The Radiation Tolerance of Specific Optical Fibers for the LHC Upgrades

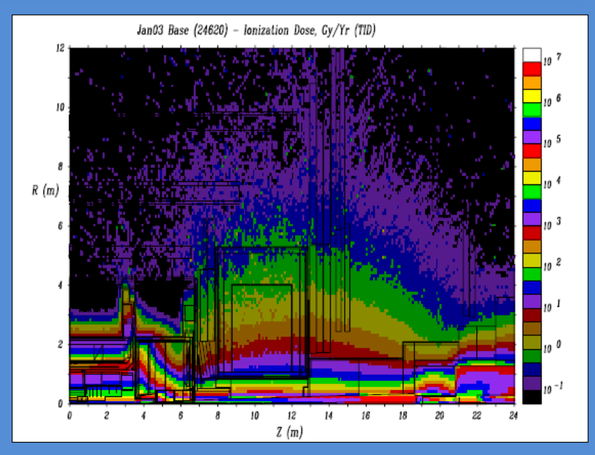
Joshua Abramovitch[1], B. Arviddson[4], K. Dunn[3], Datao Gong[1], Todd Huffman[3], C. Issever[3], M. Jones[3], Cotty Kerridge[1], James Kierstead[2], G. Kuyt[5], Chonghan Liu[1], Tiankuan Liu[1], A. Povey[3], E. Regnier[5], N.C. Ryder[3], Nnadozie Tassie[1], Tony Weidberg[3], Annie C Xiang[1], and Jingbo Ye[1]

[1] Department of Physics – Southern Methodist University, Dallas, TX, 75205, USA
[2] Brookhaven National Laboratory, Upton, NY, 11973, USA
[3]Oxford University, Oxford, OX1 2JD, UK
[4]Ericsson Network Technologies AB, Kabelv 1, SE-82482 Hudiksvall, Sweden
[5]Draka Communications, Site Date 4, Batiment DO, Routes de Nozay, 94160 Marcoussis, France

jabramovit@smu.edu

Introduction

- The Versatile Link Project was initiated in April 2008 to develop a radiation-tolerant optical interface for upgrades to the SLHC.
- As part of these upgrades, suitable optical fibers must be found for the fiber optic links at the ATLAS and CMS detectors. The new optical interface will utilize multi-mode and single-mode fibers, operating on wavelengths of 850 nm and 1310 nm, respectively.
- Optical fibers will transmit data between the various detectors and computers at monitoring stations, allowing scientists to observe particle collisions inside the proposed Super Large Hadron Collider (SLHC). The fibers must be able to transmit data bi-directionally at ~5 Gbps. Hose within 12 meters from the front-end detectors are exposed up to a 250 kGy(Si) total ionizing dose in their 10-year operational lifetime. In some applications, the 2 meters nearest to the front-end are kept in a cold environment near -25 °C."



Radiation Map of Expected Ionizing Dose (Gy) for Upgraded LHC

Experiment Setup

Radiation Source

- A ^{60}Co gamma radiation source bombarded the fibers to simulate the irradiated environment of the LHC. At SCK-CEN, the “Brigitte” source delivered dose rates of up to 27 kGy(SI)/hr while the “Rita” source provided a dose rate of 1.01 kGy(SI)/hr. At BNL, the peak dose rate was 0.4 kGy(SI); the dose rate was adjusted by placing the fibers at different distances from the source.

