JPL Lessons Learned with Space Based Optical Fiber Packaging

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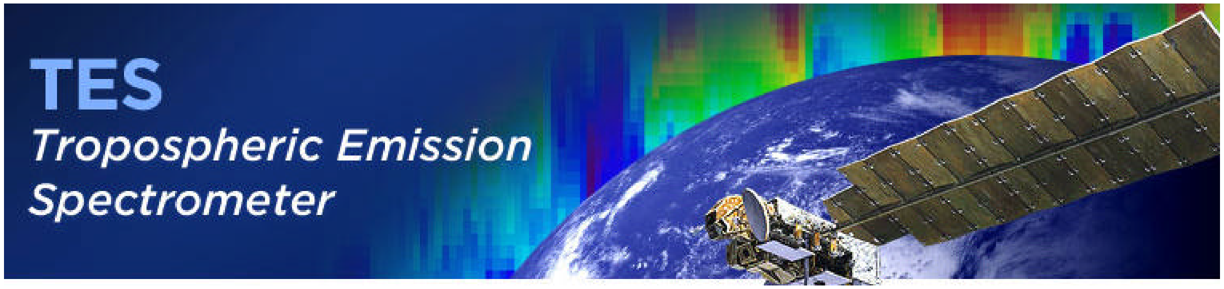
Outline

- Case Study: Lasers for the Tropospheric Emission Spectrometer (TES) Instrument
  - Mission Description
  - Laser description
  - Lessons Learned with fiber packaging:
    - Laser Build
    - Laser integration to Instrument

TES Mission

- Over a period of 5 years, the Tropospheric Emission Spectrometer (TES) will gather data describing the global distribution of tropospheric ozone and other gas molecules that will be used to create a three-dimensional model depicting tropospheric chemistry.



- Laser Assembly requirements
  - Single frequency @1064nm
  - 5 mW optical power output at End-of-Life
  - Reference wavelength for the spectrometer, providing a fringe clock

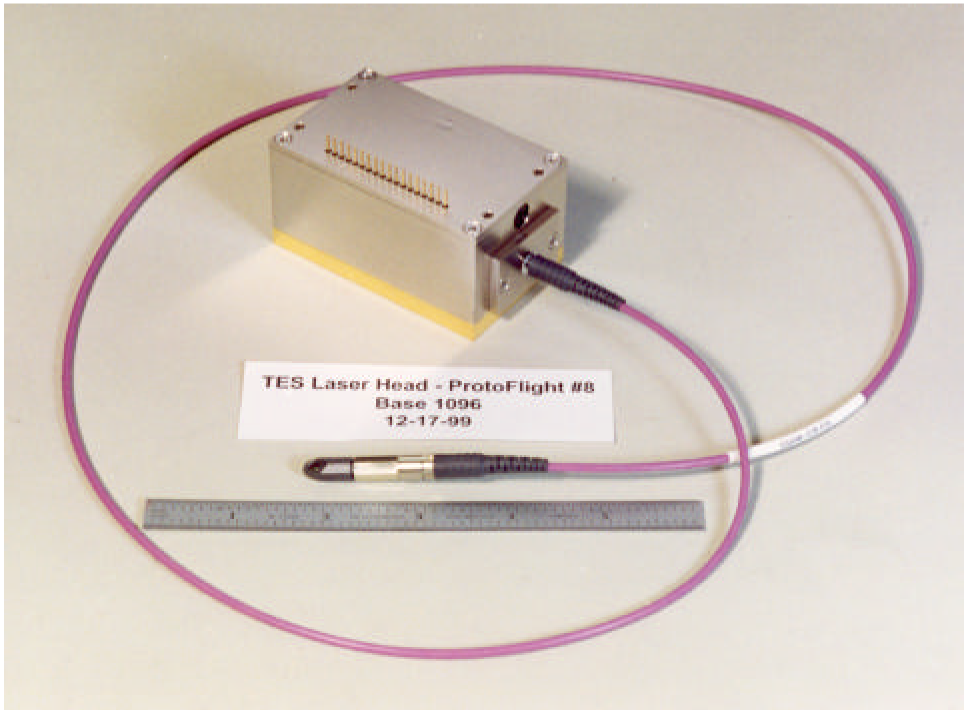
Current Status: TES Laser

- TES Launched on July 15, 2004
- The high quality of the science data show that the lasers are performing to specifications
- Laser telemetry indicates that laser performance is the same as before launch

