

The presence of the dips surrounding the length resonances in a SRO might be an additional indication that the SRO resonances are in fact the result of time-periodic coherent addition to the signal field for consecutive passes in the SRO cavity. Considering that the pump and the SRO signal mode spectra are fixed by the respective cavities, a small change in the SRO cavity length will result in the situation where a number of pump Fabry-Perot modes will correspond to the minima of the signal Fabry-Perot modes, i.e. these pump modes for the consecutive passes will interact with signal field phase-shifted by $\pi/2$. This will result in periodic and coherent deamplification of the parts of the signal field, producing dips in the output energy. This effect is not observed in a broadband DRO, as seen in Fig. 3, because the signal and idler spectra in the DRO will change in response to the cavity length variation, for instance by starting to oscillate on other mode clusters where the gain is stronger. The narrow spectral extent imposed by the VBG output coupler in the SRO should be expected to be an important factor in giving rise to the dips in the SRO efficiency as the total conversion efficiency is a result of coherent and incoherent summation over an ensemble of signal modes. For a broadband SRO pumped by partially coherent Q-switched pulses, the longitudinal mode distance variation due to group delay dispersion can be expected to decrease the amplitude of SRO length resonances and antiresonances (dips). In principle the proposed model explains both the resonant and antiresonant SRO behavior but we cannot rule out some additional effects producing dips in the SRO efficiency for certain cavity lengths. More detailed understanding would need further investigation.

In conclusion we have shown that the phenomenon of enhanced OPO efficiency for a fractional ratio between the OPO and the pump laser cavity optical path lengths is present for both singly and doubly resonant cavities. In the SRO the resonance enhancement becomes possible when there is a cross-correlation between pump and signal after one roundtrip in the OPO cavity. The mechanism is most efficient close to threshold where the OPO only reaches threshold for the periodic intensity spikes of the multimode pump laser. The efficiency of the enhancement mechanism also depends on the mutual coherence of the longitudinal modes of the pump. In the case of total coherence, as in mode-locked lasers, the SRO output enhancement mechanism should be analogous to synchronous pumping employed in picosecond and femtosecond SROs.

Acknowledgements

We acknowledge valuable discussion with Darrel Armstrong, Sandia National Labs, USA, and Gunnar Arisholm, FFI, Norway. We also acknowledge FFI, Norway, for providing us with the OPO modeling tool Sisyfos. The Swedish Research Council provided partial funding for this work.