Tuning of a synchronously pumped optical parametric oscillator via a four-plate birefringent filter

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In many optical parametric oscillator (OPO) systems it has been common practice to rely solely on tuning of the peak of the parametric gain profile (e.g. by temperature tuning) to provide frequency selection of the oscillating waves. However, there are often situations where additional frequency control (e.g. using etalons or gratings) can be beneficial. In Ref. [1] the use of a diffraction grating as a frequency selective feedback ‘mirror’ in a synchronously pumped OPO was reported. It was shown that, besides the obvious benefits of agile tuning and spectral narrowing, the filter-action of the grating was helpful in: (1) reducing sensitivity to frequency-pulling effects caused by cavity length detuning/ asynchronism, (2) achieving singly-resonant operation very close to degeneracy, (3) tuning through atmospheric absorption arising within the air path in the OPO resonator, and (4) the suppression of unwanted oscillation frequencies, which can be generated in addition to the signal in high-gain SPOPOs based on quasi-phase-matched materials such as periodically poled lithium niobate (PPLN). It should be noted that the latter effect can also be very effectively eliminated by intracavity spatial filtering. Thus, quite apart from the tuning capability, there are compelling reasons for using an intracavity-tuning element, in terms of the spectrally cleaner and more stable performance of the SPOPO.

The use of a three-plate birefringent filter (BF) in a SPOPO has been reported previously for a low-gain device operating with rather long pulses (20-30ps) [2], although this publication did not provide any details of the filter design and characteristics. Here, we will present a detailed discussion of the BF design strategy and the experimental performance characteristics obtained for a PPLN SPOPO operating with BF tuning in the 1.3 – 1.9μm region, with pulse duration of ~4ps. We have adopted a four-plate BF design in order to strongly suppress the subsidiary maxima, with plate thicknesses of 1.5mm, 3mm, 6mm, and 12mm. The transmission characteristics of this four-plate BF design were calculated to model the height of the subsidiary maxima and their dependence on the BF rotation angle φ. Our analysis has also been extended to include the fact that light of s polarization leaving the BF can, in general, return to the BF after passing through the nonlinear crystal without gain whilst the p polarization receives the usual parametric gain. Figure 1a-c (solid line) shows the calculated round-trip power transmission spectrum of the OPO resonator (including the parametric gain, which is shown separately as a dashed line) and its tuning behaviour with progressive rotation of the BF. Figure 1c shows that a frequency jump to a subsidiary maximum does not occur until the signal wave has tuned to 1.828μm (from the peak gain at 1.8μm). Thus, although frequency hopping to subsidiary maxima does indeed limit the tuning, the total tuning range of ~56nm (for these particular conditions) represents a significant fraction of the parametric gain bandwidth (~45nm, FWHM).

Experimental results will compare the performance obtained from a commercial three-plate BF (plate thickness ratio 1:2:15) with that of a new custom-designed, four-plate BF (1:2:4:8), for which a doubling of tuning range is predicted.

The performance of a synchronously pumped optical parametric oscillator based on periodically poled lithium niobate with an appropriately designed birefringent filter is described. Design considerations for the suppression of subsidiary transmission maxima to maximize tuning in these high-gain devices are presented.