Unraveling the Dual Nature of Nonlinear Absorption under Varying Laser Intensities

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Abstract

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Keywords: Norbixin; Z-scan Technique; Third-order Optical Nonlinearity; Nonlinear Optics;

Introduction

Two-photon absorption (2PA)

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Three-photon absorption (3PA)

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Objectives

The aim of this Research is to :

- Determine the process of absorption.

Methodology

- Higher order nonlinearity OA transmission [5]:

$$T_{mPA}(z) = 1 - \frac{\alpha_m I_0^{m-1} L_{\text{eff}}^{(m)}}{(1+z^2/z_0^2)^{m-1}} \frac{1}{m^{3/2}} \quad (1)$$

$m \rightarrow$ the order of absorption
$I_0 \rightarrow$ laser incident intensity
$L_{\text{eff}}^{(m)} = \dfrac{1-\exp\left(-(m-1)\alpha_0 L\right)}{(m-1)\alpha_0}$
$z_0 \rightarrow$ Rayleigh length

- Normalized Transmittance at $(z = 0)$ determined from equation (1).

$$T_{2PA} = 1 - \alpha_2 I_0 L_{\text{eff}}^{(2)} / 2^{3/2} \quad (2)$$

$$T_{3PA} = 1 - \alpha_3 I_0^2 L_{\text{eff}}^{(3)} / 3^{3/2} \quad (3)$$

$\alpha_0 \rightarrow$ linear absorption coefficient
$\alpha_2 \rightarrow$ 2PA coefficient
$\alpha_3 \rightarrow$ 3PA coefficient

- χ^2 is calculated by

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i} \quad (4)$$

$O_i \rightarrow$ observed value in category i
$E_i \rightarrow$ expected value in category i (from model)

- Null Hypothesis [H_0:] Observed non-linearity due to 2PA alone.
- Alternative Hypothesis [H_1:] Non-linearity suggests 3PA.

Results and Analyses

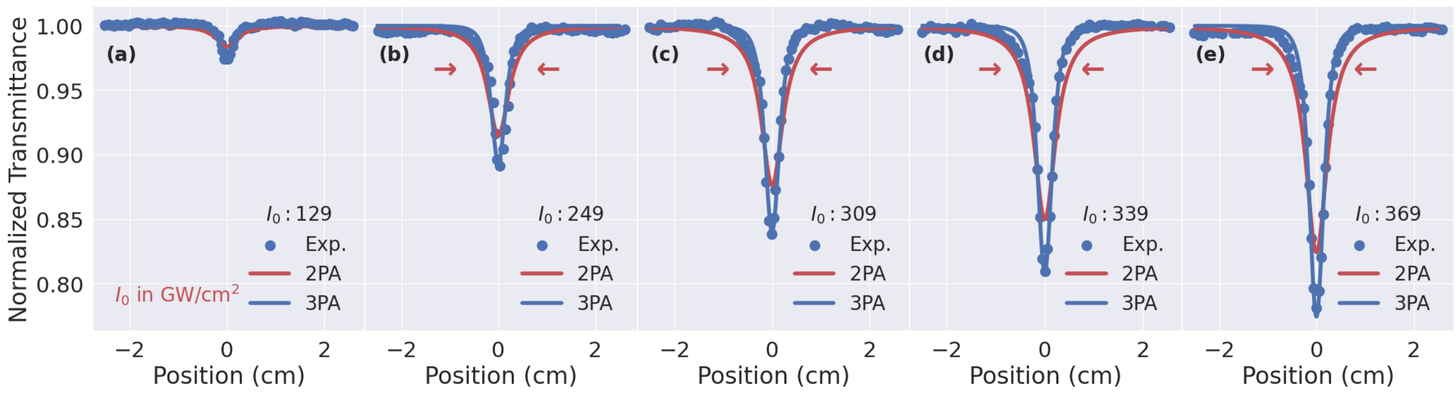

Figure 1: The Open Aperture Z-scan profiles with least square method of the material at different intensities.

