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Holographic Enhancement of Fibre Optic Sensors

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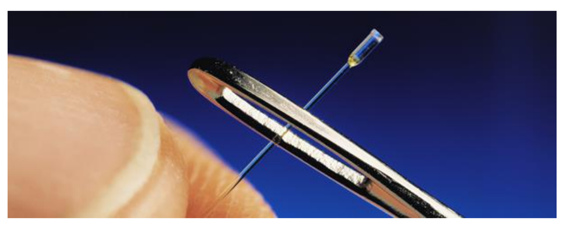
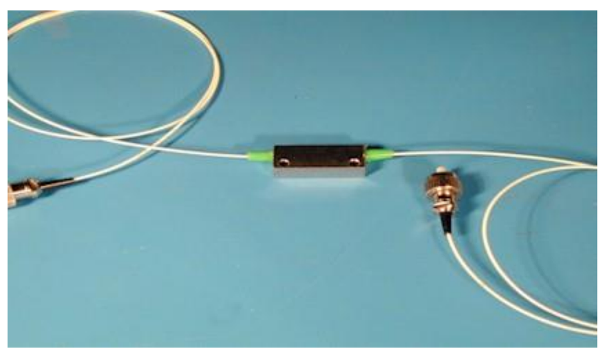
Introduction

FIBRE OPTIC SENSORS are widely available in the market today, used in many industries for various measurands.





Incorporating evanescent field sensing, Surface Plasmon Resonance, fluorescent indicators, or interferometry, Fibre Optic Sensors offer a unique set of advantages over conventional electronic sensors.

Advantages

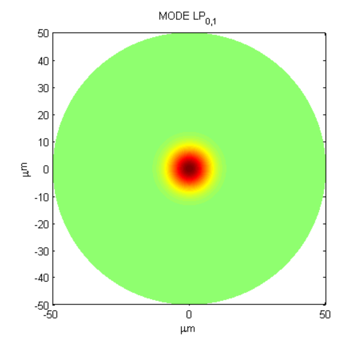
- Small size
- Light Weight
- Immune to Electro-Magnetic noise
- High temperature performance
- Distributed sensing
- Multiplexing ability

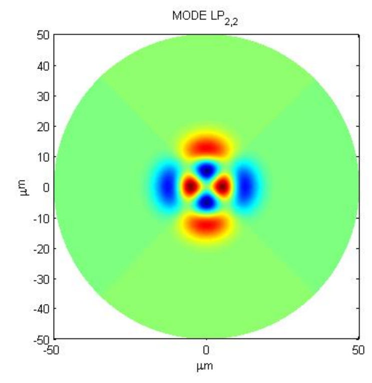
Common Measurands

- Temperature
- Strain
- Flow
- pH
- Hydrogen
- High Voltage

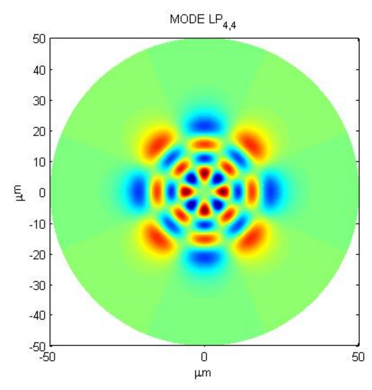
Aims and Objectives

Light propagating through optical fibres does so as a superposition of discrete Fibre Modes.





Each fibre mode has slightly different properties, such as the propagation constant, mode field diameter, bend losses and susceptibility to mode mixing.

