Visible, femtosecond, high power, ultra-broadband noncollinear optical parametric oscillator (VIS-NOPO)

Robin Mevert[1,2], Yuliya Binhammer[1,2], Christian M. Dietrich[1,2], José R. Cardoso de Andrade[3], Luise Beichert[1,2], Thomas Binhammer[4], Jintao Fan[1,2], Uwe Morgner[1,2]

1. *Leibniz University Hannover, Institute of Quantum Optics, Welfengarten 1, D-30167 Hannover, Germany*
2. *Cluster of Excellence PhoenixD, Welfengarten 1, D-30167 Hannover, Germany*
3. *Max-Born Insitute, Max-Born-Straße 2A, D-12489 Berlin, Germany*
4. *neoLASE GmbH, Hollerithallee 17, D-30419 Hannover, Germany*

In the past, the most common approaches to generate tunable femtosecond laser pulses in the visible were either to generate intracavity SHG or SFG in near-infrared OPOs [1,2] or by pumping the OPO directly with the second harmonic of a Ti:sapphire laser (VIS-OPO) [3,4]. In this work, we demonstrate the full potential of the noncollinear phase matchings scheme in the visible by pumping the OPO with the third-harmonic of an Yb-fiber laser [5]. The resulting visible radiation can just be tuned by changing the cavity length.

The setup of the VIS-NOPO is shown in Fig. 1(a). With up to 3 W of output power the third-harmonic of an Yb-fiber MOPA pump source providing a repetition rate of 50.2 MHz and an output power up to 20 W at 1040 nm and a pulse duration of 250 fs, is generated in two BBO crystals by mixing the fundamental with its second harmonic. The third harmonic is focused into a Brewster-cut BBO ($\Theta = 39°$), which allows for an ultrabroadband noncollinear phase matching in the Poynting vector walk-off compensation (PVWC) phase matching scheme with a noncollinear angle of $\alpha = 4.5°$ between signal and pump. The cavity is setup as a standing wave cavity with two curved ($\varnothing = 25.4\,\mathrm{mm},\ \mathrm{ROC} = -150\,\mathrm{mm}$) and six plane ($\varnothing = 12.7\,\mathrm{mm}$) double chirped mirrors (DCM) with a high reflectivity in a range from 400 – 800 nm and a spectral transmission window for the pump. At the lower end of the cavity an output coupler (OC) with a reflectivity of 86 % in a range from 480 – 720 nm is placed on a linear translation stage. A BK7-substrate tilted at Brewster's angle is added to the cavity to stabilize the tuning behaviour of the VIS-NOPO. During the measurements, the cavity length is changed, while the output power and the autocorrelation trace of the output are recorded. The measured autocorrelation trace is fitted with a sech²-shape to calculate the pulse duration.

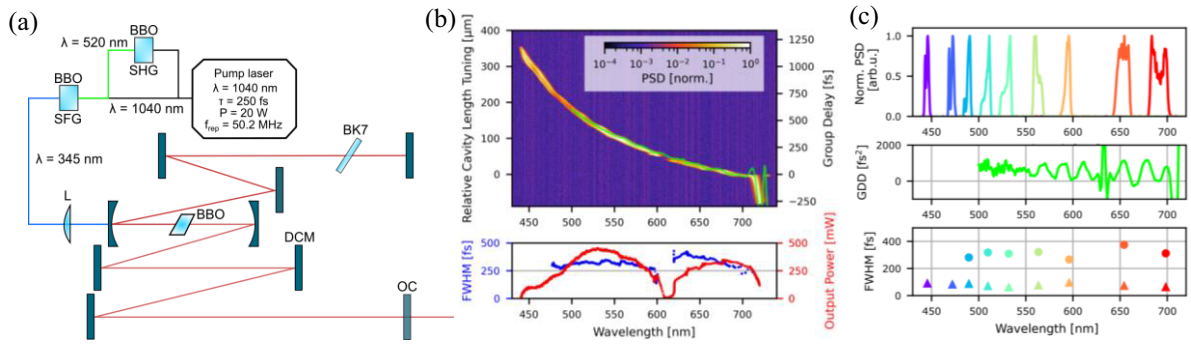

Fig. 1 (a) Setup of the VIS-NOPO: BBO SHG ($\Theta = 23.2°$, L = 1.5 mm), BBO SFG ($\Theta = 32.5°$, L = 1 mm) , L: plane-convex lens (f = 200 mm), BBO OPO ($\Theta = 39°$, L = 2 mm), BK7-substrate (L = 12 mm), OC: output coupler (R = 86 %); (b) *Upper graph:* Recorded signal spectra of the VIS-NOPO while varying the cavity length at 3 W of pump power. *Lower graph:* corresponding output power (red scale on the left) and pulse duration (blue scale on the right) for center wavelengths of spectra in the upper graph. (c) *Upper graph:* arbitraly selected signal spectra of the VIS-NOPO. *Middle graph:* calculated net group delay dispersion of the VIS-NOPO cavity. *Lower graph:* measured pulse duration for selected signal spectra (circles) and calculated transform-limited pulse duration (triangles).

The tunability range of the VIS-NOPO spans from 440 – 720 nm with a maximum output power of 450 mW at 530 nm and pulse durations down to 200 fs at 528 nm, as illustrated in Fig. 1(b). The strong decrease in output power at 613 nm arises from the parasitic SHG phase matching in BBO. In conclusion, our measurements show for the first time that the VIS-NOPO can generate high power femtosecond laser pulses quickly tuneable over nearly the visible spectral range.

References

[1] Y. Khanukaeva, T. Lang, A. Tajalli, J. R. Andrade, T. Binhammer, and U. Morgner, "Efficient fast-tunable femtosecond visible radiation based on intracavity sum-frequency generation in a NIR NOPO," CLEO 2016, OSA Technical Digest (2016), paper STh1P.6
[2] T. Joeng, S. Kim, G.Kim, K.Yee, "Visible-pulse generation in gain crystal of near-infrared femtosecond optical parametric oscilator", Opt. Express **23**, pp. 25620-25627, (2015)
[3] G.M. Gale, M. Cavallari, F.Hache, "Femtosecond visible optical parametric oscillator", JOSAB **15**, pp. 702-714, (1998)
[4] M.Ghotbi, A.Esteban-Martin, M. Ebrahim-Zadeh, "BiB_3O_6 femtosecond optical parametric oscillator" Opt. Lett. **31**, pp. 3128-3130 (2006)
[5] R. Mevert, Y. Binhammer, C. M. Dietrich, L. Beichert, J. R. Cardoso de Andrade, T. Binhammer, J. Fan, and U. Morgner, "Widely tunable, high-power, femtosecond noncollinear optical parametric oscillator in the visible spectral range," Photon. Res. **9**, 1715-1718 (2021)