

Radiation Effects Data on Commercially Available Optical Fiber: Database Summary

Melanie N. Ott

Sigma Research and Engineering, Code 562
NASA Goddard Space Flight Center
Greenbelt, Maryland, USA
melanie.ott@gsfc.nasa.gov

Abstract— Presented here are the results of a survey performed at NASA Goddard Space Flight Center on radiation data for commercially available optical fiber. The survey includes data from the past decade that can still be used for currently available parts. The objective of this work was to provide a current central location for relevant radiation data on optical fiber that could be useful for space flight projects. Only valid part numbers that are currently relevant to the manufacturers producing the optical fiber and parts that have been verified as changing number but not process, are included in this study. Presented are the currently available optical fiber types with valid part numbers and manufacturer, the relevant radiation data, and the corresponding data reference. Also included in this summary is the recent unreleased radiation data from experiments conducted at Goddard Space Flight Center on OFS (formerly Spectran) 62.5/125/250 micron optical fiber. This database will serve as a tool for engineers when selecting radiation tested optical fiber for future and current optical fiber systems for space flight applications.

Keywords—optical fiber; total dose; space flight; radiation; parts; telecommunications;

I. INTRODUCTION

Over the past two decades, a great deal of optical fiber radiation data has been published. Although much of the early work established the standard for how the testing would be conducted in later years, the optical fibers tested ten years ago or more are no longer produced. The push for greater bandwidth in telecommunications has focused the market into a situation where products are rapidly changing as improvements are made and new applications are designed. In addition, many manufacturers and vendors are becoming extinct with the subsequent saturation of the telecommunications market. Those manufacturing plants that remain in production are rapidly changing ownership. Therefore, all this perpetual change is making parts tracking a challenge for those parts that do remain in demand. In an attempt to sort out what data from the past can still be applied to currently produced optical fiber, a survey of available part numbers and manufactures was conducted to verify that the data in publication is still relevant to procurable products. Having a central database for current products with relevant radiation data will save a great deal of research time and the cost of testing for space flight projects that require performance information on commercially available optical fiber. The results of this survey, to date, are presented here.

II. CRITERIA FOR PRODUCTS INCLUDED IN DATABASE

After conducting a thorough literature search for all available data on optical fiber, it became apparent that not all papers that presented optical fiber results included part numbers that could be traced to a source for procurement. In many cases preforms or materials were tested that would be used for optical fiber but not a product that could be directly traced to a manufacturers part number for an optical fiber. Because this database is for the purpose of parts selection, the majority of the data included in the summary pertains to a final product with a part number. In a few cases, the data presented is representative of a family of optical fiber that can be traced to a manufacturers part number for fiber that only differs by dimension. In the case of fiber family data, the data is included to provide a general sense of how a fiber end product from the given family would perform. However, a majority of the survey data listed is for specific optical fiber parts (that are not in a cable configuration). This is due to the fact that a variety of parameters will affect the radiation susceptibility of an optical fiber including drawing process and outside fiber coatings.[3] In addition the lot-to-lot variability will result in enough uncertainty to dictate that other variables be limited for part selection purposes. Therefore, most of the parts and references included in this survey are for products that exist currently such that the information can be verified through the manufacturer. Parts are included if the process by which they have fabricated is unchanged even if the part number has. During this survey, each manufacturer provided information to verify the parts included here if the parts were not currently in their catalog..

III. BACKGROUND ON VENDOR CHANGES

Although it would be very difficult to capture the entire history of company procurements of other companies that produce optical fiber, some historical details are briefly discussed. One of the main vendors for graded index 100/140 micron optical fiber for space flight was Spectran. Spectran was bought by Lucent SFT in 1999, was procured by Furukawa Electric in 2002 and for a brief time was called OFS Fitel as part of the Specialty Photonics Division. They have recently settled on the name "OFS". However, the Spectran part numbers are unchanged since prior to the Lucent SFT name change. Certain Spectran part numbers contained in references 1 and 3, that were fabricated in the specialty optical fiber manufacturing plant in Sturbridge Massachusetts, are mostly obsolete now with the exception of a few.

