16.6 W, Near- and Mid-Infrared Optical Parametric Oscillator Pumped by an Yb Fiber Laser

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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 based on the most widely used nonlinear material, periodically poled $LiNbO_3$ (PPLN), have 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 power 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 of output power (8.3 W of signal and 8.3 W of idler) from a cw SRO for 26.8 W of pump power at an extraction efficiency to 62%. Moreover, the device is based on a cw Yb fiber laser as the pump source, resulting in a highly compact, practical, and portable design.

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 beam is focused to a waist radius of w_{op}~67 μm at the centre of the crystal, corresponding to a focusing parameter of ξ~1. The SRO is based on a 50-mm long multi-grating (Λ=29.5-31.5 μm) MgO:PPLN crystal and is configured in a compact ring cavity consisting of two plano-concave mirrors (r=150 mm) and two plane mirrors. All mirrors have R>99%@ 1.3-1.9 μm and T>90%@2.2-4 μm, thus ensuring SRO operation. For out-coupled SRO (OC-SRO) operation, we replaced one of the plane mirrors with an output coupler with T~5% across 1.3-1.9 μm.

We measured the output powers of SRO (idler-only extraction) and OC-SRO (both idler and signal extraction) as a function of input pump power at 100 °C crystal temperature corresponding to a signal wavelength of 1629 nm and idler wavelength of 3067 nm. Although the OC-SRO has higher threshold (11.6 W) compared to SRO (5.2 W), it can provide higher output power 16.6 W (8.3W of signal, 8.3W of idler) for 26.8 W of pump and higher efficiency of 62% compared to SRO, which provides 7.6 W of idler for 25 W of pump with a maximum efficiency of 30.4%. Under free-running condition and without any thermal isolation, the signal power shows higher peak-to-peak power stability (12%) than the idler (17.2%).

References

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