Continuous-wave green-pumped optical parametric oscillator based on fanout MgO:PPLN

Sukeert
ICFO—Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology
Castelldefels, Spain
sukeert@icfo.eu

S. Chaitanya Kumar
Radiantis & ICFO—Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology
Castelldefels, Spain
chaitanya.suddapalli@icfo.eu

M. Ebrahim-Zadeh
ICFO—Institut de Ciències Fotòniques, The Barcelona Institute of Science and Technology, & Institució Catalana de Recerca i Estudis Avançats (ICREA), & Radiantis
Castelldefels, Spain
majid.ebrahim@icfo.eu

***Abstract*— We report a green-pumped continuous-wave OPO using a fanout-grating MgO:PPLN, tunable across 813-1032 nm (signal) and 1098-1539 nm (idler) with >30% extraction efficiency in excellent beam-quality and power stability better than 3% rms over 1 hour.**

Keywords—MgO:PPLN, green-pumped, optical parametric oscillator

I. INTRODUCTION

Tunable laser sources in different regions of the optical spectrum are of great interest for a variety of applications in spectroscopy, photochemistry, and medical diagnostics. Green-pumped optical parametric oscillators (OPOs) are a viable approach for the generation of tunable radiation in the visible and near-infrared. Such OPOs in the continuous-wave (cw) regime have been demonstrated by exploiting by exploiting quasi-phase-matched (QPM) nonlinear crystals such as periodically-poled $LiNbO_3$ (PPLN), stoichiometric $LiTaO_3$ (PPSLT), and $KTiOPO_4$ (PPKTP). However, green-induced infrared absorption (GRIIRA) and photorefractive damage in PPLN and PPLT have hampered their further development. Doping with MgO increases resistance to photorefractive damage and GRIIRA in $LiNbO_3$ and $LiTaO_3$, leading to the development of green-pumped OPOs based on MgO:PPLN and MgO:PPSLT [1–3]. Wavelength tuning in such QPM OPOs is typically achieved by varying the crystal temperature, which is a slow process. Moreover, away from degeneracy, material dispersion in QPM crystals leads to a reduced temperature tuning rate. Using a fanout grating structure in the QPM nonlinear crystal is an attractive alternative for the attainment of rapid and continuous wavelength tuning, and this has been demonstrated in cw green-pumped OPOs based on MgO:sPPLT and PPKTP [4,5]. In particular, MgO:sPPLT has proved to be the most viable QPM material for green pumping, due to a high photorefractive damage threshold [1,3], but stoichiometric composition, growth, and fabrication of this material remain challenging. On the other hand, because of a mature growth and poling technology, together with high nonlinearity, MgO:PPLN can now be readily fabricated in multi-grating as well as fanout grating designs, making it a potential QPM material candidate for green-pumping, capable of generating tunable radiation in the near-IR with practical output powers with high extraction efficiencies under optimum operating conditions. Here we report a green-pumped cw OPO based on fanout-grating MgO:PPLN, for the first time to our knowledge. By using output coupling, we demonstrate simultaneous generation of signal and idler power over an extended wavelength range at a fixed temperature using mechanical tuning.

II. EXPERIMENTAL SETUP

The schematic of the experimental setup is shown in Fig. 1(a). A cw frequency-doubled $Nd:YVO_4$ laser delivering up to 10 W of single-frequency output at 532 nm in a linearly-polarized beam with M^2<1.1 is used to pump the OPO. The 5 mol% MgO:PPLN crystal used for the OPO has dimensions of 25x12x0.5 mm^3, with a fanout grating (Λ=6.9–8.1 μm) design. We use a relatively short length of 25 mm in order to minimize thermal loading in the crystal due to green pumping, since the linear absorption coefficient in MgO:PPLN is 15 times larger at 532 nm than at 1064 nm [6]. The end faces of the crystal are antireflection-coated at 532 nm (R<1%) and 750–1060 nm (R<1%), and over 1060-1850 nm (R<2%). The crystal is housed in an oven with temperature stability of ± 0.1 °C and mounted on a motorized linear translation stage with a resolution of 0.1 μm to enable fine and continuous grating tuning across its lateral dimension. The OPO is formed in a compact ring cavity comprising two concave mirrors (r=–100 mm) and two plane mirrors, all highly reflecting (R>99.8%) for the signal over 620–1030 nm. One of the plane mirrors can be replaced with a plane output coupler with variable transmission (1-2%) across 720-1000 nm, for signal extraction and OPO performance optimization. All mirrors are also highly transmitting (T>97%) for the idler across 1078–3550 nm and pump, ensuring singly-resonant oscillation for the signal. The idler output is separated from the transmitted pump using a dichroic mirror.

