X International School and Conference on Photonics
August 25 - August 29, 2025, Belgrade, Serbia

Nonlinear Optical Properties of Poly-Lactic Acid (PLA) for Photonic Applications

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Introduction

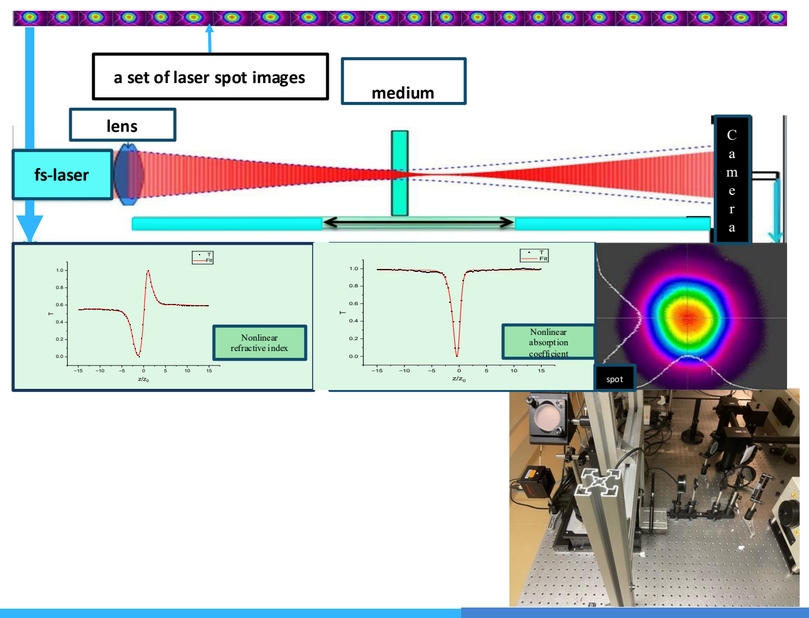
Poly-Lactic Acid (PLA)
PLA is a biodegradable polymer with high optical transparency in the UV and NIR regions and excellent processability, making it attractive for photonic applications.
Key Applications:
Integrated photonics: Suitable for waveguides and photonic crystals due to low losses and broad transmission.
Sensors: Biocompatibility and optical clarity support use in optical and biosensing platforms.
Nonlinear optics:
Z-scan measurements under femtosecond laser excitation (35 fs, 408 nJ) reveal a nonlinear refractive index and **multiphoton absorption** comparable to borosilicate glass and much higher than fused silica.
PLA also exhibits filamentation at low pulse energies, enabling its use in harmonic generation, switching, and nonlinear optical devices.

Main objectives

- ✓ **Observation of nonlinear effects induced by femtosecond laser pulses in synthesized transparent polymer layers of poly-lactic acid (PLA).**
- ✓ **Adjustment, optimization, and calibration of the Z-scan technique for determining the nonlinear parameter – the nonlinear refractive index.**

Method

A modified Z-scan technique was employed to characterize the nonlinear optical properties of transparent poly-lactic acid (PLA) biopolymer layers. The modification involves the implementation of femtosecond laser pulses (replacing conventional pico- and nanosecond sources) and the substitution of the standard aperture-detector setup with a camera-based optical detection system. This approach enables the transformation of phase distortions into measurable amplitude variations during beam propagation, enhancing spatial resolution and sensitivity in nonlinear parameter extraction.

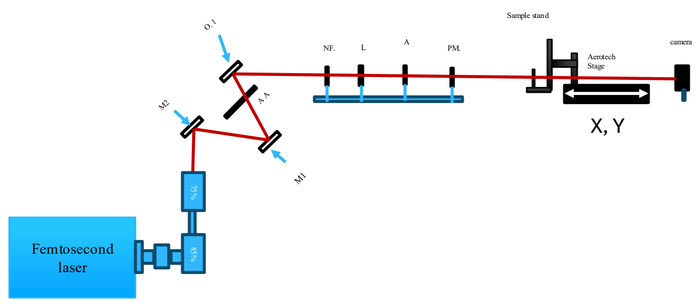


How?
Nonlinear processes—self-focusing and multi-photon absorption

⬇ **can be measured** the nonlinear refractive index *n*2 and the multi-photon absorption coefficient β

⬇ **by changing** the intensity (diameter) of the Gaussian laser beam by focusing the beam

