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Coherent Signal from Incoherently cw-Pumped Singly Resonant Ti:LiNbO$_3$ Integrated Optical Parametric Oscillator.

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Quasi-phase-matched, singly resonant integrated optical parametric oscillators (SR-IOPO), with feedback at the signal wavelength only, offer simplified tuning, high stability, high conversion efficiency, and a low threshold in comparison with bulk devices [1]. Usually, they are pumped by narrow linewidth sources as the spectral properties of the pump are transferred to signal and idler. However, this coherence transfer is strongly determined by the dispersion properties of the waveguide material leading to surprising phenomena. Therefore, we investigate in this contribution the coherence properties of signal and idler generated by the parametric non-degenerate three-wave interaction in a SR-IOPO. In particular, operation with a broad-bandwidth cw-pump and the resulting coherence transfer to signal and idler are studied. To get a highly coherent signal we take advantage of the convection-induced phase-locking mechanism, based on a group-velocity difference between the resonant signal and the pump and idler waves, and a good group-velocity matching of the last two [2]. However, in contrast to the previous investigation for a type II configuration [2], we show here the feasibility of coherent signal generation from an incoherent cw-pump at $\lambda_p = 1.535$ µm in a type I {eee} Ti:LiNbO$_3$ SR-IOPO. The wavelength of the resonant signal is $\lambda_s = 3.941$ µm, near the infrared transparency limit. Around this wavelength triple (λ_p, λ_s, and $\lambda_i = 2.514$ µm) the substrate dispersion yields significant group-velocity differences $\Delta v_{sp,si} = |v_s - v_{p,i}|$ between resonant signal and pump / idler, but a small $\Delta v_{pi} = |v_p - v_i|$ only. Both properties are necessary to get an efficient convection-induced phase-locking mechanism.

In order to simulate the planned experiment we consider an SR-IOPO of length $L = 3.2\, v_p\, \tau_0 = 8$ cm. A periodicity of the ferroelectric domain structure $\Lambda_{QPM} = 30.24$ µm is assumed yielding quasi-phase matching for the wavelength triple given above. The end face mirrors have a reflectivity R = 98% at the signal wavelength; optical propagation loss coefficients $\alpha_p = \alpha_i = 0.1$ dB/cm, $\alpha_s = 0.26$ dB/cm and a pump power $P_p = 1.3$ W are used as simulation parameters.

The spatial amplitude evolution in the cavity at time t = 16384Ln/c = 18 µs is shown in the left figure. The random phase modulation of the pump at the input (z = 0) generates strong amplitude fluctuations during propagation to the output due to dispersion in the waveguide (upper graph). As the pump power level is above threshold, signal and idler waves are generated. It can be observed that the pump fluctuations are transferred to the growing (non-resonant) idler only, whereas the (resonant) signal has nearly a constant amplitude. The mean fluctuation intensity of the signal is about three orders of magnitude smaller than the corresponding fluctuation of the pump. Pump and signal spectra are shown in the middle and right figures. Whereas the pump spectrum has a width of about 90 GHz, a very coherent signal can be observed with a linewidth of < 2 MHz only. The spectral coherence transfer satisfies $\Delta v_s < 2 \times 10^{-5}\, \Delta v_p$.

In conclusion, at selected wavelengths – determined by the dispersion properties of the waveguide material - SR-IOPOs generate a highly coherent (resonant, long wavelength) signal emission though operated with an incoherent pump. This might allow developing MIR-IOPOs of narrow linewidth output for spectroscopy pumped by low coherence, cheap semiconductor lasers.

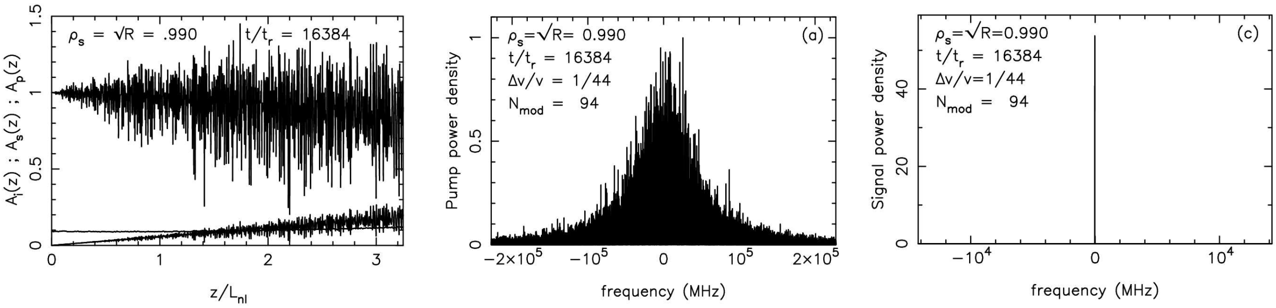

Fig. 1: Simulation results for a Ti:LiNbO$_3$ SR-IOPO (λ_p = 1.53 µm, λ_I = 2.51 µm, λ_s = 3.94 µm): Left: Spatial field amplitude evolution of pump (upper graph), idler and signal waves in the cavity. Middle: Incoherent pump power spectrum ($\Delta v_p \approx 90$ GHz). Right: Power spectrum of generated signal ($\Delta v_s < 2$ MHz).

References:

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