We present results of experimental and theoretical studies of the formation of refractive index voxels in photorefractive crystals with high power femtosecond laser pulses. We used 150fs pulses at 800nm wavelength (energy 6-130nJ) tightly focused inside the iron-doped lithium niobate crystal in a single shot regime [1]. This resulted in a formation of a micrometer size ($2\times2\times8\mu m^3$) region of elevated refractive index which may be used as memory bits in information storage/retrieval application [2]. The index contrast as high as $10^{-3}$ has been obtained with an average light intensity of ~Tw/cm$^2$ that is close to the breakdown threshold in dielectrics [see Fig.1(a-b)]. The writing process is independent of the polarization of the laser beam and is fully reversible. Once written local modulation of the refractive index can be removed (erased) by the action of a low intensity broad beam and induced again at the same place (re-written) by using a tightly focused pulse. Up to 20 same-spot rewriting cycles have been performed without any deterioration of the recorded bits. Moreover, by moving the crystal in vertical direction few independent layers of memory dots have been recorded [see Fig.1(c)]. In this talk we discuss various aspects of the recording/erasing process including mechanisms of laser absorption, electron excitation and recombination, formation of charge separation field, as well as methods for control of the size and longevity of the refractive index changes. The analysis shows that the photovoltaic effect [3] is mainly responsible for these changes. The presented results suggest the possibility of suitability of properly chosen femtosecond pulses for fast 3D write-read-erase optical memory application.

Fig.1. (a) Transmission image of voxels recorded by a single-pulse irradiation at 50 µm depth in Fe: LiNbO$_3$. Polarization of recording beam along the c axis; imaging nonpolarized; separation Δy between recording spots is marked in each line. (b) Cross section of the transmission along several recorded lines. (c) Layered recording of bits forming letters A, T, and Y using objective lens of numerical aperture NA=1.4, plane separation 3 µm, and pulse energy 6 nJ.

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