Institute of Solid State Physics, Bulgarian Academy of Sciences
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Nonlinear Optical Properties of Borosilicate Glasses with Silver Nanoparticles for Photonic Applications

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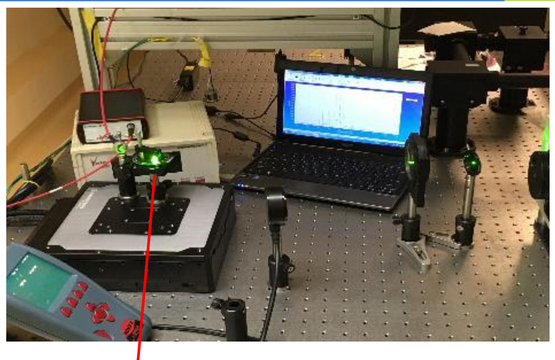
Introduction

Advantages of Glasses in Nonlinear Optics
Glasses provide significant advantages over single crystals and polycrystals, primarily due to their ability to exhibit **second-order nonlinearity** by breaking macroscopic symmetry. Combined with their broad transmission window and versatile processing capabilities, glasses are highly suitable for modern optoelectronic applications.
Benefits of Femtosecond Lasers
Femtosecond lasers are particularly effective in nonlinear optics because of:
1. **Minimal thermal impact** – ultrashort pulses suppress heat diffusion, preserving the material's structural integrity;
2. **Enhanced nonlinear effects** – the high peak intensities amplify processes such as second- and third-harmonic generation (SHG, THG);
3. **Precise polarization control** – stable management of polarization is critical for reproducible optical properties and for optimizing nonlinear interactions.
4. **Study on Filament Formation**

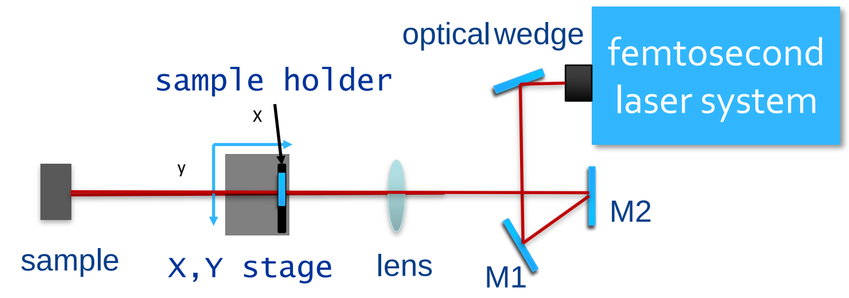
This study investigates filament formation in **silver-ion-doped glasses**, transparent in the visible spectral range, under femtosecond laser irradiation. The results provide deeper insights into the mechanisms of nonlinear interaction and self-focusing, supporting the development of advanced, high-efficiency photonic technologies.

Experimental setup configuration



Pulse width	<35 fs
Pulse energy	> 6 mJ
Repetition Rate	1 kHz
ACE	800 nm
Pulse energy	440 nJ

