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Multiline Optical Parametric Oscillators Based On Periodically-Poled Lithium Niobate

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Abstract: Simultaneous multiple wavelength operation of optical parametric oscillators based on periodically-poled lithium niobate with different period gratings arranged in series or parallel is reported. The relative merits of these different OPO designs are discussed.

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Summary

Coherent sources emitting in the mid-infrared (3-5 μm) spectral region have received growing interest over the last few year owing to their numerous applications. Optical parametric oscillators, pumped by reliable diode-pumped solid-state lasers offer an attractive route to this wavelength region providing flexibility in operating wavelength and, via the use of periodically-poled nonlinear crystals, very high efficiency [1,2]. For many applications the requirement for a particular operating wavelength is satisfied by the appropriate choice of grating period. In such situations the emission linewidth is typically rather narrow with its upper limit determined by the phase-matching bandwidth (≈few nm). For some remote sensing applications, multiple wavelength emission spanning a much wider spectral region (>100nm) is desirable. In here we report two approaches for producing multiple signal and idler wavelengths in an OPO based periodically-poled lithium niobate with multiple grating periods.

The two approaches differ in the geometrical arrangement of the grating periods, one having a series arrangement and the other a parallel arrangement, but in both cases sharing common cavity mirrors. For this study the number of grating periods was limited to three with the aim of generating three different signal/idler wavelength pairs. In both cases the periods, were selected so that the idler wavelengths (3.523μm,3.660μm and 3.758μm) coincide with regions of high atmospheric transmission. The pump laser was a diode-pumped, Q-switched, single-frequency Nd:YLF laser at 1.053 μm [3], producing pulse energies up to 1.5mJ in 150ns (FWHM) at a repetition frequency of 250Hz.

The series grating OPO (shown in fig.1(a)) was configured so that the first and second gratings had a length of 10mm, and longer the third grating had a length of 30mm, with the aim of equalising pump depletion in the different gratings. The cavity mirrors were selected to resonate only the signal wavelengths.

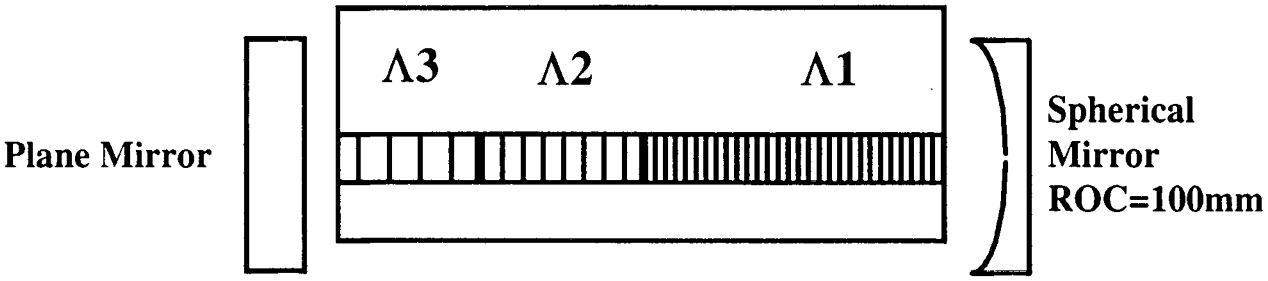

Fig 1(a) Diagram showing the series grating PPLN sample

We obtained a maximum combined idler pulse energy of 0.19mJ for 1.2mJ of pump energy(Fig.1(b)). The distribution of energy between the idler wavelengths was in the ratio 4:2:1, indicating that the operating lengths were not optimised for equal energy distribution.

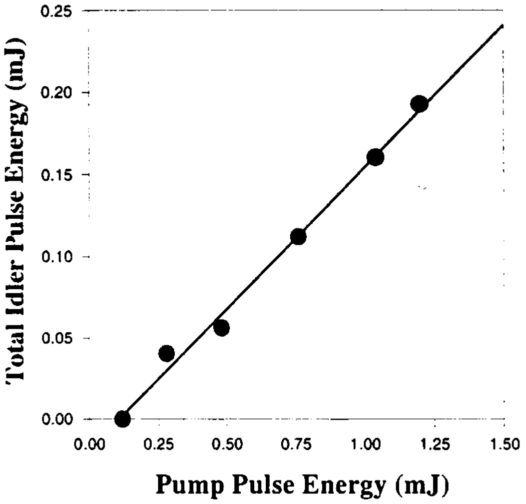

Fig.1(b) Graph to show the total idler pulse energy as a function of input pump pulse energy for the series PPLN sample.

