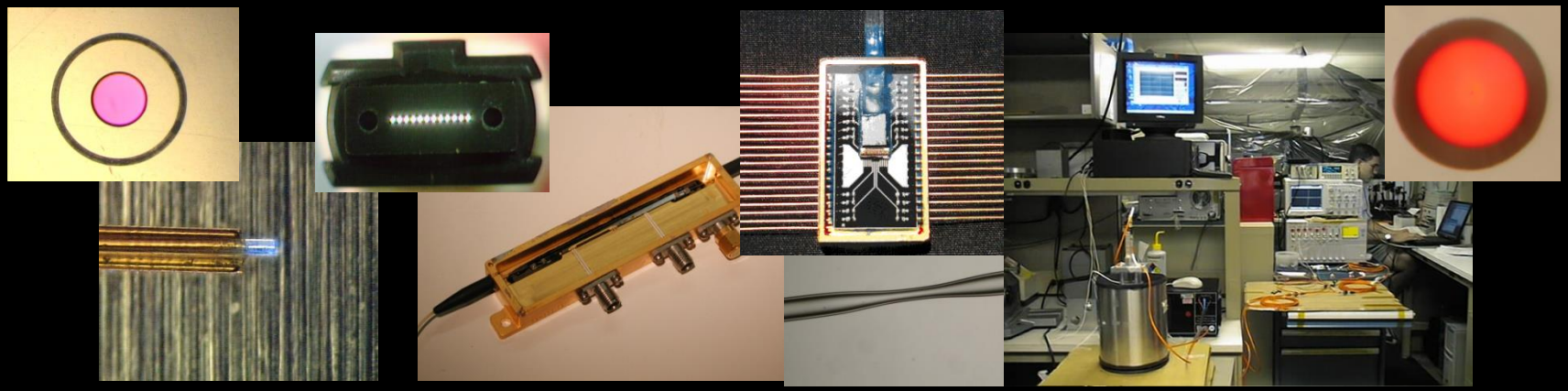
Optical Assemblies for Space Environments: Characterization of W.L.Gore Flexlite with Diamond AVIMS for Space Flight Environments



Melanie N. Ott

Sigma Research and Engineering/

NASA Goddard Space Flight Center

More information: 301-286-0127, melanie.ott@gsfc.nasa.gov

URL: nepp.nasa.gov/photonics

misspiggy.gsfc.nasa.gov/photonics

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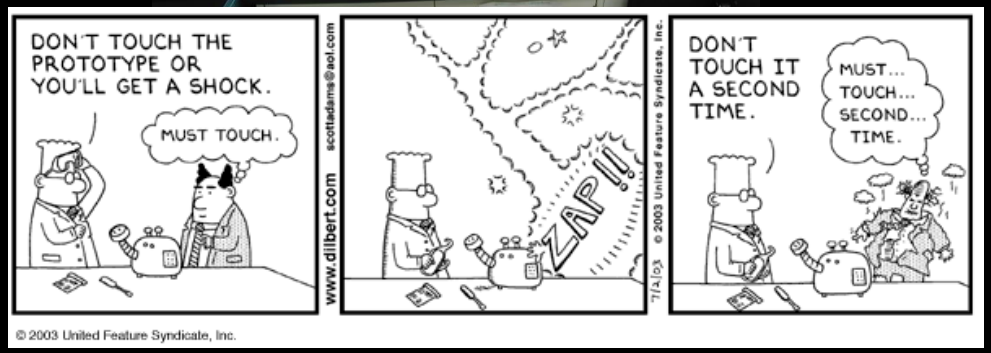
Technical Team: Shawn Macmurphy, Marcellus Proctor, Patricia Friedberg

Photonics Manufacturing and Testing Lab
Parts, Packaging and Assembly Technologies Office
NASA GSFC, Code 562



March 30, 2004

Outline

- **MLA Requirements & Components**
- **Characterization plan**
- **Materials Study Results**
- **Vibration Testing & Results**
- **Thermal Testing & Results**
- **Radiation Parameters**
- **Radiation Testing Results**
- **Conclusions**

MLA Requirements

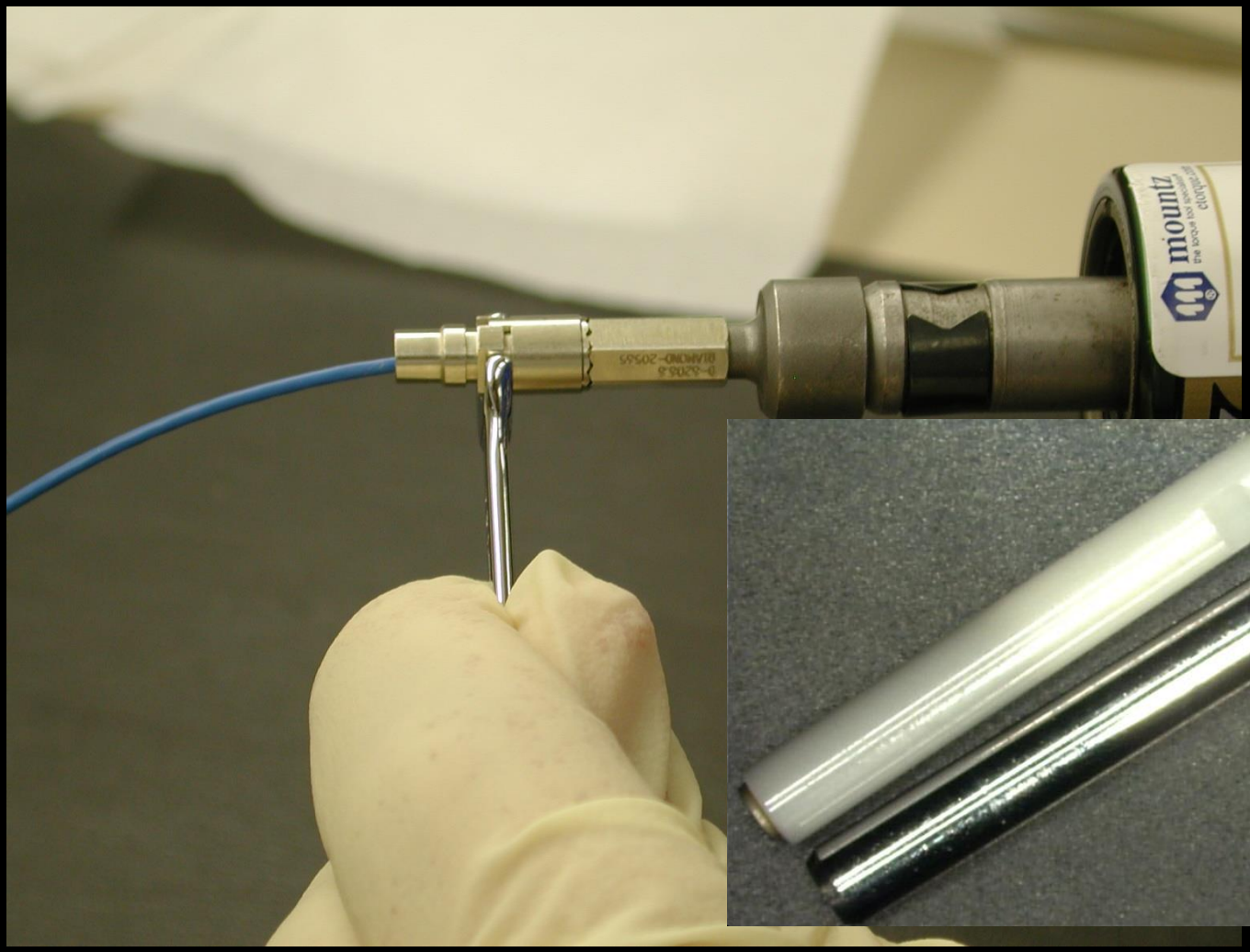
- Large diameter optical fiber, 200 and 300 micron, NA of .22 for use at 1064 nm.
- High performance assembly;
  - Low insertion loss (< 0.4 dB)
  - Repeatability.
  - Stability in harsh environment
    - thermal, vibration and radiation.
  - Non-outgassing components.
  - Assemblies 26.1 inches long used for beam delivery system, not interconnected.

