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Original Research Article

Study of nonlinear optical properties of Nd doped silica glasses using Z-scan technique

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ABSTRACT
This study uses the Z-scan method to examine the nonlinear optical characteristics of glasses that have been doped with neodymium. By using the sol-gel method, the samples were made with varying weight percentages of neodymium in silica. The range of the weight percentage was 0.1% to 0.2%. Tetra ethyl ortho silicate (TEOS), ethanol, water, HCl, and formamide were used in the following proportions to create five samples: 1:4:4:0.01:1. The samples were maintained for a month to dry. The samples were subjected to open and closed aperture z-scan studies to examine the non linear characteristics. At a wavelength of 530 nm, the nonlinear absorption coefficient of neodymium doped silica glasses was calculated. The solid matrix is favoured from the standpoint of device application since it gives the nonlinear medium stiffness and makes handling easier.

1. Introduction

There are several optical and magnetic uses for rare earth (RE) ions. Among these, single crystal, powder, and glass-based luminous devices have proved particularly significant [1]. In the 4f level structure, RE ions have optical transitions that are essential for the creation of optical amplifiers and phosphor materials. An easy, accurate, and well-liked experimental methodology for determining materials' intensity dependent nonlinear optical (NLO) characteristics is the z-scan method [2, 3]. This technique aids in determining the direction and size of the third order NLO susceptibility's real and imaginary components. The results of the open aperture z-scan tests show that a sample has nonlinear absorption. The full light coming from the sample is caught in the open aperture z-scan. Here, the output intensity is solely affected by the sample's nonlinear absorption (NLA), and the collected data may be used to determine the imaginary component of the susceptibility tensor. For the beam profile to not fluctuate significantly inside the sample, the sample thickness is kept below the Rayleigh range. At the focal point, a transmission minimum is reached if NLA, such as two photon absorption (TPA), is present. At the focal point, transmission rises if the sample is a saturable absorber. A sample with linear absorption is represented as a z-scan.

2. Sample preparation

By using the sol gel technique, the samples are created with various weight percentages of Nd in silica [4, 5]. The range of the weight percentage ranges between 0.1% to 0.2%. Tetra ethyl ortho silicate (TEOS), ethanol, water, HCl, and formamide are used in the following proportions to create five samples: 1:4:4:0.01:1. The samples are maintained for a month to dry.

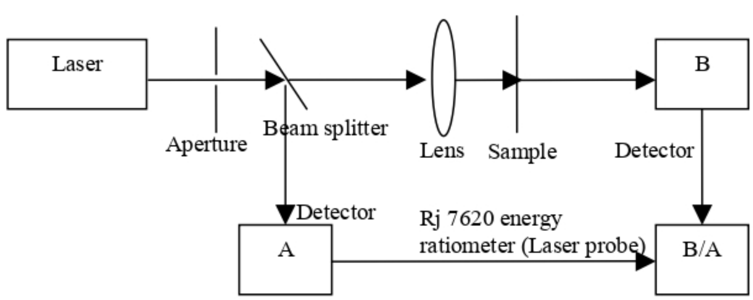

Figure 1. Experimental arrangement.

3. Experimental procedure

The samples are subjected to open aperture z-scan studies to examine the non linear characteristics. A Q-switched Nd: YAG laser pumps 530 nm nanosecond pulses from a QuantaRay MOPO for use in the experiments. With the aid of the LABView software, the data received using the energy ratiometer is recorded. A transmission minimum is seen at the focal point as a result of the sample's reverse saturable absorption. Figure 1 depicts the experimental setup in detail.

