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1557

Generation of fs pulses from order of magnitude pulse compression in a cw synchronously pumped optical parametric oscillator

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Abstract

We demonstrate the generation of 200 fs transform limited pulses tunable from near to mid -IR using a 4 ps Nd:YLF synchronously pumped optical parametric oscillator based on periodically poled lithium niobate. The twenty fold compression of the pulses results in signal peak powers exceeding those of the pump.

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Efficient sources of tunable coherent radiation in the near and mid-IR, in the fs time domain, are necessary for many applications including spectroscopy, communications etc. In this contribution we report on the generation of tunable 200 fs pulses obtained from an optical parametric oscillator (OPO) synchronously pumped by a 4 ps cw modelocked Nd:YLF source (λ = 1.047μm). Pulse compression in synchronously pumped OPO's has been previously demonstrated at high powers, eg. using a BBO OPO pumped with intense Q-switched modelocked pulses [1]. We present, what we believe to be, the first demonstration of the extension of this technique to low power cw modelocked devices pumped by diode lasers. This is made possible by the use of periodically poled lithium niobate (PPLN) which provides the required gain for much lower pump powers. The compressed pulses show excellent stability, high conversion efficiency and peak powers exceeding that of the pump.

Pulse compression can be understood as follows: if the OPO cavity is longer than that of the pump laser, the signal pulse arrives at the nonlinear crystal delayed with respect to the pump pulse. As the two pulses propagate through the crystal, the signal pulse will advance on the pump pulse and provided that there is sufficient gain, the leading edge of the signal will deplete the entire pump resulting in the observed compression.

Numerical simulations show excellent agreement between the observed compression and that predicted by theory. According to our calculations, compression is possible only when both the first and second time derivatives of the transient gain are positive. In experimental terms this implies that: i) the OPO cavity length must be *longer* than that of the pump laser and ii) the parametric gain per round trip must exceed a specific value which we call the pulse compression threshold. The range of cavity detuning where compression is observed is determined by two competing processes, namely the reduction of the output energy, w, behaving as $w \propto \exp\left(\frac{-\Delta L}{u \times \tau_p}\right)^2$, and the reduction in the compression threshold, $P_{thresh} \propto \left(\frac{\Delta L}{u \times \tau_p}\right)^2$, where ΔL is the length detuning from synchronism, and τ_p and u are the pump pulse width and group velocity respectively.

A 19mm PPLN crystal was chosen to provide difference of group delay between signal and pump comparable to the pump pulse duration for signal wavelengths in the range 1.7-1.9μm. An output coupler of 85% reflectivity enforced high gain operating conditions. With the OPO resonator exactly synchronous with the 120 MHz pump pulse train, average signal power was maximum, ~300mw, at 1.8μm for ~1W of incident pump. Increasing the resonator length by ~50μm gave compressed pulses of 200-250 fs, with slightly reduced average power of ~220mw. This corresponds to a peak power of ~7KW, exceeding the 2KW peak power of the pump. Figure 1 displays the result of an interferometric autocorrelation of the signal pulse, at the peak of the compression, from which we deduce a width of 250 fs. The time bandwidth product is ~0.33 indicating almost chirp free transform limited pulses. Figure 2 shows the observed variation in second harmonic (SH) intensity, of the signal, generated extra-cavity, with change in cavity length. The SH intensity peaks very strongly when the cavity length exceeds, slightly, its synchronous value, exactly as predicted in our simulation (see inset of figure 2).

These results demonstrate the capability of generating broadly tunable fs pulses via OPO's based on PPLN using a simple compact, ps pump source.

References

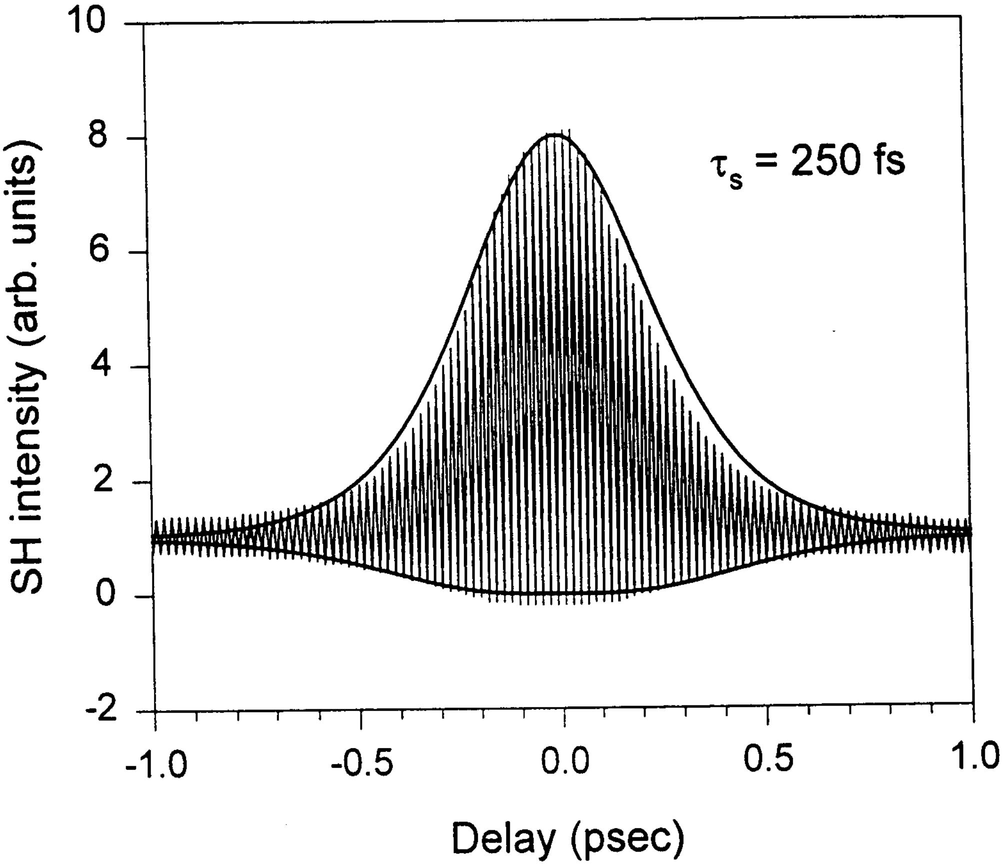
[1]. J. D. V. Khaydarov, J. H. Andrews, K. D. Singer, JOSA B **12**, 2199, 1995; J. D. V. Khaydarov, J. H. Andrews, K. D. Singer, Optics Lett. **19**, 831, 1994; J. D. V. Khaydarov, J. H. Andrews, K. D. Singer, Appl. Phys. Lett. **65**, 1614, 1994.

