Title: All-in-fiber sensing and light generation based on specialty fibers

Abstract:

All-in-fiber sensing and light generation devices are facing increasing demand due to their distinct features of being free standing and robust, great compactness, easy handling, low waveguide losses and low cost for mass produce. Compared with conventional fibers, specialty fibers are able to provide better sensing and light generation performance since they enable great flexibility in manipulating light guidance property through simply tuning fiber structures, and enhanced light-matter interaction by hosting aqueous matter in the air channels running along the entire fiber length. Currently, the development and applications of high performance all-in-fiber sensing and light generation are still limited by low sensing sensitivity, bulky setup introduced by free space light coupling and difficulties in the replacement or manipulation of liquids in the air channel.

To address the aforementioned challenges and difficulties, we design, fabricate, and systematically investigate a number of all-in-fiber sensing and light generation systems. Firstly, we design and fabricate a side channel photonic crystal fiber (SC-PCF) for developing highly sensitive aqueous sensing. SC-PCF has a solid core and triangular lattice cladding structure. Partial lattice cladding is intentionally removed to enable fast liquid infiltration speed and strong light-matter interaction. By precisely splicing this SC-PCF to side-polished single mode fiber (SMF), a fiber long period grating and a Sagnac interferometer are experimentally realized and investigated for all-in-fiber optofluidic refractive index (RI) sensing and biological sensing. We achieve a high RI sensitivity of 1145 nm/RIU with the SC-PCF long period grating, and more importantly we are able to detect 1 μ M cardiac troponin T protein with the highly sensitive Sagnac interferometer. Secondly, an ultrasensitive surface enhanced Raman sensing platform is demonstrated with optimized geometry of the SC-PCF. With this new fiber structure, we achieve an ultra-low detection limit of 50 fM Rhodamine 6G solutions. Thirdly, to generate a unique light emission for biomedical analysis and phototherapy with minimal invasion, we develop a multilayer photonic bandgap (PBG) fiber laser with quantum dots (QDs) solution as the gain medium infiltrated in the hollow core. The PBG fiber laser platform has unique characteristics of large emission surface perpendicular to fiber axis and remote pumping configuration, which provides a substantial impact on both studies of lasing mechanism and future developments of a variety of applications for biomedical analysis. Finally, we investigate the performance of a plasmonic random laser fabricated via polymer cold-drawing. As the flexible polymer based random laser can be easily attached to fiber end face, integrated with the pumping configuration provided by the optical fiber waveguide, this random laser has great potential of serving as a flexible and versatile light source with large surface emission area for *in vivo* sensing and speckle-free optical imaging.

In this thesis, design, fabrication and applications of specialty fibers and structures for all-in-fiber sensing and light generation with high performance are presented. Further investigations on the integration of all-in-fiber light generation and chemical/biological analysis will be carried out in the near future.