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Mid-Infrared Continuous-Wave Singly Resonant Optical Parametric Oscillator with Periodically Poled Ti:$LiNbO_3$ Waveguide

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Singly resonant, quasi-phase-matched integrated optical parametric oscillators (SR-IOPO) are attractive candidates for efficient frequency conversion, continuously tunable in a broad wavelength range. Using annealed proton exchanged waveguides near-infrared devices have been demonstrated with an oscillation threshold of 1.6 W [1]. On the other hand, low-loss Ti:$LiNbO_3$ waveguides allow to reduce the threshold considerably. This was recently demonstrated by a mid-infrared device with a doubly resonant configuration [2].
In this contribution the first continuous-wave mid-infrared SR-IOPO with periodically poled Ti:$LiNbO_3$ waveguide is reported. It consists of a 90 mm long channel guide of 17.5 µm width in a Z-cut, X-propagation $LiNbO_3$ substrate. The waveguide losses are as low as 0.06 dB/cm measured at $\lambda = 3391$ nm. Using the electric field poling technique the substrate has been periodically poled over a length of 80 mm with a domain periodicity of 31.6 µm. Dielectric mirrors on a sapphire substrate ($R > 95$ % for $3200 < \lambda < 3800$ nm, $R < 5$ % for $2650 < \lambda < 2980$ nm) are in contact with the waveguide end face to form the resonator.
A tunable narrow linewidth extended cavity semiconductor laser, amplified by a high power EDFA (33 dBm), is used as pump source to operate and to investigate the SR-IOPO. As an example, Fig. 1 presents the power characteristic of the device in cw operation as signal plus idler power in forward direction versus the external pump power ($\lambda_P = 1552.5$ nm). The oscillation threshold is 480 mW in good agreement with the theoretical prediction, if a 60 % coupling efficiency is assumed. At 1.5 W pump power the mid-infrared emission ($\lambda_S = 2883$ nm, $\lambda_I = 3364$ nm) grows up to 310 mW; this result corresponds to an overall slope efficiency of 30 %. Due to the SR-configuration of the oscillator the signal power always exceeds the idler power considerably. The SR-IOPO output power has been tuned within the range $2880 \text{ nm} < \lambda_S, \lambda_I < 3360$ nm by tuning the pump wavelength λ_P from 1552.5 nm to 1579 nm (see Fig. 2).

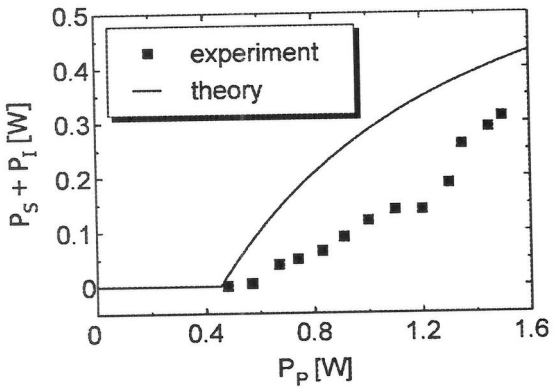

Fig. 1: Signal and idler power as function of external pump power; $\lambda_P = 1552.5$ nm

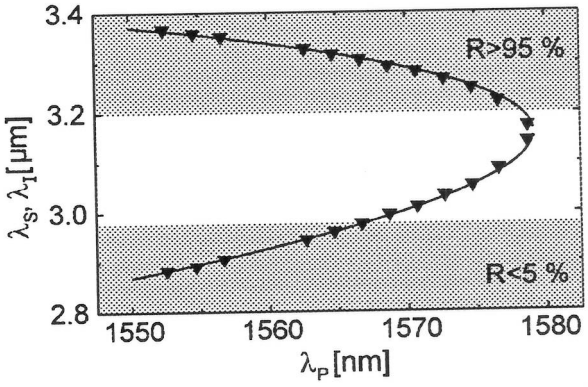

Fig. 2: Signal and idler wavelength plotted versus pump wavelength

[1] *M. A. Arbore, M. M. Fejer, "Singly resonant optical parametric oscillation in periodically poled lithium niobate waveguides", Opt. Lett. 22, 151 (1997)*
[2] *D. Hofmann, H. Herrmann, G. Schreiber, W. Grundkötter, R. Ricken, W. Sohler, "Continuous-wave mid-infrared optical parametric oscillators with periodically poled Ti:$LiNbO_3$ waveguide", Proceedings ECIO'99, paper FrE4, Torino, April 13-16 (1999)*