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Frequency Doubling of Ultrashort Pulses in a Nonlinear Photonic Strontium Tetraborate Crystal

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Abstract—The second harmonic generation (SHG) of the femtosecond titanium–sapphire laser radiation was experimentally studied in the mode of nonlinear diffraction in the nonlinear photonic strontium tetraborate crystal. The spectrum of reciprocal lattice vectors of domain structures includes components responsible for the efficient frequency-tunable SHG in the spectral range of 355–510 nm. The maximum SHG efficiency was 1.9%. The SHG spectrum narrowing does not exceed 10–20%. The measured spectral dependence of the nonlinear diffraction angle is in good agreement with calculation.

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Key words: second harmonic generation, ultrashort pulses, nonlinear photonic crystal.

Broadening of the spectral region of laser radiation still remains an urgent problem of modern quantum electronics. Of special importance is production of coherent radiation in the vacuum ultraviolet region, including femtosecond radiation, since there is a narrow range of choice of nonlinear media in this region. In this respect, the strontium tetraborate (SBO) crystal, whose transmission band extends to 125 nm and nonlinear coefficients are relatively high, is attractive. However, angular synchronism in SBO is absent due to small birefringence. In this case, quasi-phase matching can be an alternative for achieving efficient nonlinear-optical transformation. The matching feasibility is associated with irregular domain structures formed in SBO crystals during growth. The structures under consideration represent a one-dimensional nonlinear photonic crystal (NPC) [1] and are characterized by a broad spectrum of reciprocal lattice vectors, which provides efficient radiation generation in a wide spectral range. Nonlinear-optical conversion of radiation becomes possible in such structures due to the effect of random quasi-phase matching [2] and the phenomenon of nonlinear diffraction [3]. Previously, we studied both processes for nanosecond radiation conversion [4, 5]. In this report, we present the latest experimental results on frequency doubling of the femtosecond titanium–sapphire laser radiation in the mode of nonlinear diffraction by the SBO domain structure. As a pumping radiation source, the titanium–sapphire laser generating 40–100-fs pulses with an energy of 12.5 nJ was used. The nonlinear diffraction pattern is shown in Fig. 1. The frequency-tunable second harmonic generation (SHG) in the spectral range of 355–510 nm was obtained. Figure 2(a) shows the spectral dependence of the SHG power for a fixed crystal position and with tuning to the maximum power of the second harmonic. The maximum SHG efficiency was 1.9% which significantly exceeds the conversion efficiency achieved in a similar study in a strontium barium niobate crystal [6]. Normalization of the spectral dependence of the second harmonic power to the squared power of the Ti:sapphire laser makes it possible to become free of pump energy parameters, thus revealing the spectrum of reciprocal lattice vectors (Fig. 2(b)). It can be seen from the figure, the spectrum of reciprocal lattice vectors is rather extended; at the same time, it contains particular maxima and minima. Narrowing of the second harmonic spectrum does not exceed 10–20% (Fig. 2(c)). The measured spectral dependence of the nonlinear diffraction angle is in

Fig. 1. Nonlinear diffraction pattern. The central spot corresponds to pump radiation.

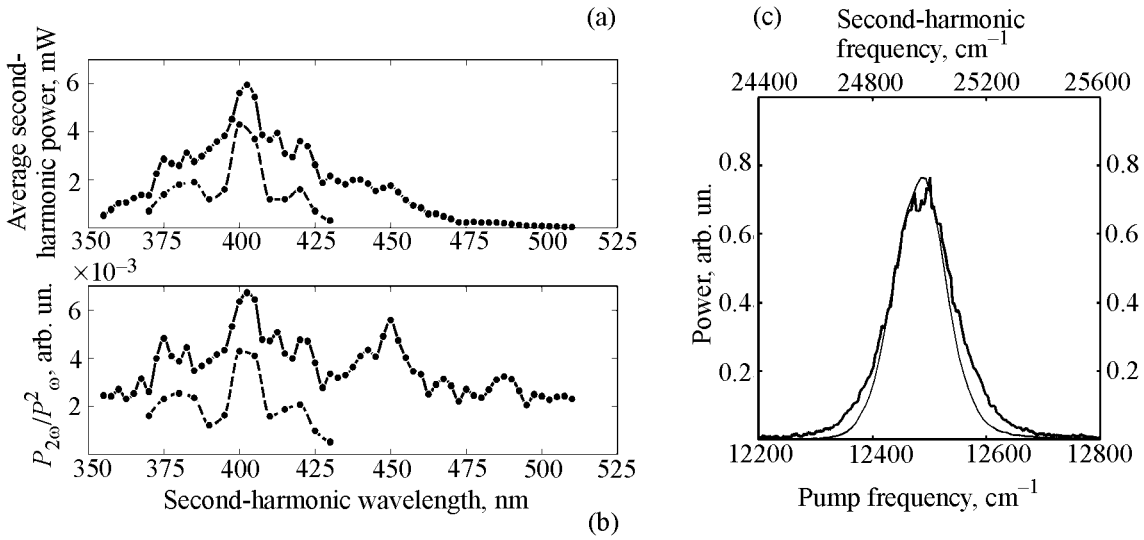

Fig. 2. (a) Spectral dependence of the average power of the second harmonic. (b) The ratio of the second harmonic power to the squared pump power. Solid and dashed curves correspond to crystal tuning to the maximum SHG power and a fixed crystal position, respectively; dots are experimental data. (c) Pump spectrum (bold curve) at the central wavelength of 800 nm and the second harmonic spectrum (thin curve).

good agreement with calculation. The linear run of the dependence of the SHG efficiency on the pump power indicates the absence of thermal self-focusing in the crystal under study.

The results obtained demonstrate a promising application of domain structures in the strontium tetraborate crystal for ultrashort pulse conversion to the ultraviolet spectral region in the mode of nonlinear diffraction. The nonlinear photonic strontium tetraborate crystal can be taken as the basis of the autocorrelator for ultrashort pulse diagnostics.

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