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Study on Second and Third Order Nonlinear Optical Properties of Triglycine Sulpho Succinate Single Crystals

S.Nazarath Begam[1], A. Ayeshamariam[2], M.Sheik Dawood[3], S.H.Mohamed Ameen[4], M.Sivabharathy[5]

[1,4] Sadakathullah Appa College, Dept of Physics, Tirunelveli-627011, India
[2] Dept of Physics, Khadir Mohideen College, Adirampattinam (Affiliated to Bharathidasan University), Thiruchirappalli, 620 024, India
[3] Sethu Institute of Technology, Department of ECE, Pulloor-626115, India
[5] Sethu Institute of Technology, Department of Physics, Pulloor-626115, India

Abstract: A third orders nonlinear optical single crystals of Triglycine Sulpho Succinate (TGSSu) has been grown by slow cooling method. The grown crystals were characterized using X-ray diffraction analysis technique and its found the grown crystals in monoclinic structures.Thermal analysis of TGSSu crystal were carriedout and its compared to TGS crystal. The second harmonic generation efficiency was studied Kurtz-Perry powder technique. The third-order nonlinearities of grown crystals have been investigated by Z-scan method. Nonlinear refractive index (n2), the nonlinear absorption coefficient (β) and third-order nonlinear susceptibility (χ(3)) were estimated for the sample. The results were discussed in detailed.
Key words: TGS; single crystal; SHG; NLO; Third order nonlinear susceptibility

1. Introduction

Nonlinear materials have been broadly utilized for media transmission, optical gadgets, signal handling and capacity gadgets. Triglycine Sulfate (TGS) gems as one of the well known NLO material and its have flexible properties for different optoelectronic applications in the obvious and infrared otherworldly ranges and assumed a critical part in the progression of infrared indicators because of the presence of pyroelectric nature in the precious stone. Assortments of actual properties, for example, unconstrained polarization, piezoelectric and versatile properties of TGS precious stones were concentrated by different analysts [1-5]. Despite the fact that numerous scientists have considered the actual properties of TGS, those examinations don't call attention to how to make most extreme bit of leeway of TGS particularly in its function as a facilitator in the utilization of infrared identifiers. TGS is the main ferroelectric material that goes through stage progress above room temperature and accordingly more helpful than other ferroelectric materials in the use of infrared indicators. [6]. In this work, glycine, sulfuric corrosive and succinic corrosive were blended to frame Triglycine Sulpho Succinate (TGSSu) test. The point of this paper is to report and to talk about the subsequent request and third request nonlinear optical properties of

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Triglycine Sulpho Succinate single gems so it tends to be put to greatest utilization in various helpful applications.

2. Materials and methods

2.1 Synthesis, Solubility and Growth

Unique: A third request nonlinear optical single precious stones of Triglycine Sulpho Succinate (TGSSu) has been developed by moderate cooling technique. The developed gems were described utilizing X-beam diffraction investigation method and its found the developed gems in monoclinic structures.Thermal examination of TGSSu gem were carriedout and its contrasted with TGS gem. The second consonant age productivity was considered Kurtz-Perry powder strategy. The third-request nonlinearities of developed gems have been explored by Z-check technique. Nonlinear refractive list (n2), the nonlinear retention coefficient (β) and third-request nonlinear defenselessness (χ(3)) were assessed for the example. The outcomes were examined in itemized.