Experimental setup configuration

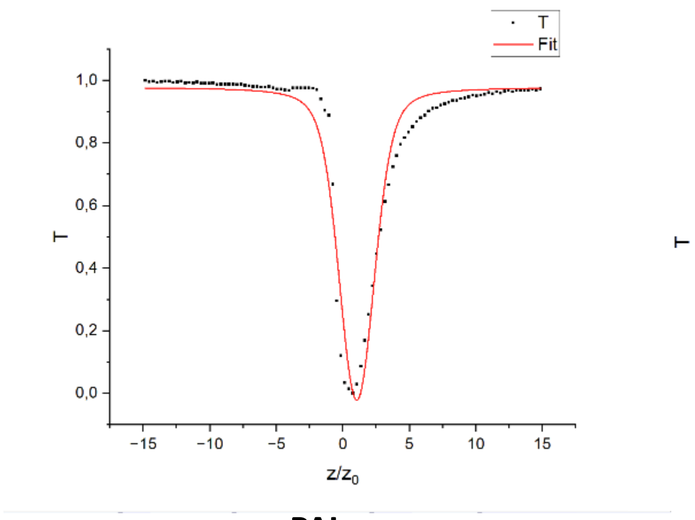


1. **Femtosecond laser** – Spitfire Ace, 35 fs pulse duration, adjustable energy from 30 to 500 nJ.
2. **Beam splitters (x2)** – sequential attenuation of beam intensity (85% and 75%).
3. **Wedge prism** – 2% deviation, used for energy monitoring and calibration.
4. **Mirror** – low-GDD mirror for precise beam steering.
5. **Focusing lens** – creates a beam waist at 25 cm.
6. **Sample (PLA layer)** – positioned along the Z-axis for scanning.
7. **Precision stage AEROTECH (PlanarDL)** – XYZ positioning with 3 nm resolution.
8. **Camera** – records the transmitted beam intensity profile.
9. **Software and visualization** – real-time spot fitting and nonlinear parameter extraction (n_2, β).
10. **Mounting** – the entire system is installed on an AEROTECH optical table with vibration isolation.

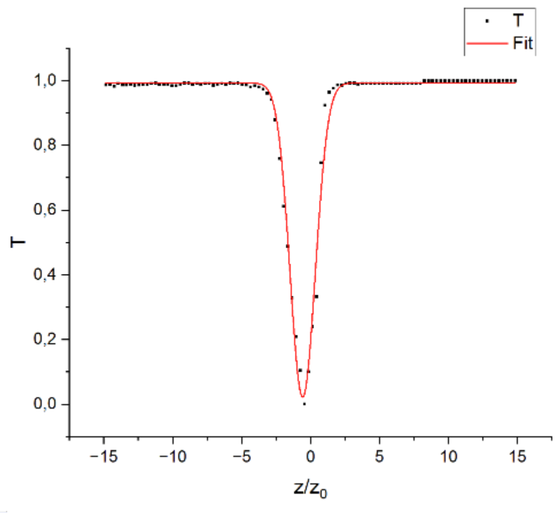
Pulse width	<35 fs
Pulse energy	> 6 mJ
Repetition Rate	1 kHz
ACE	800 nm
Pulse energy	408 nJ
Laser spot	10 mm
Focal length	250 mm
Z step	300 µm
Effective camera area	23 mm x 23 mm

Results

Nonlinear refractive index n_2

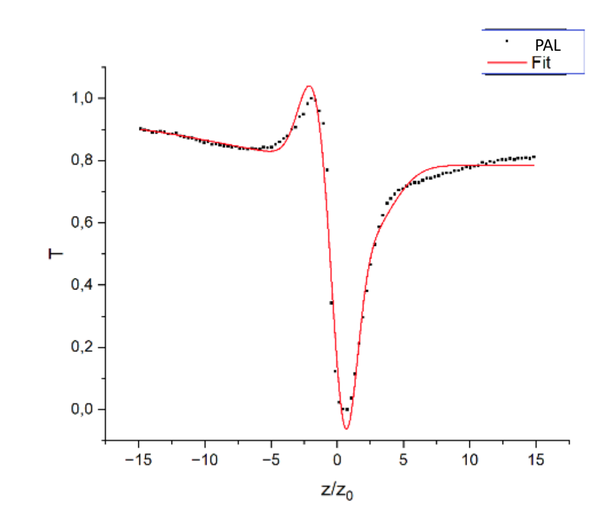


PAL

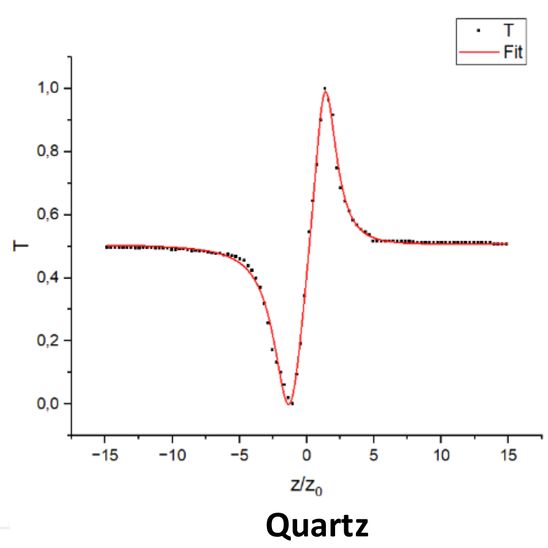


Quartz

Nonlinear absorption β



PAL



Quartz

Nonlinear coefficients	Quartz (0.5 mm thickness)	PAL (0.86 mm thickness)
n_2 [m^2/W]	5.569e-20	8.8e-19
β [m/W]	6.4e-14	9.1e-12

Acknowledgements

This research was funded by the This work was supported by the Extreme Light Infrastructure – European Research Infrastructure Consortium (ELI ERIC), under contract DO1-102/26.06.2025.