

# Tunable Diode Laser Spectroscopy for Sensing - Principles and Applications

## Overview

Photonic sensors are capable of sensing physical and chemical changes in inaccessible locations and under very harsh operating conditions. This often makes them the only viable option in applications such as industrial process control, oil and gas prospecting, environment monitoring, detection of hazardous chemicals, space explorations and medical diagnostics. The field of industrial sensing has undergone huge transformations as regards the potency and versatility of sensing technology. This course aims to introduce to the participants the technique of **tunable diode laser spectroscopy (TDLS)**, which is currently very widely used in a variety of inter-disciplinary research and industrial applications. TDLS with wavelength modulation, known as **wavelength modulation spectroscopy (WMS)** is an ultra-high resolution spectroscopic method of making simultaneous, absolute quantitative measurements of several parameters (pressure, concentration and temperature) of gases that have overlapping rotational-vibrational spectra.

**Chemical sensing** in particular, relies heavily on TDLS that has firmly established itself worldwide as the preferred technology particularly for industrial sensing applications. TDLS is very widely used in a large number of harsh industrial environments such as process control, in which efficiency and safety cannot be compromised. In India, however, TDLS is relatively unknown although the potential for applying this technology is perhaps greater here than anywhere else in the world essentially because of the sheer variety of problems that could be effectively addressed if this technology was to be adopted. The availability of **near-infrared and mid-infrared tunable laser diodes** and optoelectronic components has enabled fiber-optic sensing to take giant strides. The growth has been greatly fueled by the development of compact, low-power, widely tunable, narrow-linewidth and frequency-agile tunable near-infrared and mid-infrared semiconductor lasers. The availability of mid-infrared lasers (semiconductor inter-band cascade laser and quantum cascade lasers) has been a telling factor in the extremely rapid progress that has been made in the field of chemical sensing. TDLS in conjunction with wavelength modulation affords very **high detection sensitivity** (ppm, ppb, ppt), **very high selectivity** (isotope detection) and the capability to **multiplex several lasers to remotely and continuously monitor vast areas and sensitive installations in real-time**. The versatility of this technique is borne out by the fact that one can simultaneously measure the concentration, pressure, temperature of several gases. Crucially, recent research has led to the development of **calibration-free measurement approaches** that tremendously increases the potency of the technique as regards field applications where one does not have the luxury of periodically re-calibrating the measurement system. Measurements can now be done in real-time with fast embedded electronics that allows compact, portable land-based or airborne systems to be developed for use in industrial applications as well as in cross-disciplinary research that may involve field measurements.

This course will begin by introducing the basic principles of optical sensors and will quickly shift its focus to TDLS. The course will introduce the technology and its potential applications and then delve deeper in to the engineering details. **Specific case studies from the University of Strathclyde's pioneering work in the UK** will be used to emphasize practical aspects that are not normally discussed in university courses. The prospects of this technology in the Indian context will be highlighted in particular. The faculty of the University of Strathclyde and IITGN have strong existing research ties. This will help to make the course more rewarding in terms of the transfer of knowledge.

The course will have a **strong hands-on component** that will complement the lectures. The participants will carry out planned experiments in the **Photonic Sensors Lab at IITGN** under the supervision of faculty and graduate students.

