Hollow Core Photonic Bandgap Fibers for Gas Sensing applications: Progress and Current Challenges

M.N. Petrovich*, C. Grivas, F. Poletti, D.J. Richardson
Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1 BJ, UK
(*) mnp@orc.soton.ac.uk

Abstract: Hollow core Photonic Bandgap Fibers (PBGFs) enable new concepts for fiber-based sensor devices. In this paper, we review the current status of their application in the area of gas sensing, focusing in particular on two as yet open challenges. Firstly we discuss the issue of gas access and present recent improvements of a femtosecond laser machining technique, which allowed us to achieve cells with multiple side access channels and low additional loss. Furthermore we analyze the impact of modal properties of PBGFs on the performance of practical sensor devices, and we address the issue of controlling the modal properties of these fibers.

1. Introduction

Hollow core Photonic Bandgap Fibers (PBGFs) enable light guidance in a low-index air core [1] and thus provide an ideal platform for achieving efficient interaction between the guided light and formulations in-diffused in the holes. PBGFs have therefore been the subject of acute scientific interest for chemical and in particular gas sensing applications [2], where they open up the possibility for high sensitivity devices with extremely compact and flexible footprint, and format compatible with conventional fiber networks for remote interrogation [3]. The performance of PBGFs gas sensors is currently limited by a few significant drawbacks. Firstly, the slow gas diffusion into the holes severely limits the sensor's response time [2]. Another crucial but perhaps less recognized drawback originates from modal interference (MI), due to the multimode nature of the most commonly used types of PBGF [4]. MI severely limits the ability to discern gas lines, in particular at low concentration levels. In this paper we focus on these two key issues and aim to identify suitable solutions.

2. Micromachined PBGF Cells

Open end filling of PBGF gas cells is extremely slow and also leads to issues of poor stability of input/output optical coupling. A possible solution is to provide points of access for the gas along the fiber; however, this must be accomplished by introducing minimal loss and retaining a compact arrangement.

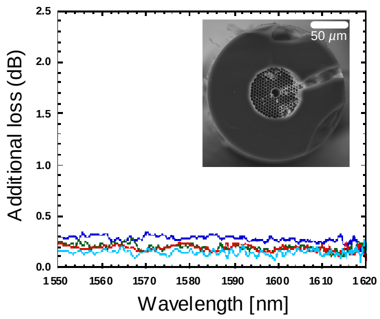

Fig.1: Additional loss due to microchannels machined in a PBGF

We developed a fs-laser machining technique capable of realizing side-access fluidic microchannels which connect the hollow core of a PBGF with the outside environment. This technique affords a high degree of precision and control, allowing the fabrication of channels with minimal structural damage and thus very low additional loss (Fig.1). Compact, meter-length PBGF cells with several microchannels were obtained, which were employed in practical gas sensing configurations.

3. Modal Interference in PBGFs

PBGFs can in general support a number of optical modes, including air-guided modes, surface modes and cladding modes. Such modes can propagate over short fiber lengths and originate modal interference effects, which is highly detrimental for gas sensing. We have investigated the close interplay that exists between the number and type of modes supported by these fibers and the fine details of their structure, aimed at controlling their modal properties. We also have investigated in detail which modes are responsible for MI in different PBGFs (Fig.2), aimed at identifying strategies for suppressing this effect or alleviating its impact on gas sensing.

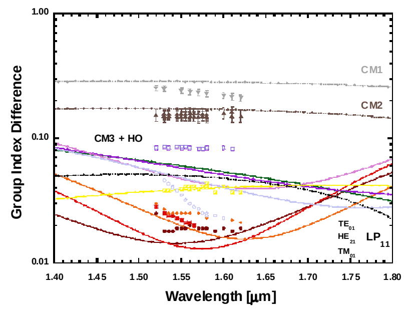

Fig.2: Calculated and measured differential group index for optical modes in PBGFs

REFERENCES

[1] R.F. Cregan, et al., *Science*, **285**, 1537 (1999)
[2] M.N. Petrovich, et al., SPIE Proc. **6005**, 78 (2005).
[3] A. van Brakel, et al., *OFS-19*, Perth, 2008.
[4] M.N. Petrovich, et al., *Opt. Express* **16**, 4337 (2008).