1.047 μm synchronously-pumped optical parametric oscillator in bulk periodically poled $LiNbO_3$

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Abstract

Picosecond pulses have been efficiently generated over the tuning range 1.674-2.795 μm via 1.047 μm synchronously pumped optical parametric oscillation in periodically poled $LiNbO_3$.

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Over the last few years progress in the area of optical parametric oscillators (OPOs) has shown them to be attractive sources of coherent light with the capability of being tunable over a wider wavelength range than conventional lasers. OPOs, which produce picosecond pulses, have great potential for example in time and frequency resolved spectroscopy. Among the optical nonlinear materials for OPOs, periodically poled lithium niobate (PPLN) has attracted much interest over the last year. Its high effective nonlinear coefficient (d_{eff}) >15 pm/V can be exploited over the entire transparency range of the material (0.4-4.8 μm). In particular singly resonant OPOs, quasi-cw and Q-switched pumped at 1.064 μm [1] and Q-switched pumped at 0.532 μm [2], have been demonstrated. Recently we have also reported a picosecond OPO based on PPLN, synchronously pumped at 523.5 nm by the second harmonic (SH) of an amplified 10 μs pulse train from an additive pulse mode-locked (APM) Nd:YLF laser [3]. Pulses of ~2 ps duration were produced over the tuning range 883-1285 nm. The effective interaction length (l_{eff}), due to group velocity mismatch (GVM), was limited to ~2 mm for 2.3 ps pump pulses at 523.5 nm. Despite this, the results indicated that PPLN should be considered as a competitor to $KTiOPO_4$ (KTP) and LiB_3O_5 (LBO) for picosecond OPOs tunable at around 1 μm.

In the case of pumping at 1 μm the constraint on l_{eff} due to GVM is less significant and samples as long as ~15 mm can be used for interactions involving 2 ps pulses, making PPLN very promising for efficient picosecond OPOs oscillating at around 2 μm. Here we report a singly resonant OPO based on PPLN which generates picosecond pulses over the wavelength range 1.73-2.65 μm. This OPO is synchronously pumped at 1.047 μm by an amplified cw APM Nd:YLF laser.

The sample of PPLN, 0.5 mm thick, used in the experiment was fabricated by applying electric field pulses as previously described [2,3]. The final grating, of pitch 30.5 μm, was 6 mm long. The grating was initially examined by etching the z+ and z- faces of the sample (before end-polishing). The periodic inversion was regular over the whole 6 mm length with an estimated mark/space ratio between 40/60 and 45/55 which should provide a d_{eff} in 1st order quasi-phase-matching (QPM) greater than 95% of the theoretical value. This was confirmed by carrying out SH measurements using a Ti:Sapphire laser where the ratio of the measured d_{eff} in 5th and 6th order QPM indicated an average mark/space ratio of 42/58. Fig.1 shows the QPM curve (SH power vs. fundamental wavelength) for the 5th order interaction. Both faces of the PPLN sample were anti-reflection coated (AR) with a single layer of MgF_2 for 1.9 μm. This coating should provide a surface reflectivity <2% in the range 1.6-2.4 μm.

The scheme for the OPO is shown in fig.2. The curved mirrors were HR @1.65-2.1 μm while the transmittivity of the plane output coupler (o/c) varied over this range. All the mirrors had reflectivity <30% @2.2-2.65 μm (round trip idler feedback <0.8%). The pump source (APM Nd:YLF laser with amplifier) delivered 2.6 ps pulses at 105 MHz with average powers up to 700 mW, corresponding to ~500 mW in the PPLN sample. The pump and the signal spot sizes in the PPLN sample were 33 and 39 μm respectively.

The OPO was tuned from 1.674 to 2.094 μm for the signal branch and corresponding from 2.795 to 2.094 μm for the idler branch by changing the crystal temperature from 60 °C to ~190 °C. Fig.3 shows the typical output and corresponding pump depletion at a crystal temperature of 170 °C. The o/c transmittivity for the signal wavelength of 1920 nm is ~8%. From these curves it is possible to estimate slope efficiencies of ~33% and 25% for signal and idler respectively. From a further measurement of the threshold of ~54 mW with all HR mirrors we estimated an excess round trip loss (i.e. other than o/c transmission) of ~5%. This value agrees well with the estimate of signal/idler output powers from the corresponding pump depletion (fig.3).

In conclusion we report a highly efficient picosecond OPO based on PPLN, synchronously pumped at 1.047 μm. 123 mW signal and 92 mW idler average powers have been generated with efficiencies of ~25% and 18% respectively. We plan to scale output powers and increase tuning range by using different mirror sets and PPLN samples with different periods of domain reversal.