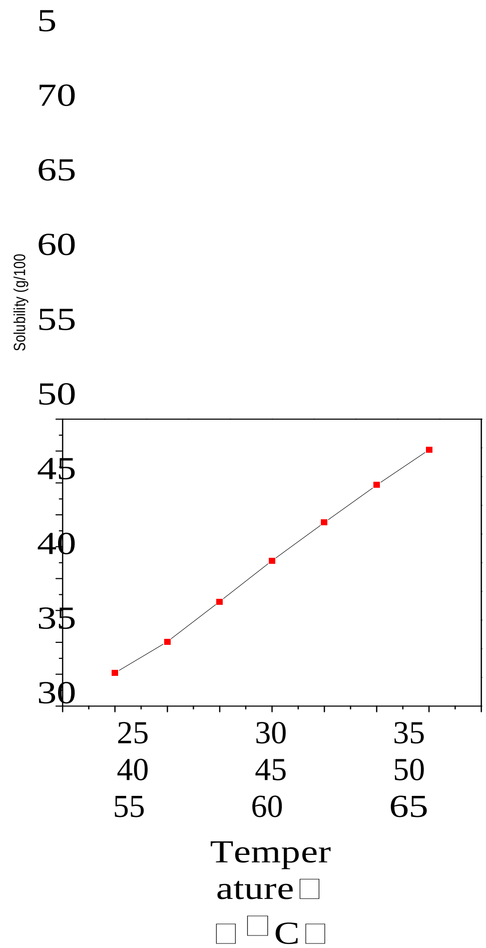

Figure 1 Solubility curve for TGSSu crystal

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Figure 2 Photograph of TGSSu crystal

2.2 Characterization Techniques

Single gem X-beam diffraction (XRD) contemplates were done on the become Succinic corrosive admixtured TGS precious stone by utilizing a Nonius CAD-4/MACH single gem X-beam diffractometer with MoKα radiation (α = 0.71073 Å). The hardness of the precious stone is estimated as the proportion of applied burden to the extended zone of space. The crack sturdiness, weakness record, Yield strength and versatile solidness coefficient of TGSSu precious stone were likewise determined by Vickers microhardness utilizing MATSUZAWAMMTZ-7 (Singapore) arrangement. Kurtz and Perry powder SHG test was done for the developed precious stone utilizing Nd:YAG Q-exchanged laser which discharges the primary symphonious yield of 1064 nm [8]. The third request NLO studies, for example, nonlinear refractive record, nonlinear ingestion coefficient, genuine and nonexistent pieces of the developed gems were determined by misusing Z-check method.

3. Results and discussions

3.1 X ray Diffraction

The developed precious stones have been portrayed by powder X beam diffractometer. Fig.3, speaks to the powder X-beam example of the developed TGS. The framework is found to display monoclinic structure with the space bunch P21/c and the cross section boundaries of tri Glycine sulpho succinate precious stone are a = 9.601 Å, b = 11.560 Å and c = 5.450 Å which are in acceptable concurrence with the writing [9].

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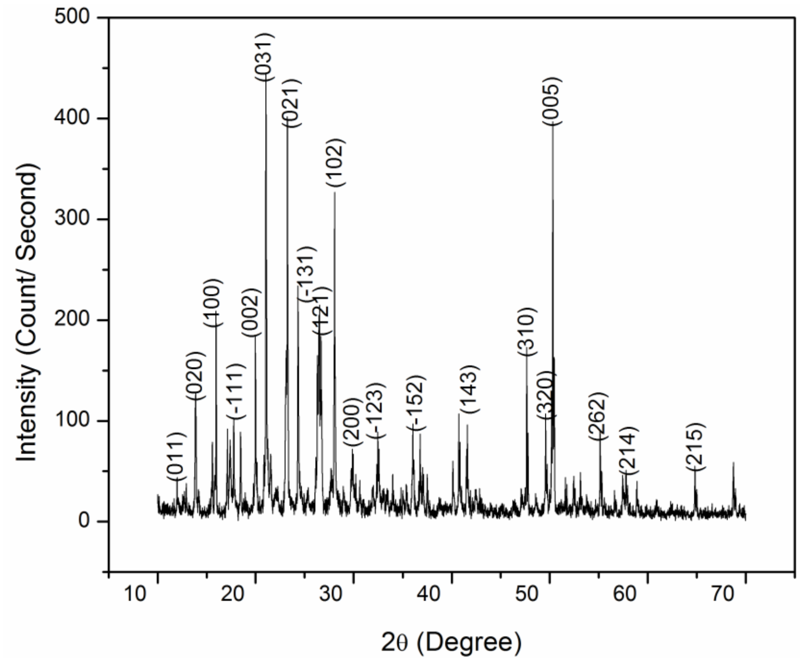