Siecor was formed from a venture between Siemens and Corning and was primarily a cabling plant in the United States but had a fiber manufacturing plant in Germany. Corning later absorbed company Siecor and called it Corning Cable Systems. This entity currently remains another division of Corning. Corning licensed their patent for polarization maintaining (PM) fiber to Fujikura who now supplies Corning with their PM fiber. There have been slight modifications to the drawing process due to the large quantities that were required in the past five years from Fujikura. There have also been slight variations of the dopant concentration in the fiber but the basic dopant structure has remained unchanged. The Corning PM fiber data is included in this database for reference purposes but is not completely transferable to the current Fujikura products. The company Litespec was closed in May of 2002 and will no longer represent parent company Sumitomo Electric Lightwave Corp. Finally, the parent company of Plasma Optical Fibre is Draka Fibre Technology B.V. in the Netherlands.

IV. DATA RESOURCES INCLUDED IN STUDY

Data included in this summary was collected from a variety of sources with most of the information gathered from peer reviewed conference and journal publications. The dose rate and total dose parameters used for a majority of the experiments that are included in this database do not represent actual space flight radiation environments. This data is included however, for reference purposes. Where possible,

this data that is more representative of military concerns instead of space flight conditions, was included with extrapolation results to lower dose rate conditions. Other high dose rate data that does not include extrapolation equations for a lower dose rate environment is present as well.

All available data is included provided the product tested can be traced to a part number and is still in production today. Many of the references used in this study include both valid and obsolete part numbers. For those interested in which parts are now obsolete, more information on this can be extracted by examining the references themselves and is left as an exercise for the reader. The focus for this database is to gather current part numbers and radiation data. The references themselves are included that have been already accepted in the public domain. The few publications that were not extracted from journals and proceedings are from authors and researchers that are well known for other relevant references that have been peer reviewed and published.

V. SUMMARY OF OPTICAL FIBER IN DATABASE

Table I presents the summary of multimode optical fiber parts that are still available for procurement with a brief description and the reference that was used to provide the radiation data. Table II contains the collected information on single mode products and Table III contains the summary of polarization maintaining single mode products still in production.

TABLE I. MULTIMODE OPTICAL FIBER INCLUDED IN THE DATABASE

Fiber ID	Manufacturer	Part number	Description	Ref #
MM-P1	Polymicro	FVP100140170	100/140/170 high OH, UV enhanced, step index, .22 NA, (was FHP100140170), polyimide coating	1
MM-P2	Polymicro	FIA100140250	100/140/250 low OH with acrylate coating	20
MM-P3	Polymicro	FVP100110125	100/110/125 high OH, UV enhanced, step index, .22 NA, polyimide coating,	16
MM-P4	Polymicro	FIP100110125	100/110/125 low OH, step index, .22 NA polyimide coating	16
MM-F1	Fiberguide	SFS100/140Y	100/140/250 um acrylate, step index, .22 NA	1
MM-O1	OFS	BF05444	100/140/500 um acrylate carbon coated, rad hard, .29 NA, graded index	2
MM-O2	OFS	BF05202	100/140/172 um rad hard, .29 NA, graded index carbon, polyimide coated,	4
MM-O3	OFS	CF04530-04	100/140/172 carbon, polyimide, standard, .29 NA	4
MM-O4	OFS	BF04431-01	62.5/125/250 acrylate, .275 NA	5
MM-O5	OFS	CF04406-01	100/110/140 step index, high OH, .22 NA, polyimide,	6,7
MM-O6	OFS	BF04437	Flightguide 100/140/172 polyimide, .29 NA	19
MM-O7	OFS	BF04673	Flightguide 100/140/172 polyimide, rad hard	1
MM-CO1	CeramOptec	UV100/140	100/140 microns, high OH silica core/F doped clad, acrylate coating, step index, .22 NA	15
MM-CO2	CeramOptec	WF100/140	100/140 microns, Low OH silica core/F doped clad, acrylate coating, step index, .22 NA	15
MM-CO3	CeramOptec	Optran UV200/220P	200/220/245 micron, with high OH silica core, F doped, polyimide coated, step index	12
MM-H1	Heraeus	Fluosil SS	Family of optical fiber; high OH	3
MM-H2	Heraeus	Fluosil SSU1.2	High OH content, 104/125/250, Step Index	11
MM-H3	Heraeus	Fluosil SWU1.2	Low OH content	11
MM-C1	Corning	62.5/125 standard	62.5/125 with CPC coating	19
MM-D1	Draka	407	Plasma Optical Fibre 50/125/250 Ge graded index	9
MM-D2	Draka	457	Plasma Optical Fibre 62.5/125/250 Ge graded index	9, 13