- Instrument itself is in good health

TES Laser

- Ruggedized and space-qualified version of commercial laser built by Lightwave Electronics Corp.



- Diode-pumped, Nd:YAG solid-state laser
- Fiber Pigtail Output

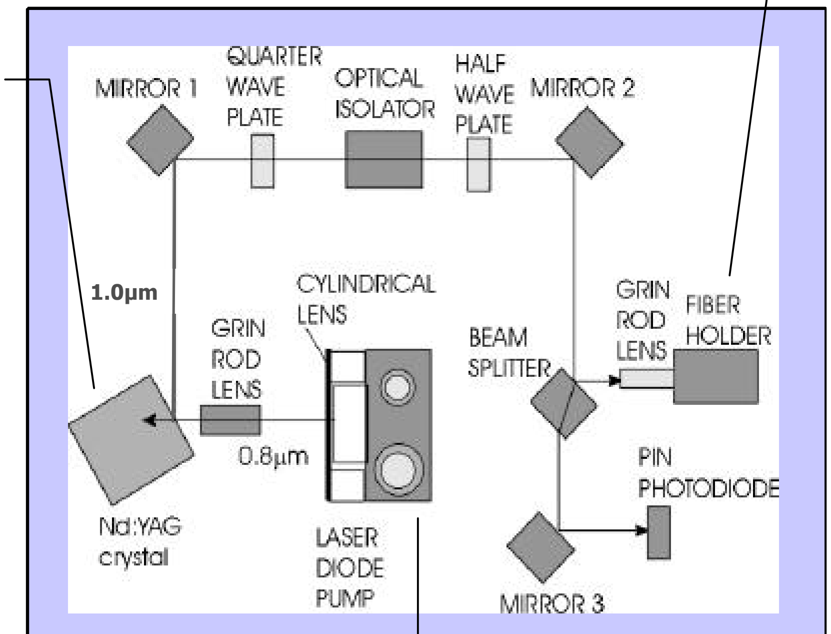
Key Challenges

- Verifying system stability after making materials and process changes that were necessary to space-qualify laser
  - To improve thermal stability
  - To reduce outgassing
- Ensuring mechanical stability of fiber mount components to preserve output fiber coupling efficiency over mission life

Ruggedization done for TES

Pump to NPRO:

- Re-designed mechanical mount for laser diode
- Used high Tg epoxy to mount NPRO crystal to carrier



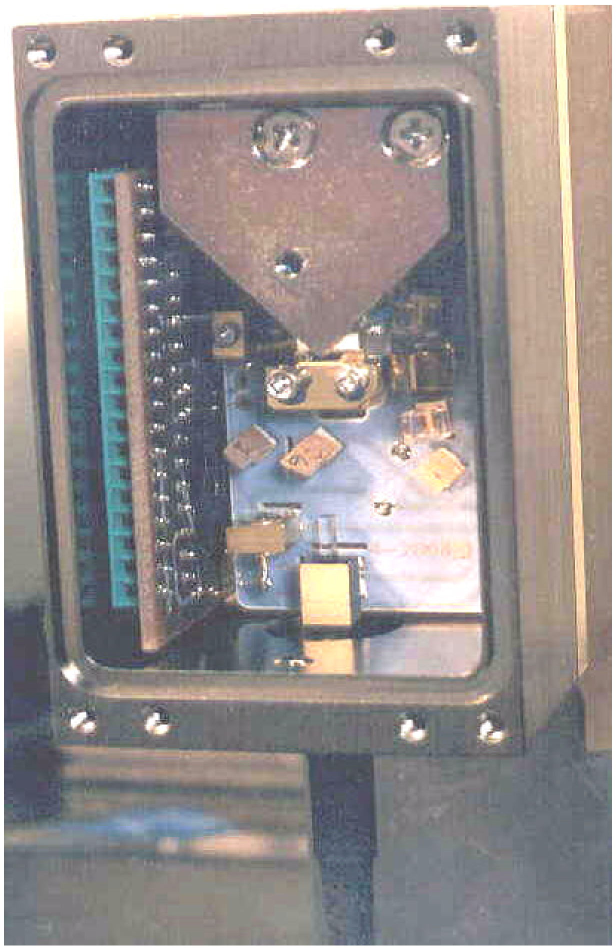
NPRO to fiber:

