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Efficient frequency doubling of 1.5 µm femtosecond laser pulses in Quasi-Phase-Matched optical fibres

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Abstract

We report on the realisation of periodically thermally poled glass fibres for frequency doubling of ~1.5 µm. Using ~100 fs pulses, average second-harmonic powers of 1.05 mW at 768 nm were generated with a conversion efficiency ~1.2%.

Summary

Periodically poled glass fibres (PPGF) have recently been demonstrated to produce quasi-phase-matching for second-order nonlinear optical processes [1]. So far PPGF have been used to perform Quasi-Phase-Matched Second-Harmonic-Generation (QPM-SHG). However their potential applications are much wider, e.g. twin photons generation for quantum cryptography [2], routing in WDM networks [3]. Compared to nonlinear crystals, e.g. $LiNbO_3$, PPGF have several advantages, such as high optical damage threshold and low cost and, despite their lower nonlinearity (~1 pm/V), the lower dispersion allows longer interaction lengths for the same acceptance bandwidth, thus achieving comparable efficiencies. Besides, the Group Velocity Mismatch (GVM) between pulses at different frequencies, e.g. fundamental at 1.5 µm and SH at 0.775 µm, is ~10X smaller than in $LiNbO_3$, thus making PPGF very suitable for frequency conversion of short pulses [4]. Here we report on the fabrication of $\chi(2)$ gratings up to 7.5 cm long for QPM-SHG of ~1.5 µm and their use for ultrashort pulsed frequency conversion. It is shown that PPGF are very promising for QPM-SHG and parametric processes involving high-power sources, e.g. amplified Q-Switched and modelocked fibre lasers.

The fabrication technique used to produce the PPGF is the same as described in ref.[4]. The thermal poling is performed by applying ~5 kV at ~270°C in vacuum (P ~ 10^{-9} atm) on D-shape silica fibres with a GeO_2 doped core.

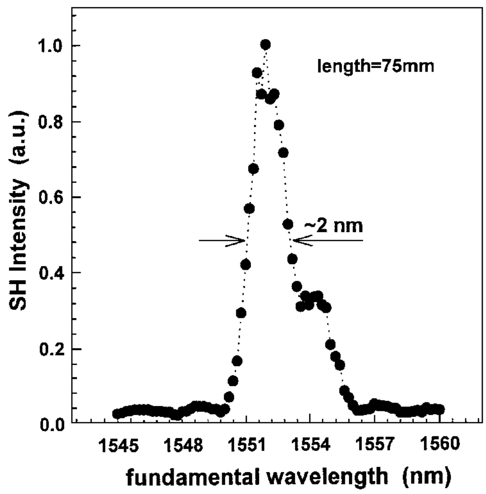

Fig 1. QPM curve (SH power as a function of the fundamental wavelength) for a $c^{(2)}$ grating 7.5 cm long with a period of 57.35 µm. The NA and the core radius of the fibre are 0.191 and 3.12 µm respectively. The bandwidth value ~ 2 nm is close to the theoretical value for a uniform grating with the same length.

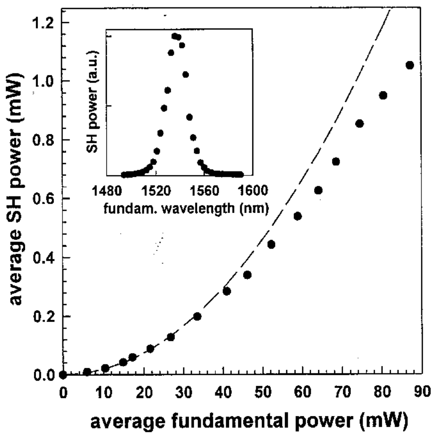

Fig 2. Average SH power as a function of average fundamental power for the QPM-SHG of 107 fs pulses at 1537 nm. The dashed curve represents the quadratic behaviour which fits the experimental points at fundamental powers below 30 mW. The inset is the QPM curve obtained with 107 fs pulses in the low power regime.

Fig.1 shows a typical QPM curve (SH power versus fundamental wavelength) for a 7.5 cm long grating, as obtained via cw SHG measurements. The ~2 nm bandwidth is in close agreement with the value for a transform-limited grating, indicating a good uniformity all over its length. For the QPM experiments involving 107 fs pulses from a synchronously pumped LiB_3O_5 optical parametric oscillator, we opted for shorter gratings in order to meet the limitations imposed by the GVM between the SH and the fundamental as well as by undesirable higher order detrimental effects, according to which the optimum length would be 1 cm. We obtained average SH powers up to ~1.05 mW with an average conversion efficiency ~1.2%. Fig.2 shows the SH power as a function of fundamental power at the QPM wavelength of 1537 nm, while the inset in the same figure shows the QPM curve obtained scanning the OPO wavelength. The bandwidth of this curve reflects the broadband spectrum of the 107 fs pulses which at this wavelength, is ~20 nm broad.

In conclusion we have reported, for the first time to our knowledge, efficient frequency doubling of telecom wavelengths around 1.5µm in a PPGF. These results indicate that by optimising the fabrication process (the effective nonlinearity is still 5-10 times lower than the optimum), it is possible to achieve output powers of tens of mW with conversion efficiencies of tens of %.

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