Advances in single-mode poled fibres

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Abstract:

Integration of optical functions in fibre is a subject of constant investigation. If most of the basic functions like splitting, wavelength combining, filtering, amplification, dispersion management, etc, are already solved in fibres, others like isolation, pulse gating or frequency conversion are still subject of research. This is part of the current investigation performed in the frame of the EU project CHARMING (FP7-288786) and presented here.

Unlike ferroelectric crystals, silica glass does not intrinsically exhibit second-order nonlinearity $\chi^{(2)}$. However, it is possible to induce an effective $\chi^{(2)}$ in silica by poling [1-2], which consists in creating a quasi-permanent charge distribution by cooling the fibre under a strong electric field applied.

All-fibre pulse gating function at adjustable MHz repetition rate can be accomplished with electro-optical fibres. After electrostatic charging [3], it becomes possible to electrically modulate the phase of the optical wave travelling the fibre by applying a modulated high voltage on both sides of the fibre core. Then, a fibre interferometer like Sagnac configuration [4], permits to transform the phase to amplitude modulation. Making use of a longer electro-optical fibre decreases V_π but increases the propagation loss. Longer electrodes also mean longer rise time due to larger capacitance. Nonlinear coefficient $\chi^{(2)}$ up to 0.26 pm/V have already been demonstrated, leading to a pulse selector at up to 1 MHz (and can be lower on demand), with an extinction ratio as high as 30 dB and a modulation depth of 99.2%.

On the other hand, periodic erasure of the uniformly poled silica fibre allows phase-matched frequency doubling. In a periodically poled fibre, the parameters we can play with in order to get high conversion efficiency are: the length of the poled device; the nonlinearity induced by poling and the overlap of the fundamental and second harmonic (SH) fields related to the fibre design. For a first order quasi-phase matching (QPM) interaction, which proves to be the most efficient, the required period is the one that compensates for the wave-vector mismatch between fundamental and SH mode. In the literature, QPM between the interacting waves was primarily achieved by periodical UV erasure (λ = 244 nm) of the second order of nonlinearity in uniformly poled GeO2-doped fibres. To date, the benchmark result for frequency doubling in a periodically poled fibre is represented by the all-fibre SH generation [5]. Conversion efficiency of 15% was demonstrated at pump peak power of 207 W and at the wavelength of 1550 nm. Recently, in the nanosecond pulsed regime, we obtained up to 5.4% conversion efficiency with only 49 W peak power at 1040 nm fundamental wavelength, which is already an improvement of previous results.

Subsequently, further work has been done to improve the efficiency of poled fibre components [6, 7]: poling, UV erasure, microstructured fibre design (for instance to extend the spectral bandwidth acceptance and fields overlap), etc. in order to address different wavelengths in the visible for advanced microscopy applications [8].

References:

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