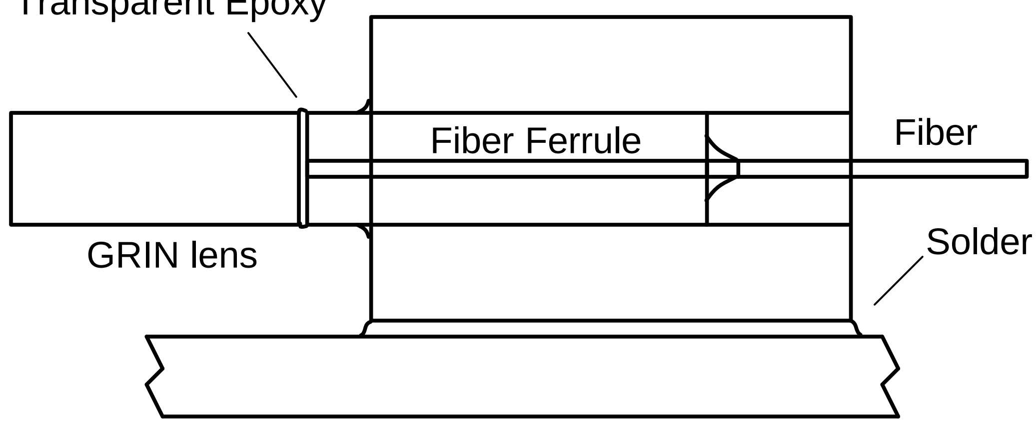
- Tightened tolerance of internal fiber mount to constrain movement
- Used high-Tg epoxy
- Used pre-shrunk fiber pigtail cabling
- Removed unnecessary reinforcing ring
- Re-designed fiber feedthrough

Pump Diode:

- Bought upscreened devices from Space Division of SDL
- Contracted SDL to perform 1-year lifetest
- Operated diodes at de-rated current