TABLE II. SINGLE MODE OPTICAL FIBER INCLUDED IN THE DATABASE

Fiber ID	Manufacturer	Part number	Description	Ref #
SM-C1	Corning	SMF-28™	$\lambda=1310, 1550, 9.2 \text{ MFD}@1310, \text{ acrylate}$	1,8,14
SM-D1	Draka	268	Plasma Optical Fibre, was 267E, has a different coating DLPC8,	8
SM-O1	OFS	CF04246-32	6/125/250 bend NA=.17, bend insensitive, SM	10
SM-O2	OFS	SMT-1310 series	BF04446,BF04447, polyimide coated 1310/1550 nm	1
SM-M1	3M	FS-SC-7324	9/125/250 1550 nm acrylate, .16 NA	6,10

TABLE III. POLARIZATION MAINTAINING OPTICAL FIBER INCLUDED IN THE DATABASE

Fiber ID	Manufacturer	Part number	Description	Ref #
PM-C1	Corning (Fujikura)	850 nm PM	850 nm PureMode, MFD = 5.5, acrylate coated	3
PM-C2	Corning (Fujikura)	1300 nm PM	1300 nm PureMode, MFD=9.5, acrylate coated	3
PM-M1	3M	FS-PM-4611	820 nm NA=.13, acrylate coated	17
PM-M2	3M	FS-PM-6811	1300 nm NA=.18, acrylate coated	17
PM-M3	3M	FS-PM-7621	1550 nm NA=.13, acrylate coated	18
PM-FC1	Fibercore	HB800	830 nm, NA = .16, MFD = 4.2, bend insensitive, acrylate.	21
PM-FC2	Fibercore	HB1250	1300 nm, NA = .16, MFD = 6.6, bend insensitive acrylate.	21

Tables IV- VII contain the actual radiation data results, details of testing, and extrapolation information with reference to usage in space flight applications. Tables IV - VI contain gamma radiation exposure data and Table VII contains two entries of neutron exposure results. Neutron exposure is less damaging to optical fiber performance than gamma radiation. Fiber type MM-D2 has data entries in Table VI for gamma exposure and Table VII for neutron exposure for comparison purposes. For a more in-depth comparison on the differences between neutron and gamma radiation more information is available in reference 13.

In Tables IV-VI it is evident that in many cases extrapolation data is not available for space flight environments. The dose rates are too high or the references do not provide enough information such that an extrapolation can be made. The information included in these tables provides the parameters that are considered significant to the performance of an optical fiber during radiation exposure. In most cases unless otherwise noted, the data was collected using optical power of 1 microwatt or less. In some cases optical power used was not specified or the source used was from an optical time domain reflectometer (OTDR) instrument. It was noted in the details when a test was conducted using a source power greater than 1 microwatt if this information was available. Lengths for testing usually ranged from 50 m to 100 m and the data was scaled to km. In some cases the attenuation data was represented in terms of dB/m and for the sake of being consistent for this database was converted to dB/km.

For guidance purposes, most space flight environment gamma exposure rates are typically less than 1 rad/min and more likely less than .01 rad/min. In a few other cases due to solar activity the rates can be quite high for short durations. For example, the actual dose rate requirements for the International Space Station (ISS) were 42 rads/min for two hours at -125°C and then down to typical space flight exposure rates for the remainder of the mission [4]. Although it is less common to find higher dose rate requirements for space flight missions, almost all missions have unique requirements.