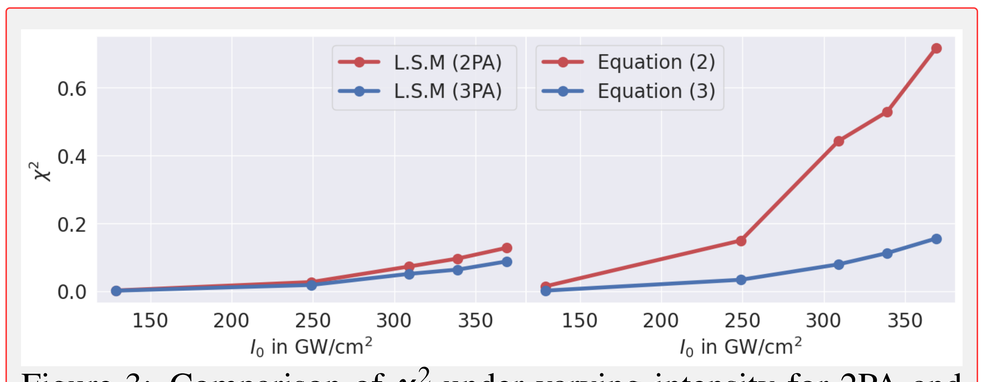

Figure 3: Comparison of χ^2 under varying intensity for 2PA and 3PA.

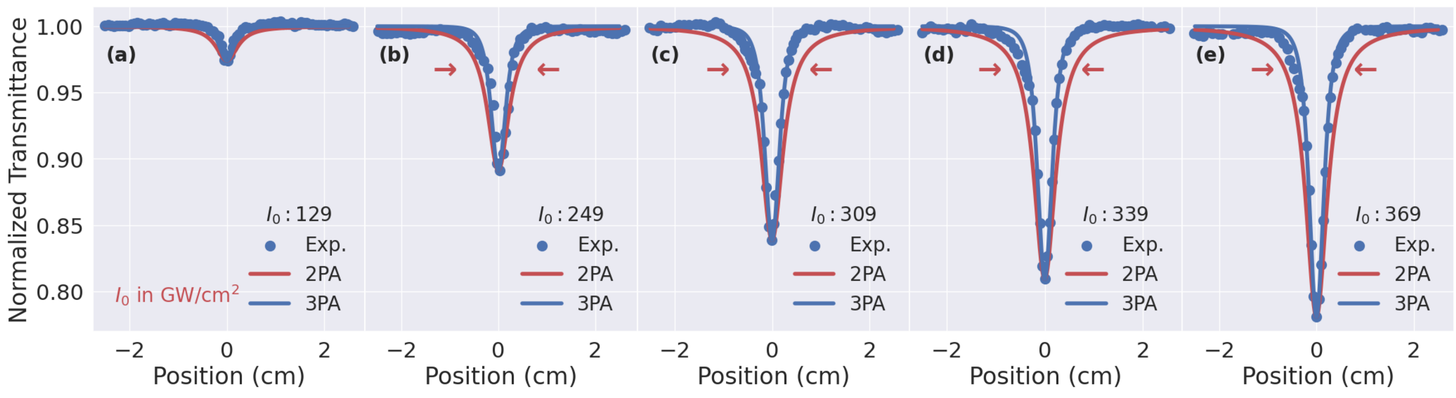

Figure 2: The Open Aperture Z-scan profiles with Eq^n-(2) and (3) of the material at different intensities.

Table 1: Calculations of χ^2, two (α_2) and three (α_3)-photon absorption coefficients.

I_0	χ^2 (2PA)		χ^2 (3PA)		α_2 (cm/W)		α_3 (cm^3/W^2)	
(GW/cm^2)	L.S.M	Eq^n-(2)	L.S.M	Eq^n-(3)	L.S.M ($\times 10^{-13}$)	Eq^n-(2) ($\times 10^{-23}$)	L.S.M ($\times 10^{-13}$)	Eq^n-(3) ($\times 10^{-23}$)
129	0.0025	0.0149	0.0019	0.0021	1.08	0.56	1.35	8.10
249	0.0273	0.1497	0.0187	0.0341	4.42	1.23	2.25	9.10
309	0.0731	0.4429	0.0514	0.0795	4.71	1.47	1.98	8.78
339	0.0966	0.5297	0.0641	0.1128	5.58	1.59	2.12	8.61
369	0.1281	0.7170	0.0880	0.1557	6.06	1.68	2.07	8.36

Summary

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References

1. Brito e Silva, N. J., et al. (2022). Third- and fifth-order optical nonlinearities of norbixin. *Results in Optics*, **6**, 100205.

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