References

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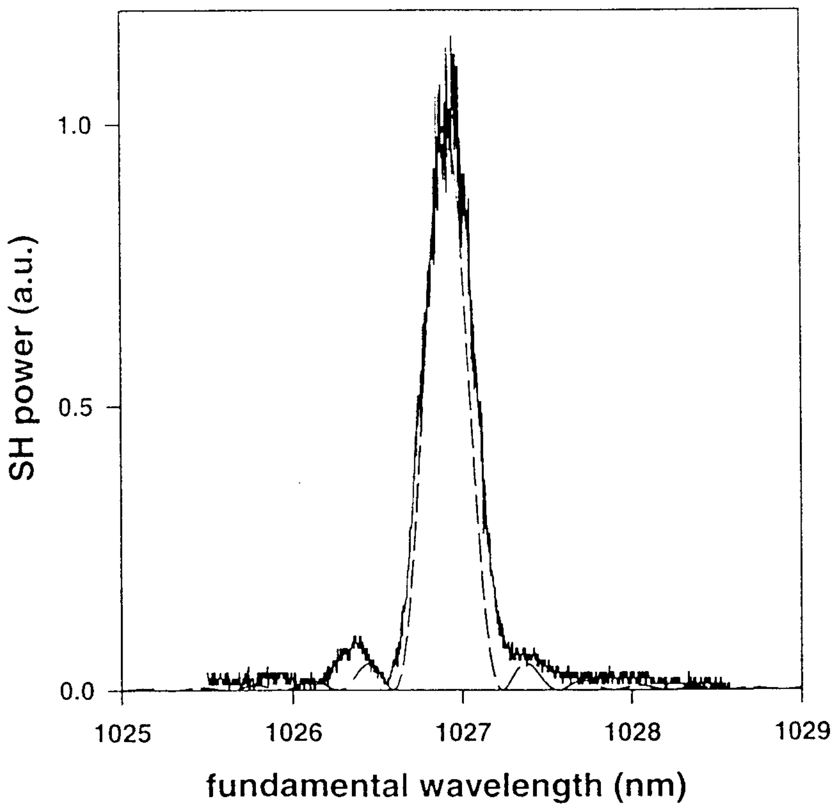

Fig.1 SH power vs. crystal temperature for 5th order QPM. The dashed line is a theoretical curve.

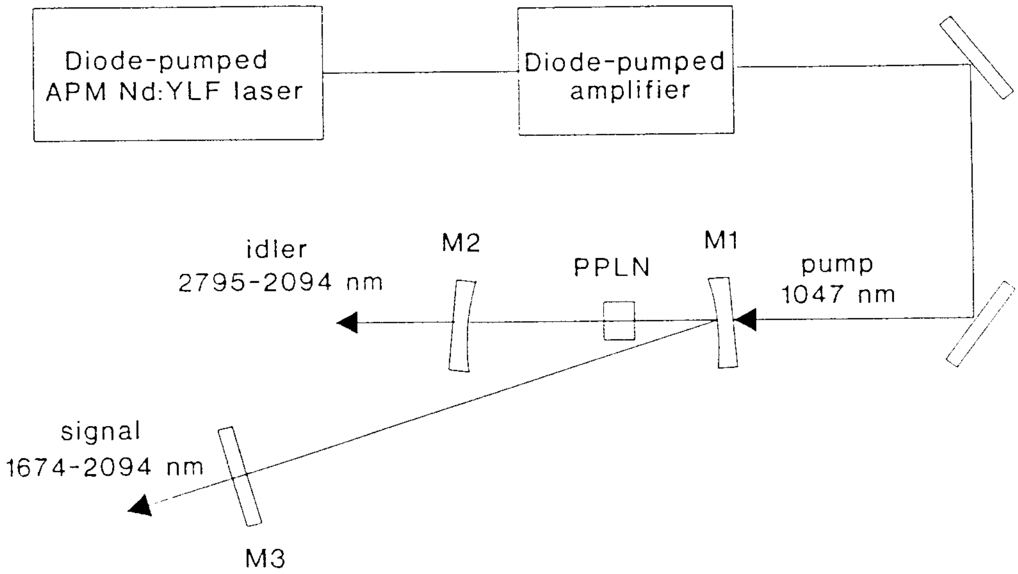

Fig.2 Layout of the OPO and of the pump source. M1:ROC=100mm & HR; M2:ROC=150mm & HR; M3:plane o/c or HR.

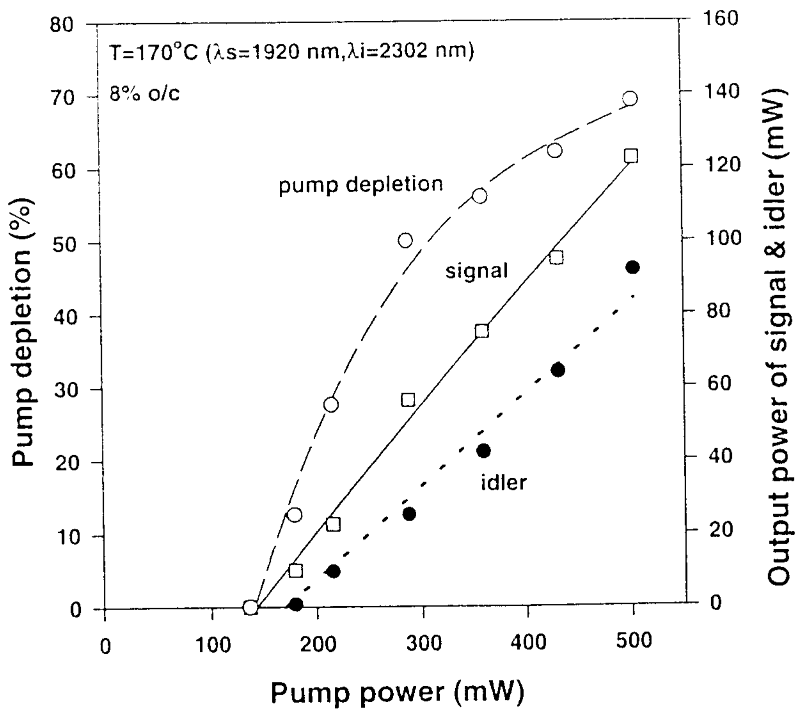

Fig.3 Dependence of the average output signal and idler powers and of the pump depletion on pump power for the crystal at 170 °C (λ_s=1920 nm and λ_i=2302 nm).