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AI-Enabled Radiation Dose Prediction Using Proton-Irradiated Fibre Bragg Grating Sensors

Radiation monitoring is critical for evaluating the performance and lifetime of detector components in high-energy physics (HEP) experiments. Fibre Bragg grating (FBG) sensors are particularly attractive for such environments due to their small size, electromagnetic immunity, multiplexing capability, and potential radiation tolerance. Beyond conventional temperature and strain monitoring, radiation-induced changes in the optical response of FBGs may provide information on the radiation exposure experienced by the sensor.

This work investigates the use of artificial intelligence and machine-learning (AI/ML) techniques to predict radiation dose from experimental proton-irradiation data obtained from FBG sensors. The evolution of the FBG reflection spectrum during proton irradiation is characterised using multiple optical parameters, including Bragg wavelength, reflected peak power, full width at half maximum, and integrated spectral intensity. These parameters are used as input features for machine-learning regression models trained to establish relationships between the measured optical response and accumulated radiation dose.

The performance of different regression approaches is evaluated using appropriate prediction metrics, while feature-importance analysis is used to determine which spectral characteristics provide the greatest sensitivity to radiation exposure. Particular consideration is given to the coupled and potentially nonlinear evolution of the FBG spectral parameters with increasing dose, as well as the influence of environmental variables that may introduce competing changes in the measured optical response.

The proposed approach demonstrates how experimental proton-irradiation data can be combined with data-driven modelling to investigate FBGs as intelligent radiation-sensing elements. The methodology could ultimately enable fibre-optic sensor networks to provide both conventional environmental monitoring and distributed estimation of accumulated radiation exposure within particle detectors and other high-radiation environments.

Primary authors: CASSIM, Abdool Sattar (University of Johannesburg); CONNELL, Simon (University of Johannesburg); CONNELL, Matt (University of Johannesburg); TRUONG, Thi Ngoc Loan (University of Johannesburg (ZA)); MAPEKULA, Xola (CERN); UNWUCHOLA, Doornull Attah (University of Johannesburg); Dr IGUMBOR, Emmanuel (University of Johannesburg); Prof. HARLEY, Charis (University of Johannesburg); Mr BROOKS, Tim (University of Johannesburg); Prof. MADYIRA, Daniel Makundwaneyi (University of Johannesburg)

Presenter: CASSIM, Abdool Sattar (University of Johannesburg)

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