The theory of the z scan experiment is given in Ref. [2]. The intensity dependent NLA coefficient $\alpha(I)$ can be written in terms of the linear absorption coefficient α and the TPA coefficient β as:

$$\alpha(I) = \alpha + \beta I. \tag{1}$$

The irradiance distribution at the exit surface of the sample of length l is:

$$I_r(z,r,t) = \frac{I(z,r,t)e^{-\alpha l}}{1+q(z,r,t)} \tag{2}$$

where $q(z,r,t) = \beta I(z,r,t) L_{eff}$. (3)

The effective length may be expressed as:

$$L_{eff} = \frac{1-e^{-\alpha l}}{\alpha}. \tag{4}$$

The total transmitted power is given as:

$$P(z,t) = P_l(t)e^{-\alpha l}\frac{\ln[1+q_0(z,t)]}{q_0(z,t)}, \tag{5}$$

where

$$P_l(t) = \frac{\pi\omega_0^2 I_0(t)}{2}, \tag{6}$$

and

$$q_0(z,t) = \frac{\beta I_0(t) L_{eff} z_0^2}{z^2+z_0^2}. \tag{7}$$

For a pulse of Gaussian temporal profile, Eq. (5) can be integrated to give the transmission as:

$$T(z) = \frac{C}{q_0\sqrt{\pi}}\int_{-\infty}^{\infty}\ln(1+q_0 e^{-t^2})dt . \tag{8}$$

NLA coefficient is obtained from fitting the experimental results using Eq. (8).

If $|q_0| < 1$, then

$$T(z, s=1) = \sum_{m=0}^{\infty}\frac{[-q_0(z,0)]^m}{(m+1)^{3/2}}. \tag{9}$$

From the oopen aperture z-scan, the nonlinear β can be unambiguously deduced.

4. Results and discussion

On samples at 530 nm, open aperture z-scan tests are carried out with varied laser energy levels. A plot similar to that in Figure 2 is created, and the linear and nonlinear absorption coefficients are assessed using theoretical fitting. The third order nonlinearity resulting from reverse saturable absorption is confirmed by the drop in the z-scan figure. The outcome is tallied.

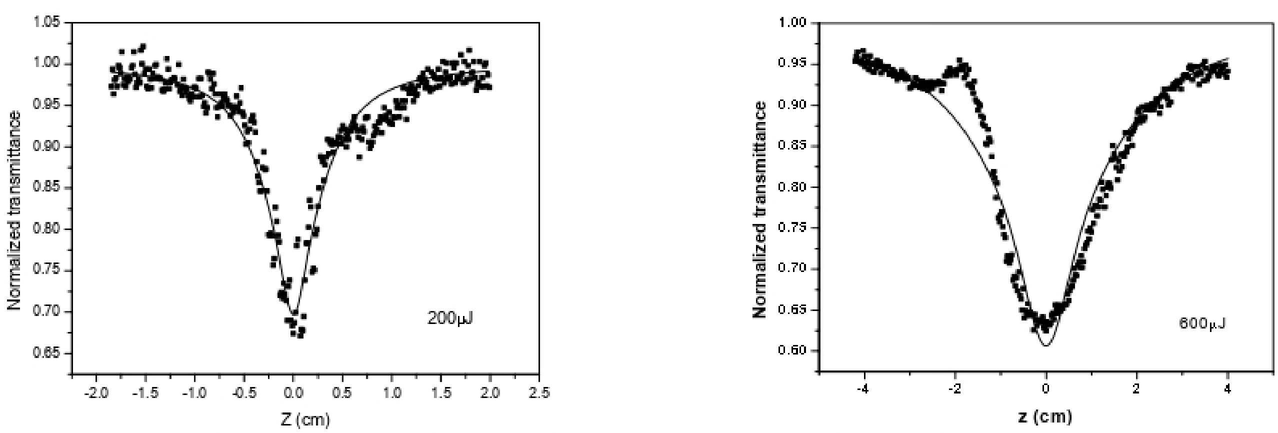

Figure 2. Open aperture z-scan plot (theoretical and experimental) of Nd doped silica glass (0.12wt%).

Table 1: Nonlinear parameters obtained for 0.12 wt% Nd doped silica glasses

α (cm^{-1})	E (μJ)	I_0 (W cm^{-2})	β (cm W^{-1})
10.458	200	7.286×10^{8}	3.40×10^{-8}
	600	21.86×10^{8}	1.31×10^{-8}

5. Conclusions

Using the open aperture z-scan technique, the nonlinear absorption coefficient β of Nd doped silica glasses at 530 nm has been calculated. On the device application point of view the solid matrix is preferred as it provides rigidity to the nonlinear medium and the handling is more convenient.

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