Temperature Control

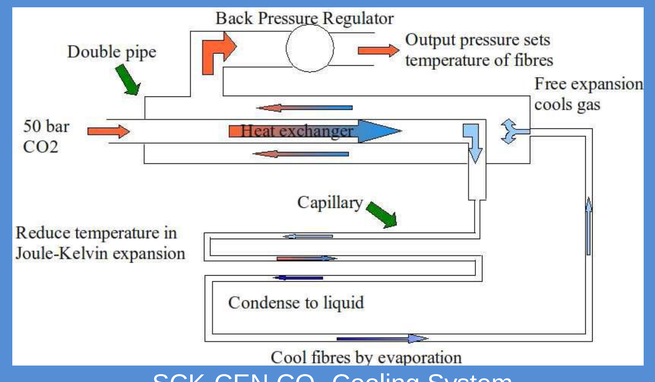
- The warm tests were conducted at room-temperature, with no system of temperature control.
- For the cold tests at SCK-CEN, a dual-phase CO_2 cooling system kept the fibers at a temperature of -25°C for some of the tests. CO_2 entered the system at 50 bar and condensed into liquid via the Joule-Kelvin Effect. The fibers were cooled via evaporation of CO_2 in liquid-gas dual phase.
- For the cold test at BNL, a chest freezer was used to maintain a temperature of -25°C. Its control electronics were shielded with lead bricks.

Light Sources, Light Meters, and Fibers

- Vertical Cavity Surface-Emitting Lasers (VCSEL’s) channeled light with a wavelength of 850 nm through the MM fibers. The light channeled through the SM fibers was of a 1,310 nm wavelength produced by Edge-Emitting Lasers (EEL’s).
- Light from the VCSEL’s and EEL’s was directed through each fiber and converted to a voltage to determine RIA. During irradiation, the light and its measurement were continuous.

SCK-CEN Setup

BNL Room-Temperature Setup

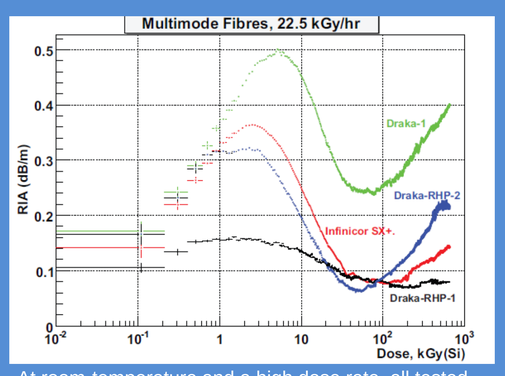


SCK-CEN CO_2 Cooling System

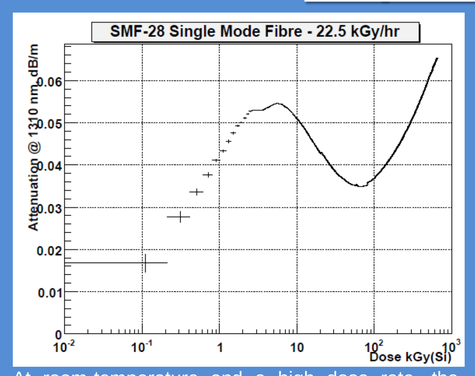
BNL Low-Temperature Setup

Manufacturer	Part Number	MM/SM	Operational Wavelength (nm)
Corning	ClearCurve OM3	MM	850
	Infinicor SX+	MM	850
	SMF-28	SM	1310
	SMF-28e+	SM	1310
	SMF-28XB	SM	1310
Draka	Draka-1	MM	850
	RHP-1	MM	850
	RHP-1 SRH	MM	850
	RHP-2	MM	850
	SRH-SMF	SM	1310
Manufacturer X	Fibre X	SM	1310

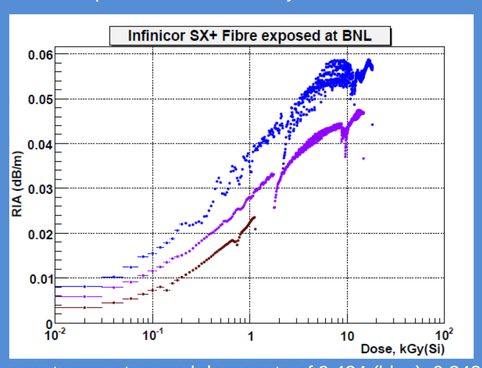
Experimental Results



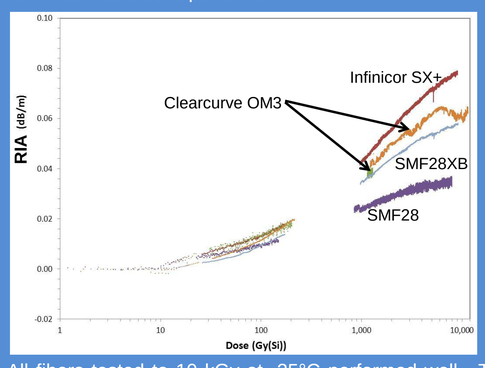
At room-temperature and a high dose rate, all tested MM fibers performed satisfactorily.



