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Vibration Performance Comparison Study on Current Fiber Optic Connector Technologies

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SPIE Optics + Photonics 2008

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Overview

- Vibration Profiles
- Connectors tested in this part of study
- Review of other commonly used connectors
- Recommendations
- Future testing

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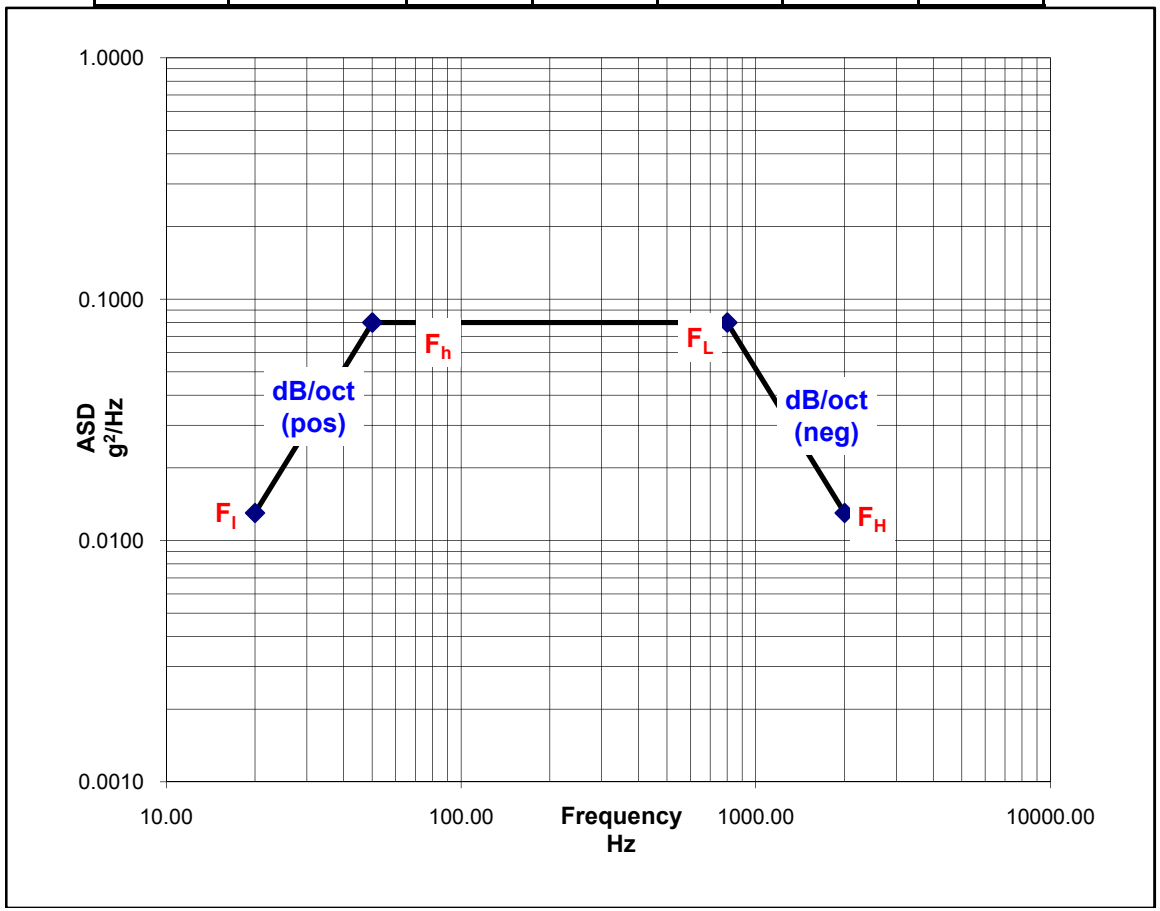
Vibration Profiles

- 10.0 G_{rms} based on GEVS Acceptance Level Tests

FREQ(Hz)	ASD(G^2/Hz)	dB	OCT	dB/OCT	AREA	Grms
20.00	0.0130	*	*	*	*	*
50.00	0.0800	7.89	1.32	5.97	1.25	1.12
800.00	0.0800	0.00	4.00	0.00	61.25	7.83
2000.00	0.0130	-7.89	1.32	-5.97	99.91	10.00



3 min/axis

GEVS
General Environmental Verification Standard published by GSFC to be used for testing space flight hardware unless superseded by mission specific requirements GSFC-STD-7000

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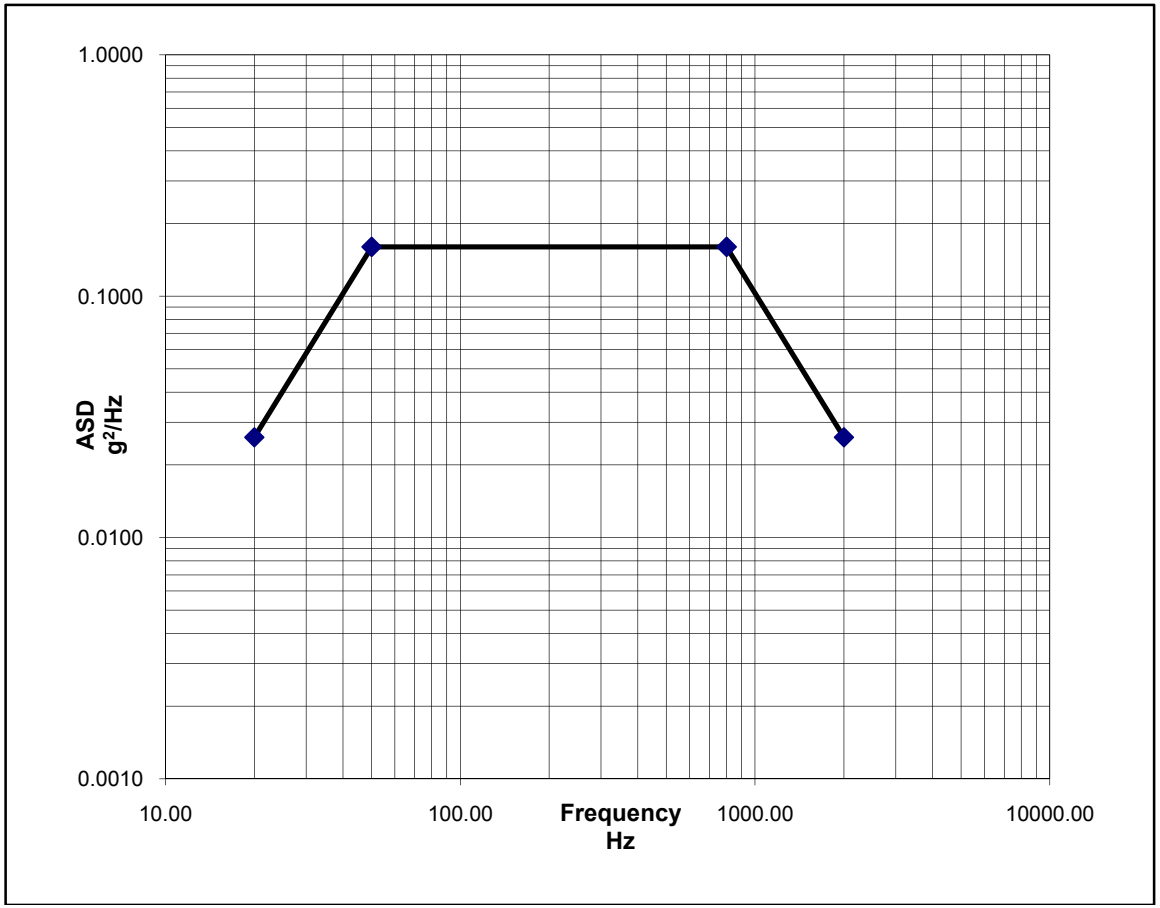
Vibration Profiles