Figure 3 XRD pattern of TGSSu crystal

3,2 Thermal Analysis

TG/DTA bends of TGSSu developed precious stones are appeared in Fig. 4, TG and DTA concentrates on the developed precious stones have been completed utilizing SDT Q600 V 8.3 (Universal V4.7A TA) warm analyzer in the temperature range 30 ^{o}C to 1010 ^{o}C. The liquefying point temperature of the precious stones were resolved from the endothermic pinnacle showed up on TG/DTA bend, The rate mass change and remaining mass for TGSSu gem got from the bends. It is discovered that in closeness to the TGS crystal[10].

3.3 Mechanical studies

The microhardness contemplates were done to decide the mechanical strength of the developed TGSSu precious stone. The hardness worth should be autonomous of applied loadfor an ideal precious stone. The static spaces were made on the (010) substance of the gem by shifting the heap from 25 - 100 g at room temperature. The variety of microhardness number with various burdens applied to the example is given in the Fig.5, and it is seen that Vickers hardness number (Hv)

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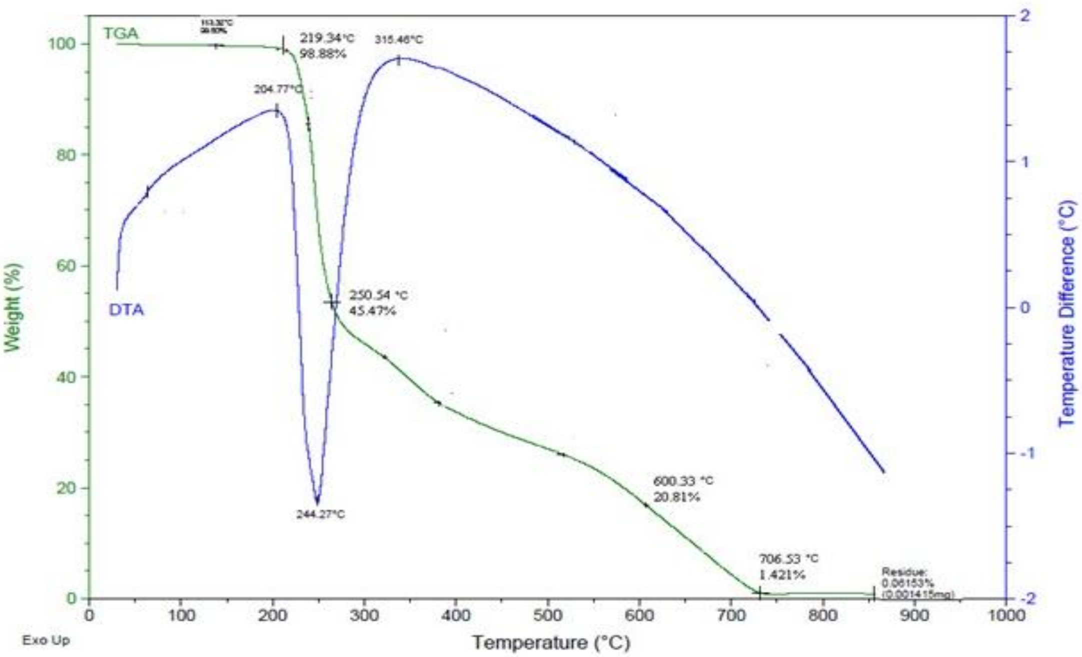

Figure 4 **TG/DTA curves for TGSSu crystal**

Increments with the applied burden fulfilling the converse space size impact [11]. The connection among burden and size of the space is given by notable Meyer's law P = adn; Here an and n are constants relying on the material. The plot between the log P and log d for TGSSu gem was appeared in Fig.6. The estimation of the work solidifying coefficient n was discovered to be 4.35 According to Onitsch, $1.0 \leq n \leq 1.6$ for hard materials and $n > 1.6$ for delicate materials [11]. Henceforth, it is finished up from the examination that the TGSSu precious stone is a delicate material sort.