Final Design: Fiber Mount

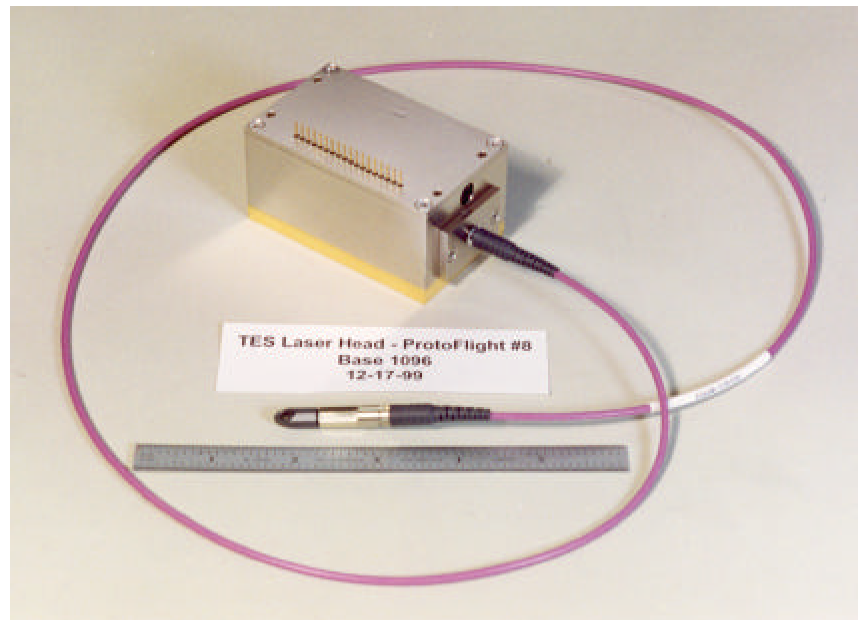




- Tightened opto-mech part tolerance
- Used high-Tg epoxy
- Used pre-shrunk fiber pigtail cabling
- Removed unnecessary “reinforcing” ring
- Re-designed fiber feedthrough

Final Design: Fiber Cabling

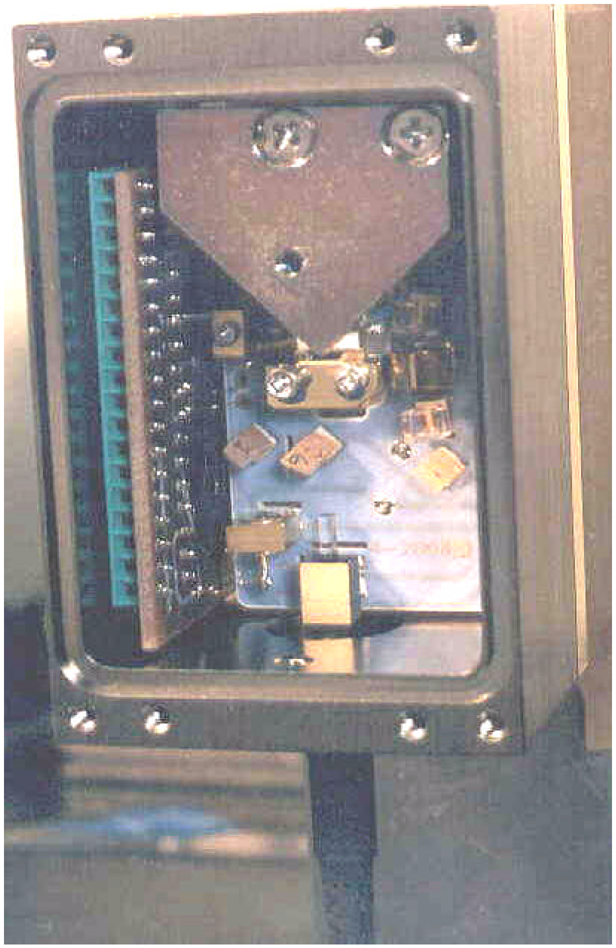
- Used pre-shrunk 3mm fiber jacketing that had been space-qualified by NASA
- Used rugged Diamond AVIM connectors when clearance allowed
- Qualified a thermal-mechanical fiber stripping method for fiber termination process