- 14.1 G_{rms} based on GEVS Qualification Level Tests

FREQ(Hz)	ASD(G^2/Hz)	dB	OCT	dB/OCT	AREA	Grms
20.00	0.0260	*	*	*	*	*
50.00	0.1600	7.89	1.32	5.97	2.51	1.58
800.00	0.1600	0.00	4.00	0.00	122.51	11.07
2000.00	0.0260	-7.89	1.32	-5.97	199.82	14.14

3 min/axis

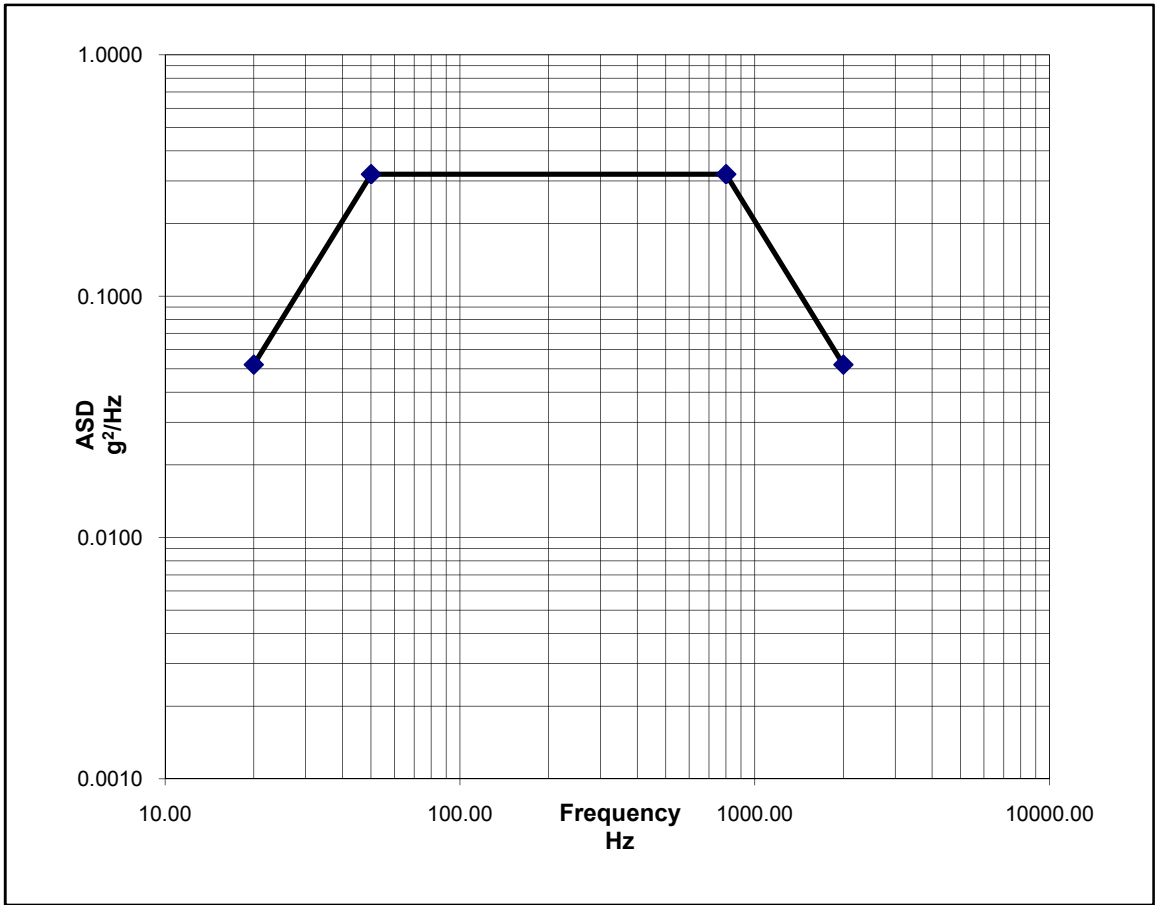


Vibration Profiles

- 20.0 G_{rms} based on Photonics Group Qualification

FREQ(Hz)	ASD(G^2/Hz)	dB	OCT	dB/OCT	AREA	Grms
20.00	0.0520	*	*	*	*	*
50.00	0.3200	7.89	1.32	5.97	5.01	2.24
800.00	0.3200	0.00	4.00	0.00	245.01	15.65
2000.00	0.0520	-7.89	1.32	-5.97	399.63	19.99

3 min/axis

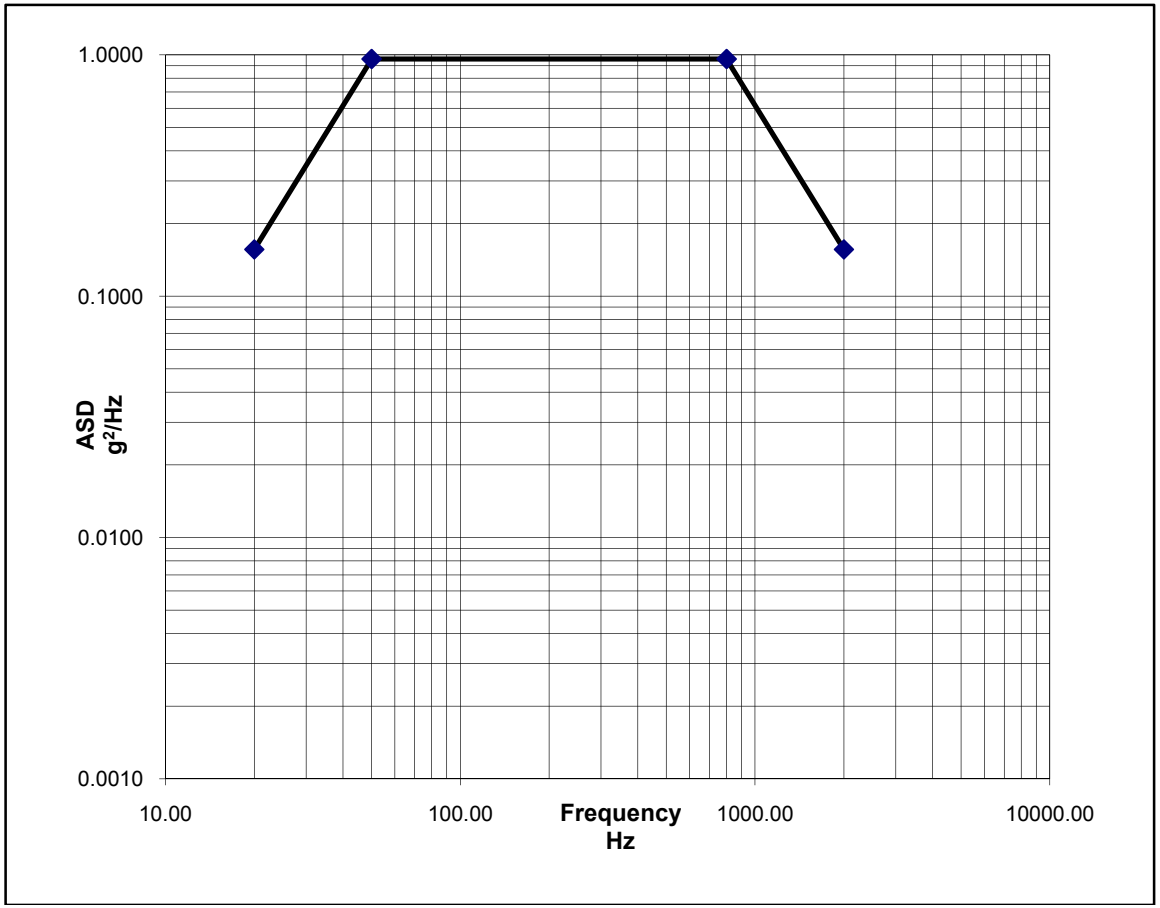


Vibration Profiles

- 34.6 G_{rms} based on limit of vibration system displacement

FREQ(Hz)	ASD(G^2/Hz)	dB	OCT	dB/OCT	AREA	Grms
20.00	0.1560	*	*	*	*	*
50.00	0.9600	7.89	1.32	5.97	15.04	3.88
800.00	0.9600	0.00	4.00	0.00	735.04	27.11
2000.00	0.1560	-7.89	1.32	-5.97	1198.89	34.63