There are a variety of lengths required for space flight missions. ISS required lengths between 30 m and 100 m while missions such as the NASA Microwave Anisotropy Probe (MAP) and Earth Observing 1 (EO-1) required lengths of assemblies less than 3 m. For the Geoscience Laser Altimeter System (GLAS), most of the assemblies were less than 3 m with the exception of the delay line which was 2 km. In cases of short lengths and forgiving power budgets, even some of the “poor” performers can be used since the values here are in terms of km. Therefore, an optical fiber with an attenuation of 1 dB/km at low temperature will be 3 dB total for a 3 m length and then could be even lower when the temperature is increased. When comparing performance, the lengths of assemblies, thermal requirements, operational wavelength, dose rate and total dose are the important parameters to consider for choosing a fiber based on the collected data presented here.

TABLE IV. DATABASE OF RADIATION EFFECTS ON MULTIMODE OPTICAL FIBERS

Fiber ID	$\lambda(\text{nm})$	Dose Rate	Total Dose	Temp	Attenuation	Details
MM-P1	850	1.1 Krads/min	1 Mrad	50 °C	15 dB/km	Actual Experimental Data
	850	.191 rads/min	1 Mrad	50 °C	1.4 dB/km	Extrapolated
	850	.032 rads/min	100 krad	50 °C	1.0 dB/km	Extrapolated
	850	.032 rads/min	100 krad	-20 °C	3.0 dB/km	Extrapolated
MM-P2	850	11.4 krads/min	10 krad	-55 °C	98 dB/km	Actual Experimental Data
	850	11.4 krads/min	100 krad	-55 °C	150 dB/km	Actual Experimental Data
	850	11.4 krads/min	1 Mrad	-55 °C	210 dB/km	Actual Experimental Data