Parts selection to meet requirements:

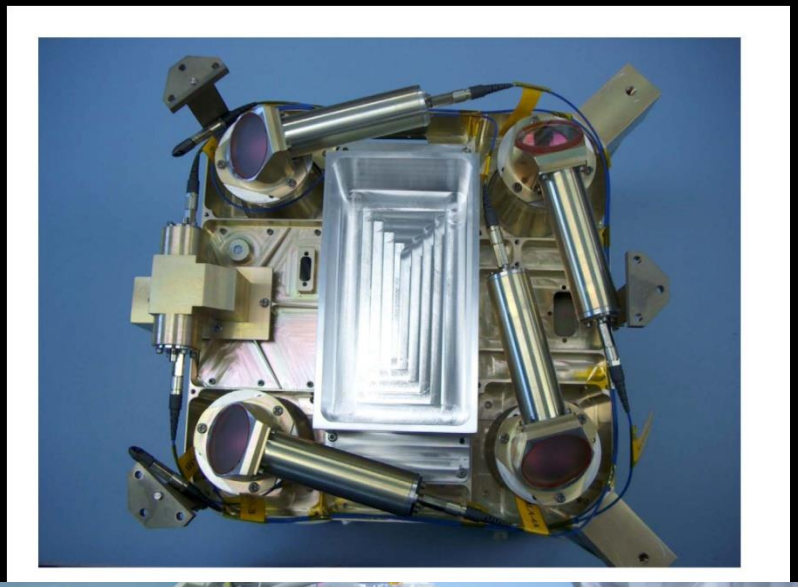
- Diamond AVIMs with custom ferrule drilling, D-6201.1
  - Part # E070040095VNAS1 Ferrule custom drilled for 220 fiber.
  - Part # E070040095VNAS2 Ferrule custom drilled for 330 fiber.
  - Part # 070015048V001, Hytrel boots.
- W.L.Gore, Flexlite simplex cable, FON1173, FON1174
- Polymicro Technologies optical fiber,
  - FIA200220500, 200 micron, acrylate, .22 NA, step index
  - FIA300330500, 300 micron, acrylate, .22 NA, step index
- Epoxy, Epo-Tek 353ND.

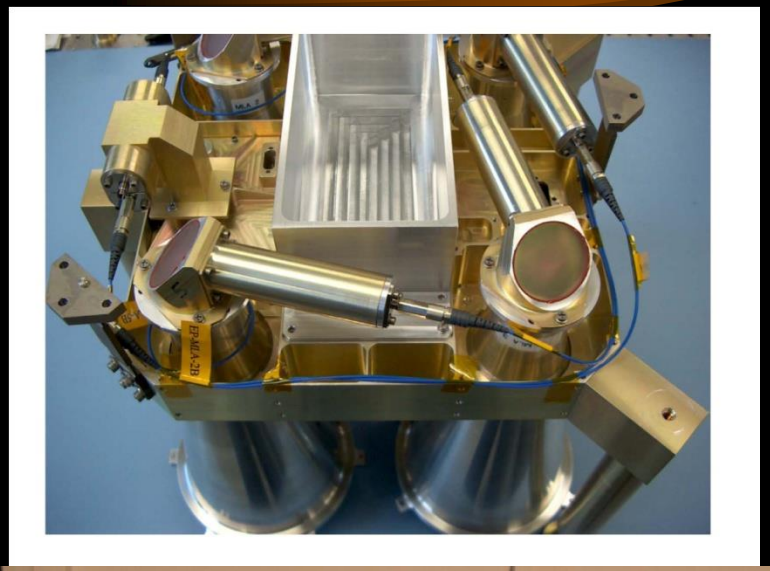
AVIMs and Flexlite Assembly

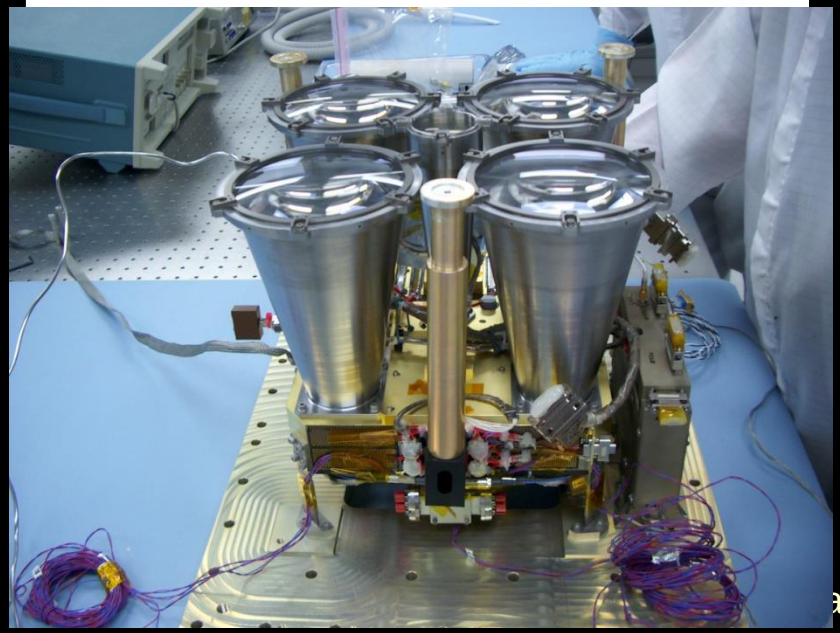
Terminations performed to NASA-STD-8739.5 and procedure 562-WI-8700.2



Mercury Laser Altimeter







Characterization Plan

All testing conducted: recorded before and after optical performance data as well as in-situ optical data.

