Distributed Fiber Sensors and Applications

Credits : 2
Duration : 2 weeks
Instructors : Luc Thevenaz (EPFL), Balaji Srinivasan (IITM), Deepa Venkitesh (IITM)
Office Hours : Scheduled by appointment
Grading : As suggested and agreed by the GIAN team
Venue : IIT Madras

I. Rationale:

Distributed sensing of strain is a key requirement in several applications including structural health monitoring of aerospace vehicles, bridges, oil pipelines, and dams, as well as real-time power monitoring. Optical sensors, which are based on the sensitivity of the optical density materials to changes in strain and temperature are preferred for such applications since they are non-invasive, immune to electromagnetic interference (EMI), and non-destructive. In particular, sensors based on optical fibers have added advantages of providing for localized probing and efficient modulated light collection, as well as being able to bend around corners, and amenable to array sensing. More specifically, fiber sensors based on resonant interactions are quite attractive since the strain information is encoded in the frequency domain which is impervious to noise. In this course, we will introduce the fundamentals of distributed fiber sensing and then go into depth covering advanced topics such as Brillouin Optical Time Domain Analysis (BOTDA) and Brillouin Optical Correlation Domain Analysis (BOCDA). The target audience for this course is research scholars, and engineers/scientists from Government laboratories.

II. Course Aims and Outcomes:

Aim:

This course is intended for early stage researchers and research scholars interested in the area of distributed fiber sensors.

Specific Learning Outcomes:

The following are the objectives of this course.

- Understand the fundamentals of distributed fiber sensors
- Develop the ability to design distributed fiber optic sensing system
- Learn basic issues such as dynamic range, spatial resolution, and dynamic sensing
- Study advanced concepts such as pulse coding and correlation-based interactions.

III. Format and Procedures:

The course comprises of 24 lecture hours and 4 laboratory sessions, conducted at IIT Madras. Students are expected to attend all the sessions to obtain course credit. Lecture material would be shared through Google Drive by the GIAN team.

IV. Course Requirements:

Class attendance and participation policy: Students are expected to attend all lectures and laboratory sessions to earn complete credits.

Course readings:

1. "Fiber Optic Communication Systems", G. P. Agrawal, Wiley.
2. "Advanced Fiber Optics", Luc Thevenaz, Chapter 9, EPFL Press.
3. "Optical Fiber Sensors: Advanced Techniques and Applications", Ginu Rajan, Chapter 12, CRC Press.

V. Academic Integrity

Each student in this course is expected to abide by the academic rules and regulations and code of conduct of IIT Madras. Any work submitted by a student in this course for academic credit should be the student's own work.

VI. Tentative course schedule (each session is of 1.5 hours duration, 4-7 PM*)

I. *Fundamentals of Fiber optics (2 sessions – Deepa Venkitesh)*

1. Modes in optical fiber, attenuation and dispersion
2. Optical sources and receivers – noise analysis

II. *Optical fiber sensors (2 sessions – Balaji Srinivasan)*

1. Typical configuration
2. Amplitude/Phase/Wavelength/Polarization modulated sensors

III. *Distributed fiber sensors (2 sessions – Balaji Srinivasan)*

1. Fundamentals of OTDR/OFDR
2. SNR improvement

IV. *Distributed sensing mechanisms (4 sessions – Luc Thevenaz)*

1. Elastic/inelastic scattering – Rayleigh, Raman and Brillouin
2. Strain/temperature sensitivity

V. *Advanced concepts (4 sessions – Luc Thevenaz)*

1. Specific case studies
2. Long range sensing using BOTDA
3. Key issues for increasing number of measuring points
4. Limitations and mitigating configurations
5. Introduction to high spatial resolution sensing using BOCDA

VI. *Applications and Future Prospects (2 sessions – Luc Thevenaz)*

<u>Assignments:</u>

1. Sources and receivers
2. OTDR and power budget
3. BOTDA

<u>Laboratory sessions:</u> (* to be conducted during the morning session 9 AM -12 Noon)

1. Source and receiver characterization
2. FBG-based strain/temperature sensing
3. OTDR characterization
4. Brillouin OTDA simulations