	850	11.4 krad/min	10 krad	25 °C	23 dB/km	Actual Experimental Data
	850	11.4 krad/min	100 krad	25 °C	23 dB/km	Actual Experimental Data
	850	11.4 krad/min	1 Mrad	25 °C	18 dB/km	Actual Experimental Data
MM-P3	600	500 rads/min	41 krad	25 °C	100 dB/km	Actual Experimental Data
	600	500 rads/min	465 krad	25 °C	275 dB/km	Actual Experimental Data
	600	500 rads/min	1.52 Mrad	25 °C	450 dB/km	Actual Experimental Data
	600	500 rads/min	12.4 Mrad	25 °C	550 dB/km	Actual Experimental Data
MM-P4	600	500 rads/min	17 krad	25 °C	275 dB/km	Actual Experimental Data
	600	500 rads/min	54 krad	25 °C	400 dB/km	Actual Experimental Data
	600	500 rads/min	3.9 Mrad	25 °C	1100 dB/km	Actual Experimental Data
	600	500 rads/min	14.4 krad	25 °C	1200 dB/km	Actual Experimental Data
MM-F1	850	1.1 krad/min	1 Mrad	50 °C	2.0 dB/km	Actual Experimental Data
	850	.191 rads/min	1 Mrad	50 °C	0.5 dB/km	Extrapolated
	850	.032 rads/min	100 krad	50 °C	0.2 dB/km	Extrapolated
	850	.032 rads/min	100 krad	-20 °C	0.0 dB/km	Extrapolated
MM-O1	1310	34 rads/min	100 krad	25 °C	6.45 dB/km	Actual Experimental Data
	1310	34 rads/min	200 krad	25 °C	9.18 dB/km	Actual Experimental Data
	1310	50 rads/min	100 krad	25 °C	9.60 dB/km	Actual Experimental Data
	1310	50 rads/min	200 krad	25 °C	12.21 dB/km	Actual Experimental Data
	1310	.001 rads/min	5 krad	25 °C	.011 dB/km	Extrapolated
	1310	.001 rads/min	100 krad	25 °C	.057 dB/km	Extrapolated
	1310	.01 rads/min	50 krad	25 °C	.11 dB/km	Extrapolated
	1310	.01 rads/min	100 krad	25 °C	.17 dB/km	Extrapolated
	1310	0.1 rads/min	100 krad	25 °C	.48 dB/km	Extrapolated
	1310	0.1 rads/min	500 krad	25 °C	1.1 dB/km	Extrapolated
MM-O2	1310	14.2 rads/min	5.1 krad	-125 °C	144 dB/km	Actual Experimental Data
	1310	28.3 rads/min	5.1 krad	-125 °C	149 dB/km	Actual Experimental Data
	1310	42 rads/min	5.1 krad	-125 °C	157 dB/km	Extrapolated
	1310	14.2 rads/min	100 krad	-125 °C	1.39 kdB/km	Extrapolated
	1310	28.3 rads/min	100 krad	-125 °C	1.45 kdB/km	Extrapolated
	1310	42 rads/min	100 krad	-125 °C	1.50 kdB/km	Extrapolated
MM-O3	1310	14.2 rads/min	5.1 krad	-125 °C	53 dB/km	Actual Experimental Data
	1310	28.3 rads/min	5.1 krad	-125 °C	41 dB/km	Actual Experimental Data
	1310	42 rads/min	5.1 krad	-125 °C	33 dB/km	Extrapolated*
	1310	14.2 rads/min	100 krad	-125 °C	101 dB/km	Extrapolated*
	1310	28.3 rads/min	100 krad	-125 °C	80.1 dB/km	Extrapolated*
	1310	42 rads/min	100 krad	-125 °C	64.3 dB/km	Extrapolated*
MM-O4	1310	20.7 rads/min	35.7 krad	-25 °C	517 dB/km	Actual Experimental Data
	1310	20.7 rads/min	100 krad	-25 °C	1.6 kdB/km	Extrapolated
	1310	5 rads/min	29 krad	-25 °C	459 dB/km	Actual Experimental Data
	1310	5 rads/min	100 krad	-25 °C	1.4 kdB/km	Extrapolated
	1310	0.1 rads/min	100 krad	-25 °C	914 dB/km	Extrapolated
	1310	0.01 rads/min	100 krad	-25 °C	726 dB/km	Extrapolated
	1310	32.3 rads/min	46.8 krad	25 °C	581 dB/km	Actual Experimental Data
	1310	32.3 rads/min	100 krad	25 °C	1.3 kdB/km	Extrapolated
	1310	5 rads/min	37.1 krad	25 °C	498 dB/km	Actual Experimental Data
	1310	5 rads/min	100 krad	25 °C	1.0 kdB/km	Extrapolated
	1310	0.1 rads/min	100 krad	25 °C	593 dB/km	Extrapolated
	1310	0.01 rads/min	100 krad	25 °C	429 dB/km	Extrapolated
MM-O5	1310	1.67 krad/min	20 Mrads	25 °C	10 dB/km	Actual Experimental Data [6]
	850	500 rads/min	20 Mrads	25 °C	9 dB/km	Actual Experimental Data [7]
	850	1.17 krad/min	23.1 Mrads	25 °C	12 dB/km	Actual Experimental Data [7]
	850	1.83 krad/min	73.7 Mrads	25 °C	16 dB/km	Actual Experimental Data [7]
	850	2.67 krad/min	52.8 Mrads	25 °C	17.5 dB/km	Actual Experimental Data [7]
MM-O6	850	1.26 krad/min	2.1 krad	-41 °C	250 dB/km	Actual Experimental Data [#]
	850	1.26 krad/min	67.2 krad	-41 °C	250 dB/km	Actual Experimental Data [#]
	850	1.26 krad/min	4.2 krad	-30 °C	210 dB/km	Actual Experimental Data [#]
	850	1.26 krad/min	98.7 krad	-30 °C	210 dB/km	Actual Experimental Data [#]