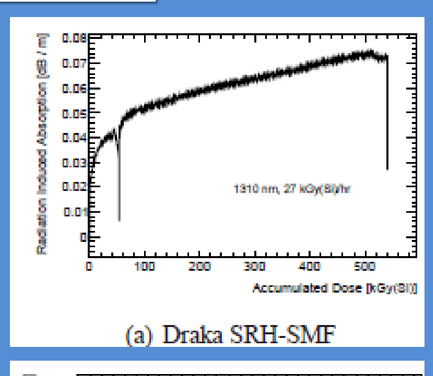
At room-temperature and a high dose rate, the SMF-28 was a solid performer.



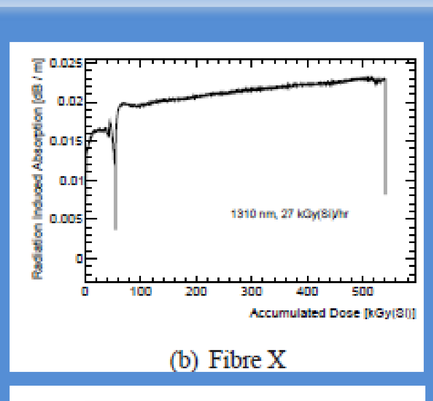
At room-temperature and doses rate of 0.424 (blue), 0.343 (purple), and 0.0265 (brown) kGy(SI)/hr, the Infinicor SX+ performed well.



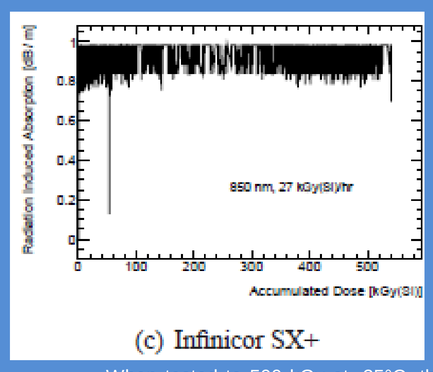
All fibers tested to 10 kGy at -25°C performed well. The final result for the Infinicor SX+ fiber’s estimated RIA in the ATLAS tracker at the SLHC is 0.41 +/- 0.05 dB.



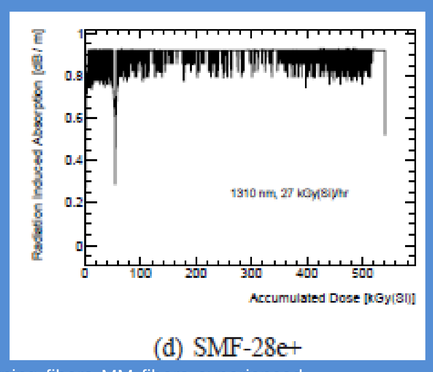
(a) Draka SRH-SMF



(b) Fibre X



(c) Infinicor SX+



(d) SMF-28e+

When tested to 500 kGy at -25°C, the Corning fibers MM fibers experienced very high RIA, while that of the Draka and Fibre X was very low.

Conclusions

- Two MM fibers (the Infinicor SX+ and Draka-RHP-1) and one SM fiber (SMF-28) have been qualified for warm operations at the LHC.
- Two SM fibers (Draka SRH-SMF and Fibre X) were qualified for low-temperature operations at the LHC in a high-dose test. During this test, all MM fibers experienced very high RIA.
- The Infinicor SX+, despite experiencing high RIA at a high dose rate, is still a viable MM candidate because it exhibits low RIA at a low dose rate. The newer ClearCurve OM3 performs even better at a low dose rates, but still must be tested at high doses.

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