SHG and SFG processes at a 100 kHz picosecond diode-pumped Yb:YAG thin-disk laser

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Generation of harmonic frequencies is an efficient tool by which the spectral region of exploitable wavelengths of a laser can be substantially broadened. Besides the second harmonic, which is a prerequisite for further sum frequency processes, the UV and deep UV (below 300 nm, DUV) radiation is used for processing of different materials. The picosecond pulses enable short intense contact between the laser radiation and material. Such type of material processing shows specific features which cannot be attained otherwise (very precise microstructuring with sharp edges and high aspect ratio).

The fundamental beam is generated in a chirped pulse amplification laser system PERLA C running at 100 kHz [1]. It consists from a front end (fiber oscillator, fiber amplifiers) followed by a diode-pumped thin-disk Yb:YAG (1030 nm) regenerative amplifier. At present the 1-2 ps pulses are available up to 2 mJ energy. The SHG is realized in an LBO crystal, the wavelength of 515 nm is then doubled in a CLBO or BBO crystal to generate the DUV radiation of 257.5 nm. By SFG processes the third harmonic of 343 nm in an LBO crystal and the fifth harmonic of 206 nm in a CLBO or BBO crystal are generated. A challenging factor in the harmonics generation is the conversion efficiency related to the fundamental beam. Whereas the SHG from the fundamental beam can reach conversion around 70% [2], the SHG from the frequency doubled beam faces an adverse effect of the two-photon absorption leading to a conversion efficiency decrease, see e.g. [3]. The SFG process is used as ($2\omega + 1\omega$) for the third harmonic generation and ($4\omega + 1\omega$) for the fifth harmonics. The generation of DUV radiation meets challenging effects to be overcome: different group velocities of 1ω and 4ω pump beams inside the crystal and nonlinear absorption of both DUV photons. A mitigation to the group velocity mismatch is matching the group velocities by tilting the pulse fronts and noncollinear interaction of the beams inside the crystal [4]. The nonlinear absorption, however, is difficult to mitigate, the only way to lower its effect is to use low intensity beams together with higher crystal temperature, when the coefficient of the nonlinear absorption is getting lower, see e.g. [5]. The nonlinear absorption also presents a serious problem for DUV beams exiting the boxes containing protective atmosphere for crystals (nitrogen, argon). The exit windows should be produced from materials with low nonlinear absorption coefficient, such as MgF2, CaF2, LiF, or crystalline quartz [6].

In our contribution we present the up-to-date status of our harmonics generation system and its readiness for the users' experiments. At present our users have at a disposal 50W in 2^{nd}, 25 W in 3^{rd}, 10 W in 4^{th}, and 1 W in 5^{th} harmonics, in pulses of 1-2 ps duration.

References

[1] M. Smrz, M. Chyla, J. Muzik, S. S. Nagisetty, O. Novak, Compact, picosecond, kW-class thin disk laser PERLA for hi-tech industrial applications, MM Science, 2019, December, 3621.
[2] H. Fattahi, A. Alismail, H. Wang, et al., High-power, 1-ps, all-Yb:YAG thin-disk regenerative amplifier, Optics Letts. **41**(6), 1126 (2016).
[3] H. Turcicova, O. Novak, L. Roskot, et al., New observations on DUV radiation at 257 nm and 206 nm produced by a picosecond diode pumped thin-disk laser, Optics Express **27**(17), 24286, https://doi.org/10.1364/OE.27024286 (2019).
[4] B. Willenberg, F. Brunner, Ch. Phillips,and U. Keller, High-power picosecond deep-UV source via group velocity matched frequency conversion, Optica **7**(5), 485 (2020).
[5] M. Takahashi, A. Osada, A. Dergachev, et al., Effects of pulse rate and temperature on nonlinear absorption of pulsed 262-nm laser light in BBO, Jap. J. Appl. Phys. **49**, 080211 (2010).
[6] S. Patankar, S. T. Yang, J. D. Moody, et al., Two-photon absorption measurements of deep UV-transmissible materials at 213 nm, Applied Optics **56**(30), 8309.