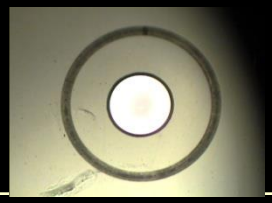
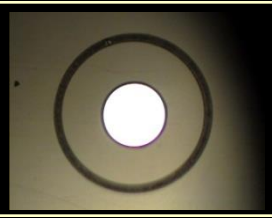
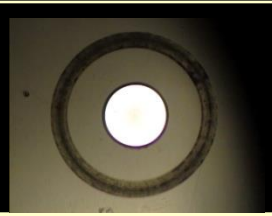
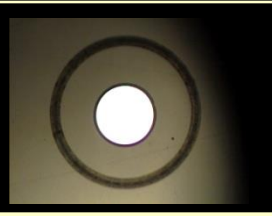
- Vacuum Outgassing,
  - All materials must pass ASTM-E595.
- Vibration Induced Effects
  - Verified survival and operational ability during launch using typical launch parameters for small box components.
  - 3 minutes per axis, 14.1 grms total, 3 assemblies tested.
- Thermal Induced Effects
  - -30°C to +50 °C, 90 cycles, last 42 monitored, (tests are conducted at 10°C higher than expected environmental extremes).
  - 25 minute soak, 2 °C/min ramp rates.
- Radiation Effects
  - Space flight environments from GSFC are less than 1 rad/min and more typically less than 0.1 rads/min. Two dose rates used to possibly provide a model for extrapolation to lower dose rates.
    - 11.2 rads/min for lower dose rate, 22.7 rads/min for higher dose,
    - Up to 30 Krads while maintaining a cold temperature of –20° C.
    - Actual projected dose rate for MLA: 16.44 rads/day, .685 rads/hour, .011 rads/min

Materials Results, nonmetallic parts

- Cable
  - Flexlite passed when tested previously in configuration during development of ICESAT (GLAS) with acrylate coated fiber.
  - Cable does require preconditioning for thermal stability
    8 cycles, 60 min @ 60°C, 25 min @ -20°C, < 2°C/min
- Connector Boots
  Hytrel 8068 require de-gas preconditioning,
  10^2 to 1 Torr, 140°C, 24 hours.
  Once preconditioned, ASTM-E595 results were:
  0.48 % TML, 0.10% CVCM.
- Epoxy
  EpoTek 353ND is contained in GSFC outgassing database.

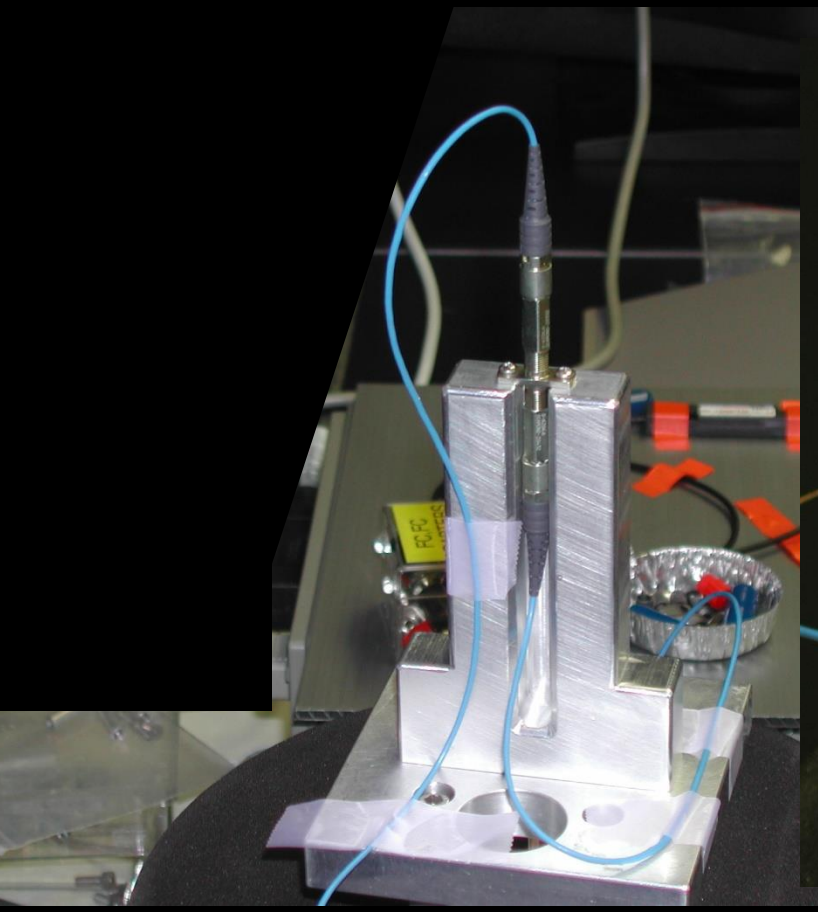
Cable Designations and Initial Visual Inspection