Yield strength (σ_y) is a significant factor for gem contemplates. The connection $(\sigma_y) = (H_V/3)(0.1)^{n-2}$ was utilized to compute yield strength of the material. Utilizing Wooster's observational recipe C11= $H_v7/4$ was utilized to assess versatile solidness consistent (C11) for various burdens. The break length is determined from the focal point of space imprint to the break end. The break length (l) can be estimated from normal of two break lengths for every space. Protection from crack demonstrates the durability of material. The break strength (Kc) of the space cycle gives a balance connection for an all around created break stretching out under the middle stacking condition;

$$K_c = \frac{P}{\beta_0 l^{3/2}}, l \geq \frac{d}{2} \tag{1}$$

Where β0 is the indenter constant which is equal to 7 for the Vickers's diamond pyramid indenter [12].

Weakness influences the mechanical conduct of a material, and is communicated regarding the

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fragility file (Bi) as.

$$B_i = \frac{H_V}{K_c} \tag{2}$$

The varieties of yield strength, firmness consistent, break sturdiness and Brittleness with various burdens for the created precious stone is introduced in the Table.1

Table.1: Yield strength, stiffness constant, fracture toughness and brittleness for TGSSu

Crystal with different loads

Sample	Load(g)	Yield strength (σy)	Stiffness constant(C_{11})	Fracture toughness (K_c) 10^5 Kg $m^{-3/2}$	Brittleness (Bi) $m^{-1/2}$
	25	0.797	1.4207	1.7746	25.67
	50	1.242	3.0881	2.9503	24.06
	75	1.291	3.3083	3.3525	22.02
TGSSu	100	1.439	3.996	3.9067	21.06

The above table shows that the value of yield strength, stiffness constant and fracture

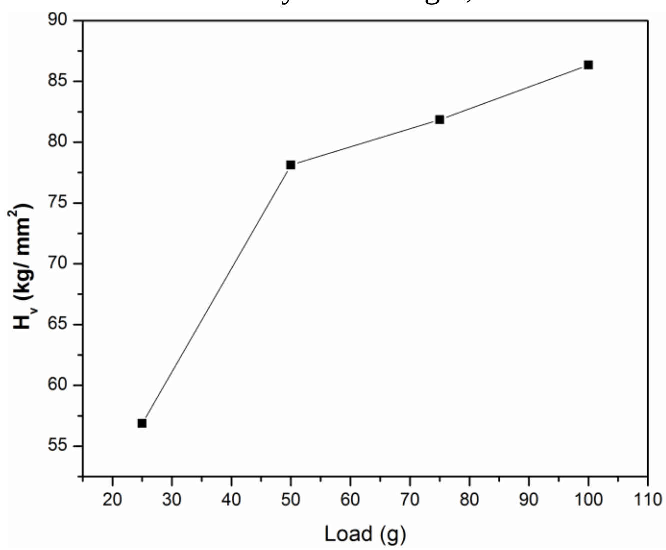

Figure 5 Dependence of hardness number (H_V) with loads in grams for TGSSu crystals

