Funded Project Title

Development of Indigenous Sensor for Salinity and Temperature Measurements suitable for Oceanographic Applications

Funding Agency	**: Naval Research Board, DRDO, New Delhi**
Principal Investigator	**: Dr. S. Dhanalakshmi, Prof., ECE**
Reference	**: NRB/4003/PG/405 & NRB-405/OEP/17-18**
Total Amount	**: Rs. 27,14, 994**
Duration	**: 2017 to 2019**
Lab Venue	**: Underwater Optical Sensor R&D Lab, Tech Park, TP1306a**

Aim of the Project:

To develop an indigenous fiber optic sensor for accurate measurement of sea water salinity and temperature

Proposed objectives:

- ✔ To design and develop optimized salinity and temperature sensors based on fiber optic methods such as Fiber Bragg Grating (FBG) and Evanescent Wave Absorbance (EWA) effect.
- ✔ To build a test bench for performance evaluation of designed sensors and to validate the final laboratory model against commercially available CTD sensors.

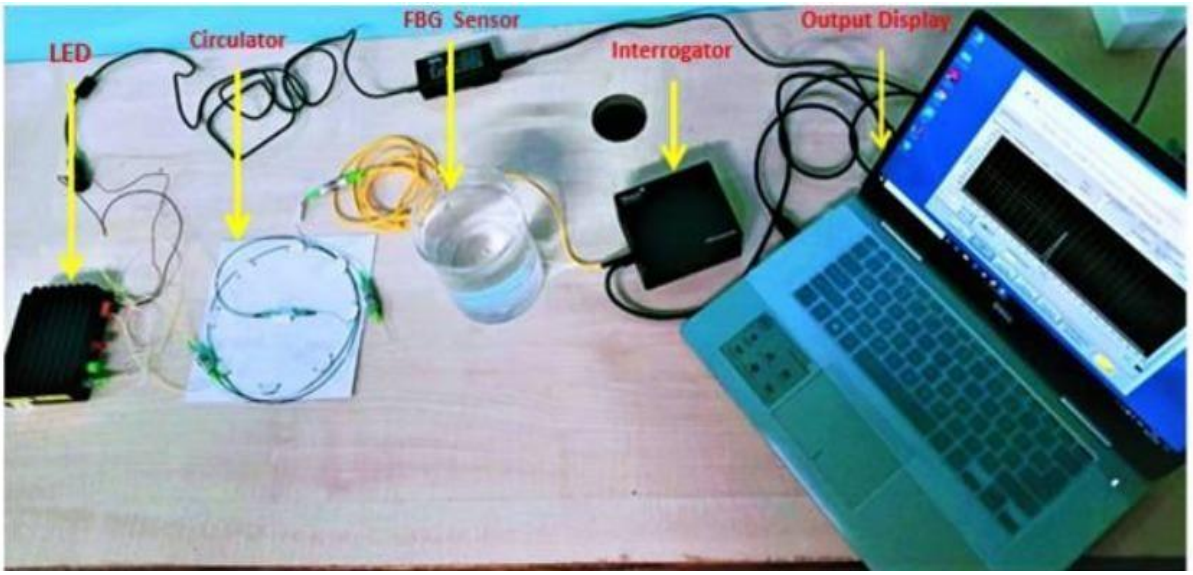
Abstract highlighting the salient features of the project:

The proposed project is focused on design and development of fiber optic sensors for measuring important ocean parameters such as salinity and temperature. Sensing probes based on Fiber Bragg Gratings (FBGs) are fabricated, after having optimized apodization profile and coating material. Salinity sensing probe is obtained by coating a layer of hygroscopic polymer named polyimide on a Nuttall apodized FBG, whereas for temperature sensing, acrylate coated Nuttall apodized FBG is used. These apodized FBG sensors based on wavelength interrogation exhibit sensitivity of 2.6 pm/PSU and 13 pm/°C for salinity and temperature measurements, respectively. In addition to FBG based sensing, Evanescent Wave Absorbance (EWA) effect is also analyzed for its salinity sensing nature using intensity interrogation. The sensing probe of EWA sensor is fabricated from dip coating methodology which makes use of Tollens reagent for coating silver layer on the un-clad region of single mode optical fiber. EWA sensor for salinity measurement shows a sensitivity of 0.02 dBm / PSU in the salinity range of 0 PSU to 40 PSU. The proposed sensors are validated against commercially available CTD sensor, resulting in a systematic bias of 0.2015 PSU, 0.2342°C and 0.3593 PSU for FBG based salinity sensor, FBG based temperature sensor and EWA based salinity sensor, respectively.