Pre-environmental Testing Visual Inspection

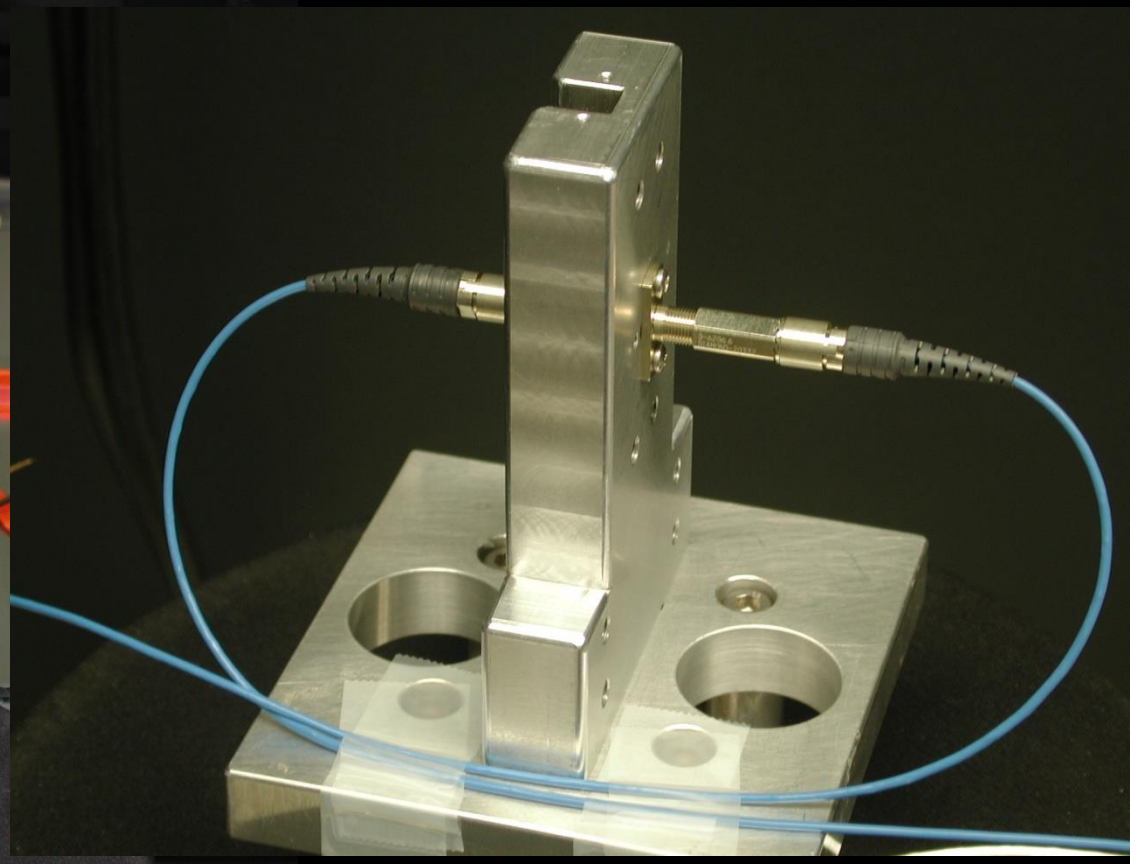
Assembly Code	Side A	Side B
MP1		
MP2		
MP3		

MPX Test assemblies were made of two AVIMS/AVIMS interconnected with an AVIMS adapter, each ~ 24 inches long. Presented above are end face pictures of the mated sides that were exposed to environmental testing

