L.4: Development of fiber Bragg grating (FBG) based distributed temperature sensor

Fiber Bragg gratings based distributed temperature sensor has been developed and tested upto 500 °C in Laser Systems Engineering Section (LSES) of RRCAT. For this purpose, the FBGs at different wavelength were inscribed using bi-prism interferometer by in-house developed 6 kHz repetition rate 255 nm coherent UV source. Practical testing of the distributed sensor was performed, in measuring temperature at different spatial location of CuBr laser tube in high EMI environment.

Fig.L.4.1 shows the experimental set-up of FBG inscription using bi-prism interferometer. The copper vapour laser (CVL) beam diameter was reduced from 28 mm to 2.8 mm by two achromatic lenses and line focused by a cylindrical lens on BBO crystal to generate the UV beam at 255 nm. The UV beam is magnified and focused on the fiber by a cylindrical lens of focal length 7.5 cm. A bi-prism with angle 24° was used for the inscription of FBGs at different Bragg wavelengths in the C-band of the telecommunications region. About 300 mW average power UV beam of diameter 8 mm was selected using an aperture and is allowed to fall on the bi-prism to write the type I FBG in photosensitive germanium doped SM-1500 fused silica fiber. The fiber was placed at the maximum overlap region. The online growth of the FBGs was monitored using a broadband ASE source and optical spectrum analyzer.

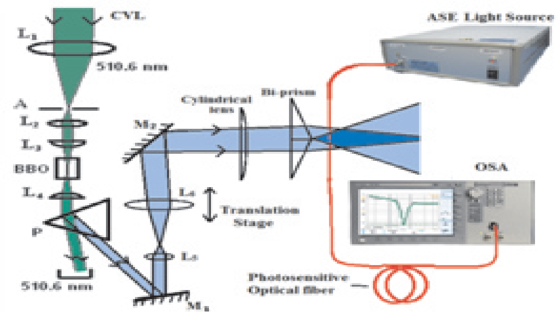

Fig. L.4.1: Schematic of FBG inscription set up

The bi-prism splits the incident wave-front. These two beams produces interference fringes in the rhombus-shaped overlap region parallel to the apex edge of the prism. The Bragg wavelength of the inscribed FBG is given as,

$$\lambda_B = 2\, n_{eff}\, \Lambda = n_{eff} \frac{\lambda_{uv}}{\sin \alpha} \quad (1)$$

where λ_{uv} is UV beam wavelength, n_{eff} is the effective refractive index, Λ is grating period and α is the angle of intersection which depends upon the angle of incidence. The Bragg wavelength of each FBG was slightly changed by changing the divergence of the incident beam by shifting the position of lens L_6. The total length of fused silica fiber was taken about 2 meter. Four FBGs were inscribed at 30 cm apart from each other in this single fiber. The Bragg wavelengths were 1531.5 nm, 1533 nm, 1540.55 nm and 1548.5 nm for reference FBG, FBG1 (sensor #1), FBG2 (sensor #2) and FBG3(sensor #3) respectively.These distributed FBGs were used to monitor online temperature of CuBr laser tube. Temperature measurement by contact sensing on the laser discharge tube of electrically pumped pulse gas discharge laser is almost an impossible task by other conventional sensor because of very high EMI back ground. Out of four FBGs, three FBGs were placed all along the CuBr laser fused silica tube and fourth FBG at 1531.5 nm kept outside the tube for reference temperature. Fig.L.4.2 shows the experimental set-up for online temperature monitoring of CuBr laser tube. As the voltage of CuBr laser tube is increased, the temperature of the tube increased. This led to shift in the Bragg wavelengths of the FBGs.

Fig. L.4.2:FBGs based distributed temperature sensors for monitoring temperature of CuBr laser tube

Fig.L.4.3 shows the Bragg wavelength shift corresponding to temperature of laser tube. By measuring the wavelength shifts during operation of laser, the temperatures of 462.3, 485.7 and 499.6 °C were estimated at three sensor locations. The average temperature sensitivity of FBG was about 11.6 pm/°C.These FBG based distributed temperature sensors are very useful for precise (±0.5 °C) simultaneous multipoint temperature sensing applications in hazardous environment.

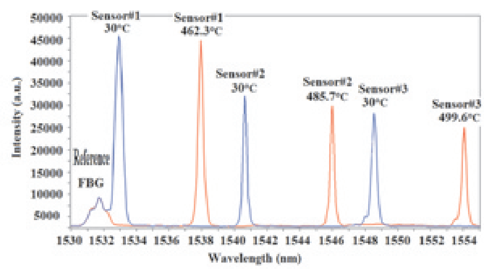

Fig. L.4.3: FBG traces showing the Bragg wavelength shifts corresponding to temperature of laser tube

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