	850	1.26 krads/min	98.7 krads	27 °C	140 dB/km	Actual Experimental Data [#]
	850	1.26 krads/min	98.7 krads	71 °C	140 dB/km	Actual Experimental Data [#]
	1300	1.26 krads/min	67.2 krads	-41 °C	275 dB/km	Actual Experimental Data [#]
	1300	1.26 krads/min	98.7 krads	-30 °C	150 dB/km	Actual Experimental Data [#]
	1300	1.26 krads/min	81.9 krads	27 °C	15 dB/km	Actual Experimental Data [#]
	1300	1.26 krads/min	97.7 krads	27 °C	10 dB/km	Actual Experimental Data [#]
	1550	1.26 krads/min	67.2 krads	-41 °C	155 dB/km	Actual Experimental Data [#]
	1550	1.26 krads/min	98.7 krads	-30 °C	100 dB/km	Actual Experimental Data [#]
	1550	1.26 krads/min	81.9 krads	27 °C	18 dB/km	Actual Experimental Data [#]
	1550	1.26 krads/min	97.7 krads	71 °C	10 dB/km	Actual Experimental Data [#]
MM-O7	1300	1.1 krad/min	1 Mrad	50 °C	20 dB/km	Actual Experimental Data
	1300	.191 rads/min	1 Mrad	50 °C	12.8 dB/km	Extrapolated
	1300	.032 rads/min	100 krad	50 °C	4.2 dB/km	Extrapolated
	1300	.032 rads/min	100 krad	-20 °C	7 dB/km	Extrapolated
MM-CO1	600	42 krads/min	21 krads	27 °C	400 dB/km	Actual Experimental Data
	600	42 krads/min	84 krads	27 °C	600 dB/km	Actual Experimental Data
	600	42 krads/min	250 krads	27 °C	1.0 kdB/km	Actual Experimental Data
MM-CO2	750	42 krads/min	21 krads	27 °C	350 dB/km	Actual Experimental Data
	750	42 krads/min	84 krads	27 °C	500 dB/km	Actual Experimental Data
	750	42 krads/min	250 krads	27 °C	600 dB/km	Actual Experimental Data
MM-C1	850	1.36 krads/min	4.53 krads	-27 °C	250 dB/km	Actual Experimental Data
	850	1.36 krads/min	4.53 krads	-30 °C	230 dB/km	Actual Experimental Data
	850	1.36 krads/min	93 krads	28 °C	125 dB/km	Actual Experimental Data
	850	1.36 krads/min	106 krads	71 °C	40 dB/km	Actual Experimental Data
	1300	1.36 krads/min	107 krads	-30 °C	260 dB/km	Actual Experimental Data
	1300	1.36 krads/min	93 krads	28 °C	30 dB/km	Actual Experimental Data
	1300	1.36 krads/min	106 krads	71 °C	10 dB/km	Actual Experimental Data
	1550	1.36 krads/min	107 krads	-30 °C	170 dB/km	Actual Experimental Data
	1550	1.36 krads/min	93 krads	28 °C	28 dB/km	Actual Experimental Data
	1550	1.36 krads/min	106 krads	71 °C	15 dB/km	Actual Experimental Data
MM-H1	850	50 rads/min	2.75 krads	-150 °C	15 dB/km	Actual Experimental Data**
MM-H2	829	276 rad/min	100 krad	25 °C	3.1 dB/km	Actual Experimental Data
MM-H3	829	276 rad/min	100 krad	25 °C	114 dB/km	Actual Experimental Data
MM-D1	830	288 rads/min	86 krads	25 °C	80 dB/km	Actual Experimental Data
	1310	288 rads/min	86 krads	25 °C	15 dB/km	Actual Experimental Data
MM-D2	850	1.26 krads/min	1.26 Mrad	25 °C	50 dB/km	Actual Experimental Data [9]
	830	128 rads/min	46 Krad	25 °C	50 dB/km	Actual Experimental Data**[13]
	1000	1.26 krads/min	1.26 Mrad	25 °C	20 dB/km	Actual Experimental Data [9]
	1300	1.26 krads/min	1.26 Mrad	25 °C	13 dB/km	Actual Experimental Data [9]

* MM-03 may not fit typical power law growth behavior model used here to determine extrapolation values.

** Data was taken using 10 microwatts of power, where less than 1 microwatt is typical, therefore photobleaching is present.

Gamma radiation data calculated from 63 MeV proton data using a conversion program.

