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BLUE LIGHT GENERATION BY QUASI-PHASE-MATCHED FREQUENCY DOUBLING IN THERMALLY POLED OPTICAL FIBRES

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Abstract

A periodically modulated second-order nonlinearity is created in optical fibre using thermal poling *in vacuo*. CW quasi-phase-matched frequency conversion to the blue is demonstrated.

Summary

Following the initial report by Myers et al of second-order nonlinearities of order 1 pm/V in thermally poled silica [1], there has been considerable interest in the possibility of efficient second harmonic conversion in glass waveguides and fibres [2,3]. A problem encountered in thermal poling is the spreading out that occurs when one attempts to create high resolution $\chi^{(2)}$ structures using a patterned electrode [4]. Although we have indicated that this problem can be side-stepped by selective *erasure* of a uniformly poled sample (using a focused electron beam or excimer laser beam at 248 nm), we recently discovered that the spreading is caused by electrical breakdown in the air. This means that it can easily be eliminated by poling in vacuum [5].

Poling in a vacuum evaporator using one periodic and one uniform electrode, we have been able to create a periodic $\chi^{(2)}$ (of pitch 20 μm) in thermally poled samples of silica glass and optical fibre. The on/off ratio is excellent, as can be seen from the photograph in Figure 1, where a bulk periodically poled sample of flame-fused silica glass (Herasil 1). In order to achieve QPM at 830 nm in the optical fibre with this mask, it was necessary to tilt it through 45°. This resulted in a much lower effective spatial modulation depth of the $\chi^{(2)}$.

The initial fibre used was dual-moded at 1.5 μm, so it supported many modes at 830 nm, which is the wavelength where phase-matching between fundamental modes at the pump and second harmonic frequencies was expected. The fibre was side-polished and poled (*in vacuo*) using the technique already reported [6]. The value of $\chi^{(2)}$ (estimated using a Nd:YAG laser in a uniformly poled sample) was 0.2 pm/V. We then measured the frequency-doubling characteristics of a periodically poled fibre using a CW Ti:sapphire laser. The resulting power versus wavelength behaviour is given in Figure 2. Several phase-matching peaks are apparent. Note that the experimental figure-of-merit, Q_{exp}, in units of %/Wcm^2, is plotted. Keeping the wavelength constant on one of the peaks, and varying the power, the quadratic relationship expected of true frequency doubling was obtained.

In an optimised fibre, in which the $\chi^{(2)}$ modal overlap has been improved and the fibre is single-mode at the pump wavelength, an effective $\chi^{(2)}$ of 1 pm/V is expected. For a mode area of 12 μm^2, the expected figure of merit would then be ~3 %/Wcm^2. For 10 cm of periodically poled fibre (something which should be technically feasible given that the QPM period is ~30 μm), a SH conversion efficiency approaching 100% should be feasible. It is worth also noting that the bandwidth of phase-matched SH conversion in poled fibre is an order of magnitude larger than in an equal length of periodically poled lithium niobate, owing to the lower group velocity mismatch.This may be of importance in short pulse work, where large acceptance bandwidths are required.

References

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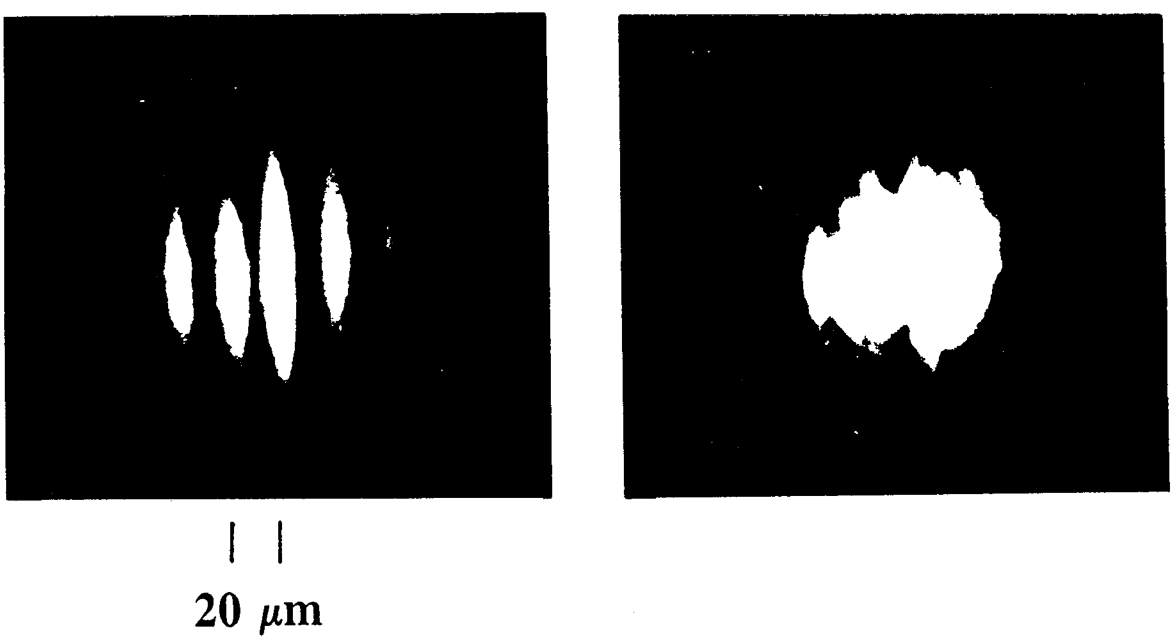