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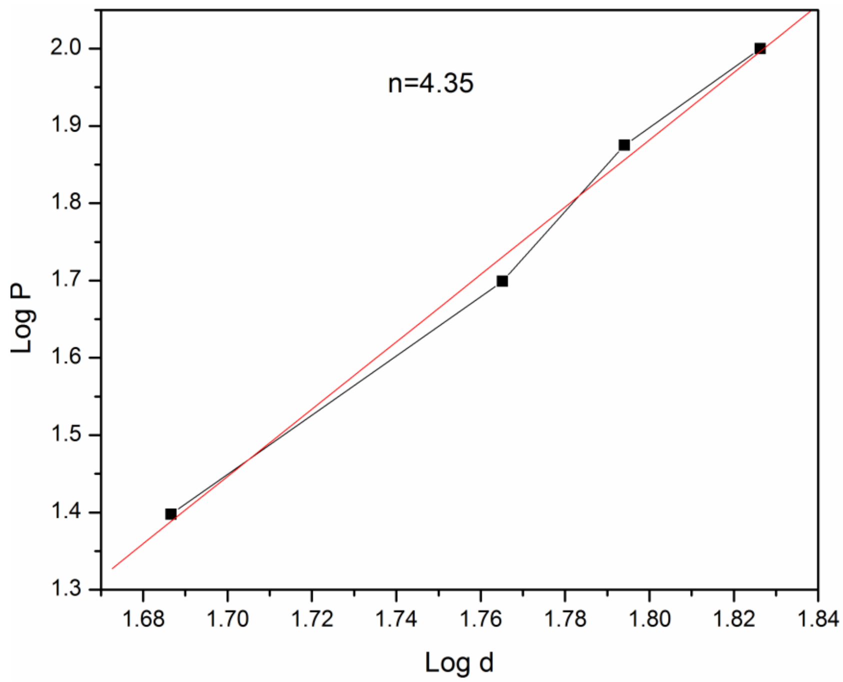

Figure 6 Plot of log P versus log d of TGSSu crystal

3.4 Second order linear optical studies

Toughness of the grown crystals increases and brittleness decreases with the applied load. From the results it is predicated that the grown crystals have relatively high mechanical strength. The NLO movement concerning Second Harmonic Generation (SHG) of an example can be checked utilizing the Kurtz and Perry strategy [14]. The extreme focus Nd:YAG laser (λ = 1064 nm) with a heartbeat span of 6 ns was gone through the powdered example. The SHG perform was affirmed from the yield of the laser shaft having the green emanation (λ = 532 nm). The second symphonious age sign of 6.4 mJ for TGSSu test was acquired for an info energy of 0.68 J. The standard estimation of KDP gem gave a SHG sign of 8.8 mJ for a similar information energy. Subsequently, it is seen that the SHG effectiveness of the developed TGSSu test is 0.72 occasions that of the standard KDP gem. It is to be referenced here that the molecule size has been kept up at around 10 microns for both TGSSu and KDP tests. Along these lines, the developed TGSSu test has NLO properties not at all like unadulterated TGS precious stone

3.5 Third order non linear optical studies

The investigations of nonlinear refraction and nonlinear retention in nonlinear optical precious stones are specifically compelling now a days because of examinations of different second-request nonlinear optical cycles (second consonant age, parametric wave age and enhancement, wave blending, electro-optical impact ,and so on) infemtosecond scale range .The advancement of

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femto second heartbeat intensification strategy prompted the need of high-request non-direct optical cycles effect on second-request ones to beta-ken into account .Such high-request nonlinear cycles can be brought about without anyone else – activity of laser radiation. For the investigation of spatial, unearthly, and worldly boundaries varieties of high-power laser radiation it is important to know the nonlinear optical attributes liable for self-activity measures, for example, self-centering, self-actuated stage tweak in nonlinear medium, nonlinear ingestion, and so on The estimations of precious stone nonlinearities were done utilizing Z-check procedure. Z-check is the most norm and advantageous strategy to decide the nonlinearity of the optical materials (i.e., the nonlinear refractive record (n_2) a blemished nonlinear retention coefficient (β)) precisely. This straightforward procedure permits estimating different nonlinear optical boundaries with high affectability. The "Gaussian disintegration" technique was utilized for exploratory information translation. This technique was generally utilized already for the examination of estimated results. The depiction of "Gaussian deterioration" technique is introduced in for estimations of both nonlinear refractive files and non-straight assimilation coefficients [15, 16]. The shut gap (for example opening is set in the far field) for deciding non straight refraction is appeared in Fig.7, where the example is moved along the proliferation course z while keeping the force fixed. The standardized conveyance of the example is observed in the far field as a component of the position Z. The power subject to the refractive file causes the pillar span of the communicated bar to change while holding the Gaussian profile. The open aperture(a focal point supplanted the gap) is appeared in Fig.8, measures the adjustment in force of a pillar, centered by focal point and in the far field a locator which catches the whole bar gives absorptive nonlinearity of the example. The absorptive non linearity can be expected to(i)saturable absorption(SA),in which the assimilation coefficient diminishes bringing about the conveyance increment with the expansion in the information laser power, and (ii)reverse saturable absorption(RSA),in which the ingestion coefficient increments bringing about the conveyance decline with the expansion in the info laser force.

