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Gamma Irradiation of Minimal Latency Hollow-Core Photonic Bandgap Fibres

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Hollow-core photonic-bandgap fibres (HC-PBGFs) offer many advantages over conventional fibres, such as low latency and radiation hardness; properties that make HC-PBGFs interesting for the HEP community. This contribution presents the results of gamma irradiation tests carried out using a new type of HC-PBGFs that combines low enough attenuation over distances that are reasonable for HEP applications together with a transmission bandwidth that covers the 1550nm region. The HC-PBGF showed two orders of magnitude lower radiation induced attenuation than a conventional single-mode fibre during a 67.5h exposure to gamma-rays, resulting in an RIA of 2dB/km at an accumulated dose of 1MGy.

Summary

Radiation hardness is one of the primary concerns when designing optical data transmission links for HEP applications. As a part of the link, optical fibres must withstand high radiation levels. Radiation tolerance grades for the High Luminosity LHC are 10kGy for calorimeter-grade and 500kGy for tracker-grade applications. These radiation levels cause significant darkening in a conventional glass core optical fibre, where radiation creates light absorbing defects, colour centres, into the core material. In a hollow-core photonic-bandgap fibre (HC-PBGF) more than 99.8% of the light is confined in a radiation-insensitive air filled core using a surrounding regular lattice structure. Also, in an air filled core the propagation of light is almost 50% faster than in a glass core. Due to the low latency HC-PBGFs could replace electrical links, and provide all the advantages of optical data transmission, in places where the latency of conventional optical fibres has been a limitation. These properties make HC-PBGFs very interesting for the HEP community.

We used two HC-PBGF samples (lengths 201m and 243m) together with a standard fibre (255m, Corning SMF28e+). The HC-PBGF samples were produced at the Optoelectronics Research Centre at the University of Southampton using a two-stage stack-and-draw method, where 19-cells of material were omitted from the microstructured cladding generating a hollow core 26μm in diameter. These HC-PBGFs have 160nm transmission bandwidth around a wavelength of 1550nm. The samples were pigtailed using single-mode fibres and FC/APC connectors and spooled around plastic (POM-H) bobbins. The samples were irradiated with a dose rate of 12.2kGy/h to 15.0kGy/h for 67.5h resulting in a total dose close to 1MGy, which is compatible with the dose expected in HL-LHC inner detectors. A super luminescent diode (SLED) was used to illuminate all samples. The optical spectra and optical powers were measured in fixed time intervals (1-3min). After the irradiation the recovery process was observed for several weeks, and additional time of flight measurements and transmission tests were carried out.

After the total dose of 1MGy, the radiation induced attenuation (RIA) in the HC-PBGF was only around 2dB/km, two orders of magnitude better than in the SMF. In fact, the SMF sample became practically opaque (200dB/km) during the irradiation. The RIA of the HC-PBGF is even one order of magnitude better than in a special radiation hard optical fibre, if we compare the results with earlier studies. Almost no change was observed in the optical transmission spectrum of HC-PBGF; only a minor increase in attenuation was present in limited regions of the spectrum. Post-irradiation time of flight measurements using picosecond optical pulses confirmed that the signals propagate in HC-PBGF samples at close to (>99%) the speed of light in vacuum. High-speed transmission tests up to data-rates of 10Gbps resulted in good quality eye diagrams, which were comparable with non-irradiated SMF eye diagrams.

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