# Periodic UV erasure of the nonlinearity for quasi-phase-matching in optical fibres

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**Abstract:** A periodic second-order nonlinearity is obtained exposing uniformly poled samples to a periodic UV pattern. Second-harmonic conversion efficiencies around 6% were achieved for 29 mW of fundamental average power from a high power pulsed EDFA system.

**OCIS codes:** (160.4330) Nonlinear optical materials; (190.2620) Frequency conversion

Recently more than 20% efficient second-harmonic generation (SHG) [1] and parametric fluorescence [2] from periodically poled optical germanosilicate fibres were reported, opening new prospects for the realisation of second-order nonlinear optical processes in all-fibre devices. In both cases the fibre samples were thermally poled [3] subjected to a periodic electric field (*Periodic Thermal Poling*, PTP), generated by the anodic electrode which had been photolitographically defined on the flat side of a D-shape optical fibre [4]. The field periodicity induced a periodic second-order nonlinearity ($\chi^{(2)}$), necessary for quasi-phase-matching (QPM).

Although very promising, this process is inherently limited by the photolitography setup, permitting at most the definition of $\sim 1\ \mu$m features over $\sim 10$ cm long structures. In this paper we report on a new technique, *periodic UV erasure of second-order nonlinearity* (PUESN), which presents a few important advantages over PTP: device lengths of $\sim 1$ m or more can be obtained by scanning the UV beam through and amplitude mask over the uniformly poled fibre; much shorter periods can be achieved by using a phase mask to create UV interference fringes, thus making in principle possible more complicated and finer patterns for example for backward parametric interactions; also a fairly complex photolitography process can be skipped altogether. The possibility of fabricating much longer devices is of particular interest if we recall the figure of merit for waveguide parametric processes, proportional the device length squared: for example through a three-fold improvement in the current effective nonlinearity value and the realisation of a regular 1 m long nonlinear grating, a normalised SH conversion efficiency in continuous wave (CW) regime of $\sim 10\%/W$ would be obtained [1].

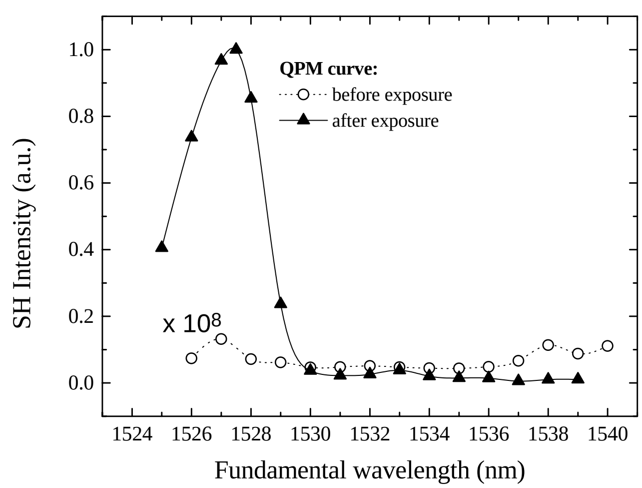


Fig. 1. QPM curves before and after exposure to UV light. The data collected before exposure are multiplied by $10^8$ in the graph.

The samples were fabricated starting from D-shape germanosilicate optical fibres (NA $\simeq 0.19$, core radius $\simeq 6\ \mu$m). After having been etched in order to reduce the core-flat side distance to $\sim 5\ \mu$m, the samples are thermally poled over a length of 6 cm, typically at 270 $^0$C with an applied voltage of 4 kV, and then cleaned

and cleaved. The fundamental source used in the SHG experiment is a diode seeded EDFA amplifier chain delivering 2 ns pulses at 4 kHz rep rate and is coupled into the samples through a microscope objective. The fibre is exposed through a periodic amplitude mask to deep UV radiation from a non-collimated mercury lamp, emitting mainly at 254 nm and 185 nm. The nonlinearity is erased in the regions exposed to UV, so that the periodicity of the amplitude mask is reproduced in the nonlinearity structure, allowing for quasi-phase-matching. The SH output is monitored in real time and the process parameters can thus be optimised. Before exposure the SH output is typically in the pW range and in a higher order mode ($LP_{11}$), due to modal-phase-matching (MPM) occurring in the fibre. After exposure the second-harmonic is generated in the fundamental mode ($LP_{01}$), because of the quasi-phase-matching provided by the induced periodic nonlinearity. Fig. 1 shows the corresponding QPM curve collected after exposure, exhibiting a bandwidth of $\sim 3$ nm, in close agreement with the transform-limited value for a 6 cm long grating and a peak at 1527 nm. For comparison the tuning curve collected before exposure, exhibiting the features of MPM, is shown too (with peak conversion efficiencies 9 order of magnitude smaller).
When pumping at 1527 nm, corresponding to the expected peak wavelength given the period of the amplitude mask of 56.45 $\mu$m, we obtained 1.8 mW of average second-harmonic power for a coupled fundamental average power of 29 mW (peak power $\sim 4$ kW), giving thus an average conversion efficiency $\sim 6$ %.

In conclusion we have reported on a new technique, *periodic UV erasure of second-order nonlinearity*, which although showing at present a smaller efficiencies ($\sim 6\%$) than periodic thermal poling, possesses key advantages over the latter. A large room for optimisation and improvement is still left, in particular with respect to the fabrication of long all-fibre frequency conversion devices with larger nonlinearity, allowing the achievement of normalised CW SH conversion efficiencies of the order of 10%/W, a significant value considering the power levels available from current fibre lasers/amplifiers systems.

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