The series grating OPO has the attraction of a relatively low threshold, but is difficult to scale to a more operating wavelengths, since more grating periods would require a greater pump intensity, eventually leading to damage.

In the parallel grating OPO (Fig. 2(a)), the gratings all had equal lengths of 19mm, with the outer gratings having a width of 1mm and the inner grating a width of 0.5mm.

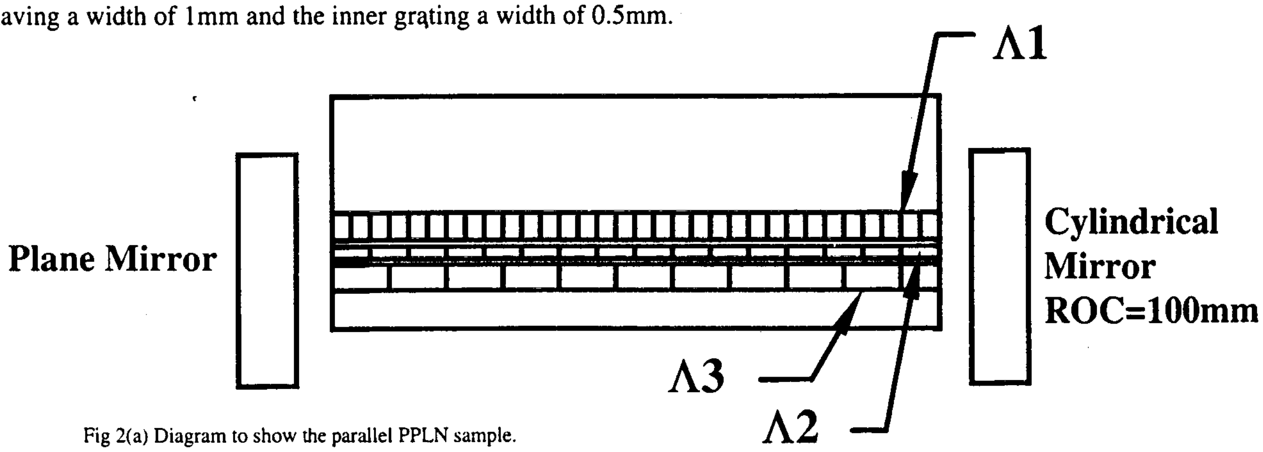

Fig 2(a) Diagram to show the parallel PPLN sample.

The gratings were transversely displaced from each other by a small distance, 20 µm, to prevent over-poling at the interface between the gratings. The output mirror was cylindrical to give a stable mode in the plane perpendicular to the lithium niobate wafer. The pump beam was focused to a beam size of 90 µm x 1200 µm to illuminate all of the gratings. We obtained a maximum combined idler energy of 0.11mJ for a pump pulse energy of 1.35mJ(Fig. 2(b)).

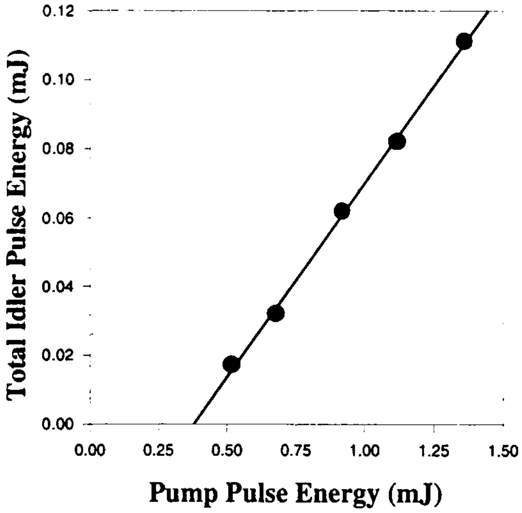

Fig 2(b) Graph to show the total idler pulse energy as a function input pump pulse energy in the parallel PPLN sample.

In this case the threshold energy was higher (0.3mJ) due to the larger mode size. The distribution of idler energies was 6:7:5 indicatinga much more even distribution of energy than for the series grating OPO. The parallel grating geometry offers the attraction that extending operation to a greater number of wavelengths should be possible by simply adding more grating periods and increasing the pump energy and beam size, thereby avoiding damage.

In conclusion, we have demonstrated multiple line OPOs based on periodically-poled lithium niobate with series and parallel grating geometries. These devices offer a compact and efficient means generating multiple wavelengths and should find applications in a number of areas.

References

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