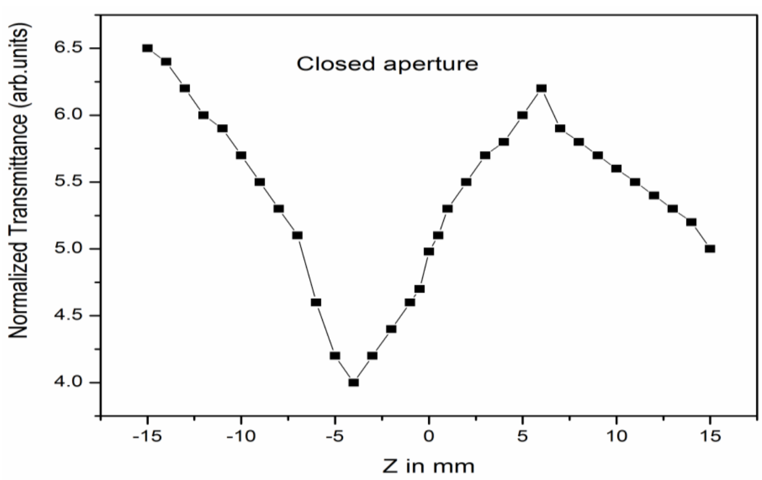

Figure 7 Z-scan pattern for the sample in closed aperture

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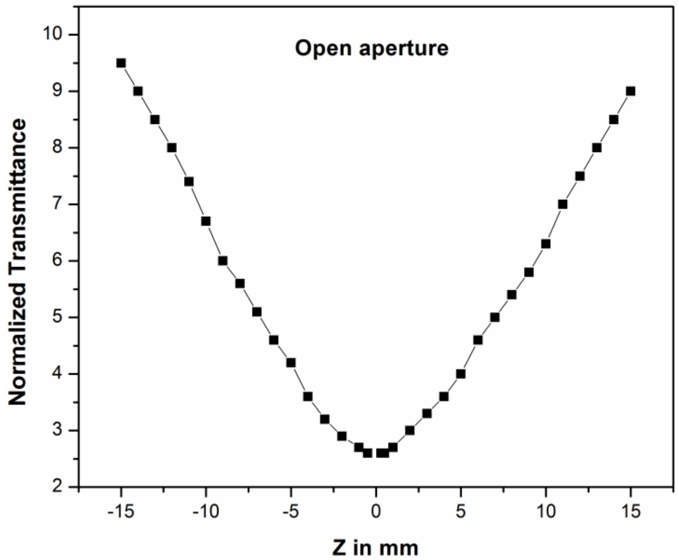

Figure 8 Z-scan pattern for the sample in open aperture

3.5.1. Self-focusing and Self-defocusing

Self-centering is an outcome of the non-uniform spatial profile of the laser Gaussian bar. On the off chance that the force of the sent light shaft is adequately high, the refractive file change will alter the light engendering concerning polarization as well as in its mathematical properties as well. For a Gaussian light emission ω_o (shaft waist)the Kerr-focal point central length is given by condition $F=b\omega_o^2/4LIn_2$, where b is the revision term, L is the thickness of the nonlinear medium (example) and I is the irradiance. In the event that n_2 is negative , the above condition shows negative central length and consequently there exists self-defocusing of the occurrence bar [17]. A pre-central conveyance greatest (top) trailed by a post-central conveyance least (valley) which is the mark for negative non linearity and it is known as self-defocusing impact that is because of nearby variety of refractive list with temperature while for positive nonlinearity (the other way around) the valley ought to followed by a pinnacle offering ascend to self-centering impact which is the consequence of the non-uniform spatial profile of the laser Gaussian shaft. A spatial circulation of the temperature in the gem surface is delivered because of the restricted retention of a firmly engaged pillar engendering through the retaining test. Subsequently a spatial variety of the refractive file is delivered which goes about as a warm focal point bringing about the stage contortion of the spreading bar. (ΔTp-v), the contrast between the pinnacle and valley transmission as far as the on pivot stage move at the center can be assessed utilizing following condition [15,16].

