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Contaminant free end-capped acetylene PMC for sub-Doppler spectroscopy

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Gas-filled Hollow Core Photonic Cristal Fibres (HCPCF) or Photonic MicroCell (PMC) [1] has proven to offer an outstanding gas-cell for laser metrology and spectroscopy applications. Sub-Doppler spectral features, generated via electromagnetically induced transparency (EIT) or saturated absorption (SA), have been generated in molecular gases despite the weak strength of their optical transitions [1-4], and an optical frequency reference with excellent accuracy has been demonstrated [1]. So far, the reported stand-alone PMCs are either made by hermetically splicing the HCPCF tips to an all-solid optical fibre [1,2] or by encapsulating them to a glass cell [3]. All these techniques show limitations. For example, the splicing based all-fibre PMC technique is not adapted to all fibres as it requires matching the outer-diameter and/or mode-field-diameters of the two fibres. Also the use of fibre tapering to reduce this mismatch [2] remains too cumbersome for the obtained splice-loss figures, which are >2 dB and exhibit asymmetric loss. Furthermore, the use of Helium (He) gas during the “air-ambient” splicing process to avoid air pollution in the fibre core renders this technique too sensitive to residual gas contamination. Conversely, the technique of encapsulating the fibre tip in an enlarged borosilicate capillary [3] presents potential contamination during and after fabrication because of the use of Epoxy glue, and the ensued outgassing, which is detrimental for optimized observation of sub-Doppler features and for the life time of the PMC.

Here, we report on fabrication and spectroscopic (EIT and SA spectroscopy) characterisation of contaminant free acetylene PMC where no He or glue is required. The assembly process of this PMC is based on end-capping both ends of a HCPCF by collapsing a sleeve capillary while the system is still connected to the vacuum preventing any air pollution. The end-cap is then polished and mounted onto FC/APC connectors for easy system integration. Fig. 1(a) shows a photography of the developed PMC with a fibre patchcord-like physical-outline. The PMC is made with a 7 m long section of an IC-HCPCF with low loss of 10dB/km around 1540nm. The IC-HCPCF has a hypocycloid core of an inner diameter of 30 μ m. The fibre was filled with acetylene at a pressure of 0.04mbar corresponding to a pressure collisional broadening of 8MHz [4]. The loss of each end cap is found around 1dB. The mode quality is stable motionally, illustrated by the near field intensity profile in Fig.1(b). The formed C₂H₂ PMC was characterised by generating and monitoring sub-Doppler transparencies using both EIT and SA spectroscopy. Fig. 1(c) shows the PMC transmission EIT trace when pumped at P13 of the acetylene $\nu_1 + \nu_3$ ro-vibrational overtone band and probed at the R13. The EIT contrast and FWHM evolution with the pump power is shown in Fig.1(d), expressed in Rabi frequency. Both quantities fit well with the expression in [4]. The EIT linewidth shows an asymptotic minimum of 18 $\pm$ 3MHz. This figure is close to the transit time induced linewidth which is about 19MHz for the fundamental core mode. Consequently, no collision dephasing is observed. Furthermore, we generated SA (Fig.1(e,f)) with a contrast of 8% and a linewidth of 17MHz.

Fig. 1 (a) Overall picture of the FC/APC connectorized PMC, (b) PMC output near field mode at 1530nm, (c) EIT spectrum of R13 line pumped by at 100mW centered on the P13 (line) and a Gaussian fit (dashed line). (d) The EIT contrast (blue) and FWHM (green) vs Rabi frequency for experimental data (dots) and theory (line). (e) SA measurement of the P9 line with 32mW pump power (Gaussian fit in dashed line). (f) Difference between SA spectrum and Gaussian fit from (e).

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