L.7: Studies on fiber Bragg gratings under 1 MGy gamma radiation dose

Nuclear radiation exposure of optical fiber containing fiber Bragg grating (FBG) leads to radiation induced attenuation as well as shift in the Bragg wavelength peak. The quantification of these effects is a must before applying any FBG based optical sensor in nuclear environment. In the present work, the effect of gamma radiation accumulated dose (~1 MGy) is studied on a variety of FBGs. The FBGs are fabricated in Fibre Sensors and Optical Spectroscopy Section (FSOSS) of RRCAT and the radiation exposure studies are carried out at High Intensity Radiation Utilization Project (HIRUP) facility of BARC.

The FBGs used for the experiment were written by phase mask technique using in-house developed UV beam of parameters, λ ~ 255 nm, average power ~ 350 mW, pulse repetition rate ~ 5.5 kHz, pulse width ~ 30 ns and pulse energy ~ 54 μJ. FBG-1 & FBG-2 were type-I gratings inscribed within one minute of UV exposure. FBG-1 was connected with single mode telecommunication (SMF-28) fiber and FBG-2 was connected with single mode radiation hardened (SM-RH) fiber obtained from CGCRI. FBG-3 was type-IIa FBG inscribed in ~ 44 minutes of UV exposure with cumulative UV fluence of 31.68 kJ/cm^2. FBG-4 was thermally regenerated FBG (RFBG) obtained by high temperature annealing of type-I FBG written in hydrogenated SMF-28 fiber. A step annealing schedule from room temperature to 900 °C with different dwell times was applied for the regeneration of grating. FBG-3 and FBG-4 were connected with single mode telecommunication fiber (SMF-28). FBG-1, FBG-2 and FBG-3 were inscribed in SM-1500 (Fibercore) fiber and FBG-4 was inscribed in SMF-28 (Corning) fiber. FBG-1, FBG-2 and FBG-3 were pre-annealed at 400 °C to wipe out the unstable components of refractive-index change. Table L.7.1 shows the parameters of the FBGs used for the experiment.

Table L.7.1: FBGs used in gamma irradiation experiment

FBG	Type of the FBG	Patch cord fiber	Bragg wavelength (nm)	Intensity (A.U.)
FBG-1	Type-I	SMF-28	1546.396	16000
FBG-2	Type-I	SM-RH	1546.502	11700
FBG-3	Type-IIa	SMF-28	1546.610	28600
FBG-4	RFBG	SMF-28	1534.978	6110

The radiation source at HIRUP was cobalt-60 with dose rate of ~11.7 kGy/hour. The experiment of irradiation of FBGs with this gamma radiation was carried out for ~90 hours. The Bragg wavelength and reflection peak intensity of investigated FBGs were recorded before and after exposure to radiation dose of ~1MGy by interrogator (JPhotonics, JFBG3000). Figure L.7.1 shows the typical reflection spectra of FBG-3 before and after gamma irradiation. It is clear that Bragg wavelength shift is very small (Δλ~39 pm) but reflection intensity changed significantly from 29000 to 12500 (ΔI~57%). Figure L.7.2 shows the changes in Bragg wavelength and reflection intensity after irradiation for all investigated FBGs.

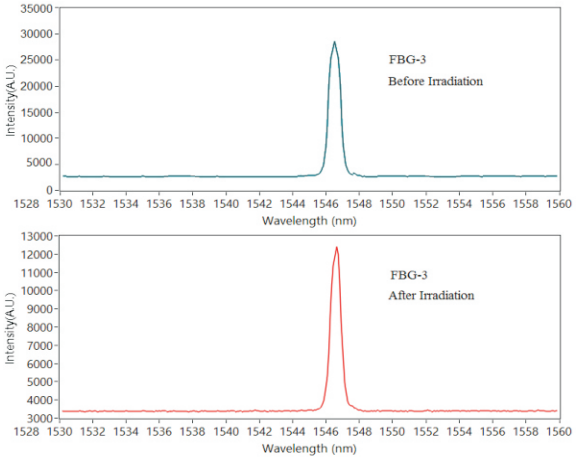

Fig. L.7.1: FBG spectra before and after gamma exposure.

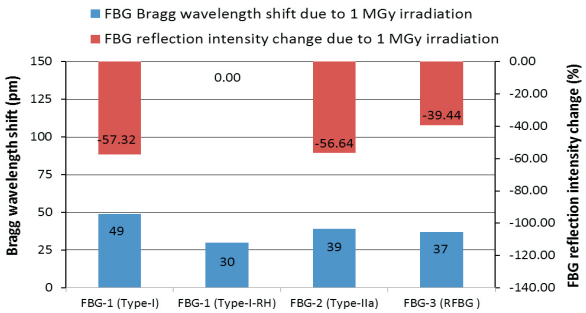

Fig. L.7.2: Changes in Bragg wavelength and reflection intensity due to irradiation.

It is concluded that the maximum change in Bragg wavelength was less than ~50 pm and the maximum change in reflection intensity was ~57% after the accumulated dose of 1 MGy. The FBG connected with radiation hardened fiber has produced much better results in terms of reduced Bragg wavelength shift and changes in reflection intensity. This study paved the way for application of FBG sensor in nuclear environment.

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