# Abstract

Fiber Bragg Grating (FBG) sensors have become increasingly popular for applications in biomedical engineering. Amongst these, use of FBGs in 'smart instruments' for minimally invasive diagnostic and surgical procedures look promising as FBG sensors provide significant advantages compared to other sensing modalities in terms of size, electromagnetic immunity, and ability to withstand sterilization procedures.

Minimally invasive procedures provide lower discomfort to the patients and faster healing time. Procedures based on use of needles as well as flexible medical instruments like endoscopes form an important part of these procedures. As a natural progression, there is a growing trend towards robotic and robot-assisted procedures. Effective sensing of interactions between the instruments and tissues and the state of the devices plays an important role in this. This thesis showcases the effectiveness of FBG sensors in the estimation of forces during device-tissue interactions and the shape of flexible devices through two applications.

The first application demonstrates the feasibility of estimating needle transitions through tissues using force estimation at the needle tip. Needles with integrated fiber Bragg grating sensors have been developed for this purpose and experiments have been conducted using multi-layered Polydimethylsiloxane (PDMS) phantoms. The design has been extended to handle temperature induced effects and the experiments have also been performed using heated chicken tissue.

The second application demonstrates the feasibility of estimating the shape of a flexible medical instrument like endoscope using strain information from fiber Bragg grating sensors embedded in a polymer filled tube. This overcomes some of the constraints of solutions based on sensors bonded on nitinol wires which have been used earlier. The computation of shape from strain data has been explained.

Widespread use of FBG sensors in such applications is dependent not only on sensor characteristics but also on the interrogation system. Since the number of sensors per fiber and the distance between the source and the sensors are small in these applications, interrogation systems based on linear detector arrays provide a good option. However, their accuracy depends on the curve fitting method used. For this purpose, a comparison of accuracies of interrogation systems based on swept tunable laser and In GaAs linear detector arrays has been performed. The choice and effectiveness of curve fitting techniques to achieve accuracies similar to tunable laser-based systems have been investigated. The computational feasibility of the algorithm on embedded hardware has been demonstrated.