3 min/axis



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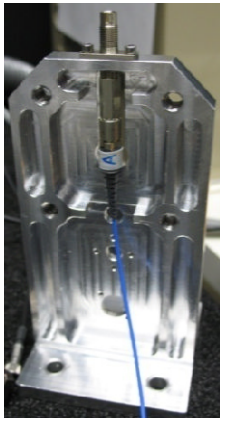
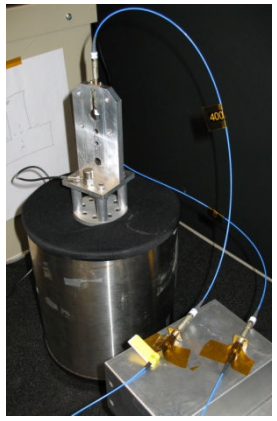
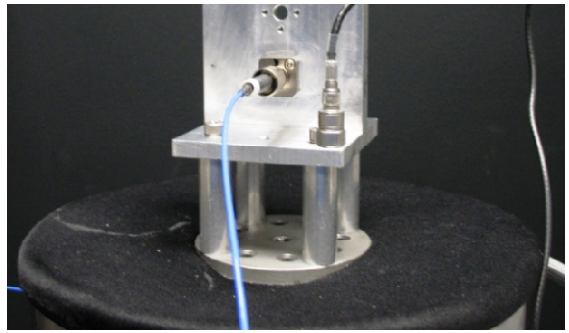
Vibration Test Plan

- Connectors were tested in three mutually perpendicular axes for 3 min/axis
- Vibration testing at 10.0, 14.1, 20.0, and 34.6 G_{rms}
- Endface pictures and interferometry performed after every axis at each vibration level
- Connectors tested in a mated pair
- Connectors monitored for loosening during vibration testing
- Accelerometer mounted in close proximity to fiber adapter



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Fiber Optic Connectors

- Connectors chosen based on current or anticipated use for space flight

- Connectors analyzed
  - Diamond AVIMS
  - FC
  - SMA
  - MIL-SPEC 38999 with 29504 termini
  - MTP
  - ST

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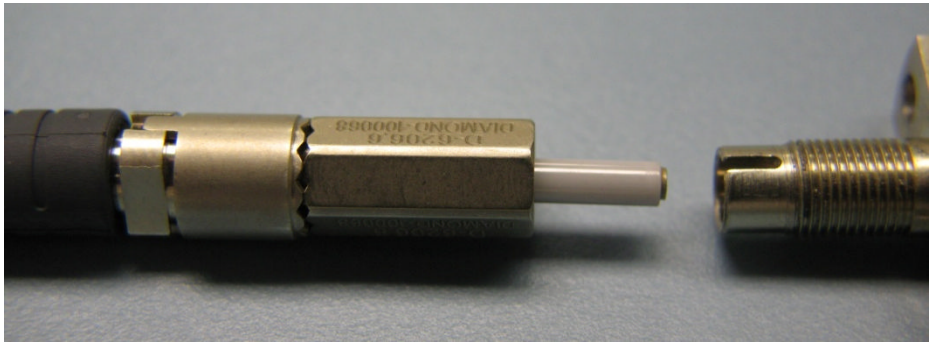
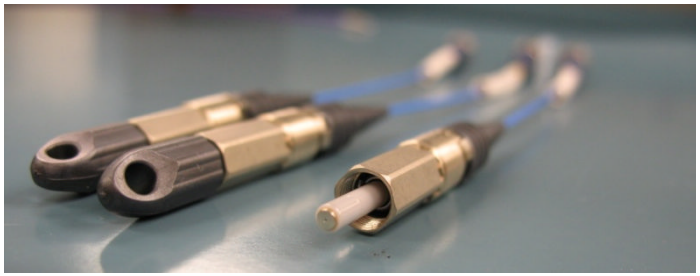
Diamond AVIM

- Spring loaded ferrule
  - 2.5 mm diameter
    - Ceramic or metal outside
    - Metal insert



- Keyed to adapter



- Outer nut screws onto adapter with ratcheting mechanisms that prevents nut from backing off
  - Does not require secondary locking

Baseline connector for NASA missions

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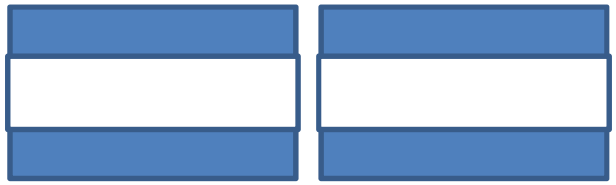
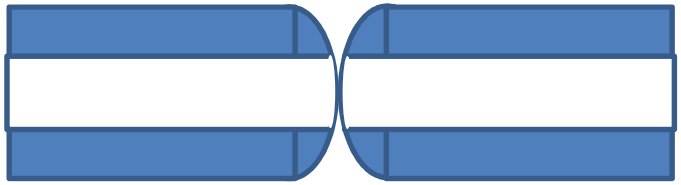
Vibration Testing of Diamond AVIM

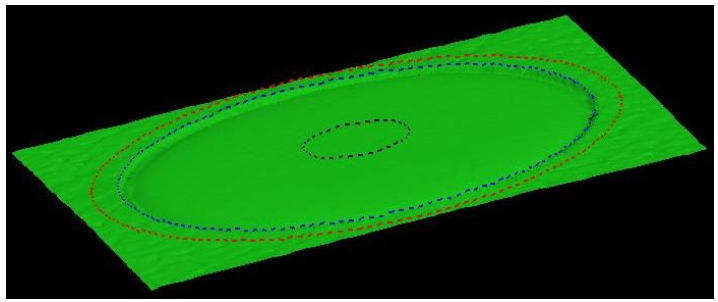
- Three fiber types tested
  - 100/140 step index fused silica with flat polish
  - 400/440 step index fused silica with flat polish
  - 100/140 graded index fused silica with PC polish

