University of Basel

Department of
Biomedical Engineering

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Master of Science – Biomedical Engineering
Thesis Proposal

**Investigating the impact of bending-induced phenomena on the performance of eFBG shape sensors**

In minimally invasive surgeries, it is often required to use non-rigid instruments in order to maximize accessible regions. However, using flexible tools will raise some safety concerns as there are uncertainties about their shape and tip position. Consequently, an accurate tracking system is desirable to provide positioning feedback for the surgeon. Shape sensors based on Fiber Bragg Gratings (FBG) are suitable for this task as they are small, biocompatible, immune to electromagnetic interference, and require no line of sight.

One of the most recent types of fiber shape sensors is based on eccentric FBGs (eFBG), where the Bragg gratings are inscribed on the edge of the core in a single-mode optical fiber. The amplitude of the Bragg peaks is sensitive to external perturbations such as mechanical strain and temperature. The main challenge in these sensors is to accurately model their behavior, as the main signal is often affected by many bending-induced phenomena. Preliminary results show that the complicated relationship between the amplitude of eFBGs and the sensor's shape can be described using deep-learning techniques such as convolutional neural networks (CNN). However, the remaining question is which bending-induced phenomenon affects the Bragg resonances the most.

This master thesis aims to study the impact of cladding mode coupling, bending loss oscillations, and bending-induced birefringence on the performance of eFBG sensors. This will be done by experimentally isolating each effect and monitoring the spectral change of the propagating light. The following steps describe the main work packages:

- Preparing an experimental setup to measure spectral changes of the propagating mode in an optical fiber with no eFBGs when shape deformations are applied. Both reflected and transmitted light should be analyzed.
- Repeating the experiment with an eFBG fiber and analyzing the sensor's signal.

**Nature of the Thesis**
Experimental: 70%
Programming: 20%
Documentation: 10%

**Specific Requirements**
Programming experience using MATLAB, basic knowledge of optics, and experience with optical fibers.

**Group Leader / Supervisor**
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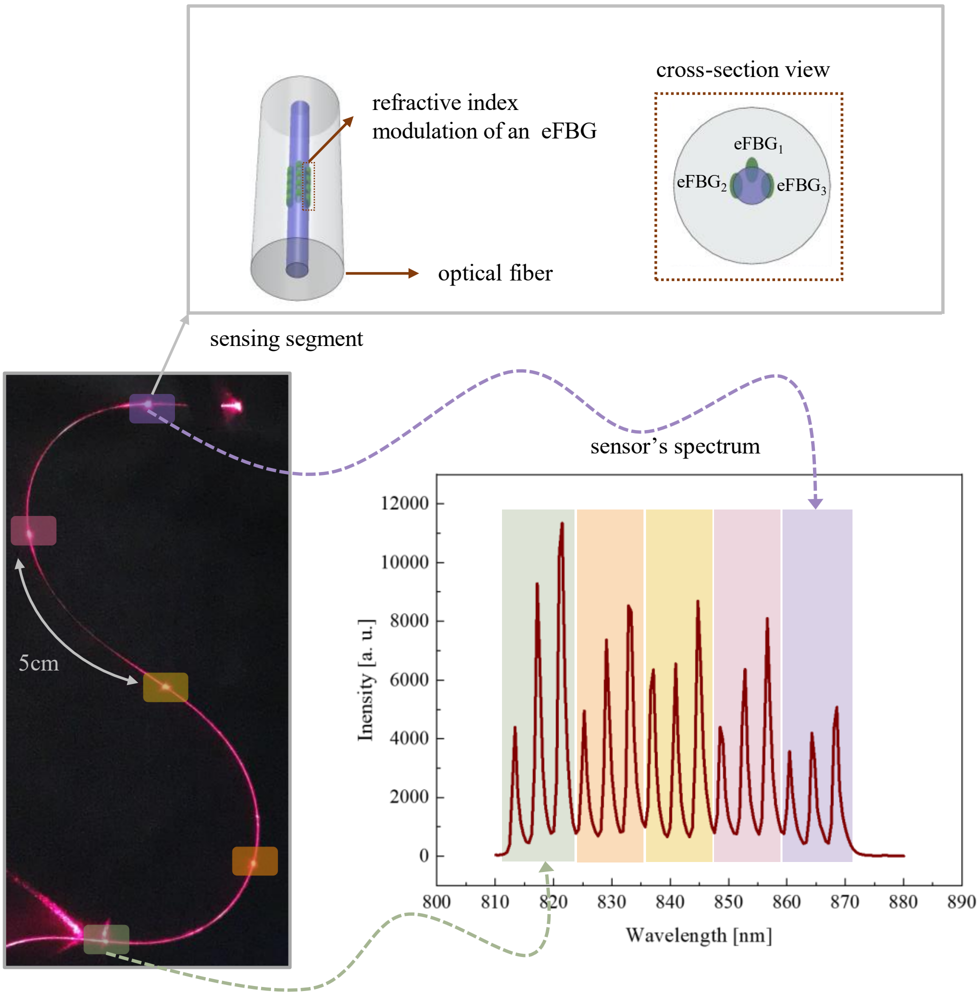


Figure 1. Eccentric FBGs are highly localized FBGs, written off-axis in the core of a single-mode fiber, designed by our collaborators at Fraunhofer HHI in Goslar, Germany. The eFBG shape sensor we used is 30 cm long and features five sensing segments that are 5 cm apart. Each sensing segment has three eFBGs with ~90˚ angular separation. The sensor's spectrum contains the reflected signal of 15 eFBGs from the five sensing segments.

**More information**

[1] SM Roodsari, et al., "The secret role of undesired physical effects in accurate shape sensing with eccentric FBGs", arXiv preprint arXiv:2210.16316, 2022, https://doi.org/10.48550/arXiv.2210.16316

[2] SM Roodsari, et al., "Using Supervised Deep-Learning to Model Edge-FBG Shape Sensors", arXiv preprint arXiv:2210.16068, 2022, https://doi.org/10.48550/arXiv.2210.16068