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Optical parametric oscillator synchronously pumped by a tunable Yb^{3+} fibre laser

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Abstract

Operation of a synchronously pumped optical parametric oscillator driven by a modelocked fibre laser is reported. The broad tunability of the pump laser allows continuous tuning of the oscillator without varying the crystal temperature.

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Periodically poled lithium niobate (PPLN) has emerged as an extremely useful nonlinear optical material, offering a large nonlinear coefficient and non-critical phase-matching across its extensive transmission range. The suitability of PPLN as a basis for harmonic frequency generators and optical parametric oscillators (OPOs) has been widely demonstrated. For OPOs, tunability of the pump[1] can be a major convenience since it removes the need for temperature tuning. The need then is for a compact, reliable and tunable pump source. Fibre lasers, with their broad tunability and high gain are obvious candidates, and in this paper we report what is, to our knowledge, the first operation of a PPLN based synchronously pumped OPO driven by a modelocked fibre laser. We demonstrate continuous tuning of the output by varying the pump wavelength.

Our laser was a Yb^{3+} frequency-shifted-feedback fibre laser[2] pumped at 980 nm producing 20 ps pulses tunable from 1020 nm to 1060 nm (figure 1). Frequency-shifted-feedback and spectral filtering were achieved by a double pass through a 110 MHz acousto-optic modulator (AOM) via a 1200 lines/mm diffraction grating; the interplay between frequency shifting, filtering, and self phase modulation in this laser produces a strong nonlinear mechanism

resulting in very stable operation in the modelocked regime which is self starting and shows excellent environmental stability. The laser operated with an average output power of 80 mW and a repetition rate of 85 MHz (peak pulse powers ~ 40W). These pulses were then passed through an optical isolator and relaunched into a Yb^{3+} fibre amplifier where the average power was increased to 240 mW.

Two PPLN samples (from Crystal Technology) were used, containing domain inverted gratings with periods from 26 μm to 30.2 μm, with overall sample lengths of 20 mm. The spot sizes in the crystal for the pump and signal waves were 22 and 27 μm respectively. Operation of the parametric oscillator was achieved with an estimated threshold of 100W peak pulse power. In order to operate the OPO well above threshold an AOM was placed between the fibre laser and amplifier which was gated on and off at a frequency of 60 kHz with a duty cycle of 20%, thus increasing the peak power of the pulses to around 600 W. In this regime with an output coupler of T = 15% we observed depletion of the pump beam of approximately 70% (see figure 2), with an average output power of 38 mW for the signal wave and 13 mW for the idler. By tuning the wavelength of the fibre laser and translating the PPLN crystal between gratings we were able to continuously tune the signal (idler) from 1.6 (3.14) μm to 1.78 (2.5) μm (figure 3). Note that the limitations on the tuning range of the pump laser are imposed by the transmission characteristics of the wavelength division multiplexer (WDM) used in the fibre amplifier - utilising the full tuning range of the pump will enable continuous tuning from 1.4 to 4.8 μm.

Planned future developments are aimed at further simplification of the fibre laser, extension of the tuning range and operation of the OPO in the CW modelocked regime without the need for a fibre amplifier.

References

1. S.D Butterworth, P.G.R Smith and D.C Hanna, Optics Letters **22**, 618 (1997)

2. N.J Traynor, Z.J Chen, J. Porta, J.D Minelly and A.B Grudinin, The 1997 Pacific Rim Conference on Lasers and Electro-Optics, postdeadline paper No. PD1.2.

Figure captions

Figure 1 - Tuning range of the Yb^{3+} fibre laser with (inset) typical spectrum

Figure 2 - Build up dynamics of parametric oscillation. The solid line denotes the intensity of pump radiation during the on time of the AOM gate, with the dashed line showing depletion of the pump as parametric oscillation builds up (the rapid oscillations reflect the pulsed nature of the pump). It can be seen that depletion reaches around 70% towards the end of the pulse train.

Figure 3 - Tuning characteristics of the parametric oscillator for several grating periods at a crystal temperature of 160 °C.