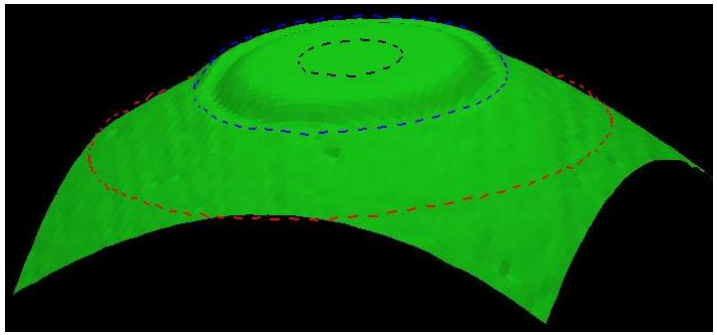


Flat Polish



PC Polish





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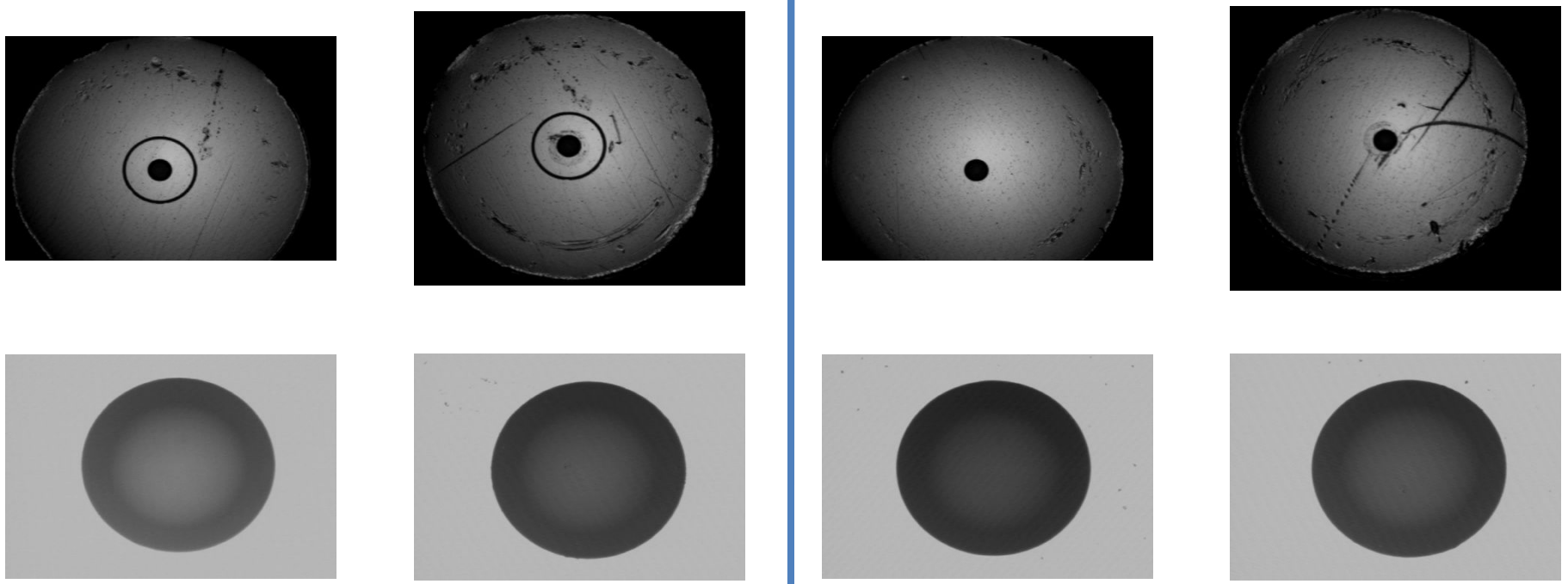
Vibration Performance of Diamond AVIM



After 10.0 G_{rms} Testing

After 34.6 G_{rms} Testing

After 10.0 G_{rms} Testing

After 34.6 G_{rms} Testing

100/140 Graded Index PC polish

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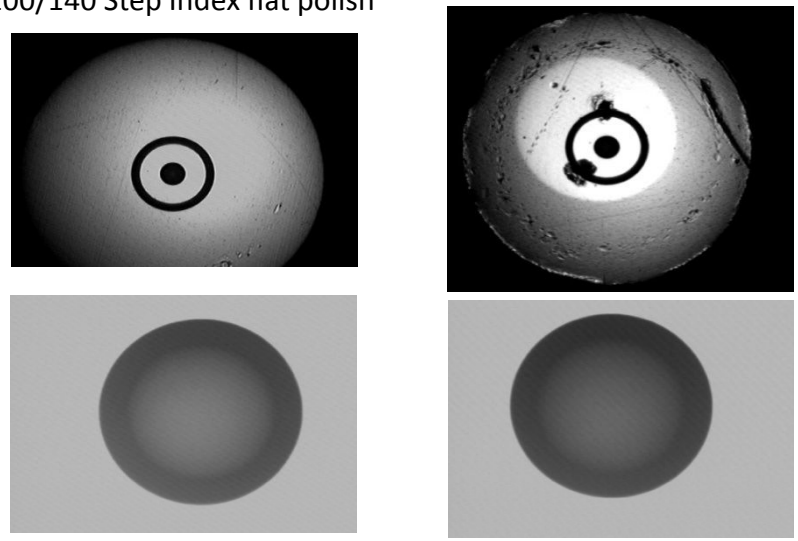
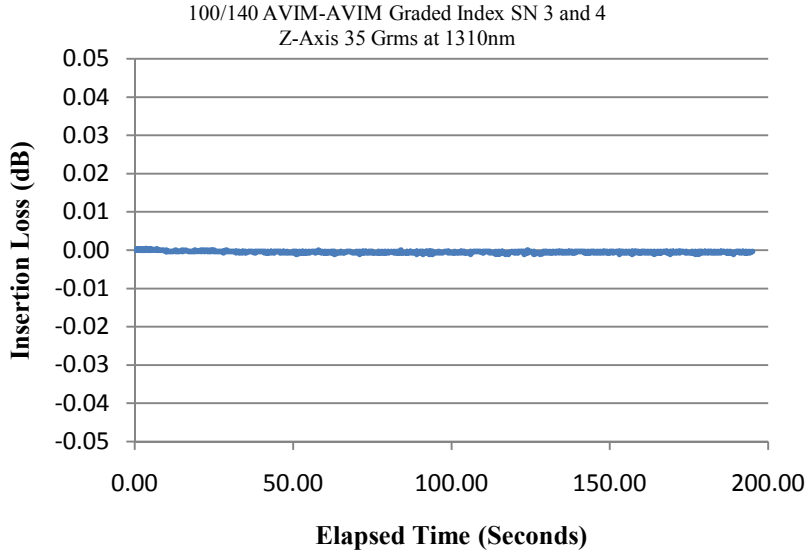
Vibration Performance of Diamond AVIM

