УДК 802.0:62

NONLINEAR CRYSTAL FOR VACUUM ULTRAVIOLET

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Half a hundred years ago the laser was invented. Since then the engineers dreamed to cover the entire spectral range with coherent laser radiation, i.e. to obtain laser radiation at arbitrary wavelength. First of all, they obtained the radiation that covered all the visible part of spectrum. Then they managed to cover the near infrared part of the spectrum with coherent radiation. At last, with larger difficulties, they covered with coherent radiation the ultraviolet part of spectrum and penetrated into the vacuum ultraviolet (VUV, 200 nm), that is, the spectral region where the radiation is absorbed even in the air.

The main problem associated with the conversion of radiation into VUV is the absorption with the nonlinear crystals. For instance, the excellent nonlinear crystal for visible spectral range named Potassium Titanyl Phosphate (KTP) has the fundamental absorption limit at 350 nm. Another widely used nonlinear crystal, β-Barium Borate (BBO) is transparent till 190 nm. But the shortest wavelength where fundamental absorption starts, was found in Strontium Tetraborate (SBO); this wavelength equals to 125 nm. This is the motivation for studying this nonlinear crystal and the processes of nonlinear optical radiation conversion in it.

One of the methods to obtain efficient nonlinear conversion is called angular phase matching. The nonlinear conversion is a coherent process, and since then it requires the consideration of the interacting radiation phase. If the relative phase of laser radiation and generated radiation is favourable, then energy is transferred from laser radiation to the generated radiation. If the phase in not favourable, then backward transfer takes place. Therefore, for efficient conversion the relative phase must keep the same value along all the length of the nonlinear crystal. This is achieved by choosing strictly definite direction of laser propagation insight the anisotropic nonlinear crystal. However, not all nonlinear crystals are anisotropic enough to enable the existence of angular phase matching. Unfortunately, this is the case of SBO, and until 2007 no prospects for enhancement of nonlinear conversion could be seen.

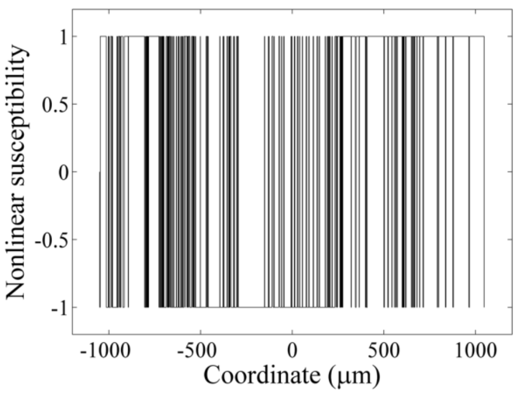

Fig.1. Domain thickness in the sample of SBO.

In 2007 the physicists from Krasnoyarsk Institute of Physics discovered that the samples of SBO can contain the so called domain structures with opposite orientation of atoms in one domain with respect to another. These structures are attractive for nonlinear optics since every domain generates the radiation with the phase shifted relatively to the neighbours, and this phase shift can be used for compensation of the phase mismatch. The studies revealed that domains are plate-shaped with domain walls perpendicular to crystal axis *a*. The dimensions of domains along directions of *c* and *b* axes can be up to 1 cm, providing large aperture for propagation of laser radiation. However, the thickness of domains in *a* direction is a random value and varies from tens to tenths of micron, as one cane see from Fig.1.

When laser radiation propagates normally to the domain walls, one may expect the enhancement of nonlinearly generated radiation due to partial phase matching along the thickness of domain structure. It should be noted that in this case the generated radiation propagates strictly collinearly to the incident laser radiation. The experiment was performed with the domain structure that contained 262 domains. The overall thickness of domain structure was 2.3 mm. Initially no phase matching effect was detected at zero incidence angle, but when the sample was rotated by 10 degrees, 500 times enhanced generation was observed. It means that at normal incidence the interference of radiation generated by all domains in the definite random structure is mainly destructive. The variation of the incidence angle allows tuning of the relative phases and turns this interference into a constructive one. The possibility of angular tuning of the domain structure is illustrated in Fig.2.

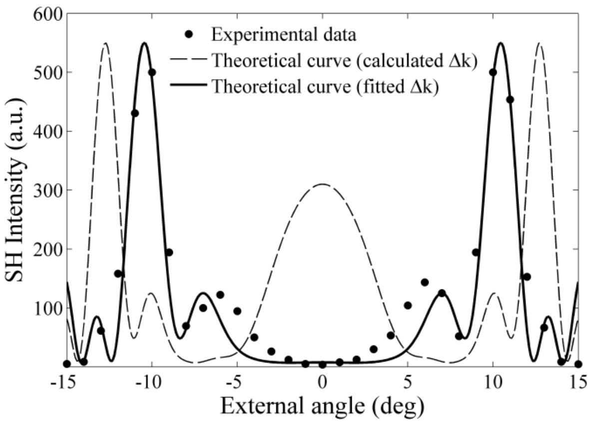

Fig.2. Angular tuning of domain structure for nonlinear optical conversion. (532 nm->266 nm).

When the laser radiation propagates in the plane of domain walls, the phase of nonlinearly generated radiation becomes modulated. This results in diffraction of generated radiation, in full analogy with phase diffraction grating. In this case the generated radiation propagates obligatorily non-collinearly to the incident laser radiation. In the experiment a femtosecond laser was used with the central wavelength of 800nm. Its radiation was focused into the domain structure with 5 cm focal length lens. The picture of the nonlinear diffraction is demonstrated in Fig. 3.

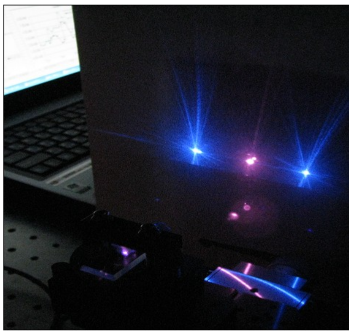

Fig.3. Nonlinear diffraction in the domain structure of SBO.

In conclusion, domain structures in SBO are promising medium for the nonlinear conversion of lasers to the VUV. However, the development of the SBO growth is necessary for further improvement of the operational characteristic of laser converters based on SBO.