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Optical Fibre at HL-LHC

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We present results on all aspects of fibre reliability after exposure to the expected doses at HL-LHC. The results for the cold Radiation Induced Attenuation (RIA) are reviewed. The results of new studies of the effect of radiation on fibre bandwidth and mechanical reliability are presented. The fibre bandwidth was studied using measurements of chromatic dispersion and Differential Mode Delay (DMD). The mechanical reliability was studied using dynamic testing and the quality of the cladding was determined by micro-bending trials. These studies allowed us to qualify one SM fibre for use at HL-LHC.

Summary

The readout of the upgraded ATLAS and CMS detectors at HL-LHC will use high speed optical links. The fibres will receive a dose of up to about 500 kGy(Si). The fibres will be largely inaccessible during the 10 year operation. It is therefore vital to understand all aspects of fibre performance in this harsh environment. This paper will summarise the results that allow us to qualify multi-mode (MM) and singlemode (SM) fibres for use at the HL-LHC. The main effect of radiation damage on fibres is to increase the Radiation Induced Absorption (RIA) and this effect is exacerbated by the low temperature which reduces the rate of beneficial annealing. The cold RIA studies will be briefly reviewed.

This paper will focus on new results on two other aspects of radiation damage to fibres; the decrease in bandwidth and the degradation of the mechanical reliability. It is well known that the RIA is wavelength-dependent. Therefore according to the Karmers-Kronig relation, there must be an associated change in the real part of the refractive index. This effect on the chromatic dispersion will tend to reduce the fibre bandwidth. The high bandwidth MM fibres have very precisely defined refractive index profiles over the fibre core, in order to achieve the optimal modal bandwidth. Therefore even a very small change due to radiation damage, could potentially induce a large decrease in the modal bandwidth. We have studied these effects in collaboration with Prysmian for one of the MM fibres that we qualified for use at HL-LHC from the RIA perspective. The chromatic dispersion was studied by measuring the delay time over long lengths of fibre at several different wavelengths and the dispersion was determined by fitting analytic functions to the data. The modal bandwidth was studied using the Differential Mode Delay (DMD) technique. These studies allowed us to qualify a MM fibre from the perspective of bandwidth after radiation.

Very little was known about the mechanical reliability of fibres after radiation damage. We have studied the mechanical reliability of fibres before and after radiation damage for SM and MM fibres. The mechanical reliability of fibres decreases with time because of the growth of micro-cracks at the surface of the glass. The n-value (a proxy for lifetime) of the fibre was estimated from dynamic pull tests at different pull speeds. From our study of irradiated and unirradiated fibre using axial pull testing we were able to qualify one SM fibre from the perspective of mechanical reliability after radiation damage. On-going studies using 2-point bend tests aim to qualify a second SM fibre and two MM fibres. We also performed micro-bending trials and determined that the quality of the cladding was not affected by radiation damage.

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