Towards maintenance and management of infrastructures such as bridges, role of instrumentation is vital and the choice of a sensor plays the most important one. In this project a smart sensor system for distributed strain measurements based on fiber optics has been developed. These sensors are suitable for civil infrastructural monitoring such as buildings, bridges, roads, dams, power plants, transmission lines etc.

The Fiber optic sensors (FOSs) have certain advantages such as their small size, light weight, immunity to Electromagnetic fields (EMI), ability to work in harsh environment, suitability for embedding, multiplexing and remote sensing, which make them perfect alternative to ESGs. Fiber Brag Grating (FBG) based fiber optic sensors are intrinsic fiber elements inscribed in photosensitive fibers where index of refraction in the fiber core is periodically modulated by illuminating with UV light. If light from a broadband source is transmitted through such a fiber, one particular wavelength is scattered by this periodic refractive index variation and will be missing from the transmission spectrum and after due calibration can sense strain in the system.

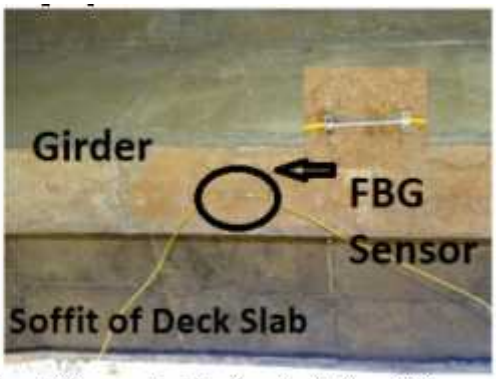
Single and multiple FBGs on acrylate coated photosensitive silica optical fibers were designed, fabricated, recoated, characterized and used as strain sensors. These were embedded in reinforced concrete beams and tested in the laboratory. Packaged FBG sensors have been designed and developed for surface strain mapping. Strain-temperature discrimination technique based on dual FBG sensors has been developed. Besides measurement of strain in structure, wavelength calibration and temperature characteristics of the FBG sensors were also studied.

(A) The Packaged Sensor

(B) Packaging for FBG Sensor

Packaging of FBG sensors is an important aspect due to its long term usability and handling issues. FBG sensors have been packaged using appropriately designed and precisely fabricated mild steel fixture which can respond to the structure perturbations. Figures (A) and (B) show the 3D view of FBG packaging fixture and of photograph of packaged FBG sensor as developed at CSIR for cementitious mounting, respectively. Cross sensitivity for strain and temperature measurement in FBG sensors is an important issue. Accurate measurement of strain and temperature requires elimination of cross sensitivity effect. FBG sensor is becoming an integral part of smart structure health monitoring. In this technique, two FBGs have been fabricated at two different wavelengths in the single optical fiber.

(C) The Bridge Site



(D) Different Sensors installed on the Bridge Girder

The technology behind the fabrication, packaging and installation of FBG sensors has been demonstrated for use in the concrete structures. Laboratory testing has been established involving the embedment (as well as surface mounted) of FBG sensors in the concrete beam and their performance have been observed under variable loading conditions. Installation of FBG sensors with other sensors inside the bridge during its construction under field conditions has been performed. In this DST funded project (under grant DST/TSG/NTS/2009/ 32), a low cost, simpler and more convenient approach to discriminate strain and temperature has been demonstrated. Field trials using packaged FBG sensor in distributed configuration on the concrete bridge on NH24 near Hapur have also been successfully carried out by CSIR-CRRI, New Delhi and CSIR-CSIO, Chandigarh jointly. The FBG sensors in a distributed pattern along with conventional sensors mounted on the surface of the girder of the bridge at critical locations as shown in the figures C, D. The responses of FBG sensors and conventional sensors were recorded under the bridge loading conditions and found to be excellent matching of response.

The trademark registration as an IPR has been filed. Also, following research papers have been published.

a) Umesh Tiwari, K. Thyagarajan, and M. R. Shenoy, “Strain and Temperature Discrimination Technique by use of a FBG Written in Erbium Doped Fiber,” -Optik, Vol.125, Issue 1, pp. 235-237, 2014, Impact factor 0.71, *Elsevier.*

- Umesh Tiwari, Rajeev Garg and R. Bhatnagar, “Distributed Strain Sensing of the Concrete Bridge using FBG Sensors”, Proc. of International Conference on Trends and Challenges in Concrete Structures, Indian Concrete Institute, India, Dec.19-21, 2013.
- Umesh Tiwari, Rajeev Garg, Manish Vishwakarma, Bhargab Das and R. Bhatnagar, “Strain Monitoring of Concrete Bridge using Fiber Bragg Grating Sensors” Proc. of International Conference on Fiber Optics and Photonics (PHOTONICS-2014), IIT Kharagpur, India, Dec. 13-16,2014 (http://dx.doi.org/10.1364/PHOTONICS.2014.T3A.74), ISBN: 978-1-55752-882-7.