Vibration Testing



Z axis orientation



X axis orientation

3 minutes/axis, 14.1 grms total, 3 axis test

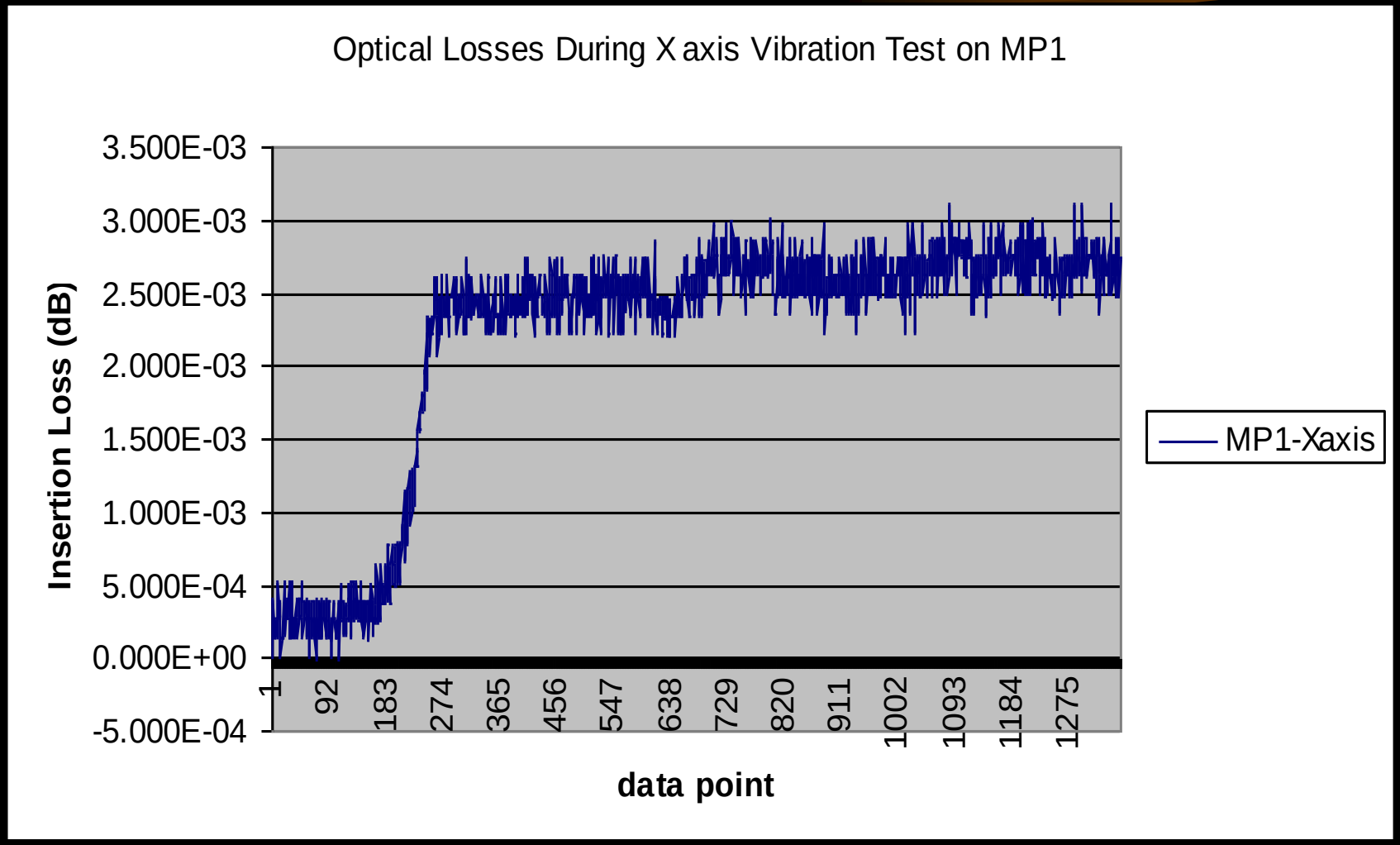
Vibration Parameters for Test

Random Vibration Profile Parameters
Based on EO-1 and MLA specifications

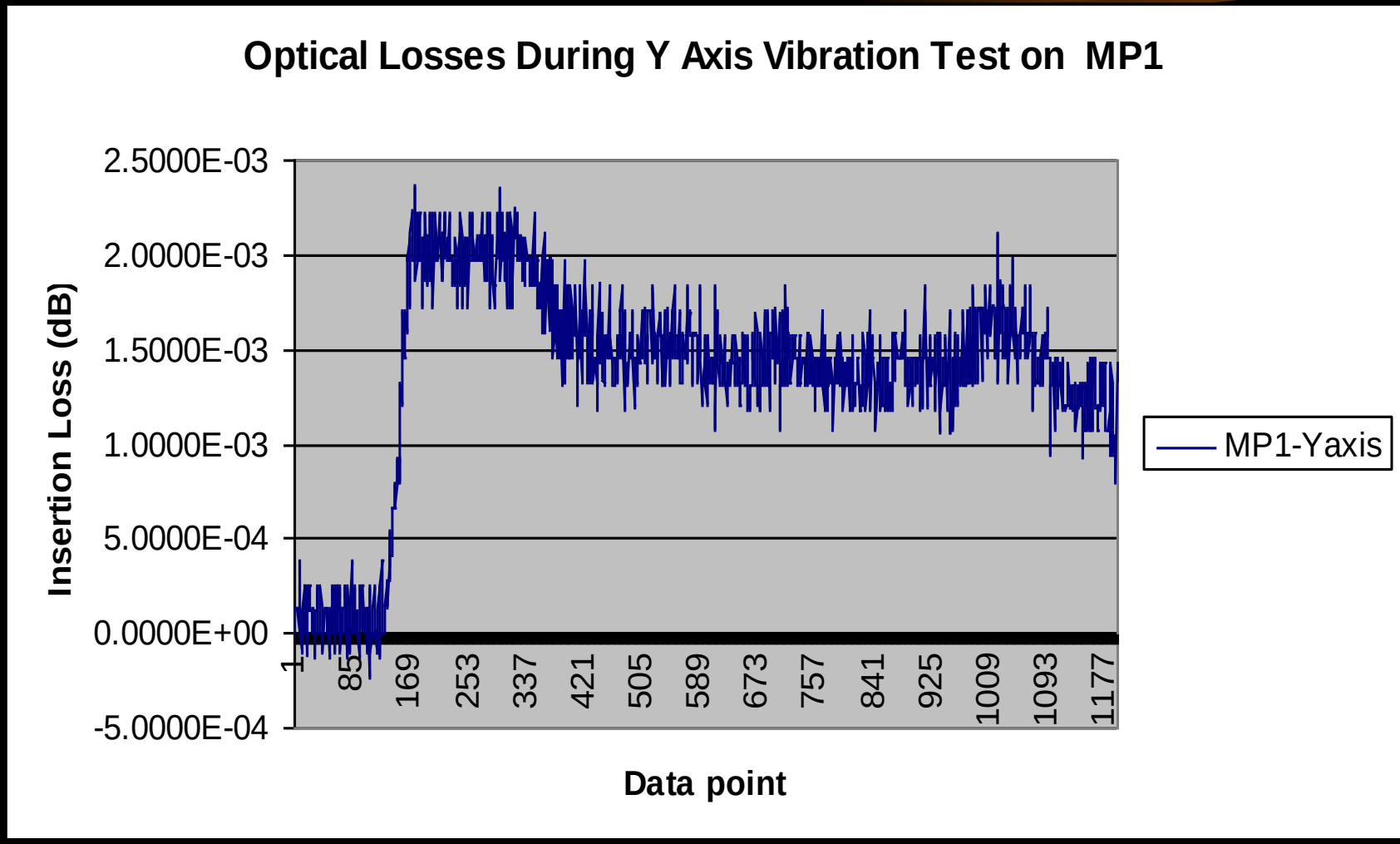
Frequency (Hz)	Protoflight Level
20	0.026 g^2/Hz
20-50	+6 dB/octave
50-800	0.16 g^2/Hz
800-2000	-6 dB/octave
2000	0.026 g^2/Hz
Overall	14.1 grms