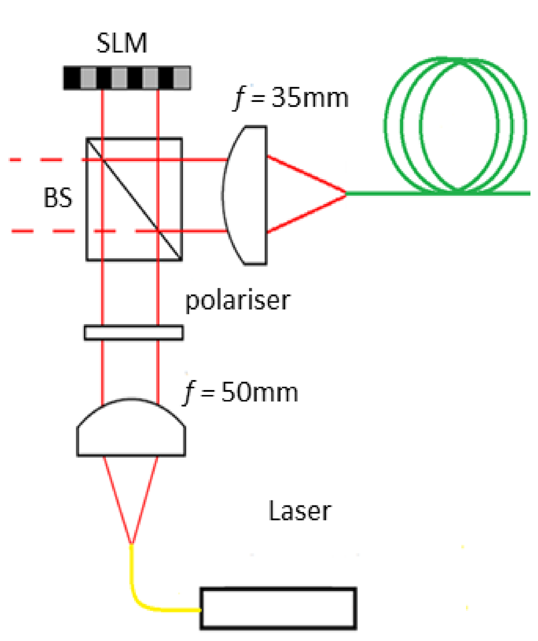


It is therefore expected that various fibre modes will have differing sensing ability.

The aim of this research is to investigate the performance of Fibre Optic Sensors with the modal composition of light propagating within the fibre, and to improve device performance by controlling the modal excitation.

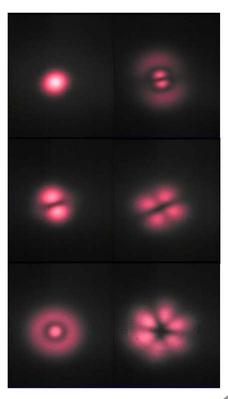
Holographic Mode Launch

In this research, specific fibre modes and mode groups are excited using Holography. To excite a specific fibre mode, Computer Generated Holography techniques are used to determine the Spatial Light Modulation that maximises the *overlap integral* between the replay field and the target mode. Thus careful control over the SLM allows for selective mode launch.



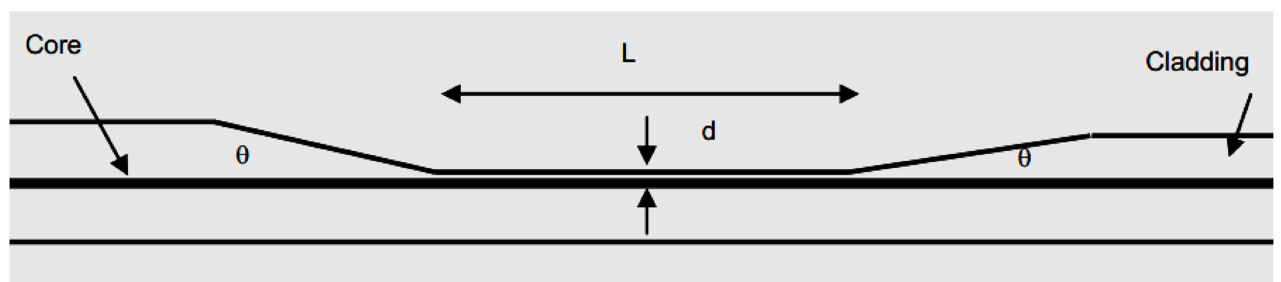
For an effective launch, the adaptive nature of the SLM is exploited to correct for aberrations and misalignments by superposing a phase pattern formed of *Zernike Polynomials* over the SLM modulation.

Viewing the spatial distribution of the fibre output where discrete modes launched at the input, confirms the efficacy of the launch. (*see right*)

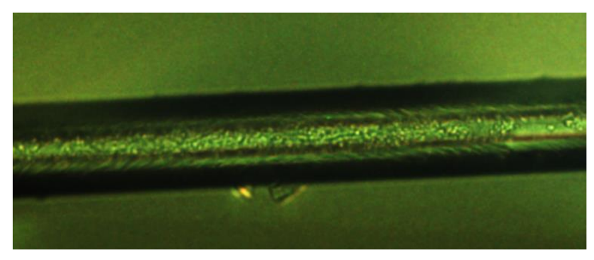


Sensing Fibres

Sensing is performed using ***Side Polished Fibres***. The depressed cladding yields an exposed evanescent field which interacts with analytes, altering the fibre transmission. The cladding is removed either by mechanical grinding, or laser ablation.