Figure 1. Near-field second pattern in thermally poled fused silica using a periodic anode and a planar cathode in vacuum (left hand side) and air (right hand side). Note the greatly improved contrast for poling in vacuum.

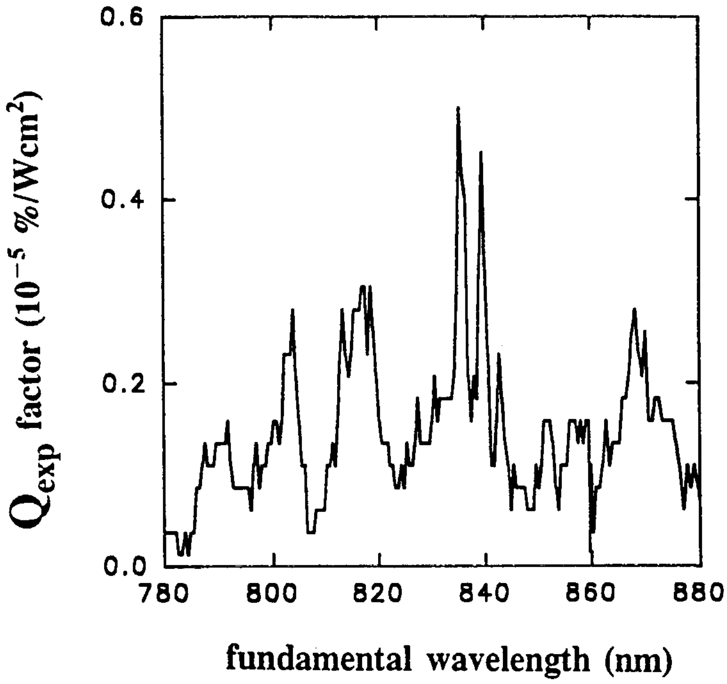

Figure 2. Wavelength dependence of the figure of merit for second harmonic generation in the periodically poled fibre. Note the multiple peaks caused by modal QPM.

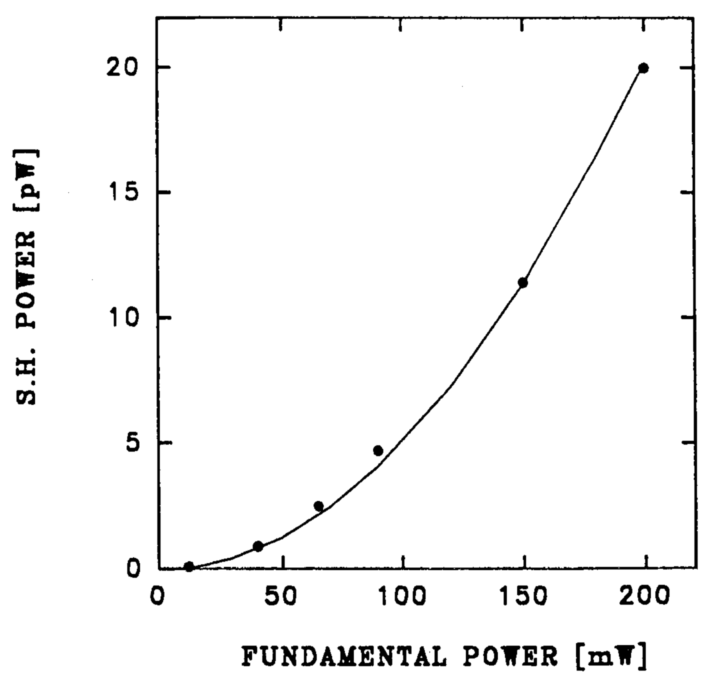

Figure 3. Dependence of second harmonic power on pump power - quadratic as expected of second harmonic generation.