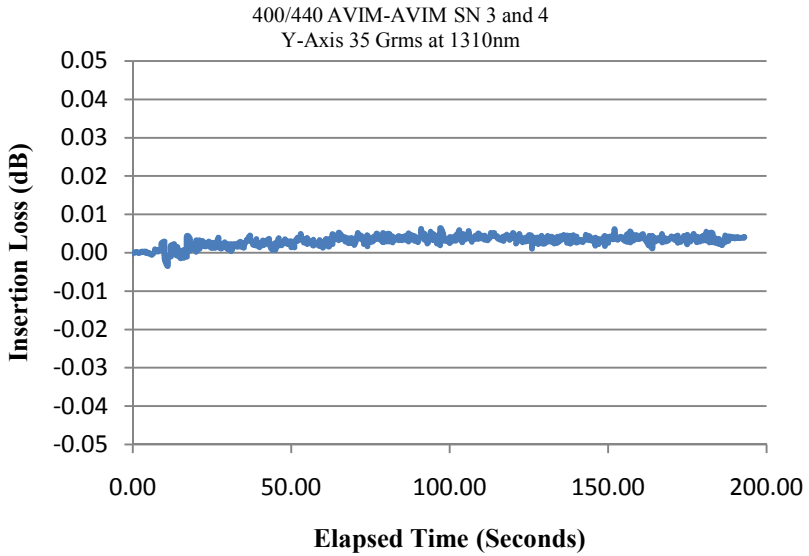
100/140 Step Index flat polish

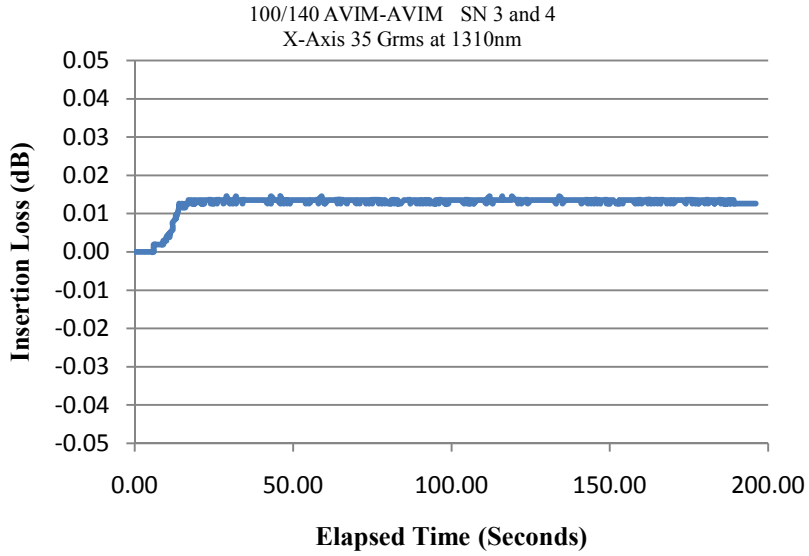


After 10.0 G_{rms} Testing

After 34.6 G_{rms} Testing







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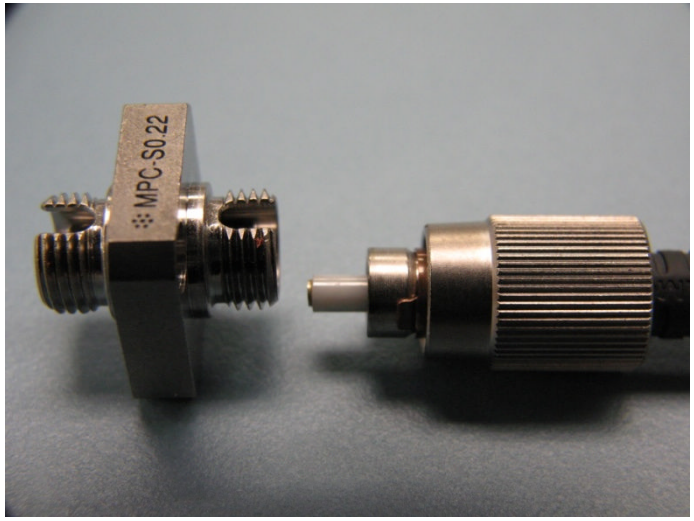
Vibration Performance of Diamond AVIM

Cable Identification	Insertion Loss Pre-Vibration Testing	Insertion Loss Post-Vibration Testing	Insertion Loss Change (dB)
AVIM-AVIM 100/140 Step Index SN – 1	0.27	0.53	0.26
AVIM-AVIM 100/140 Step Index SN – 2	0.02	0.21	0.18
AVIM-AVIM 100/140 Step Index SN – 3	0.14	0.09	-0.05
AVIM-AVIM 100/140 Step Index SN – 4	0.12	0.17	0.04
AVIM-AVIM 100/140 Graded Index SN – 1	0.01	0.14	0.14
AVIM-AVIM 100/140 Graded Index SN – 2	0.01	0.25	0.24
AVIM-AVIM 100/140 Graded Index SN – 3	0.21	0.14	-0.07
AVIM-AVIM 100/140 Graded Index SN – 4	0.01	0.16	0.15
AVIM-AVIM 400/440 SN – 1	0.72	0.68	-0.04
AVIM-AVIM 400/440 SN – 2	0.72	0.63	-0.09
AVIM-AVIM 400/440 SN – 3	0.64	0.59	-0.05
AVIM-AVIM 400/440 SN – 4	0.69	0.62	-0.07

- No significant change in fiber optic cable optical transmission during or following vibration testing
- Damage to outer metal region of ferrule during vibration testing

FC Connector



- Spring loaded ferrule
  - 2.5 mm diameter
    - Ceramic or metal outside
    - Metal insert
- Keyed to adapter
- Outer nut screws onto adapter
- Requires secondary fastening usually with epoxy

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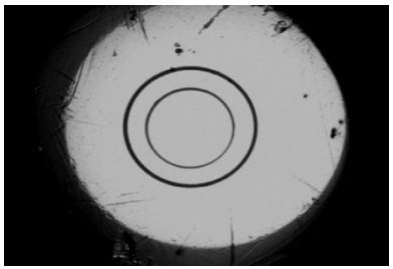
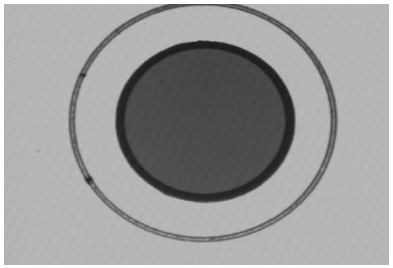
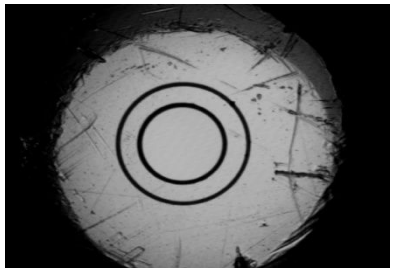
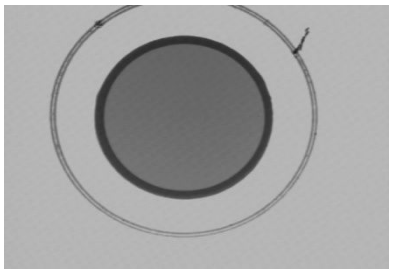
Vibration Performance of FC Connector



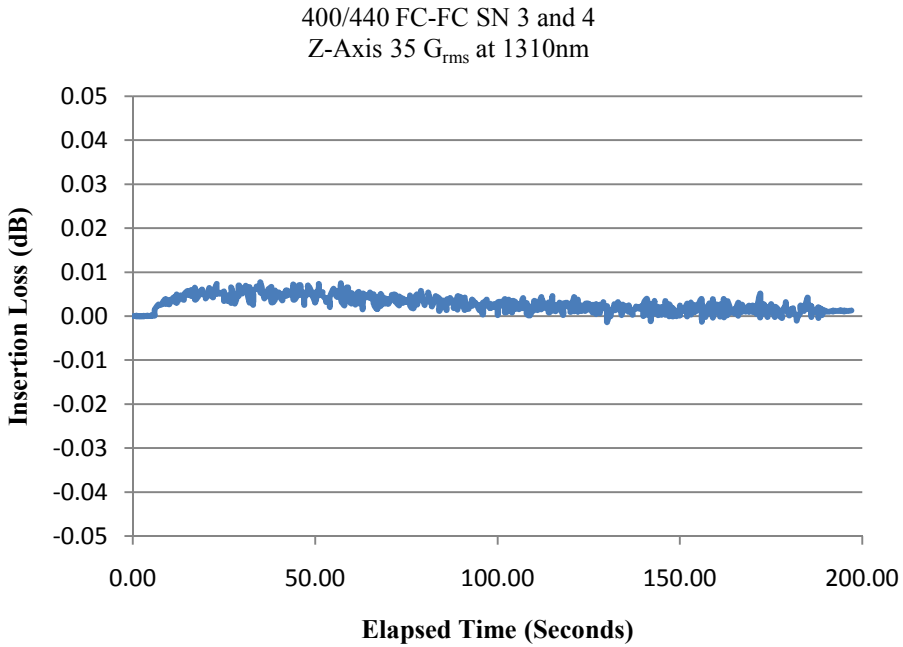


After 10.0 G_{rms} Testing





After 34.6 G_{rms} Testing



400/440 Step Index flat polish

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Vibration Performance of FC Connector