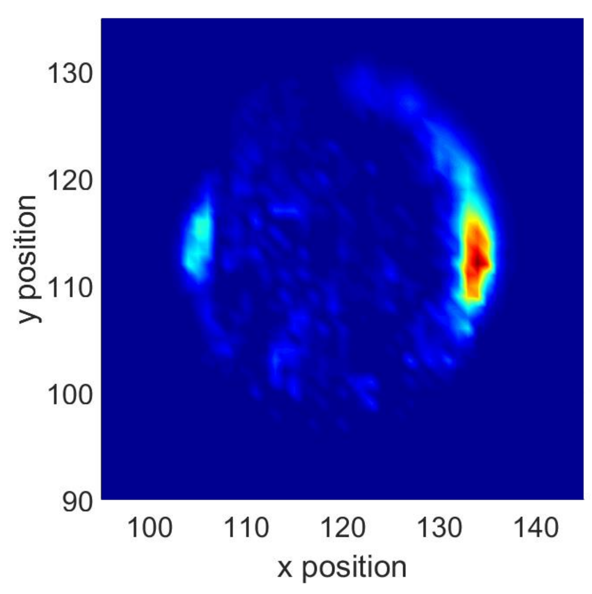
For some analytes, a poly-HEMA layer is formed on the surface of the depressed cladding by dipping the fibre in the monomer solution and passing UV light through the fibre. As polymerisation occurs via the exposed evanescent field, a thin polymer layer results.



Microscope image of polymer layer on the polished surface

Mode Group Dependant Sensitivity

To demonstrate Mode Group dependant sensitivity, using a multi-mode side polished fibre, a spot is launched into various positions across the fibre core, and the difference in transmitted power with the depressed cladding placed in high and low refractive media measured.



The further the launched spot from the central fibre axis, higher order mode groups are excited.

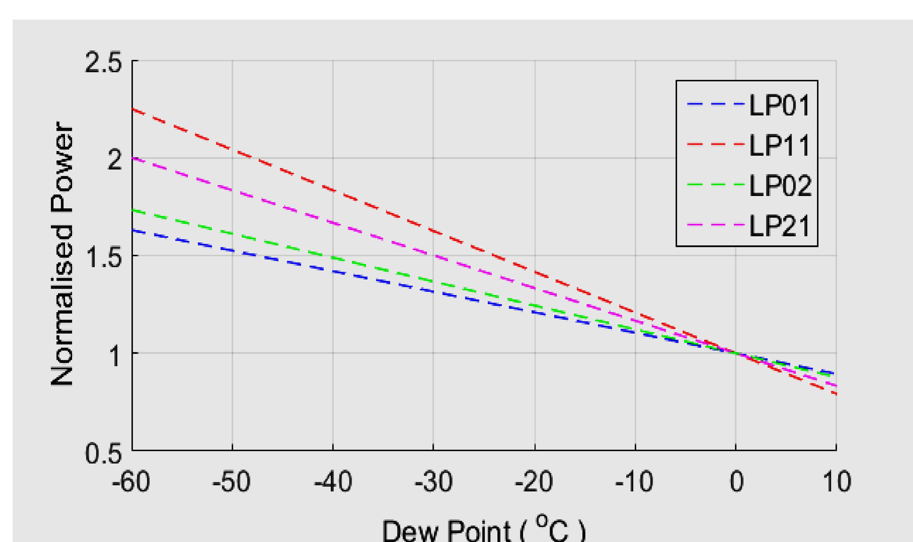
The colour-map of the above image shows the measured power shift with the spot launched into the corresponding coordinate. The peak corresponds to the launch yielding highest sensitivity, and its existence demonstrates that sensing does vary with the modal composition of light within the fibre.

Modal Sensitivity

Each mode may also correspond to a different sensitivity. The graph below shows humidity sensing results taken from a few-mode side polished fibre, where measurements are taken with each mode excited exclusively.

The gradient of each line corresponds to the sensitivity of the mode, clearly demonstrating the modal dependence of the sensor performance. In this case exciting the $LP_{1,1}$ mode can improve device performance.

The highest sensitivity does not necessarily correspond to the mode with the largest Mode Field Diameter, but the mode that yields the most intense Evanescent field.



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