3 minutes/axis, 14.1 grms total, 3 axis test for mated pair

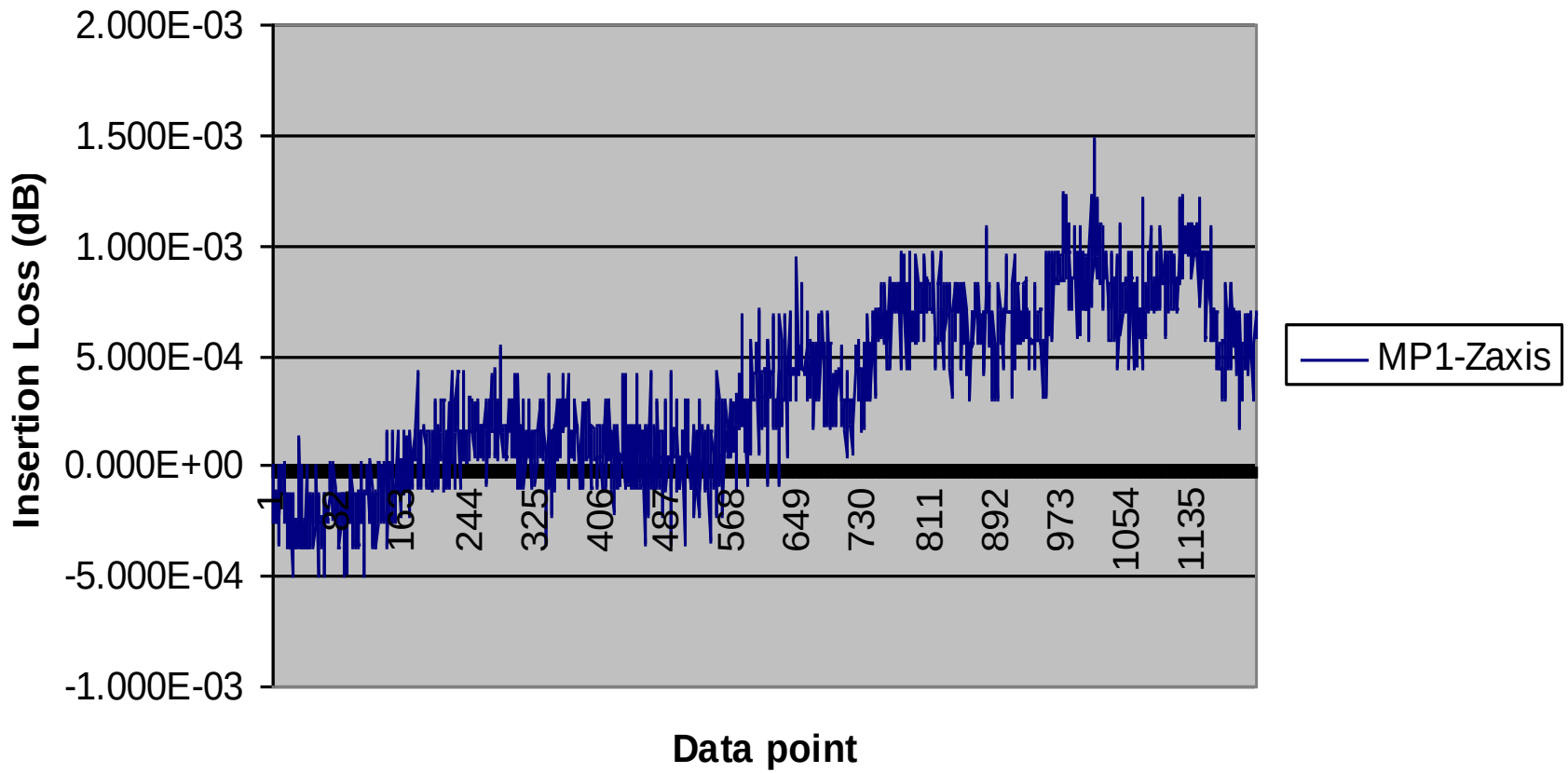
Vibration Test Results: X axis MP1



Vibration Test Results: Y axis MP1



Vibration Test Results: Z axis MP1



Vibration Test Results Summary

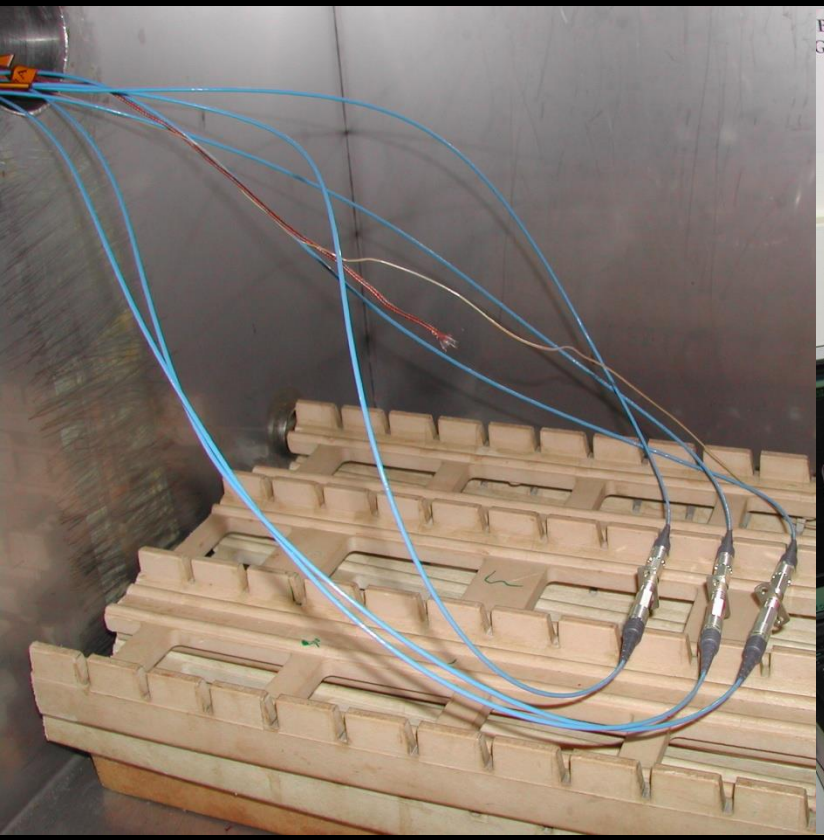
Assembly Set	Vibration Test Axis	Max Induced Insertion Loss	Final Change in Insertion Loss Post Testing
MP1	X	0.0031 dB	0.0028 dB
MP1	Y	0.0024 dB	0.0012 dB
MP1	Z	0.0015 dB	0.0006 dB
MP2	X	-0.0002 dB*	-0.0027 dB *
MP2	Y	-0.0006 dB*	-0.0012 dB *
MP2	Z	0.0027 dB	0.0004 dB
MP3	X	-0.0005 dB*	-0.0017 dB *
MP3	Y	0.0004 dB	0.00 dB
MP3	Z	0.0003 dB*	-0.002 dB *

*Indicates an increase in power post vibration testing

No endface damage was detected during post vibration visual inspection.

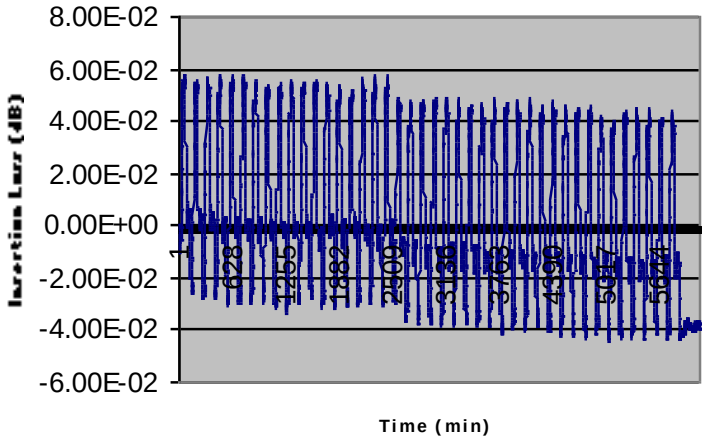
Thermal Testing

-30°C to +50 °C, 90 cycles, last 42 cycles monitored optically.

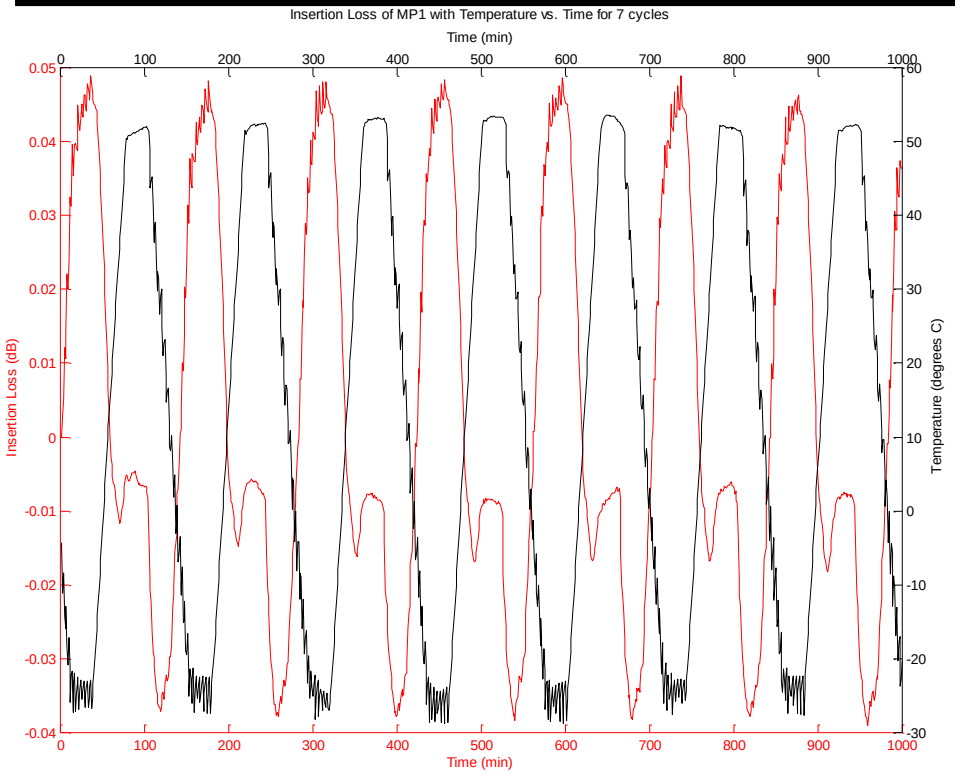


Program malfunction caused lack of data collected during the first 48 cycles.