Ministerio de Ciencia, Innovación y Universidades (MICINN) (nuOPO, TEC2015-68234-R); Generalitat de Catalunya (CERCA Programme); Severo Ochoa Programme for Centres of Excellence in R&D (SEV-2015-0522-16-1); Fundació Privada Cellex..

978-1-7281-5891-4/20/$31.00 ©2020 IEEE

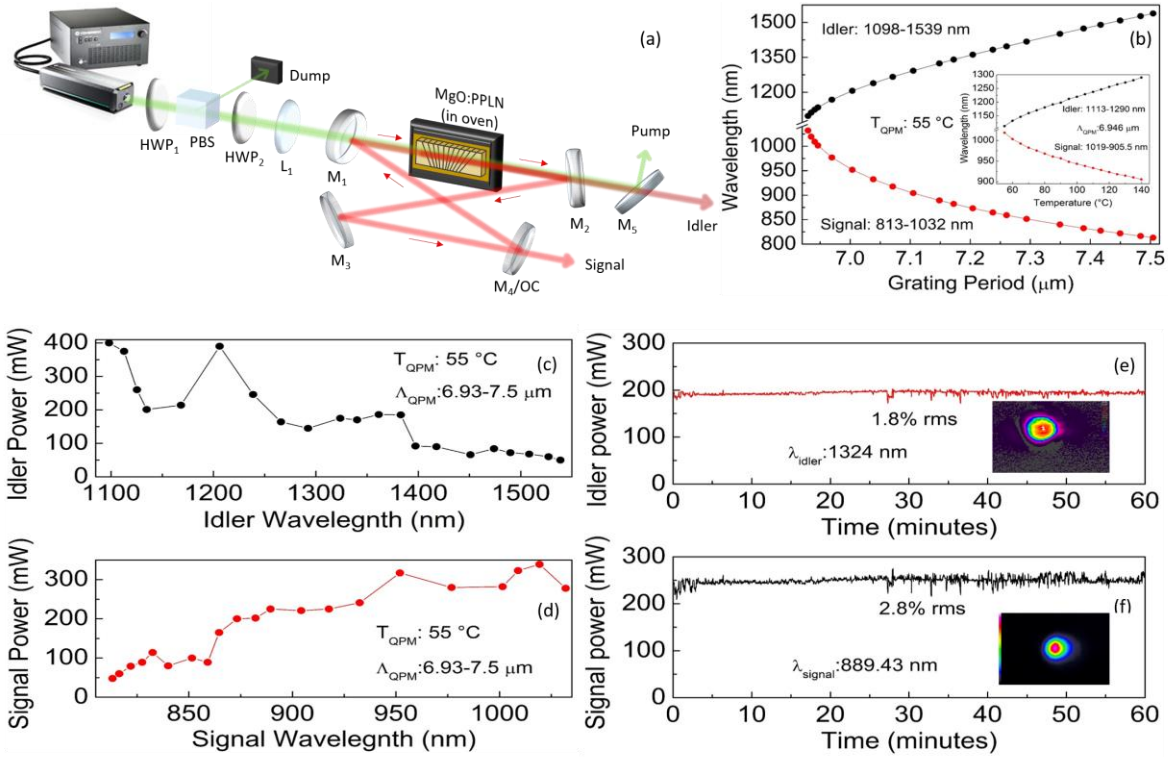

Fig 1. (a) Experimental setup, (b) tuning range, (c) idler and (d) signal power across tuning range, (e) simultaneous idler; inset:idler beam profile, and (f) signal, power stability; inset:signal beam profile, of the green-pumped cw MgO:PPLN OPO.