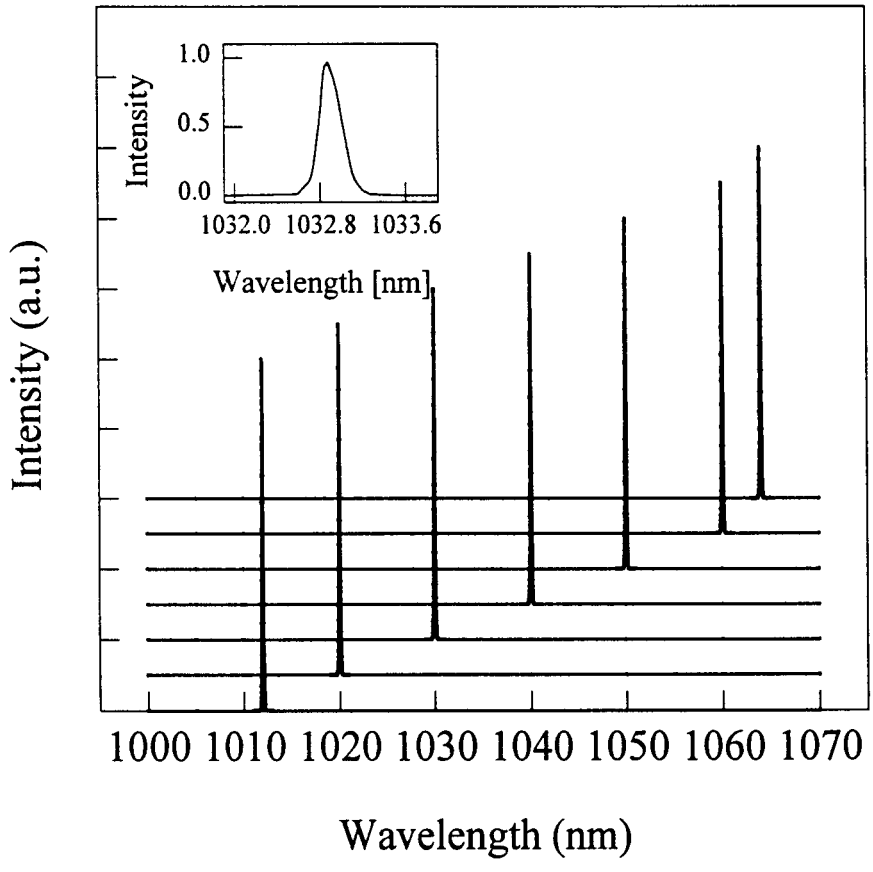
Intensity
1.0
0.5
0.0
1032.0 1032.8 1033.6
Wavelength [nm]
Intensity (a.u.)
1000 1010 1020 1030 1040 1050 1060 1070
Wavelength (nm)

Figure 1

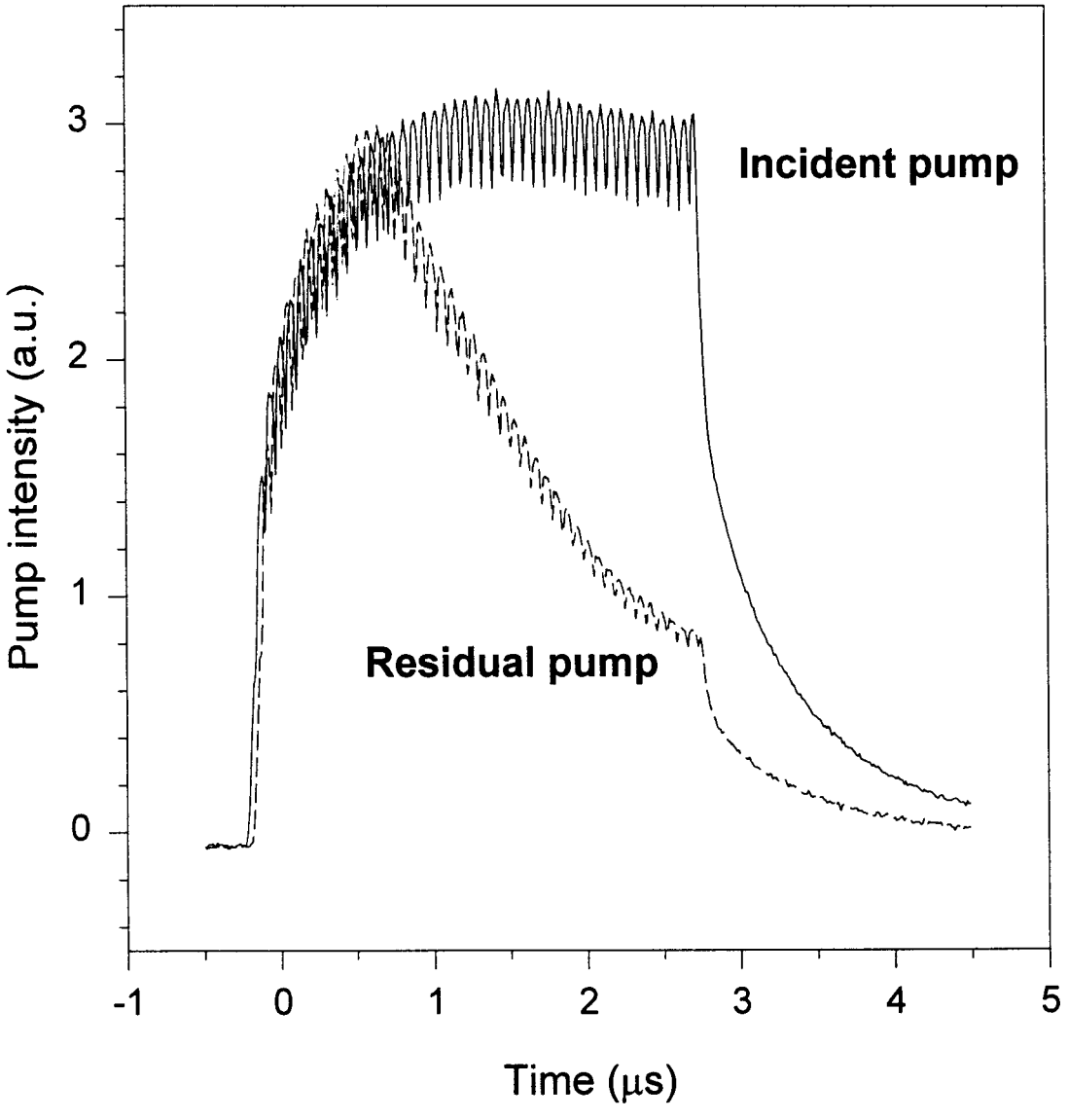
Incident pump
Residual pump
Pump intensity (a.u.)
Time (μs)
0
1
2
3
-1
0
1
2
3
4
5