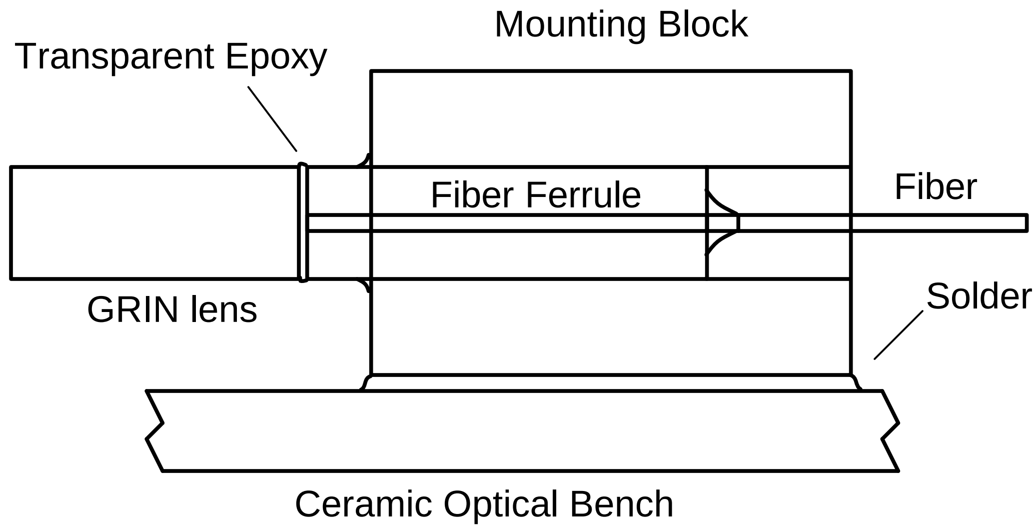


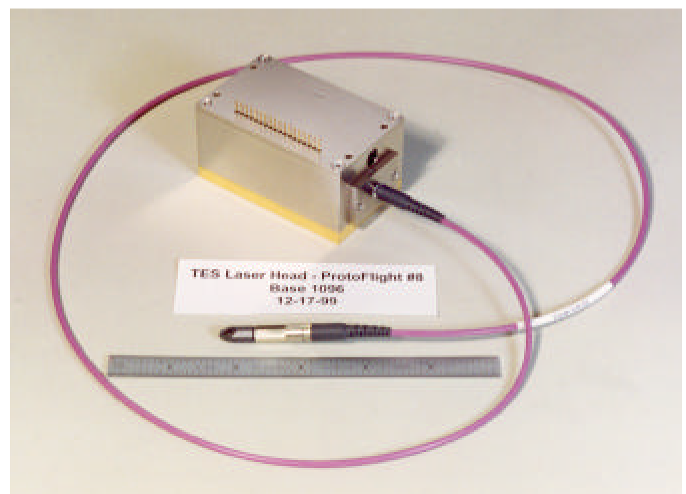
Lessons Learned: Design & Build

- No such thing as a “small” configuration change when micron-level alignment tolerances are involved
- Epoxy curing schedules can greatly affect the epoxy’s physical characteristics (e.g. Tg, CTE)
- The details of epoxy curing steps are important (beware of unintended “room-temperature cure”)
- Don’t use two different epoxies in contact with one another
- Be aware of and study all the forces in/on the system
- Avoid modifications that over-constrain the system
- Use components that are already space-qualified wherever possible, as early as possible
- Test as much of the complete system as possible
- No good way to do accelerated life-testing on a complete system
- Use the expertise from high-volume commercial fiber suppliers
- Use ruggedized, vibration-resistant fiber connector terminations