TABLE V. DATABASE OF RADIATION EFFECTS ON SINGLE MODE OPTICAL FIBERS

Fiber ID	λ (nm)	Dose Rate	Total Dose	Temp	Attenuation	Details
SM-C1	1300	1.1 krads/min	1 Mrads	50 °C	13 dB/km	Actual Experimental Data [1]
	1300	.191 rads/min	1 Mrads	50 °C	9.1 dB/km	Extrapolated, [1]
	1300	.032 rads/min	100 krads	50 °C	4.1 dB/km	Extrapolated, [1]
	1310	283 rads/min	5.6 Mrads	25°C	35 dB/km	Actual Experimental Data [8]
	1310	333 rads/min	13.2 Mrads	25°C	47 dB/km	Actual Experimental Data [8]
	1310	0.1 rads/min	100 krads	25°C	2.54 dB/km	Extrapolated [8]
	1310	0.01 rads/min	100 krads	25°C	1.64 dB/km	Extrapolated [8]
	1310	73.8 rads/min	100 krads	23 °C	7.0 dB/km	Actual Experimental Data [14]
	1310	1.59 krad/min	100 krads	23 °C	17.5 dB/km	Actual Experimental Data [14]
	1300	.032 rads/min	100 krads	-20 °C	5.6 dB/km	Extrapolated [1]
SM-D1	1550	167 rads/min	8.5 Mrads	25 °C	50 dB/km	Actual Experimental Data [8]
	1550	333 rads/min	6.6 Mrads	25 °C	48 dB/km	Actual Experimental Data [8]
	1550	0.1 rads/min	100 krads	25 °C	2.96 dB/km	Extrapolated [8]
	1550	0.01 rads/min	100 krads	25 °C	2.10 dB/km	Extrapolated [8]
SM-D1	1310	167 rads/min	7 Mrads	25 °C	34 dB/km	Actual Experimental Data
	1310	283 rads/min	11.2 Mrads	25 °C	47 dB/km	Actual Experimental Data
	1310	0.1 rads/min	100 krads	25 °C	1.47 dB/km	Extrapolated
	1310	0.01 rads/min	100 krads	25 °C	.97 dB/km	Extrapolated
	1550	167 rads/min	7.15 Mrads	25 °C	39 dB/km	Actual Experimental Data
	1550	283 rads/min	11.4 Mrads	25 °C	56 dB/km	Actual Experimental Data
	1550	0.1 rads/min	100 krad	25 °C	1 dB/km	Extrapolated
	1550	.01 rads/min	100 krad	25 °C	.7 dB/km	Extrapolated
SM-L1						
	1300	1.1 krads/min	1 Mrads	50 °C	11 dB/km	Actual Experimental Data
	1300	.191 rads/min	1 Mrads	50 °C	9.2 dB/km	Extrapolated
	1300	.032 rads/min	100 krads	50 °C	4.1 dB/km	Extrapolated
	1300	.032 rads/min	100 krads	-20 °C	5.3 dB/km	Extrapolated
SM-S1						
	1300	1.1 krads/min	1 Mrad	50 °C	7.0 dB/km	Actual Experimental Data
	1300	.191 rads/min	1 Mrad	50 °C	0.5 dB/km	Extrapolated
	1300	.032 rads/min	100 krad	50 °C	0.0 dB/km	Extrapolated
SM-M1	1300	.032 rads/min	100 krad	-20 °C	0.1 dB/km	Extrapolated
	1310	1.67 krads/min	24 Mrads	25°C	74 dB/km	Actual Experimental Data [6]
	1310	25 rads/min	20 Mrads	40 °C	75 dB/km	Actual Experimental Data [10]
	1310	25 rads/min	6.5 Mrads	60 °C	40 dB/km	Actual Experimental Data [10]
SM-M1	1550	25 rads/min	20 Mrads	40 °C	54 dB/km	Actual Experimental Data [10]
	1550	25 rads/min	6.5 Mrads	60 °C	20 dB/km	Actual Experimental Data [10]
	1550	1.67 krads/min	22 Mrads	25 °C	95 dB/km	Actual Experimental Data [6]
SM-O1						
	1310	25 rads/min	20 Mrads	40 °C	32 dB/km	Actual Experimental Data
	1310	25 rads/min	6.5 Mrads	60 °C	19 dB/km	Actual Experimental Data
	1550	25 rads/min	20 Mrads	40 °C	39 dB/km	Actual Experimental Data
SM-O2	1550	25 rads/min	6.5 Mrads	60 °C	25 dB/km	Actual Experimental Data
	1300	.191 rads/min	1 Mrad	50 °C	113.3 dB/km	Extrapolated
SM-O2	1300	.032 rads/min	100 krad	50 °C	41.9 dB/km	Extrapolated
	1300	.032 rads/min	100 krad	-20 °C	148.7 dB/Km	Extrapolated

