensor, 4 to 5 per fiber line	0.05 ^oC
Combined pressure/temperature dual FBG/MEMS sensor	Xe tank pressure	0 to 40 Bar	15 nm	2 mbar
		-40 to 70 ^oC	5 nm	0.05 ^oC
High T FBG/MEMS	Thruster Temperature	-40 to 400 ^oC	20 nm	0.1 to 0.2 ^oC