PHOTONIC CRYSTAL FIBER WITH CASCADED FIBER BRAGG GRATINGS FOR PLASMONIC REFRACTOMETRY AND BIOSENSING

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Abstract of the PhD research

Over the last decade, optical fibers have been considered for point-of-care medical diagnostics by ways of so-called lab-on-fiber probes. Such lab-on-fiber devices have gained attention owing to their sub-millimeter size, flexibility, and remote operation. They offer performance in health monitoring and medical diagnostics that rivals commercially available solutions. To ensure the accuracy of medical diagnoses and mitigate the risk of false test results, it is imperative to validate a singular measurement with a reference measurement conducted under identical conditions. This validation is achievable through the incorporation of two biosensors within a single optical fiber device.

However, one of the most advanced fiber biosensor technologies, which relies on cladding mode resonance sensing with tilted fiber Bragg gratings (FBG) in standard telecommunication-grade step-index optical fibers, has encountered challenges in biosensor multiplexing. The extended spectral response that covers a wavelength range exceeding 100 nm poses difficulties for commercial cost-effective FBG interrogation systems.

To address the issue of biosensor multiplexing, this doctoral thesis concentrates on the utilization of specialized fibers known as microstructured optical fibers (MOFs), specifically focusing on the most prevalent MOF type – photonic crystal fibers (PCFs). Previous research indicates that the inscription of a straight FBG into a PCF yields cladding mode resonances suitable for biosensing applications, comparable to tilted FBGs in step-index fibers. The advantage of PCFs over standard telecommunication fibers lies in their design flexibility, which potentially facilitates spectral multiplexing capabilities.

In this doctoral research, we initially optimize the parameters of the PCF-microstructure to position the cladding mode resonances within the refractive index range typical for biosensing (n=1.32-1.34). Additionally, we reduce the spectral span occupied by a single FBG to a few tens of nanometers. Successful optimization enables the inscription of two spectrally-multiplexed cascaded FBGs. The biosensing potential of these FBGs is evaluated through refractometry experiments with aqueous solutions mimicking biosensing conditions. The results demonstrate sensitivities comparable to tilted FBGs and superior to other reported MOF-based refractometers. Finally, we demonstrate the practical application of our PCF-

device by reliably detecting 1 μg/mL of a breast cancer protein biomarker from both biosensors in a single spectral readout.

Given its inherent temperature referencing and relatively straightforward fabrication, our PCF-biosensor emerges as an exemplary candidate for reference-compensated single-analyte detection, and potentially, for multiple-target detection.