Materials and Methods:

- Experimental set-up consists of a broad-band light source (Model No.: DL-BX9-CS5153A), 3 port optical circulator (Model No.: F-CIR-15-P-FA) and FBG interrogator unit (Model No.: I- MON 256 USB).
- Sensing probe based on apodized FBGs are coated with acrylate and polyimide for temperature and salinity measurements, respectively.
- Sensing head based on EWA effect is fabricated using Tollen's reagent for silver coating and in- line mirror coating.

Experimental Setup:



Results:

- Salinity sensor based on Polyimide coated Nuttall apodized FBG: Sensitivity of 2.6 pm/PSU (Practical Salinity Unit) in the range of 0 PSU to 40 PSU with a systematic bias of 0.2015 PSU compared to commercial CTD sensors.
- Temperature sensor based on Acrylate coated Nuttall apodized FBG: Sensitivity of 13 pm/°C in the range of 16°C to 30°C with a systematic bias of 0.2342°C compared to commercial CTD sensors.
- Salinity sensor based on end-reflective EWA sensor: Sensitivity of 0.02 dBm/ PSU in the range of 0 PSU to 40 PSU with a systematic bias of 0.3593 PSU compared to commercial CTD sensors.

Conclusions:

- FOSs based on Nuttall apodized FBGs and EWA effect was fabricated based on optimized design parameters for salinity and temperature measurements.
- Proposed sensors were evaluated experimentally and validated against commercially available CTD sensors at NIOT, Pallikaranai, Chennai.

Publications in International SCI Indexed Journals:

1. Uma Kumari.C.R, **Dhanalakshmi S**, Kumar.R, Tata Sudhakar, "Fiber Optic Sensors in Ocean Observation: A Comprehensive Review," Optik - International Journal for Light and Electron Optics, Elsevier, vol.179, pp.551–560, 2019 [**SCI IF: 2.84]** DOI:10.1016/j.ijleo.2018.10.186

2. Uma Kumari.C.R, **Dhanalakshmi S**, Kumar.R, Tata Sudhakar, "Computational Analysis of Thermally Induced Stress in Corrosion-Resistant Metal Coated Fiber Optic Sensors for Oceanographic Application," Optik - International Journal for Light and Electron Optics, vol.195, 163097, Elsevier, 2019 [**SCI IF: 2.84]** DOI: 10.1016/j.ijleo.2019.163097

3. Uma Kumari.C.R, **Dhanalakshmi S**, Kumar.R, Tata Sudhakar, "Development of a Highly Accurate and Fast Responsive Salinity Sensor based on Nuttall Apodized Fiber Bragg Grating Coated with Hygroscopic Polymer for Ocean Observation", Optical Fiber Technology, vol.53, 102036, Elsevier, 2019 **[SCI IF: 2.8]** DOI: 10.1016/j.yofte.2019.102036

4. **Dhanalakshmi S**, Venkatesh Chakravartula, Uma Kumari.C.R, AVS Kesarikiran, Kumar Shubham, Bolisetty Aakash, R.Kumar, "Enhancing Sensitivity of Fiber Bragg Grating Based Temperature Sensors through Teflon Coating", Wireless Personal Communications, Springer, 2019 [**SCI IF: 2.017]**

5. Uma Kumari.C.R, **Dhanalakshmi S**, Kumar.R, Tata Sudhakar, "Development and Experimental Validation of a Nuttall Apodized Fiber Bragg Grating Sensor with a Hydrophobic Polymer Coating suitable for Monitoring Sea Surface Temperature", Optical Fiber Technology, Elsevier **[SCI IF: 2.8]**

Presentations at International Conferences:

1. Uma Kumari.C.R, **Dhanalakshmi S**, R. Kumar, Tata Sudhakar, "Experimental Set- up & Study of Material Properties for Fiber Bragg Grating based Oceanographic Temperature Sensor", International Conference on Sonar Systems and Sensors **(ICONS-2018), NPOL, Kochi,** pp.159 – 162, Feb 2018.

2. Uma Kumari.C.R, **Dhanalakshmi S**, R.Kumar, Tata Sudhakar, "Prediction of Seawater Salinity based on Surface Plasmon Enhancement and associated Power Interrogation Method", International Conference on Fiber Optics and Photonics **(PHOTONICS-2018), IIT- Delhi**, No.FP011, ISBN 978-93-88653-41-1, Dec 2018.

3. Uma Kumari.C.R, **Dhanalakshmi S**, Kumar.R, Tata Sudhakar, "Optical Sensor based on Acrylate Coated Apodized Fiber Bragg Grating for Sea Surface Temperature Monitoring", International Conference on Optics and Optoelectronics **(ICOL-2019), IRDE, Dehra Dun**, pp.372, Oct 2019.