Thermal Testing Results

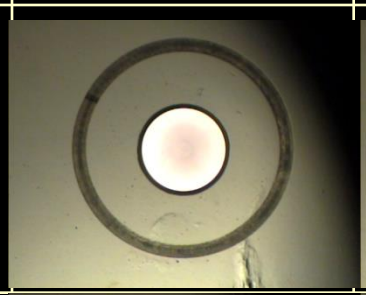
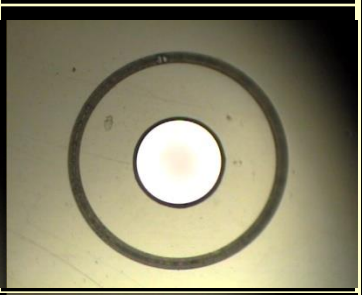
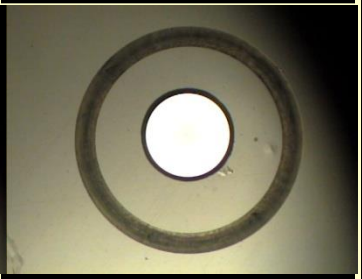
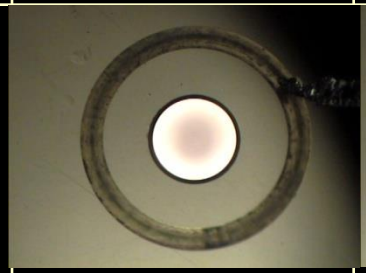
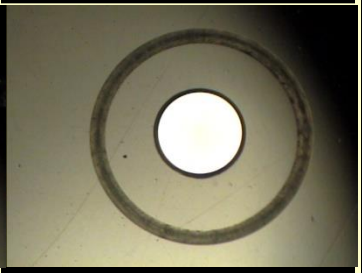


← Example of data collected for all assemblies MP1 during 42 cycles (after initial 48 cycles unmonitored)



Insertion loss for MP1 During 68th to 75th cycle (Red) with temperature (Black). Insertion loss increases with decreasing temperature. →

Thermal Testing Results Summary

Assembly Set	Δ insertion loss during testing	Overall Change in loss post testing, 90 cycles	Max insertion loss during testing	Visual Inspection post test side A	Visual Inspection post test side B
MP1	0.09 dB	-0.044 dB power increase	0.058 dB		
MP2	0.07 dB	-0.015 dB power increase	0.037 dB		
MP3	0.04 dB	-0.035 dB power increase	0.024 dB		

Radiation Test Parameters

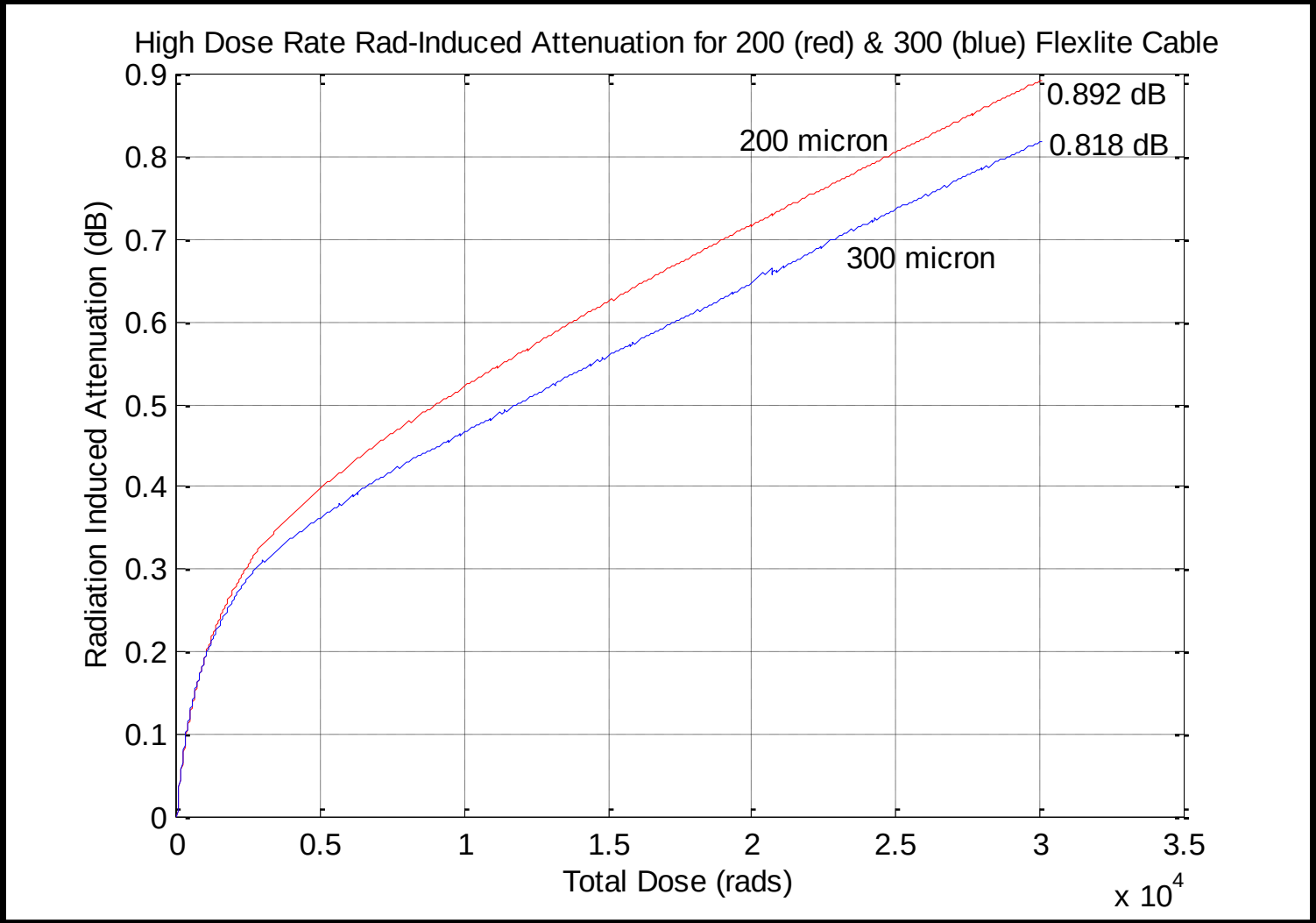
Tested up to 30 krads in Cobalt 60 chamber:

- 10 m of FON1173 (200 micron core fiber)
- 10 m of FON1174 (300 micron core fiber)
- High dose rate 22.7 rads/min
- Low dose rate 11.2 rads/min
- While maintaining at temperature of -20°C.
- Monitored optical power at 850 nm @ < 1 micro watt of power.