TABLE VI. DATABASE OF RADIATION EFFECTS ON POLARIZATION MAINTAINING OPTICAL FIBERS

Fiber ID	λ (nm)	Dose Rate	Total Dose	Temp	Attenuation	Details
PM-M1	850	12 rads/min	17 krads	25 °C	47 dB/km	Actual Experimental Data
	850	12 rads/min	200 krads	25 °C	170 dB/km	Actual Experimental Data
PM-M2	1300	12 rads/min	17 krads	25 °C	1.3 dB/km	Actual Experimental Data
	1300	12 rads/min	200 krads	25 °C	7 dB/km	Actual Experimental Data
PM-M3	1550	10.5 krads/min	500 krads	-55 °C	380 dB/km	Actual Experimental Data
	1550	10.5 krads/min	5 Mrads	-55 °C	480 dB/km	Actual Experimental Data
	1550	10.5 krads/min	10 Mrads	-55 °C	486 dB/km	Actual Experimental Data
	1550	10.5 krads/min	500 krads	25 °C	20 dB/km	Actual Experimental Data
	1550	10.5 krads/min	5 Mrads	25 °C	55 dB/km	Actual Experimental Data
	1550	10.5 krads/min	10 Mrads	25 °C	88 dB/km	Actual Experimental Data
	1550	10.5 krads/min	500 krads	125 °C	15 dB/km	Actual Experimental Data
	1550	10.5 krads/min	5 Mrads	125 °C	92 dB/km	Actual Experimental Data
PM-C1	850	.0083 rads/min	750 rads	25 °C	4.35 dB/km	Actual Experimental Data
	850	.0007 rads/min	10 krads	25 °C	57.8 dB/km	Extrapolated
	850	.0007 rads/min	100 krads	25 °C	578 dB/km	Extrapolated
PM-C2	1300	.0083 rads/min	1.5 krads	25 °C	0.65 dB/km	Actual Experimental Data
	1300	.0007 rads/min	10 krads	25 °C	4.7 dB/km	Extrapolated
	1300	.0007 rads/min	100 krads	25 °C	47 dB/km	Extrapolated
PM-FC1	837	1272 rads/min	10 krads	22 °C	45.6 dB/km	Actual Experimental Data**
PM-FC2	1309	1272 rads/min	10 krads	22 °C	11 dB/km	Actual Experimental Data**

** Data was taken using 10 microwatts of power, where less than 1 microwatt is typical, therefore photobleaching is present.

TABLE VII. NEUTRON RADIATION OF OPTICAL FIBER

Fiber ID	λ (nm)	Energy	Fluence	Temp	Attenuation	Details
MM-CO3	850	1 MeV	$2 \cdot 10^{13}$ n/cm ²	-184 °C	22 dB/km	Actual Experimental Data
MM-D2	830	14 MeV	$9.1 \cdot 10^{12}$ n/cm ²	25 °C	26 dB/km	Actual Experimental Data **

** Data was taken using 10 microwatts of power, where less than 1 microwatt is typical, therefore photobleaching is present.

VI. CONCLUSION

Presented here is a database of available optical fiber radiation testing performed in the last decade. The optical fiber products included in this study are currently available through a manufacturer catalog or by special order. Parts that are now considered obsolete by the manufacturer were not included in this survey. It is expected that the information supplied here will have to be updated every couple of years such that the parts list remains current with the available fiber technology and with the available radiation data. In future reports, more information on specialty fiber and fiber devices can be included such as rare earth doped optical fiber and fiber gratings. The actual database information is available at the website misspiggy.gsfc.nasa.gov/photronics and at www.nepp.nasa.gov.

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