Figure 2

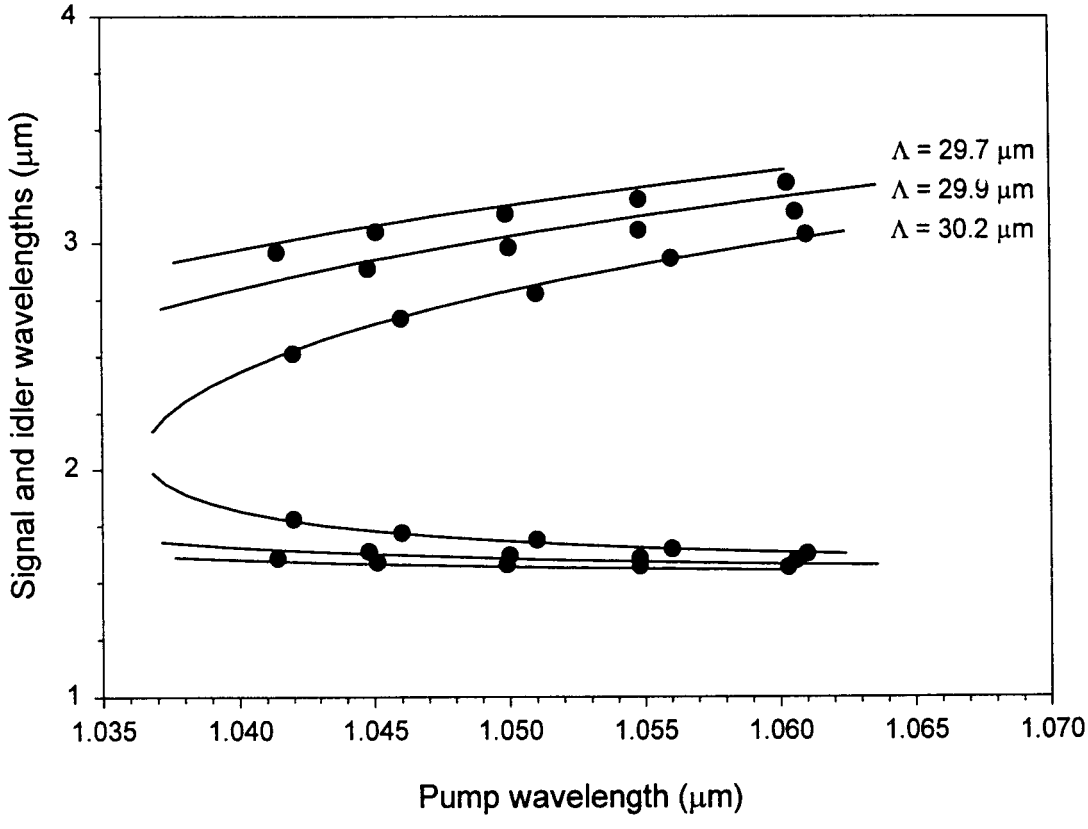
Signal and idler wavelengths (μm)
Pump wavelength (μm)
Λ = 29.7 μm
Λ = 29.9 μm
Λ = 30.2 μm
4
3
2
1
1.035
1.040
1.045
1.050
1.055
1.060
1.065
1.070

Figure 3