$$\Delta \mathbf{T}_{\mathbf{P\text{-}V}} = \mathbf{0.406\ (1\text{-}S)^{0.25}} \ |\Delta \varphi| \quad (3)$$

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Straight conveyance gap (S) was determined utilizing the connection

$$\mathbf{S = 1\text{-}exp\ (-2r^2 a /\ \omega^2 a\ )}$$
(4)

Where ra is the span of the opening and ωa the shaft sweep at the gap. The third-request nonlinear refractive file (n2) of the TGSSu gem was determined by following the connection.

$$\mathbf{n_2 = \Delta\ \varphi\ /\ K.I0.Leff} \quad (5)$$

Where I0 is the power of the laser bar and K = 2π ⁄ λ (λ is the frequency of laser pillar).

The successful thickness can be determined utilizing the connection Where α is the straight retention coefficient and L is the thickness of the example.

$$\mathbf{Leff\ = 1\text{-}exp\ (\ -\alpha\ L/\ \alpha\ )} \quad (6)$$

The nonlinear absorption coefficient (β) can be calculated using the following relation

$$\mathbf{\beta = 2\sqrt{2}\Delta T\ /\ I0\ \ L\ eff} \quad \mathbf{(7)}$$

Where Δ**T** is the valley value at the open aperture Zscan curve. The value of β will be negative for saturable absorption and positive for two photon absorption process. The real and imaginary parts of the third order nonlinear optical susceptibility (χ (3)) are defined as

$$\mathbf{Re\ \chi\ (3)\ (esu) = 10^{-4}\ (\varepsilon 0 C^2 n0^2 n^2\ /\ \pi)\ (Cm/\ W)} \quad (8)$$

$$\mathbf{Img\ \chi\ (3)\ (esu) =\ 10^{-2}\ (\varepsilon 0 C^2 n0^2 \lambda\beta\ /\ 4\pi^2)\ (Cm/W)} \quad (9)$$

$$\mathbf{\chi\ (3)\ (esu) = [\ (Re\ \chi\ (3))^2 + (Img\ \chi\ (3))^2\ ]^{\ 1/2}} \quad (10)$$

Where ε0 is the permittivity of the free-space (vacuum), n0 the straight refractive list of the example and c the speed of the light in vacuum. The blunder bar of our estimation was 5%. The primary variables of the estimation vulnerabilities were the assurance of bar midriff size in point of convergence and laser radiation power. Table.2 speaks to the exploratory subtleties and aftereffects of the Z-check method for TGSSu . The proportion of the signs with and without the opening records for the nonlinear assimilation and gives the data about absolutely nonlinear refraction. Fig.8 (shut opening) portrays the valley to top stage bending showed by developed gem demonstrating self-centering nature or positive record of refraction. The determined

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estimation of the nonlinear refractive list n_2 is 0.570468 $\times 10^{-6}$ cm^2W^{-1}.i.e., the n_2 esteem additionally have self-centering properties. It should be noticed that close θ=90°, the stage move in TGSSu gem brought about without anyone else activity surpasses the one brought about by course measure [18]. Open-gap estimations were done for the investigation of nonlinear ingestion coefficient. The nonlinear assimilation coefficient was determined in the casings of the strategy as given by Sheik Bahae [19]. It should be noticed that the impact of high-request nonlinear ingestion prompts the diminishing of the distance between the maxima and minima conveyances in shut gap plot and smother the valley width of standardized conveyance in open gap conspire. The examination of the valley width of standardized conveyance at various radiation powers permitted making a decision about the nonlinear assimilation nature. In TGSSu gems it was two-photon assimilation [18]. From the open gap Z-filter bend, it tends to be inferred that as the base lies close to the focus(Z=0), the nonlinear retention is viewed as two photon ingestion and the non-direct assimilation coefficient (β) is discovered to be 1.2485 cm/W and the third weakness of χ(3) is discovered to be 7.0269 $\times 10^{-4}$ esu. The outcome recommend that the TGSSu precious stone is the better possibility for optical applications.

