Contribution ID: **439** Type: **Oral Presentation**

A Comparative Analysis of Radiation-Induced Wavelength Shift in Radiation-Soft and -Hard Fibre Bragg Gratings Exposed to Proton Irradiation

Wednesday 9 July 2025 09:40 (20 minutes)

Fibre Bragg Gratings (FBGs) have emerged as highly sensitive sensors for monitoring environmental parameters such as temperature, strain, radiation dose, etc. Moreover, they can withstand extreme environments, of interest here, a high radiation dose environment. The goal of this work is to develop reliable sensing instruments for high radiation-hard environments, such as the ATLAS inner tracker where radiation can go up 20 MGy and in nuclear reactors which require radiation resistance up to at least 1 GGy.

This study presents a comparative investigation of radiation-induced wavelength shifts in radiation-soft and radiation-hard FBGs exposed to proton irradiation at CERN, reaching a cumulative dose of 2.6 MGy over one week. These values are extrapolated to the typical dose that would be received in a two-week to a month run in-core and full-power in a power reactor. The extrapolation is done using Monte Carlo modelling.

The core of the optical fibres consists of SiO2 base material. Dopants such as germanium (Ge), phosphorous (P), fluorine (F), and aluminum (Al) are incorporated into the silica matrix to modify its refractive index. Fibres with pure silica cores, and fluorine-doped cores, have been found to have much higher resistance to ionizing radiation (i.e. radiation-hard) than compared to other dopants.

The results highlight the degradation mechanisms in radiation-soft and radiation-hard FBGs, providing critical insights for their deployment in extreme radiation environments. This work advances the development of robust FBG-based sensors for particle physics, space instrumentation, and nuclear energy systems, where real-time dose monitoring in high-radiation fields is essential.

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Session Classification: Applied Physics

Track Classification: Track F - Applied Physics