Cable Identification	Insertion Loss Pre-Vibration Testing	Insertion Loss Post-Vibration Testing	Insertion Loss Change (dB)
FC-FC 400/440 SN – 1	0.58	0.53	-0.05
FC-FC 400/440 SN – 2	0.62	0.29	-0.33
FC-FC 400/440 SN – 3	0.52	0.58	0.06
FC-FC 400/440 SN – 4	0.72	0.39	-0.33

- No significant change in fiber optic cable optical transmission during or following vibration testing
- Damage to outer metal region of ferrule during vibration testing

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SMA Connector

- Fixed ferrule
  - 3.16 mm diameter
    - Ceramic or metal

- No keying feature

- Outer nut screws onto adapter
- Requires secondary fastening with epoxy or wire

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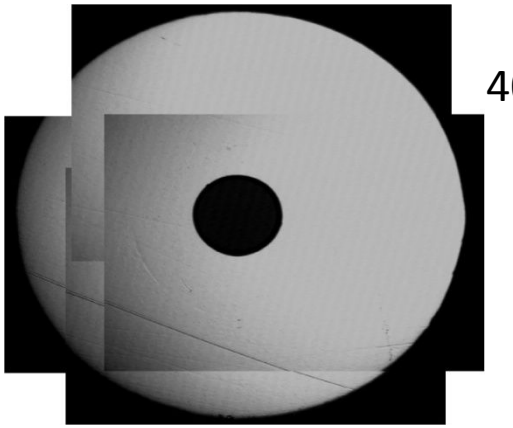
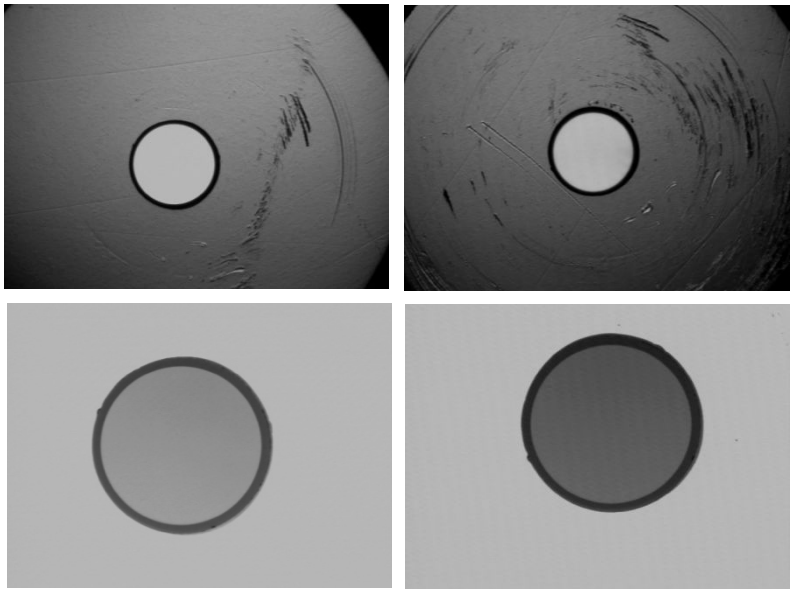
Vibration Performance of SMA Connector

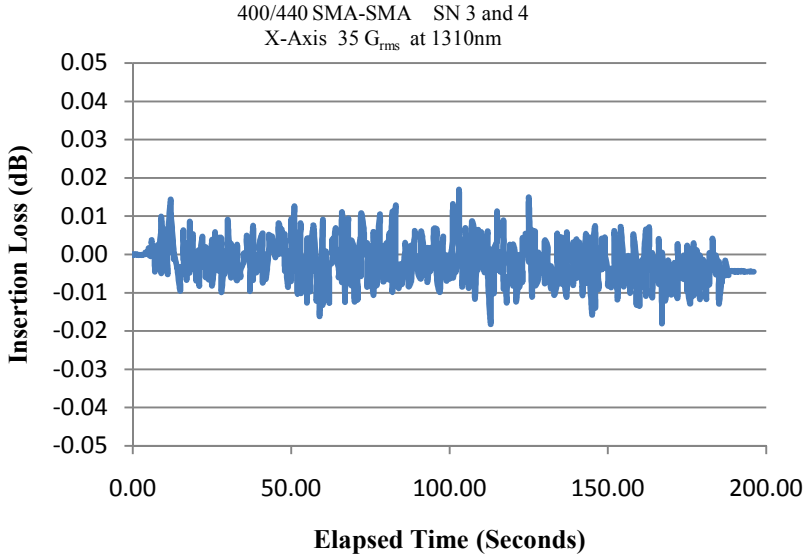


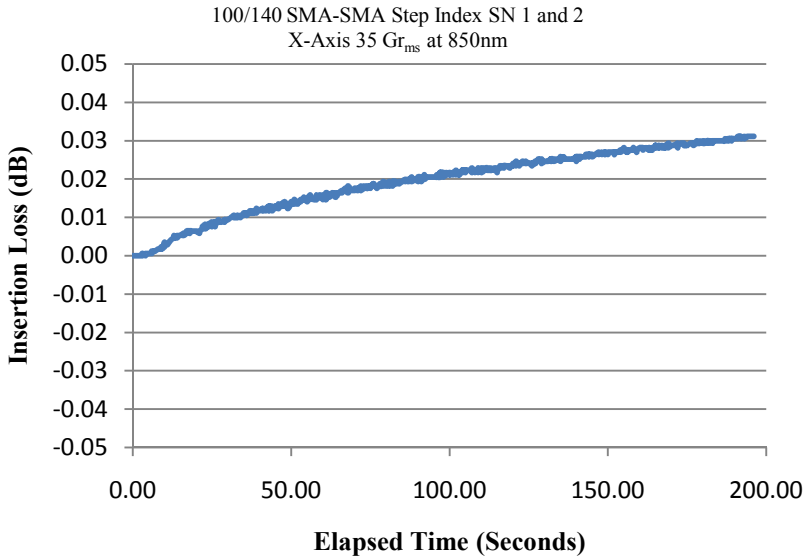
400/440 Step Index flat polish



After 14.1 G_{rms} Testing

After 34.6 G_{rms} Testing





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Vibration Performance of SMA Connector

Cable Identification	Insertion Loss Pre-Vibration Testing	Insertion Loss Post-Vibration Testing	Insertion Loss Change (dB)
SMA-SMA 100/140 Step Index SN – 1	0.419	0.528	0.109
SMA-SMA 100/140 Step Index SN – 2	0.259	0.357	0.098
SMA-SMA 100/140 Graded Index SN – 3	0.365	0.389	0.024
SMA-SMA 100/140 Graded Index SN – 4	0.652	0.541	-0.111
SMA-SMA 400/440 SN – 3	0.322	0.343	0.021
SMA-SMA 400/440 SN – 4	0.433	0.289	-0.144

- No significant change in fiber optic cable optical transmission during or following vibration testing
- Damage to outer metal region of ferrule during vibration testing
- Care must be taken when attaching SMA connectors to avoid damage due to lack of keying feature

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38999 Connector with 29504 Termini