Generation of fs pulses...., L. Lefort *et al*

Figure captions

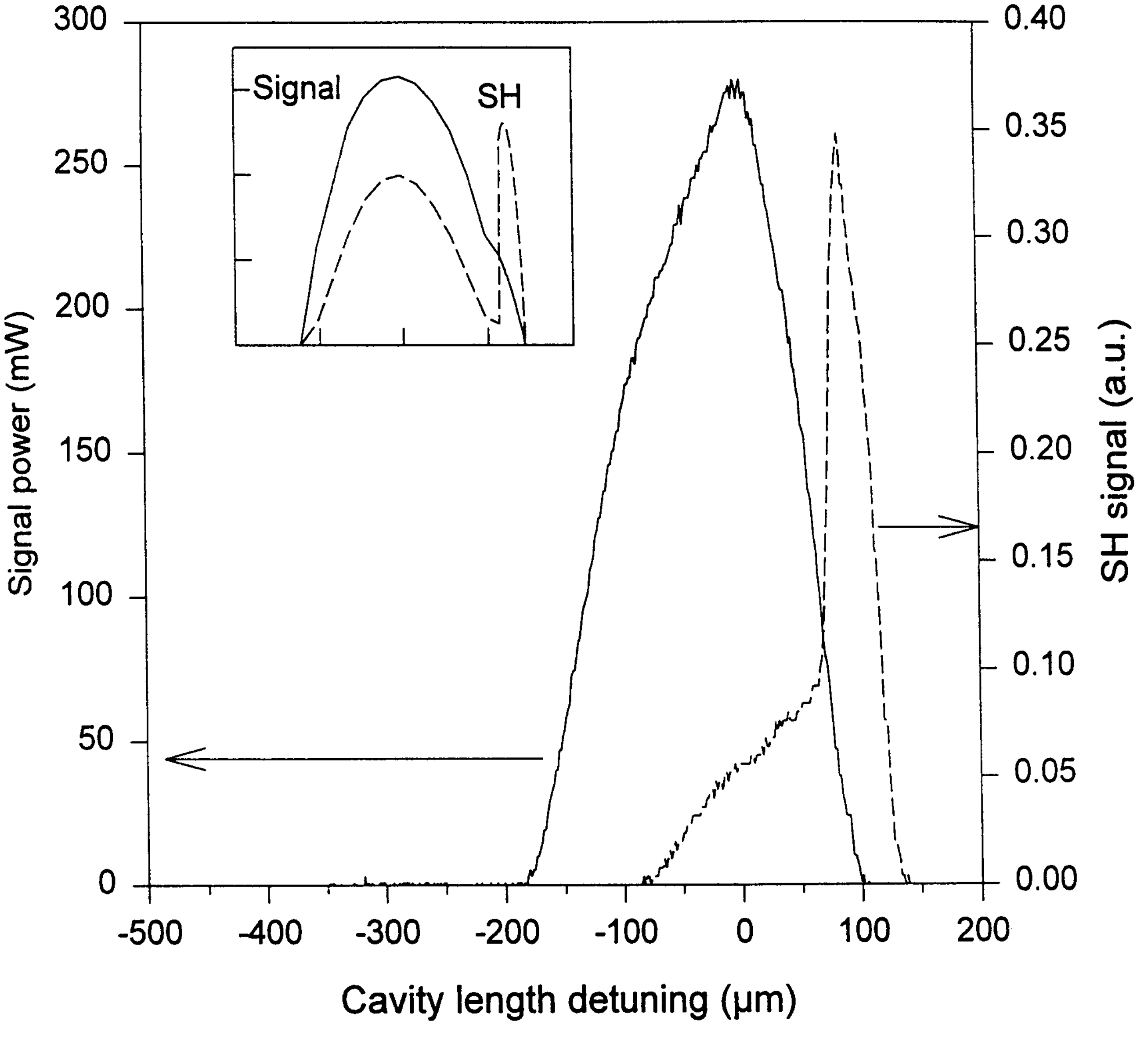
Fig. 1. Interferometric SHG autocorrelation of 250 fs signal pulses at 1.8μm

Fig. 2. Fundamental and SH power as a function of cavity length detuning. Inset: Numerical simulation.



10
8
6
4
2
0
-2
SH intensity (arb. units)
τ_s = 250 fs
-1.0
-0.5
0.0
0.5
1.0
Delay (psec)

Figure 1



Signal
SH
300
250
200
150
100
50
0
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Signal power (mW)
SH signal (a.u.)
-500
-400
-300
-200
-100
0
100
200
Cavity length detuning (µm)

Figure 2