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Anisotropic Cherenkov light generation by intense ultrashort light pulses in glass

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Abstract: Anisotropic Cherenkov ultraviolet light generation peaking in the plane of polarization of intense pump is observed. The phenomenon represents a first evidence of anisotropic diffusion of photoelectrons in isotropic condensed matter and could be used for optical encoding.

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Progress in high power ultrashort pulse lasers has opened new frontiers in physics and technology of light-matter interactions. Recent discoveries span from coherent X-ray generation [1] and nonlinear Thomson scattering [2] to anomalous anisotropic light scattering [3] and direct writing of 3D photonic structures [4-6]. In this paper we report the observation of a new phenomenon - anisotropic ultraviolet generation in the form of anisotropic Cherenkov radiation peaking in the plane of polarization of intense infrared light. The phenomenon is interpreted as a first evidence of anisotropic diffusion of photoelectrons in isotropic condensed matter. It also represents a unique optical phenomenon in which information on light polarization is revealed macroscopically via enhanced light generation that could be used for optical encoding.

In the experiments we used regeneratively amplified mode-locked (120 fs pulse duration, 1 kHz repetition rate) Ti:Sapphire laser operating at 800 nm wavelength. The laser radiation in Gaussian mode was focused via a lens into fused silica (SiO_2) glass sample (Fig. 1). The radiation after passing through the sample was imaged on a screen of white paper.

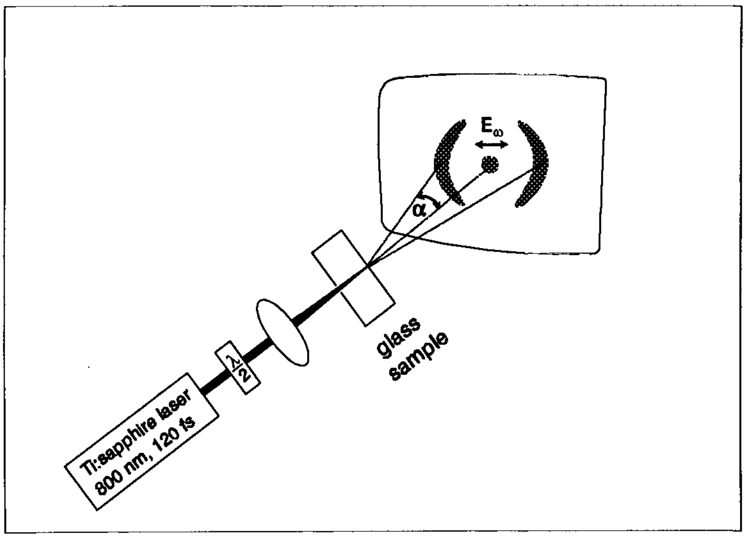

Fig. 1. Schematic of the experiment.

Unexpectedly, when radiation (0.4 μJ energy, 4 mW average power, 33 MW peak power, 2.1×10^{13} W/cm^2 intensity in the focus of a beam) was focused closer to the output surface of the sample we observed an appearance and intensification of a spectacular blue light pattern on the screen. The pattern consisted of two crescent-like lobes on both sides of the pump, along the direction of light polarization (Fig. 2). The intensity of light in the pattern increased in time and saturated after about 10 seconds of irradiation. Ultraviolet radiation generated in the sample is responsible for the observed pattern, which is visualised on the screen via luminescence of the paper in the blue spectral range. Analysing the spectrum of radiation from the output of the sample we confirmed the presence of 267 nm ultraviolet light, which is the third-harmonic of the pump at 800 nm. We measured the angle between the direction of propagation of the crescent-like ultraviolet light and the pump of about 21.6° (Fig. 2). The Cherenkov angle of the third-harmonic propagation is estimated to be 20.9° using $n_{267nm}= 1.499$ and $n_{800nm}= 1.453$ for fused silica, which confirms that the crescent-like light is generated via Cherenkov mechanism of third-harmonic generation.

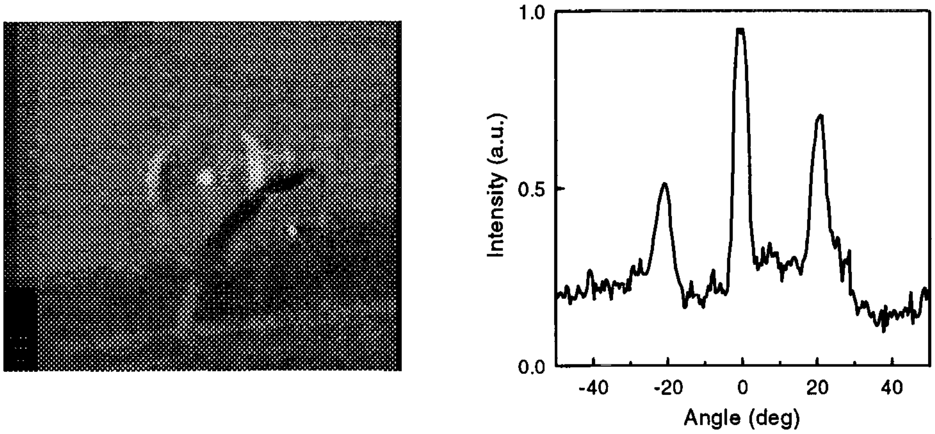

Fig. 2. The pattern of ultraviolet light generated in fused silica sample. A silhouette of the sample could also be seen (left). The angular distribution of generated light (right). Notice that the lobes are located on both sides, along the polarization of the pump.

The Cherenkov mechanism of the third harmonic generation gives clear indication that transverse surface discontinuities appear in the medium under intense irradiation. The anisotropic distribution of the Cherenkov light with a maximum in the plane of pump polarization, in contrast to isotropic "Cherenkov cone", indicates that the surface discontinuities appear only along the direction of polarization of intense light.

We believe that the transverse anisotropic boundary in glass can be induced as a result of the anisotropic diffusion of photoelectrons along the direction of light polarization. Strong electric field of intense light forces photoelectrons to move along the direction of electric field of light wave (e.g. via tunnelling process between electron traps), which results in the abrupt change in the concentration of electron-driven defects in glass along this direction. This process could be expressed as an increase of electron mobility along the polarization of intense light and could be used for optical encoding.

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