- 29504 Termini
  - 2.5 mm diameter
  - Pin or socket
  - Stainless steel body
- Termini are “snapped” into multi-fiber connector
- Connector body is electroless nickel plated aluminum based on military electrical connector
- Keyed connector with ratcheting outer shell
- In use on International Space Station

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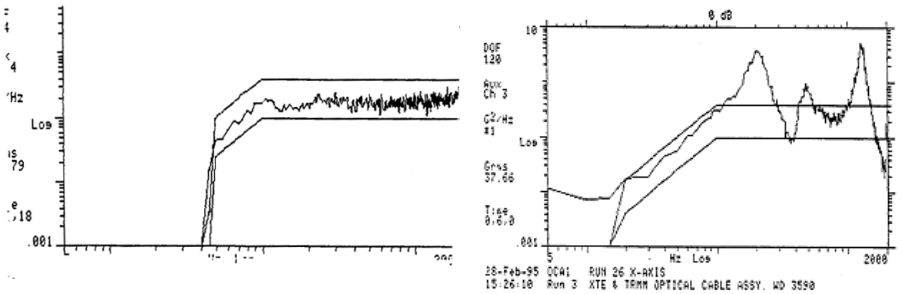
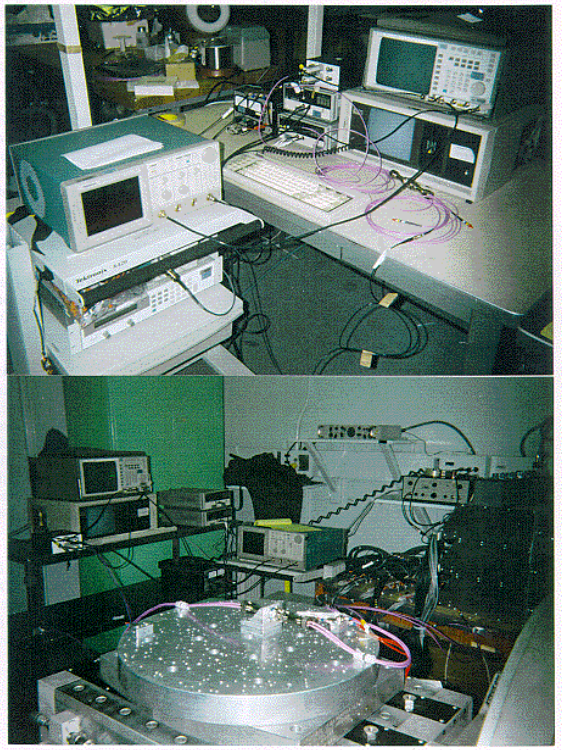
Vibration Performance of 38999/29504



Tested at 18.79 G_{rms} and 37.66 G_{rms}

Testing at 850 nm



Repeatability on SMA connections on outside cable ends was up to 1 dB

No significant degradation in optical signal above 0.5 dB, but contamination due to wearing on connector materials was noted that caused damage to fiber termini during mating

MIL-C-38999 is military version of Amphenol-Bendix 453 connector

Taken from "Evaluation Report for the Amphenol-Bendix 453 Miniature Circular Connector with Mil-T-29504 Optical Termini in a Vibration Environment," by Jeannette Plante, available at http://misspiggy.gsfc.nasa.gov/photonics (or http://photonics.gsfc.nasa.gov)

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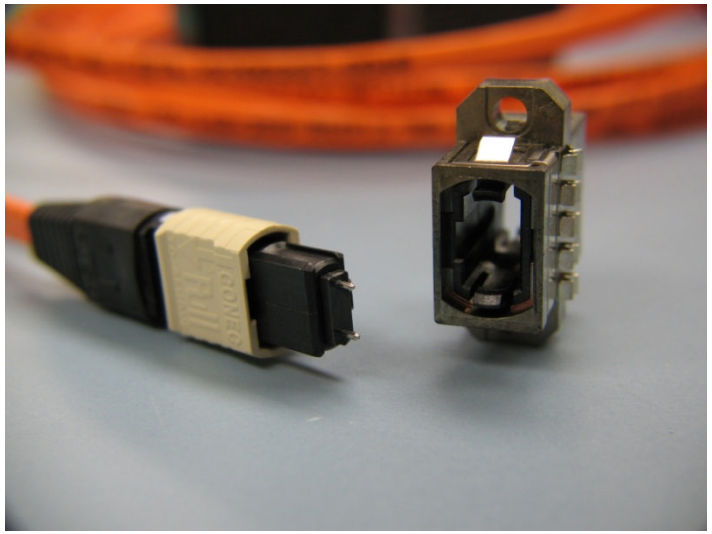
MTP Connector

- 12 fiber connector
  - 62.5/125 fiber
  - 100/140 fiber
- Ferrules are spring loaded
- Pins in connector for alignment



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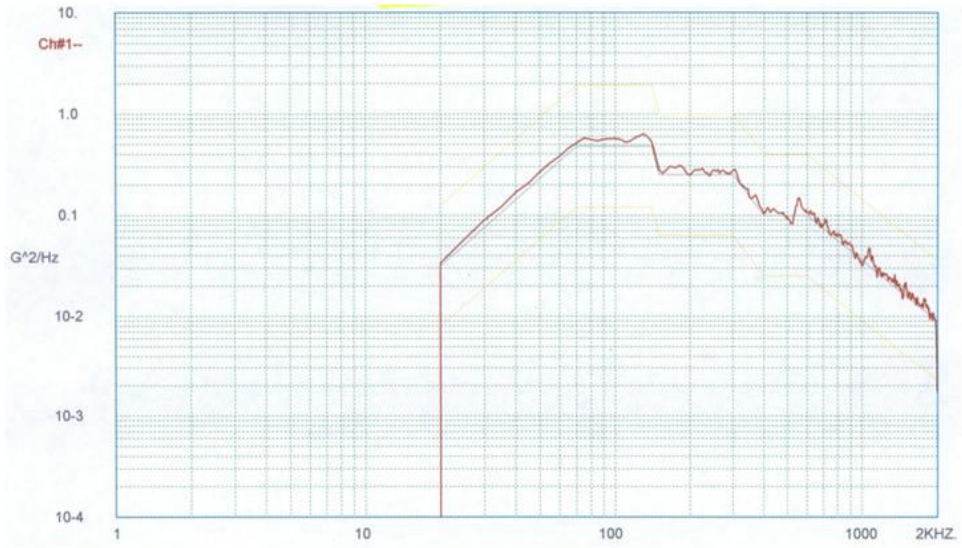
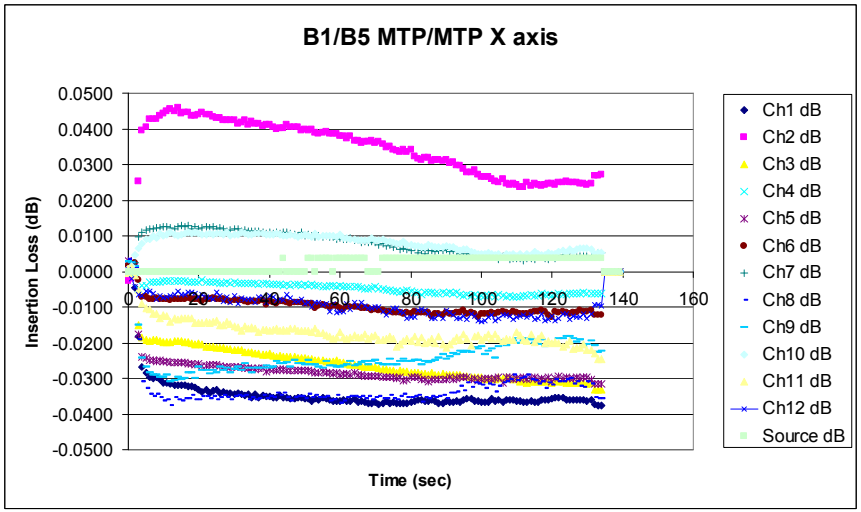
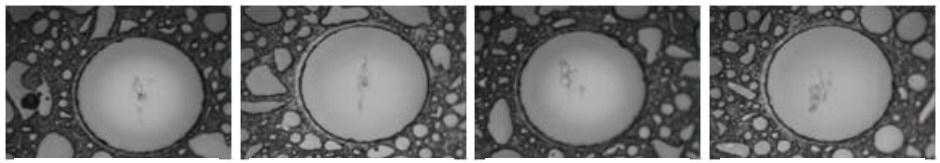
Vibration Performance of MTP Connector