III. Results

Wavelength tuning in the present OPO can be achieved by lateral translation of the MgO:PPLN crystal to vary the QPM grating period or by changing the crystal temperature, while keeping either parameter fixed. Initially, we investigated the tuning capabilities of the OPO at fixed crystal temperature of 55 °C, by varying the crystal position laterally to continuously change the QPM grating period. The grating periods across the crystal positions were then theoretically calculated using relevant Sellmeier equations for the material [7]. By varying the crystal position, and, correspondingly, the calculated grating period over Λ=6.93-7.5 µm, we were able to tune the OPO across 813-1032 nm in the signal and 1098-1539 nm in the idler, as seen in Fig. 1(b). Using all highly reflecting mirrors at a fixed grating period of Λ=6.946 µm, by varying the crystal temperature from 55 to 140 °C, we were able to tune the OPO across 905.5-1019 nm in the signal and 1290-1113 nm in the idler, as shown in the inset of Fig. 1(b). For an input pump power of 2.4 W, we measured the simultaneously generated signal and idler output power from the cw OPO. The output powers vary from 400 mW at 1098 nm to 50 mW at 1539 for the idler, and from 278 mW at 1032 nm to 48 mW at 813 nm for the signal, with the highest signal power of 339 mW recorded at 1019 nm, as shown in Fig. 1(c) and (d). The maximum total output power simultaneously generated was 714 mW at signal (idler) wavelength of 1019 nm (1113 nm), resulting in a total OPO extraction efficiency of 30%. We also performed simultaneous long-term power stability measurements of the output signal and idler under free-running conditions, as shown in Fig. 1(e) and (f). At a pump power of 2.4 W, the output idler at 1324 nm exhibits a passive power stability of 1.8% rms, and the corresponding output signal at 889 nm displays a passive power stability of 2.8% rms over 1 hour. The far-field beam profiles are shown in the insets of Fig. 1(e) and (f), confirming excellent spatial quality in Gaussian distribution with circularity better than 94%. In conclusion, we have demonstrated, what we believe to be the first cw green–pumped OPO based on fanout-grating MgO:PPLN. By exploiting the fanout grating structure and using output coupling, the OPO is continuously and finely tunable at a fixed temperature, and can provide total output power of up to more than 700 mW with 30% extraction efficiency in high spatial beam quality. Detailed characterization of the cw OPO, including spectral properties, thermal effects, beam quality, performance at different temperatures and operation in pure SRO configuration will be presented.

References

[1] G. K. Samanta, G. R. Fayaz, Z. Sun, and M. Ebrahim-Zadeh, Opt. Lett. 32, 400 (2007).

[2] I.-H. Bae, H. S. Moon, S. Zaske, C. Becher, S. K. Kim, S.-N. Park, and D.-H. Lee, Appl. Phys. B 103, 311 (2011).

[3] S. Chaitanya Kumar, K. Devi, G. K. Samanta, and M. Ebrahim-Zadeh, Laser Phys. 21, 782 (2011).

[4] K. Devi and M. Ebrahim-Zadeh, Opt. Lett. 42, 2635 (2017).

[5] K. Devi, A. Padhye, Sukeert, and M. Ebrahim-Zadeh, Opt. Express 27, 24093 (2019).

[6] J. R. Schwesyg, et. al., in *Advances in Optical Materials* (OSA, 2011), p. AIThE3.

[7] O. Gayer, Z. Sacks, E. Galun, and A. Arie, Appl. Phys. B Lasers Opt. 91, 343 (2008).