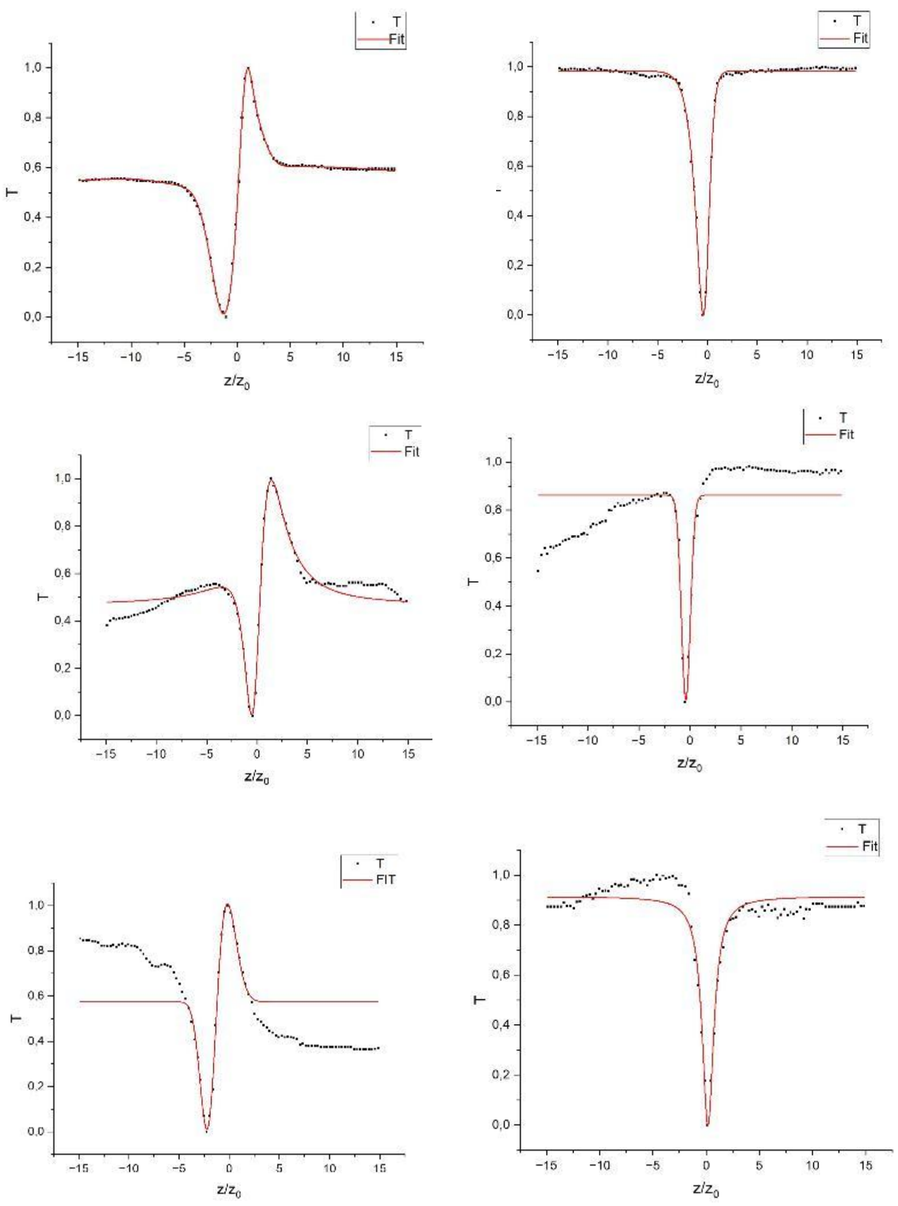
Schematic drawing



A **modified Z-scan method** was applied to synthesized glasses, enabling **simultaneous evaluation** of the nonlinear refractive index (n_2) and the absorption coefficient (β). The technique relies on the conversion of phase to amplitude distortion during beam propagation and provides higher accuracy and reliability compared to the classical setup.

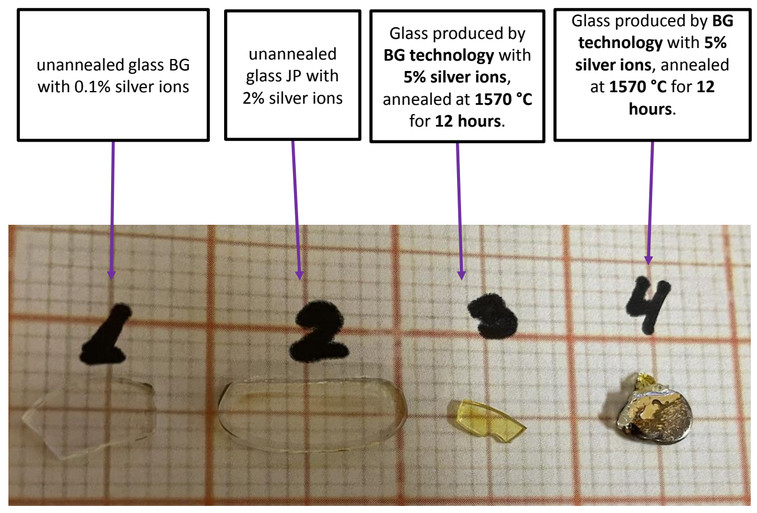
Results

non-linear research and results



- **1. Objective:** The aim of the study was to investigate the **multiphoton absorption coefficient** and the **nonlinear refractive index** in different glasses doped with silver ions. Three types of samples were examined: (i) a reference glass produced using standard technology without doping, (ii) glass doped with silver ions, and (iii) silver-ion-doped glass subjected to annealing. The experiments were carried out with a pulse energy of **440 nJ** and a pulse duration of **35 femtoseconds**.
- **2. Methodology:** The laser beam was focused to a waist radius of ρ_o = 35 µm using a lens with a focal length of 25 cm. The resulting beam profile closely corresponded to a circular Gaussian distribution with M^2 = 1.3.**3.**
- **Results:** During the experiments, no significant differences were found in the nonlinear refractive index and the multiphoton absorption coefficient between the samples, which is likely due to the low concentration of silver ions. However, in the doped and annealed glasses, **yellow coloration** was observed, confirming the restructuring and formation of crystalline structures. Additionally, the generation of second harmonic in these glasses further confirms the presence of crystalline structure.
- **4. Conclusion:** The absence of substantial differences in nonlinear optical properties indicates that the concentration of **silver ions** is a critical factor influencing these characteristics. However, the observed **yellow coloration** and the generation of second harmonic in the doped and annealed samples confirm the presence of structural changes and the formation of crystalline structures.

Glass samples



Project and Acknowledgements

Scientific team
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