



University
of Victoria

PHYSICS AND ASTRONOMY RESEARCH SEMINAR (In-Person)

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“Light as a Probe: Harnessing Optical Resonances for Sensing Chemical Diffusion and Mechanical Strain”

Abstract

Sensors are fundamental to modern technology, supporting applications from environmental monitoring and industrial safety to structural health assessment and healthcare. However, conventional electrical and mechanical sensors often face limitations in sensitivity, robustness, and scalability. Rapid advances in optics and photonics are overcoming these challenges by harnessing light-matter interactions to detect physical, chemical, and mechanical changes with exceptional precision. These optical approaches enable remote, real-time, and multiplexed measurements while offering enhanced sensitivity and immunity to electromagnetic interference. In this work, optical resonance-based sensors are used to study VOC diffusion in polymers and to perform long-range strain sensing.

In the first part of this work, extraordinary optical transmission (EOT) through metallic nanohole arrays (NHAs) is employed as a refractive index sensing platform to study the diffusion kinetics of volatile organic compounds (VOCs), specifically o-xylene, into thin polydimethylsiloxane (PDMS) films. Rigorous analytical models based on integrated solutions to Fick’s laws of diffusion are derived for both permeable and impermeable polymer films, extending classical approaches and enabling more accurate extraction of diffusion coefficients from experimental data. The resulting NHA-based sensor platform is simple to fabricate, operates in real time, and enables continuous, cost-effective monitoring of VOC sorption and desorption, providing new insights into diffusion dynamics in polymer analyte systems.

The second part of the work presents a long-range, high-resolution fiber-optic strain sensor based on a π -shifted Fiber Bragg Grating (π -shifted FBG) interrogated using the Pound-Drever-Hall (PDH) frequency locking technique. Enhanced field localization in the π -shifted FBG cavity, combined with sub-picometer wavelength resolution afforded by PDH interrogation, enables nano strain-level response over fiber tethers up to 75 km, eliminating the need for in-line amplification. A coherent PDH scheme further improves the signal-to-noise ratio, extending the theoretical sensing range beyond 150 km.

Together, these studies demonstrate how optical resonance phenomena — from plasmonic nanostructures to resonant fiber gratings — can be harnessed to probe chemical and mechanical processes with high sensitivity and range, paving the way for advanced sensing platforms in environmental and structural applications.

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