Radiation Results for High Dose Test

Induced attenuation for both 200 (red), and 300 (blue) micron cable up to 30 krads

22.7 rads/min
10 meters of cable

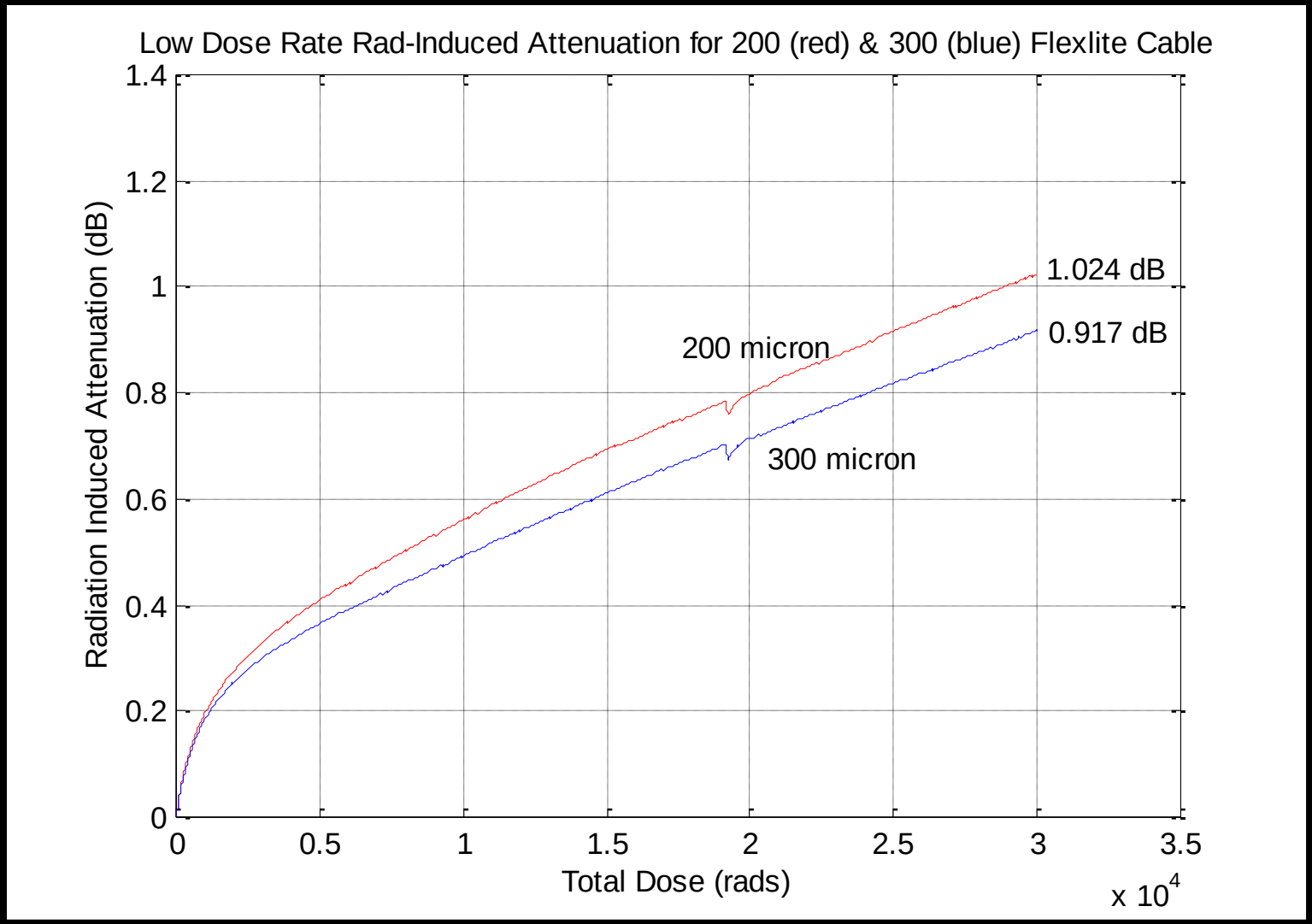


Radiation Results for Low Dose Test

Induced attenuation for both 200 (red), and 300 (blue) micron cable up to 30 krads

11.2 rads/min
10 meters of cable

Small "glitch" at ~ 20 krads due to fire alarm closing chamber shutter



Radiation Results Summary

Part #	Type OF (microns)	Dose rate	Atten. @ 30 krads	Ave. temp during testing	Expected atten. 26.1 inches @ 30 krads
FON1173	200	11.2 rads/min	1.024 dB	-24.1°C	0.068 dB
FON1174	300	11.2 rads/min	0.917dB	-24.1°C	0.061 dB
FON1173	200	22.7 rads/min	0.892 dB	-18.3°C	0.059 dB
FON1174	300	22.7 rads/min	0.818 dB	-18.3°C	0.054 dB

- Results for 200 and 300 micron fiber are ~ identical.
- Results for high and low dose rate tests for both fibers also ~ identical.
- Extrapolation model can not be used without further experimentation.
- Dose rate differences are attributed with difference in thermal environment.

Conclusions

- In general, Flexlite and AVIMs assemblies performed with superiority in comparison to other studies conducted in the past (nepp.nasa.gov/photonics for more information).
- Vibration and Thermal Conclusions: Final change in insertion loss after both vibration and thermal testing is as follows:
  - MP1, -.04 dB, resulting power increase
  - MP2, -.02 dB, resulting power increase
  - MP3, -.04 dB, resulting power increase
- Radiation Conclusions:
  - Since extrapolation method can not be used best assumption is by usage of lower dose rate results. Actual MLA dose rate will be .011 rads/min.
  - Using 11.2 rads/min results, expected losses will be less than .07 dB for each 26.1 inch assembly at –20ºC at a total dose of 30 krads under "dark conditions" or without power enough to provide photobleaching annealing effects.
  - Both FON1174 and FON1173 perform identical.

Post all environmental testing: MP1, 0.03 dB; MP2, 0.05 dB; MP3, 0.03 dB

Acknowledgements

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For more information see the websites:

http://nepp.nasa.gov/photonics

http://misspiggy.gsfc.nasa.gov/photonics