Femtosecond optical parametric generators and amplifiers for the near infrared based on BiB_3O_6

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I review the physical properties, linear and nonlinear optical characteristics, and phase-matching configurations of BiB_3O_6 (BIBO), the first low symmetry (monoclinic) inorganic nonlinear crystal that has found broad applications for frequency conversion of laser sources based on three-wave interactions.[1] With special focus on ultrafast frequency conversion, characteristics such as group velocity mismatch and spectral acceptance, parametric gain bandwidth, and group velocity dispersion are evaluated and optimum configurations for the attainment of maximum conversion efficiency and minimum pulse duration are identified and compared with the most widely established alternative borate crystal, β-BaB_2O_4.

BIBO possesses a unique combination of excellent properties for broadband parametric amplification when pumped near 800 nm in collinear geometry. Higher order dispersion terms determine in this case the parametric gain bandwidth which can be extremely broad. In addition, the group velocity matching with the pump ensures long interaction lengths and high efficiency even for femtosecond pulse durations. Hence, BIBO is very suitable for a wide range of femtosecond down-conversion schemes based on Ti:sapphire laser pump sources to produce signal and idler pulses in the 1100-3000 nm range in the near-IR. Several such schemes in the high-power regime at a repetition rate of 1 kHz have been realized.

BIBO has been implemented in a 800 nm pumped femtosecond two-stage type-II optical parametric amplifier (OPA) and showed efficient and tunable operation at 1 kHz with certain advantages (extension to the 3 μm spectral range) over BBO. The shortest pulses obtained were of the order of 100-110 fs. Using two BIBO crystals (type-II and type-I) in a two stage femtosecond OPA it was possible to increase the output energy roughly 5 times in comparison to previous work with BBO at 1 kHz repetition rate. The maximum energy obtained for a signal wavelength of 1200 nm was 1.1 mJ (signal plus idler) and the tunability extended from 1.1 to 2.9 μm. Using a two stage broadband (type-I – type-I) BIBO OPA with white light continuum (WLC) seeding, it was possible to generate sub-30 fs signal pulses near 1300 nm after compression, at energies exceeding 200 μJ, by pumping with 150-fs pulses near 800 nm at 1 kHz. The corresponding idler pulses near 2.3 μm had a duration of 55 fs without compression and energy exceeding 100 μJ.

Ultra-broadband optical parametric amplification and generation has been realized in the near-IR with WLC energy as high as 50 μJ in the case of OPA and 15 μJ in the case of the simpler optical parametric generator (OPG) scheme. These values correspond to internal conversion efficiency of 20% and 7%, respectively. In all cases the integral pulse durations achieved are in the sub-100-fs range and the spectral extension covers an octave. This is the first time such WLC has been generated or amplified by a second order nonlinear process on the femtosecond time scale. Amplification in a second stage increased the output energy to above 100 μJ.

The unique versatile nonlinear optical properties of BIBO combined with the frequency conversion methods described here provide efficient and widely tunable ultrafast laser sources in the near-IR, offering the advantages of simplicity, practicality, high average power, high intensity and pulse energy, and femtosecond pulse duration.

References:

[1] V. Petrov, M. Ghotbi, O. Kokabee, A. Esteban-Martin, F. Noack, A. Gaydardzhiev, I. Nikolov, P. Tzankov, I. Buchvarov, K. Miyata, A. Majchrowski, I. V. Kityk, F. Rotermund, E. Michalski, and M. Ebrahim-Zadeh, "Femtosecond nonlinear frequency conversion based on BiB_3O_6," *Las. & Phot. Rev.* 1-46 (2009), DOI 10.1002/lpor.200810075.

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