Table:2:Results of Z Scan

Laser beam wavelength	632.8 nm
Lens focal length	30 mm
Optical path length	85 cm
Spot size diameter in front of aperture (W_a)	3.3 mm
Aperture radius (r_a)	2 mm
Sample thickness	0.4 mm
Effective thickness (Leff)	0.33981 mm
Nonlinear refractive index (n2)	0.570468 $\times 10^{-6}$ cm^2W^{-1}
Nonlinear absorption coefficient (β)	1.2485 cm/W
Real part of the third order susceptibility [Re $\chi^{(3)}$]	6.3466 x 10^{-5} esu
Imaginary part of the third order susceptibility [Im $\chi^{(3)}$]	6.9982 x 10^{-4} esu
Third order nonlinear optical susceptibility [$\chi^{(3)}$]	7.0269 $\times 10^{-4}$ esu

3.5.2. Two photon absorption

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The two photon assimilation was one of the principal nonlinear optical marvels to be tentatively noticed, not long after the clear of exceptional beat laser sources. It is critical in the presentation of exchanging gadgets for optical processing and broadcast communications applications. For every single optical witches, two-photon assimilation must be limited comparative with nonlinear refractive file change. Figure of legitimacy (FOM),B additionally characterized as (B) = (B) = $\lambda\beta/n2$ must surpass solidarity where n2 is nonlinear refractive file and β is two-photon retention coefficient. The FOM estimation of developed gem is discovered to be 138.515 demonstrating its appropriateness for photonic applications [20]. To assess the figures of legitimacy (FOM) of the optical nonlinear materials,two boundaries are characterized, one photon figure of legitimacy $W = n_2I_0/\alpha\lambda$ and two photon figure of legitimacy $T = n_2/\lambda\beta$, where α, β are the straight and nonlinear assimilation coefficients, n_2 is non direct refractive list, I_o is the irradiance, and λ is the frequency of the laser. Note that the two-photon figure of legitimacy T, utilized here is essentially the reverse of the figure of legitimacy (FOM) proposed by Mizrahietal. [21]. The extents of W>1 and To<1 are basic necessities for applications on the whole optical exchanging [22]. For TGSSu single precious stone, the estimation of W=2.506 and the estimation of T=0.638 and B=138.515. Henceforth developed precious stone is a likely material for applications taking all things together optical exchanging.

4. Conclusion

TGSSu gem non direct optical precious stone was developed effectively by moderate dissipation strategy at room temperature. The grid boundaries of the TGSSu precious stone and relating space bunch are resolved. The solvency of TGSSu precious stone is seen to be expanding with increment in temperature. X-beam diffraction technique has been completed to affirm the crystallinity and to recognize the cross section boundaries. The NLO productivity of TGSSu test is discovered to be 0.72 occasions that of KDP. Mechanical examinations uncover that the developed gem has delicate nature with break durability 2.996 $x10^5$ Kg $m^{-3/2}$ and furthermore gangs good brightleness record and yield strength with solid firmness coefficient by making the material valuable for gadget creation. The Third request powerlessness of TGSSu gem has higher incentive than that of KDP so there by making the material reasonable for optical applications. The estimation of one photon figure of legitimacy (W) is 2.506 and the estimation of two photon figure of legitimacy (T) is 0.638 and the opposite of figure of legitimacy (B) is 138.515 shows the proof for utilizing the material in all utilizations of optical exchanging and furthermore considered as promising material for creation of optoelectronic and photonic

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