L.7: Long period fiber gratings as high dose radiation sensors: Possible applications for particle accelerators and plasma diagnostic systems in ITER

The presence of ionizing radiation makes nuclear facilities extremely hazardous, not only for human operators, but also for all kinds of devices and systems. Total gamma radiation dose level may span from 10^{-4} Gy for personal dosimetry to 10^{9} Gy near fusion reactor core and ITER locations. Increase of attenuation (optical density), luminescence, optically stimulated-luminescence (OSL), thermo luminescence, scattering and radiation induced index change have been used to design dose sensors for dose ranges up-to 100 kGy. The effect of resonance wavelength shift in fiber gratings occurs due to radiation induced index changes in the optical fiber.

We have developed a one-of-a-kind long period fiber grating (LPFG) sensor for sensing high level gamma dose up-to 1 MGy with a high dynamic range 100 Gy to 1 MG. Long period fiber gratings couple light from fundamental core mode to different co propagating cladding modes determined by the phase matching condition

Grating inscription setup is based on two dimensional scanning of CO_2 laser beam. The developed set-up can be used to inscribe specialty gratings. On-line wavelength shifts were recorded for all the LPFG up to 65 kGy gamma radiation exposure. Table L.7.1 shows the wavelength shifts observed corresponding to 65 kGy gamma radiation exposure of LPGs in different fibers for resonance loss band in the wavelength range 950-1500 nm. Initially offline measurements were made and then to confirm the observations, the measurements were made online.

Table L.7. Gamma radiation exposure effect of 65/70 kGy dose on different fiber LPGs and mode order dependence

Grating period [µm]	mode order	Wavelength shift [nm]
PS980 (B/Ge)	11	80
PS980	10	9.8
SM652 (Ge)	6	3

Table L.7.1 shows that the highest wavelength shifts were obtained with LPG in B/Ge doped fiber. Comparison of gamma induced wavelength shift written in fiber with different compositions clearly shows that Boron doping plays a significant role in increasing the sensitivity. In order to investigate high level dose effects, we further exposed the LPG in B-Ge doped fiber up to 1MGy dose levels over a period of 35 days.

Figure L.7.2 shows the shift in dip resonance wavelength observed for in-situ gamma exposures up-to 1000kGy. Figure.L.7.3 shows the plot of dose VS. resonance wavelength shift up-to 1 MGy.

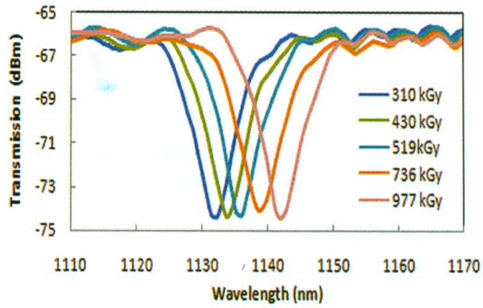

Fig. L.7.2 In situ transmission spectra of B/Ge doped fiber LPG : Wavelength shift observed in 10 th order cladding mode resonance when exposed to high dose of gamma radiation

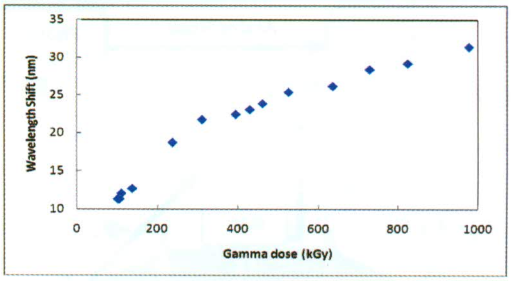

Fig. L.7.3 Gamma induced wavelength shift vs. gamma dose for 10th order coupled cladding mode for specialty LPG in B/Ge doped fiber.

We have investigated the effects of gamma radiation exposure on CO_2 laser written long period fiber gratings. The Wavelength shifts of more than 80 nm for 65 kGy dose for near TAP-Modes have been observed. This is an order higher sensitivity reported to date for any type of fiber gratings. The studies have established that CO_2 written long period gratings in B/Ge co doped fibers are suitable for real-time in situ monitoring of gamma dose up-to 1 MGy. This opens up their applications for dose monitoring in reactors and for diagnostics in accelerators and ITER thermonuclear fusion reactor.

These results are published in *IEEE PTL,* 2012, 24(9), 742-744 and *Instrumentation Science & Technology*, Taylor & Francis Online, 30 Nov.2012, DOI:10.1080/10739149.2012.747099, which can be referred for further details.

Note: 1 Gy= 1 Gray, which is S.I. unit for absorbed dose. 1 Gy corresponds to 1 Joule of energy absorbed per kilogram of material. 1 Gy corresponds to 100 rad.

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