

# 16.6W, Continuous-Wave, Yb-fiber-Laser-Pumped, Singly-Resonant Optical Parametric Oscillator based on MgO:PPLN

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High power, continuous-wave (cw), singly resonant optical parametric oscillators (SROs), tunable in the near- and mid-IR are of great importance for applications in spectroscopy, biomedicine, and atmospheric propagation. Such cw SROs using the most widely used nonlinear material, periodically poled lithium niobate (PPLN), has been extensively demonstrated previously. However, attainment of high optical powers in the near- and mid-IR is an experimentally challenging proposition, essentially due to heavy thermal loading of the nonlinear crystal resulting from the high intracavity signal power at increased pump powers. This can lead to saturation and subsequently a substantial drop in efficiency, thus limiting the available output power. To date, a maximum of 10 W at 50 W of pump at 20% efficiency has been reported in a cw SRO [1]. A substantial reduction in the thermal loading by out-coupling the resonating signal has enabled considerable increase in the overall extraction efficiency up to 59% resulting in a total power of 8.6 W (5.1 W signal, 3.5 W idler) for 15 W of pump power [2]. Recently, we also demonstrated that the use of output coupling can result in substantial enhancement in the overall performance of cw SROs without degrading output power and stability [3]. Using the out-coupling approach, we have now generated up to 16.6 W (8.3 W of signal and 8.3 W of idler) of output power from a cw SRO for 26.8 W of pump power at an extraction efficiency to 62%. Moreover, the device is based on an Yb fiber laser pump, resulting in a highly compact, practical, and portable design.

The schematic of the experimental setup is shown in Fig. 1. The Yb fiber pump laser delivers up to 30 W of single-frequency radiation at 1064 nm in a linearly polarized beam with  $M^2$  factor  $<1.01$ . The pump laser is operated at maximum power and an attenuator comprising a half-wave plate (HWP) and a polarizing beam splitter is used to vary the input fundamental power. A second HWP is used to control the pump polarization for phase matching. The pump beam is focused to a waist radius of  $w_{op} \sim 67 \mu\text{m}$  at the centre of the crystal using a lens,  $L$ , corresponding to a focusing parameter of  $\xi \sim 1$ . The SRO is based on a 50-mm long multi-grating ( $\Lambda = 29.5\text{-}31.5 \mu\text{m}$ ) MgO:PPLN crystal (HC Photonics) and is configured in a compact ring cavity consisting of two plano-concave mirrors,  $M_1$  and  $M_2$  ( $r=150 \text{ mm}$ ) and two plane mirrors  $M_3, M_4$ . All mirrors have  $R > 99\% @ 1.3\text{-}1.9 \mu\text{m}$  and  $T > 90\% @ 2.2\text{-}4 \mu\text{m}$ , thus ensuring SRO operation. For out-coupled SRO (OC-SRO) operation,

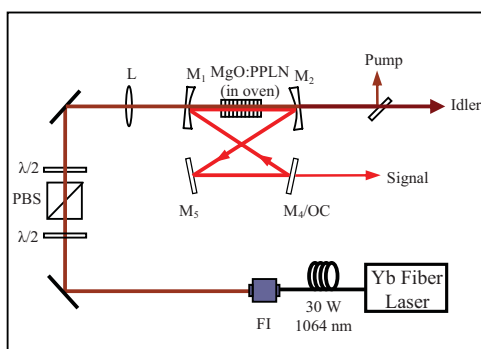


Fig. 1. Experimental setup of Yb fiber laser pumped cw OC-SRO based on MgO:PPLN crystal.

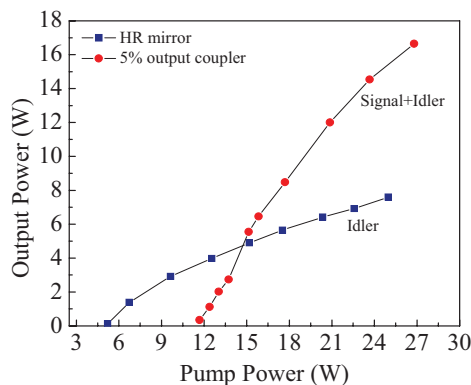


Fig. 2. Output power measured as a function of pump power in a HR cavity and 5% out-coupled cavity

we replaced mirror  $M_4$  by an output coupler with  $T \sim 5\%$  across  $1.3\text{-}1.9 \mu\text{m}$ . The total cavity length is 862 mm (FSR  $\sim 348 \text{ MHz}$ ). Figure 2, shows the output power as a function of input pump power for the OC-SRO (red circles) and SRO (blue squares) at a signal wavelength of 1629 nm (idler wavelength of 3067 nm). Although the OC-SRO has higher threshold (11.6 W) compared to SRO (5.2W), but it can provide higher output power 16.6W (8.3W of signal, 8.3W of idler) for 26.8 W of pump and higher efficiency of 62%, whereas the SRO provides 7.6 W of idler for 25 W of pump with a maximum efficiency of 30.4%. Under free running condition without any thermal isolation, the signal power shows higher pk-pk power stability (12%) than the idler (17.2%). Results on wavelength tuning and further enhancement of output power using optimum output coupling will be presented.

## References

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