<b>Modules</b>	<p>01 Feb 2016: Mon Lec 1: 09:30 - 10:45 The evolution of fiber-optics sensors  Lec 2: 11:00 - 12:15 Basic principles of optical fibers  Lec 3: 14:00 - 16:00 Wave propagation and modes in optical fibers</p> <p>02 Feb 2016: Tue Lec 4: 09:30 - 10:30 Fundamentals of optoelectronic devices  Lec 5: 10:45 - 11:45 Semiconductor laser theory  Lec 6: 14:00 - 16:00 Operational aspects of semiconductor lasers relevant to sensing technologies</p> <p>03 Feb 2016: Wed Lec 7: 09:30 - 10:30 Fundamentals of molecular spectroscopy – points of view electrical engineering and physics  Lec 8: 10:45 - 11:45 Tunable diode laser spectroscopy – basic operational details and engineering perspectives  Lec 9: 14:00 - 15:00 Measurement of gas parameters – pressure, concentration, temperature  Lec 10: 15:00 - 16:00 Laboratory visits and demonstrations</p> <p>04 Feb 2016: Thurs Lec 11: 09:30 - 10:30 Case study 1 - System challenges in TDLS  Lec 12 10:45 - 11:45 Wavelength modulation spectroscopy  Lec 13: 14:00 - 15:00 Calibration-free techniques of measurement in TDLS  Lec 14: 15:00 - 16:00 Laboratory visits and demonstrations</p> <p>05 Feb 2016: Fri Lec 15: 09:30 - 10:30 Case study 2 – Aero-engine exhaust imaging systems using TDLS – the FLITES project at Strathclyde  Lec 16: 10:45 - 11:45 Case study – Biological and medical applications – collaborative efforts of the Biological and Electrical Engineering disciplines of IITGN  Lec 17: 14:00 - 15:00 Case study – Applications of TDLS in space applications – collaborative efforts of the Space Applications Centre, Ahmedabad and IITGN  Lec 18: 15:00 - 16:00 Entrepreneurship opportunities in India  Lec 19: 16:00 - 17:00 Concluding session – general Q&amp;A session</p>
<b>You Should Attend If...</b>	<ul style="list-style-type: none"> <li>▪ Students at the postgraduate level (MSc/MTech and PhD) with interest in optical sensors</li> <li>▪ Engineers and researchers from the mining, oil and gas industry, chemical industry</li> <li>▪ Scientists from the R&amp;D laboratories of the government</li> <li>▪ Faculty from recognized academic institutions</li> </ul>
<b>Fees</b>	<p>The participation fees for taking the course is as follows:  <b>Participants from abroad : USD 100</b>  <b>Industry/ Research Organizations : INR 5000</b>  <b>Academic Institutions : INR 1000</b></p> <p>The above fee include all instructional materials, computer use for tutorials and assignments, laboratory equipment usage charges, 24-hr free internet facility. The participants will be provided with accommodation on payment basis.</p>

## The Faculty



**Prof. Walter Johnstone** graduated from the University of Strathclyde with a BSc (Hons) degree in Chemical and Materials Sciences in 1977, and a PhD in Laser Physics in 1982. He is currently Professor of Photonic Systems and Vice Dean of the Faculty of Engineering at Strathclyde

University where he has been a member of academic staff since 1986. Following senior management positions as Head of the Department of Electronic and Electrical Engineering and Associate Dean [International], he was appointed to the Vice Dean's post with responsibility for Research and International Relations. His research into optical waveguide components, fibre lasers, distributed fibre sensing systems and optical gas sensing has led to more than 200 technical publications and several patent applications. His group carries out basic research as well as engineering of systems for in situ industrial deployment. Recent research has led to two novel approaches in tunable diode laser spectroscopy (TDLS) to enable calibration-free, accurate measurement of gas concentration, pressure and temperature in complex gas processing systems such as fuel cells at temperatures up to 1000 °C and pressures of 5-8 bar or in jet (gas turbine) engines at high temperature and high gas velocity. Prof. Johnstone holds Directorships at OptoSci Ltd (estd in 1994) and the Institute for System Level Integration (ISLI). The major product lines of OptoSci include optical and fibre optic educator kits, optical instrumentation, optical fibre amplifiers and optical gas sensors. ISLI provides technical and education services to the semiconductor and electronics industries. During 1980 to 1985 he was employed by Pilkington Optronics Ltd and held various project engineering and management posts involved in the research and development of high power lasers, optical fibre communication systems and lithium niobate integrated optics. In 1985 he was appointed to the post of Development Manager at Logitech Ltd and was a full member of the company's Management Board with responsibility for all technical functions including new product development.



**Dr. Arup Lal Chakraborty** obtained his BTech (ECE) degree from the University of Kalyani, West Bengal in 2000. After a 7-year stint as a scientist in the Raja Ramanna Centre for Advanced Technology (RRCAT), Indore, he moved to the University of Strathclyde, Glasgow in 2010. His

research on calibration-free tunable diode laser spectroscopy earned him his PhD in 2010. Since then he has been a faculty member in the Electrical Engineering discipline at IIT Gandhinagar. His research focusses on mid-infrared tunable diode laser spectroscopy for industrial and medical applications. He is passionate about experimenting with teaching methods by integrating electrical engineering with photonics and music.

## Course Coordinator

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