NUMERICAL SIMULATION TECHNIQUES FOR THE PROCESSING OF NONLINEAR REFRACTIVE INDEX MEASUREMENTS

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When a material interacts with intense light its refractive index depends on the intensity of radiation. This dependency is described by a substance parameter called nonlinear refractive index (n_2). This parameter is responsible for many phenomena of nonlinear optics and in modeling such phenomena it is important to know the most precise value of n_2. Popular methods for measuring n_2, like Z-scan [1], are based on the assumption that the temporal and spatial intensity distributions of the laser radiation are in the form of a Gaussian function. In practice this is sometimes difficult to fulfill, especially in the infrared (IR) wavelength range between 2μm and 5μm, where there is a shortage of information about n_2. Therefore, a method for measuring n_2, which could include real spatial and temporal intensity distributions, is of great importance.

In this work it was chosen to measure n_2 by using an interferometer to detect a total on-axis nonlinear phase shift (*B*) after a sample and including measured spatial and temporal intensity distributions by numerically simulating the experiment. First, a theoretical model of a measurement was created. It was assumed that two identical linearly polarized waves with a plane wavefront are propagating at a small angle (as shown in Fig. 1). Wave1 propagates through a sample with n_2 and then is imaged on a charge-coupled device (CCD) matrix of a camera by two converging lenses of the same focal length, without any energy (*E*) loss and change in peak intensity. Both waves reach camera at the same time and an interference intensity pattern is formed in a form of fringes. Here *B* was found by fitting spatial intensity distribution (which can be any function) of wave1 to a spatial phase difference between two waves distribution (obtained from an interference pattern using Fourier transform method [2])

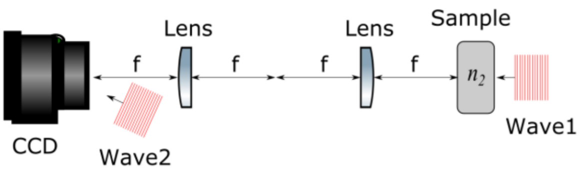

Fig. 1. Basic model of a measurement. Here f – focal length of a lens.

During numerical experimentation it was found that (because of temporal intensity modulation of a wave) this way obtained *B* value is less than the real value by some factor. This factor depends only on a shape of a laser pulse. Therefore, one can measure real pulse shape and then simulate the real experiment to correct the measured *B* values. This was demonstrated by building a real experimental setup, which realizes the model shown in Fig. 1, and measuring the n_2 of fused silica. The values of *B* were measured at different pulse energies. The results are shown in Fig. 2. Obtained *B* values were corrected according to the measured pulse shape and the n_2 was found from linearly fitted experimental data. Measured n_2 value was in good agreement with the ones given in the scientific literature.

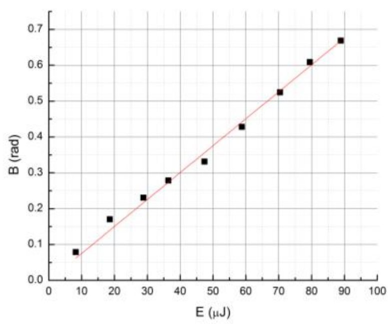

Fig. 2. Total on-axis nonlinear phase shift measuring results. Dots – experimental points, line – linear fit.

In conclusion, a method to include real temporal and spatial intensity distributions of light in n_2 measurements was successfully prepared and tested. It could be used to measure n_2 in the IR wavelength range between 2μm and 5μm, where such measurements are needed.

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[2] Mitsuo Takeda, Hideki Ina, and Seiji Kobayashi, "Fourier-transform method of fringe-pattern analysis for computer-based topography and interferometry," J. Opt. Soc. Am. **72**, 156-160 (1982).