Fiber Packaging





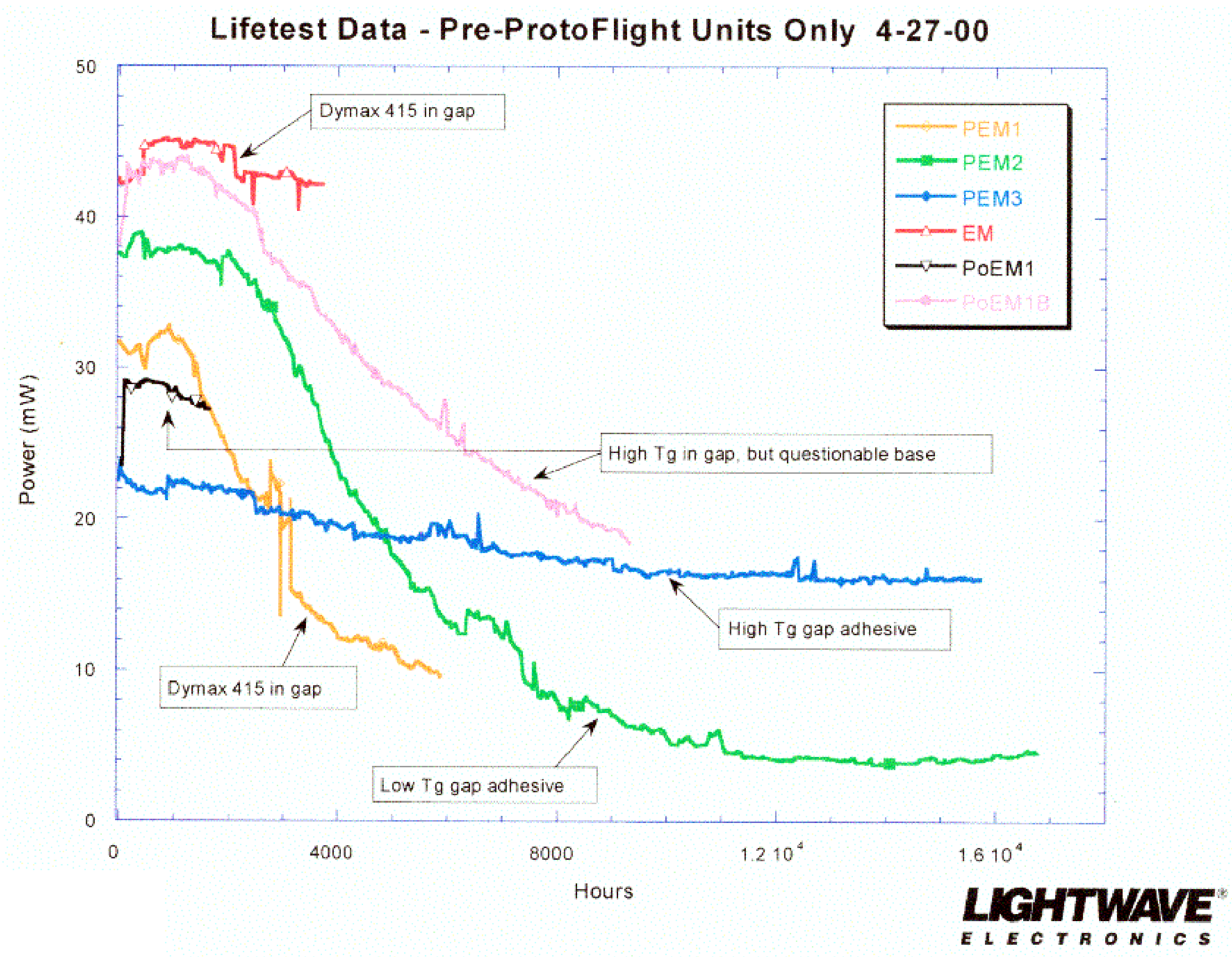


Key Lesson

Multiple early builds of Pre-Engineering Model prototypes can be critically useful!

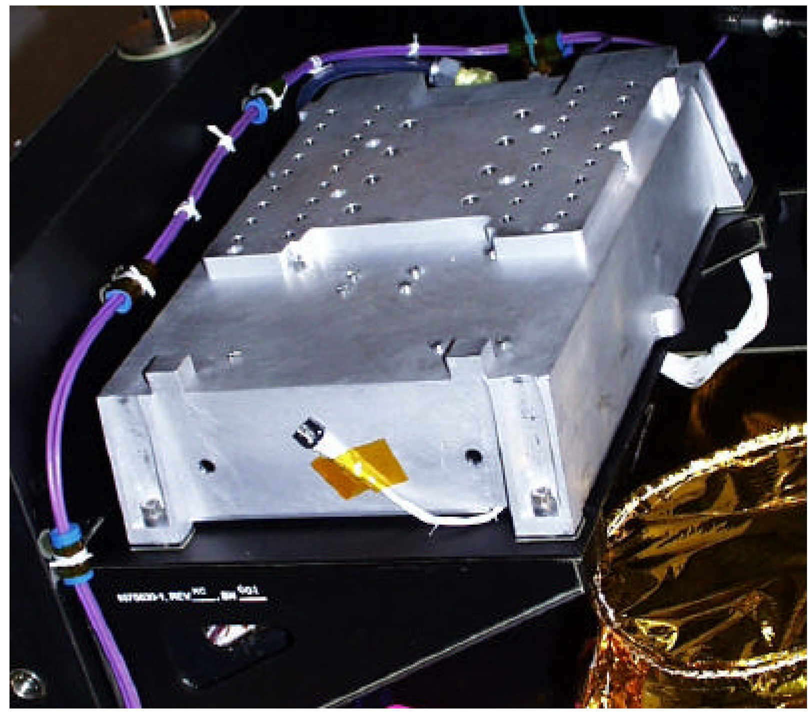
- Provided a proving ground for new materials and processes
- Allowed discovery of problems early enough to test modifications
- Enabled early identification of root causes of failures
- Enabled early determination of physics of failure
- Allowed system-level testing in flight-like configuration and environment
- Enabled collection of long-term non-accelerated laser lifetest data (8+ years) that informed trade-off decisions as early as the Preliminary Design Review