Frequency (Hz)	Level (Protoflight)	Units
20	0.03140	g^2/Hz
70	0.48150	g^2/Hz
140	0.48150	g^2/Hz
150	0.25100	g^2/Hz
300	0.25100	g^2/Hz
400	0.10000	g^2/Hz
600	0.10000	g^2/Hz
2000	0.00900	g^2/Hz
Overall	**12.78**	Grms

Testing based on an outside customer requirements







B1 MT Ch11 B5 MT Ch11 B1 MT Ch12 B5 MT Ch12

Minor endface scratching / pitting

See also: Space Flight Qualification on a Multi-Fiber Ribbon Cable and Array Connector Assembly, SPIE Vol. 6308, 2006

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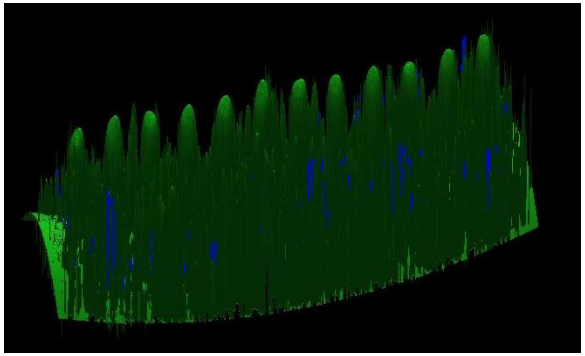
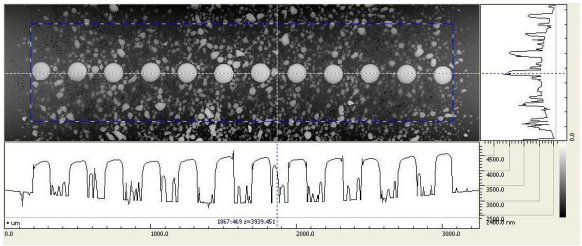
Vibration Performance of MTP Connector

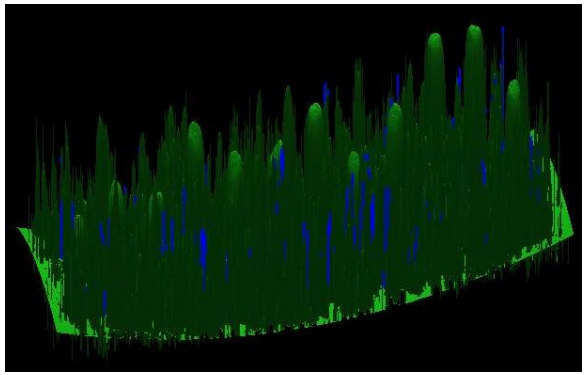
- Generally MTP connectors show 0.5 dB or less insertion loss change with vibration testing up to 12.78 G_{rms}
- Care must to used to ensure acceptable endface geometry

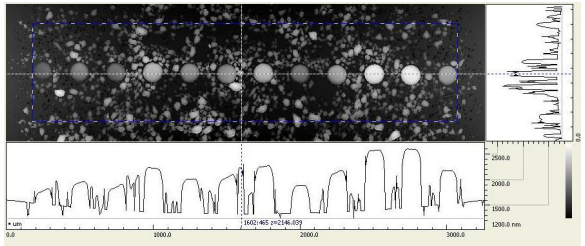




Fibers all of approximately equal height results in even loading across all fibers

Two flight fibers manufactured by an outside vendor that were sent to GSFC for characterization





Uneven polishing will cause only a few fibers to carry the entire connector force

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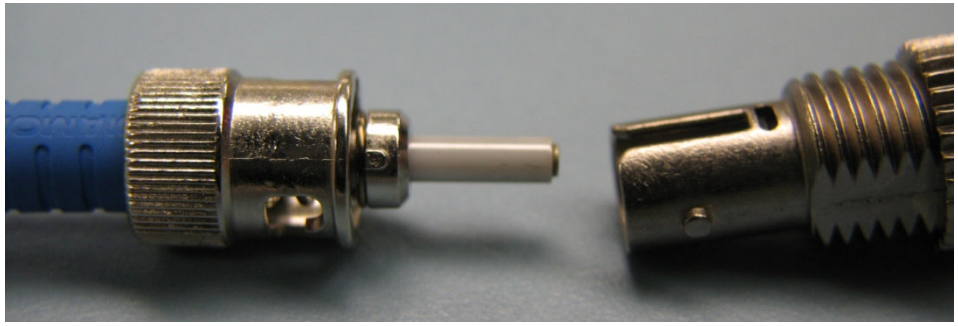
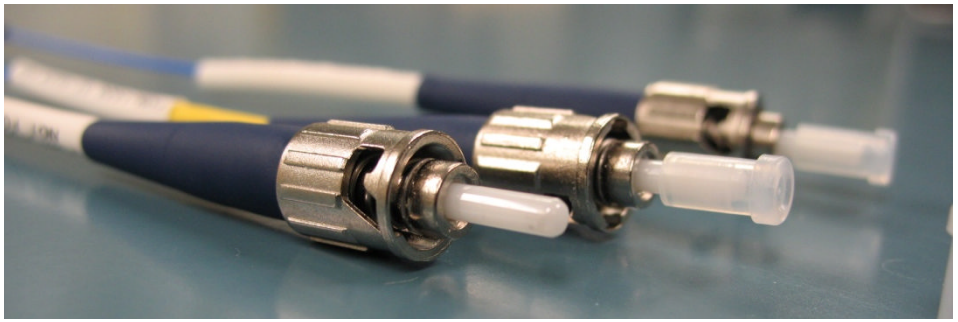
ST Connector

- Spring loaded body
- Keyed to adapter
- “BNC-like” outer nut





- Commonly used in laboratory equipment

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Suitability of ST for Space Flight

- Small rotation of outer nut causes connector to spring apart.
- Failure of small tabs would cause connector to spring apart.

- The ST connector is not suitable for space flight use and should only be used for ground support equipment if necessary (such as interfacing to existing instruments).

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Summary

- Vibration does not significantly influence a properly designed fiber optic connector and cable
- Most fiber optic connectors perform well during vibration and type used will be determined by other system constraints like size, weight, locking features
- Desirable characteristics for fiber connectors to ensure stable operation during vibration
  - Spring loaded ferrule
  - Key for alignment and to prevent damage during mating
  - Threaded outer nut to ensure stable engagement
  - Proper adapter
    - Hold alignment through harsh environments

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Future Testing

- Ongoing testing program of fiber optic connectors
- Upcoming connector tests
  - Military style connectors with smaller termini
    - Collaboration with Glenair
  - New DMI style termini for harsh environments
    - Collaboration with Diamond
- We welcome collaboration opportunities with other groups / agencies / vendors

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For additional information please see our website
http://misspiggy.gsfc.nasa.gov/photonics