Nonlinear optical properties of semiconductor thin films and multilayer structures containing such films

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Refraction and absorption indices dependencies on the optical field intensity for deposited thin films of certain semiconductors and some other materials in the near-infrared range have been experimentally obtained by using Z-scan technique. Multilayer structures containing such films with high nonlinear coefficients as one or several constituent layers are very promising in the context of low-threshold nonlinear optical devices.

Keywords—nonlinear optics, Z-scan, optical limiting

Traditional semiconductors, such as Ge and Si, on the one hand possess a small linear absorption index and very high rate of refraction index, on the other hand show the strong dependence of these indices on the incident light intensity in the near-infared, i.e. near absorption region. High coefficients of optical nonlinearity allow to make an estimation of them by the Z-scan method even for the thin films which optical thickness is close to light wavelength.

Including of non-linear materials films in composition of multi-layer structures, such as Fabri-Perot's microresonator allows to expect creation of the low-threshold optical limiter for some resonant wavelength. The spectral position of resonant wavelength is defined by the resonator length, i.e. optical thickness of the middle layer.

In the linear mode (for the low-intensity light) the considered multi-layer structure is the narrowband spectral filter which maximum of transmittance is on the resonant wavelength. Thus intensity of light on the resonant wavelength in the middle layer repeatedly exceeds intensity of the incident light, i.e. essential change of refraction and absorption indices of the middle layer requires rather low intensity of external light.

A deviation of a middle layer's refraction index brings to change of its optical thickness and to spectral offset of the transparency line as a result. Increase in absorption brings to reduction of transmittance coefficient in a maximum of the transparency line. Thus, both effects lead to transmittance falling for initially resonant wavelength with growth of intensity of the incident light, and it occurs generally because of increase in reflection, instead in absorption.

Nonlinear characteristics of structure as a whole are absolutely other than nonlinear characteristics of the central layer, but the knowledge of the last ones allows us to calculate nonlinear characteristics of structures with different parameters by specially developed computer program. Therefore determination of non-linear parameters of a single films is an important creation stage for multi-layer structures with desirable nonlinear characteristics. Even in the availability of literary information about non-linear coefficients of a researched material on the required wavelength, it is necessary to research thin put-films because values of non-linear coefficients for the films can differ strongly from their values for a volume material, and also they depend on plotting conditions.

Z-scanning is a simple method for finding of non-linear parameters on the given wavelength by means of a single laser bundle. However receiving result for thin films by Z-scanning is possible only in case of great values of non-linear coefficients. Otherwise in case of those values of intensity which already give an optical breakthrough of the film, available to measure deviation of refraction or absorption indices doesn't happen yet.