Prototype Lifetest Data



Final Fiber Integration Configuration

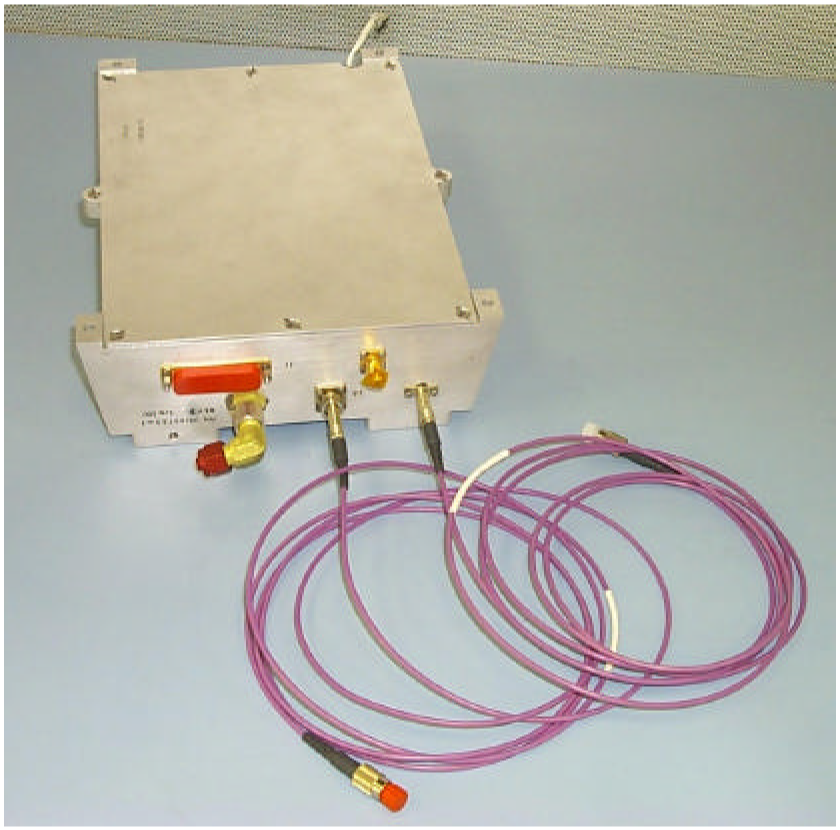
- Laser Head Assembly installed in instrument with fiber cables attached
- Added tie-down points to adhere to minimum bend radius requirements
- Added cushioning at tie-down points to avoid crimping the fiber jacket

