# Theoretical and Empirical Modelling of Long-Period Fibre Gratings

Hannes Hochreiner, PhD candidate, Dalhousie University, Halifax, Canada
Supervisor: Professor Peter Wentzell, Department of Chemistry
Co-supervisor: Professor Michael Cada, Department of Electrical and Computer Engineering

**In this project the properties and uses of long-period gratings (LPGs) as chemical sensors for environmental analytes are studied. Using fibre optic theory, a computer simulation programme was developed to predict the response of the LPG under different conditions and with a variety of coating structures. Furthermore, experimental data of different stages of the sensor development was analysed using chemometric methods. This work is important for the optimisation of the sensor element, and to ensure that the maximum information is obtained from the data produced by the sensor system.**

## Context

This project is part of a multidisciplinary collaboration among universities and industry partners aiming to produce a novel environmental sensor system. The transducers of the system are LPGs, which are sensitive to the refractive index of the surrounding medium. Applying different polymer coatings onto the LPG elements adds selectivity for the analytes of interest. Using a transducer element sensitive to a universal property of matter, as is the refractive index, and having a variety of selective coatings, a very versatile sensing system can be obtained. Other main participants are Queen's University (Kingston, Canada), where the polymers were developed and a prototype system was constructed, and ITF Labs (Montréal, Canada), which provided the LPG fibres and engineering expertise.

## Theoretical Modelling

LPGs are simple optical elements with a complex response to different physical parameters (bending, strain, temperature, refractive index). It is therefore very important to model the response of the LPGs in order to optimise the parameters of the sensor element. A computer model has been created for this purpose. The model is based on modal methods, with a choice between two different levels of theory – linearly polarised (LP) modes and hybrid modes. It uses a transfer matrix method in the radial direction allowing any number of layers to be considered. The grating is dealt with using coupled mode theory. The model was validated experimentally. Inspired by the need to solve an engineering problem, the model was also extended to be able to investigate chirped concatenated gratings. Furthermore, new coating structures have been developed providing increased sensitivity as well as flexibility.

## Empirical Modelling

Since the coating polymers generally do not show perfect selectivity for the analyte of interest, chemometric methods have to be used to extract the desired information from the data obtained. This process is further complicated by the fact that the response of the sensor elements is expected to be highly non-linear. Using data from the prototype system, a preliminary analysis was conducted. A correlation analysis provided guidance for the choice of coating polymers, which will enhance the information content of the data. Furthermore, principle component analysis was used as a tool of exploratory data analysis to examine the data. The empirical modelling will gain in importance as the sensor system matures.

## Important Results

- Provided collaborators with optics expertise and guidance in the selection of sensor parameters.
- Produced a computer program for modelling the LPG. The model has been adapted repeatedly according to the needs of the collaborators and is used extensively to optimise the parameters of the sensor element.
- Made suggestions for ways to overcome engineering challenges.
- Investigated novel overlay structures for LPGs that provide enhanced sensitivity, stability and flexibility.

## Contact

Hannes Hochreiner

hannes@hochreiner.net
+1 (902) 420 9463
www.hochreiner.net