Second-order nonlinearity profile in thermally poled twin-hole fibre

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Abstract: The second-order nonlinearity profile in thermally poled twin-hole fibre was characterized by second-harmonic scanning optical microscopy. The technique enabled us to optimize the poling parameters in order to obtain overlap between non-linear region and core.

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New prospects for all-fibres nonlinear devices were opened by reporting more than 20% second-harmonic (SH) conversion efficiency from a 7 cm long periodically poled D-shape fibre[1-2]. Yet, to obtain even higher conversion efficiencies, longer device length and higher induced nonlinearity are required. The length was limited by the photolithographic process required to fabricate the periodic electrodes, whereas the measured nonlinearity of d=0.044 pm/V was partially due to poling under vacuum, which is known to give 2 to 3 times smaller $\chi^{(2)}$ than for poling in air [3]. More importantly, the overlap between the nonlinearity profile and the core might not have been optimum. Indeed, a direct measurement of the nonlinearity profile on the cross-section of the fibre is needed to locate its position in correspondence with the core.

Twin-hole fibres with an asymmetric position of the core ~2 μm away from one of the holes were used (Fig. 1a). The core is 3 μm in diameter and the edge to edge separation between the holes is 12 μm. Thermal poling is carried out at 280°C for 45 sec. with 3.2 kV applied. To asses weather the technique is able to resolve the nonlinearity profile, we initially poled the fibre with the anodic electrode inserted in the hole further form the core. As the nonlinear profile is typically below the anodic surface, we expect in this way to avoid effects due to the presence of the core.

In second harmonic scanning optical microscopy a pump beam from a Nd-YAG laser, polarized in the same direction as the poling field, is focused by a microscope objective (NA=0.65) onto the end-face of the fibre and scanned across it [4]. First the reflected IR beam and consecutively the reflected SH beam are collected by the same objective and detected (Fig. 1b).

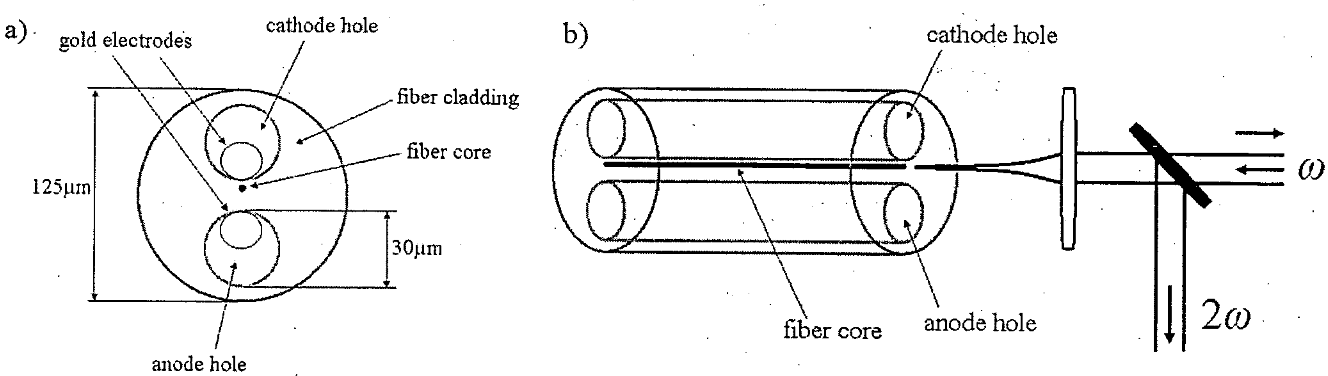

Fig. 1a) Cross-section of twin-hole fiber (not drawn to scale). Fig. 1b) Schematic of the fiber and geometry of SHG experiment.

The resolution of our set-up, which is given by the focused spot size, is estimated in ~1μm from the IR measurement (Fig. 2-squares). The reflected IR is zero when the beam is scanned across the holes. The left hand side corresponds to the anode. The SH profile (triangles) presents a small peak close to the anodic surface as expected but also a strong peak centered on the core. The latter is caused by SH generated in the body of the poled fibre and reflected at the fibre-air interface. As the reflection at the air-glass interface is 4% this effect is typically neglected, though in fibres and waveguides, because of modal-phase matching, the SH signal can grow significantly. To support this conclusion, the end of the fibre was covered by index matching gel. The large peak is greatly reduced (circles), whilst the small peak is completely unaffected, thus confirming that it is genuinely due to the induced nonlinearity. The nonlinearity profile can be obtained by subtraction. A similar method was used for a crystal of α-quartz of known nonlinearity (d_{11}=0.3pm/V) and used as a reference to determine the value of $\chi^{(2)}$ induced in the fibre (peak $\chi^{(2)}$ ~0.3 pm/V).

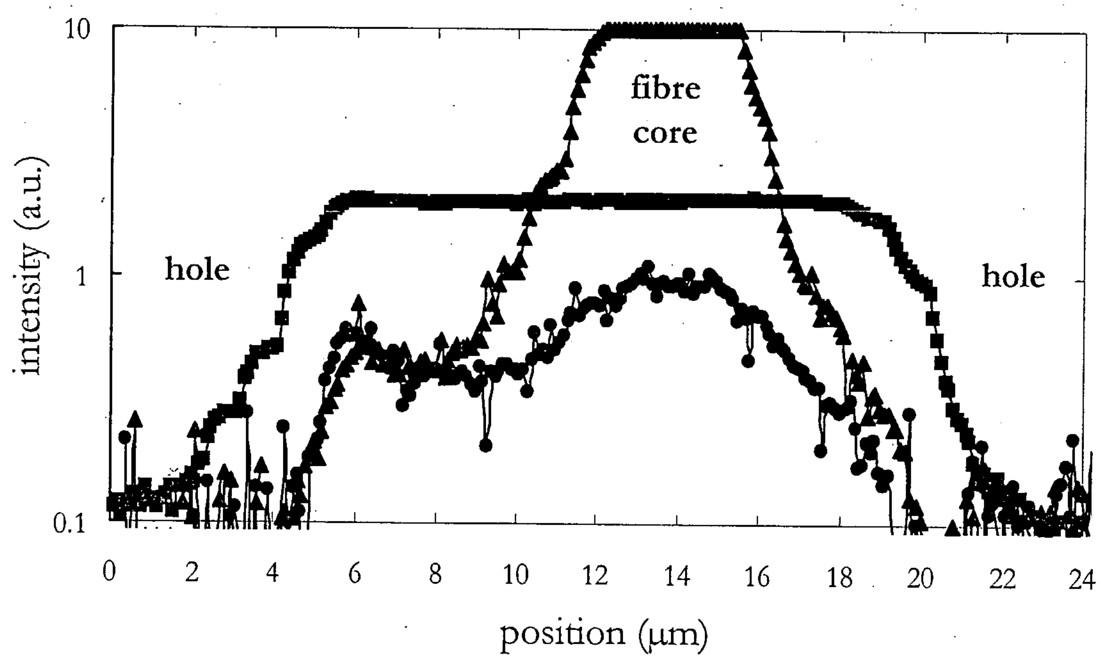

Fig. 2. IR reflected pump (squares) and SH intensity profile versus vertical translation in a twin-hole fiber poled at 280°C, 3.2 kV for 45 sec before (triangles) and after (circles) the index matching gel. SHG intensity profile changes with polarization.

In conclusion we measured the nonlinearity profile on the cross section of a thermally poled twin-hole fibre. Results showing optimization of the poling process, which are crucial to achieve efficient quasi-phase matching in fibre, will be presented.

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