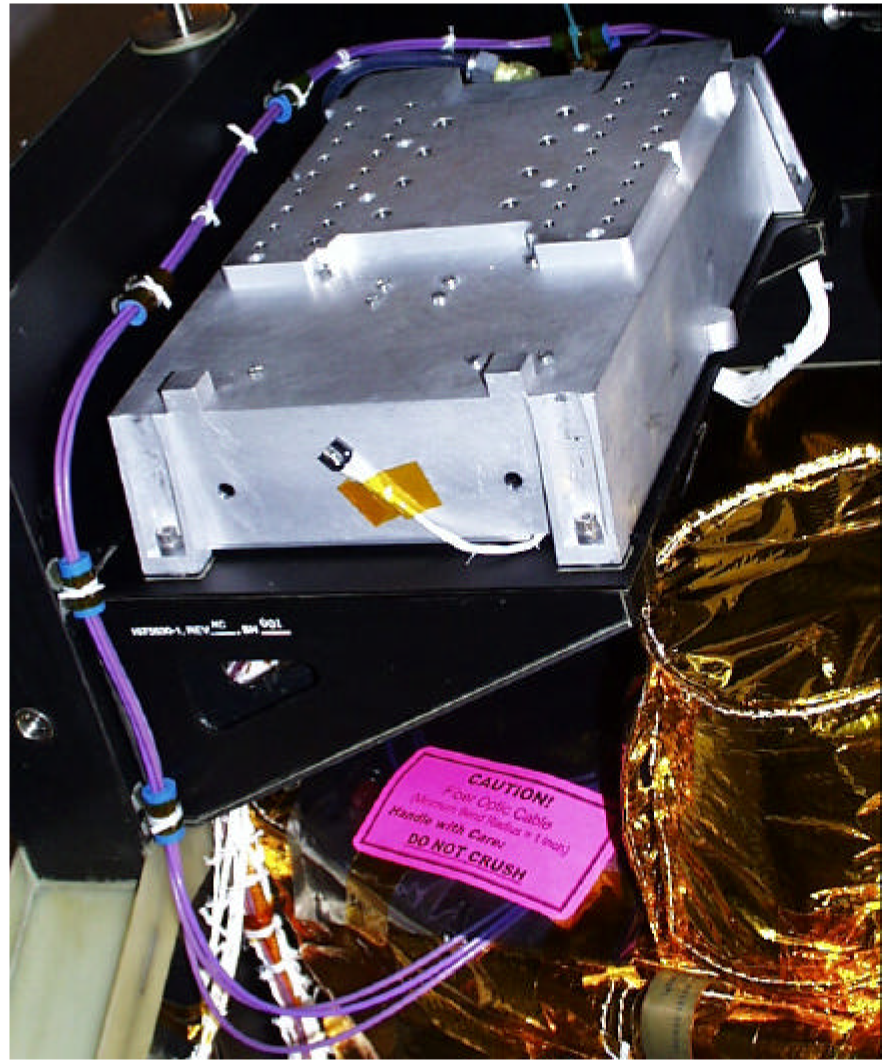


Lessons Learned: Instrument Integration

- Fiber cables are easily kinked when hardware boxes are integrated after the fiber cables are attached
- Avoid integrating hardware boxes with fibers attached by using connector adapters that allow end-face cleaning before mating
- Ensure that the placement of sub-assembly boxes in the Instrument allows enough access for mating fiber connectors (able to see alignment key and slot, clearance for finger-tightening, torque wrench has access)
- Create a safe place to store fiber cable slack during routing
- Consider cable routing paths early-on to ensure adherence to minimum bend radius requirements
- Train cabling technicians on handling of optical fiber cable – more delicate than electrical cable (don't step on it, don't lay it across sharp edges, connector cleanliness is critical)
- Fiber cables easily become "orphaned" - dedicate a knowledgeable optical engineer to the fiber cables who will be responsible for them during integration and who can coordinate with the electrical cabling engineer

Integrating Laser into Instrument





Key Points

- Prototyping is very important
  - The earlier the better
  - Proves out new materials and processes in an actual flight-like system
  - Enables long-term non-accelerated lifetesting
- Pay attention to epoxy cure schedules
- No such thing as a “small” modification
- Fiber cables need special attention during integration