*Practical Study on the Optical Limiter of KTP Crystal

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Abstract:

In this study; The optical power liming behavior was investigated for the KTiOPO₃ crystal by using the laser beam z-scan technique and Nd: YAG CW double frequency 532nm for variable powers of (10-85) mW. The threshold powers limiting was 60mW. The results show that the KTP crystal is a good nonlinear response could be used as a potential material for devices in optical applications.

Kay Words: - Optical limiter, potassium Titanyl phosphate (KTiOPO₃ or KTP) crystal, Nd: YAG CWLaser.

Physiology Classification QC350-467
1. Introduction:

KTP was first developed in the end of the 1970s [3]. It got a new attention. Tordjman et al. analyzed the crystal structure in details in 1974. Dupont Inc., USA, started to investigate KTP's nonlinear optical as well as its mechanical properties in 1976 [4]. The KTP is a biaxial crystal [5]. The crystal possesses a high nonlinear, it has a high resistant to optical and mechanical damage, and its transparency range extent from the ultraviolet to the end of the mid-infrared part of the spectrum [4]. KTP has been widely used in various nonlinear optical applications, in particular in the second harmonic generation SHG and optical parametric oscillator OPO devise based on pumping with 1 μm radiation from Nd lasers [6]. KTP crystal is orthorhombic and belong to the acentric point group mm2 [3]. For this point group symmetry class, there are five non-zero nonlinear coefficients, $d_{15} = 6.1 \text{ pm/V}$, $d_{31} = 6.5 \text{ pm/V}$, $d_{22} = 7.6 \text{ pm/V}$, $d_{32} = 5.0 \text{ pm/V}$, and $d_{33} = 13.7 \text{ pm/V}$ [7] [8]. These values are still considerably higher than for many other nonlinear materials including, $\beta$-BaB$_2$O$_4$ and LiB$_3$O$_5$ [7]. Potassium Titanyl Phosphate (KTP) crystal is nonlinear crystal. The famous type is KTiOPO$_4$. Another type such as KTiOPyz, KTiOPO$_3$. All these types are Orthorhombic and belonged to it with only slightly different lattice parameters.

Potassium Titanyl Phosphate (KTiOPO$_4$ or KTP) is the most commonly used material for frequency doubling of Nd:YAG and other Nd: doped lasers. It plays an important role for parametric sources for tenable outputs from visible (600 nm) to mid-IR. It is widely used in both commercial and military lasers including laboratory and medical systems, range finders, lidar, optical communication an industrial systems [9]. Figure (1) shows the KTiOPO$_4$ (KTP) crystal.

![Figure (1) shows the KTiPO$_3$ (KTP) crystal 6*6*3mm$^3$.](image)

An optical limiter is a nonlinear optical process in which the transmittance of a material decreases, when increased incident light intensity [2]. The study of the optical limiting (OL) of laser radiation in various materials opens the possibility of using these materials as laser shutters for protection against intense laser radiation and is important in investigating the essential properties of nonlinear optical media [1]. One of the major potential applications of these devices is sensor.
and eye protection [3]. All photonic sensors, including human eye have a threshold intensity above which they can be damaged [4]. By using the suitable materials as optical limiters, allowing them to function optimally to function at higher input intensities [3]. The figure (1) shown the idea of ideal optical limiter has a linear transmittance at low input intensities, but above the threshold intensity its transmittance becomes constant [3].

The nonlinear Optical mechanism could be employed for the design and performance of optical limiting devices, which could be classified into types. The first type is an energy spreading and the second is an energy absorption [2] [4]. The limiting function of an energy is based on intensity dependent change in spatial structure of laser beam passing through a nonlinear medium [2]. This type requirement is to place an aperture in front of a detector [5]. At low input intensity levels. This change can be neglected and the whole laser beam can be detected through a property aperture in front of a detector [2]. In high intensity levels, this Change becomes server that only. Small fraction of the transmitted beam can pass through the same aperture and finally detector [2]. In this type of mechanism, the nonlinear refraction that can be employed for optical limiting [5]. The optical limiting effect of refraction nonlinear optical mechanism was induced the self- focusing, self-defocusing, and scattering [3]. The second type of Optical Limiting is based on the intensity – dependent nonlinear attention of the laser energy in a given nonlinear materials, whereas the beam-structure changes is not so important. [2]. We only consider the second type of optical limiting power limiting device, for which the intensity dependent transmission changes in a nonlinearity absorptions material.

2. Mechanisms types of Optical Limiting

**Figure (2-15) idea of ideal optical limiting [77].**
is most important [6]. In this type of mechanism, the nonlinear absorption that can be employed for optical limiting was induced the two-photon absorption (TPA), Reverse absorption, free carrier absorption (FCA) [3].

3. Experimental part

The optical Limiting experiment was performed for KTiOPO$_3$ crystal using continuous wave second harmonic ND: YAG laser of wavelength – 532nm and power. The laser beam focuses by lens with focal length 15 cm. The crystal is placed at the position in focal point. To variable the input power used A variable beam splitter (VBS). The input power of the laser beam is varied systematically and the corresponding output power is detected by a power meter.

4. Result and Discussion

In a previous experimental study, we made a study for nonlinear KTP crystal by using Z-scan technique laser of a continuous wave length 1064 nm and frequency doubler with different powers. From the results that we obtained, the magnitude was 3.59 $\times$ 10$^{-14}$ cm$^2$/mW when the wavelength 1064 nm with their power 35mw and 3.35 $\times$ 10$^{-14}$, 3.67 $\times$ 10$^{-14}$ cm$^2$/mW for Nd: YAG frequency doubler 532nm by powers using 80mW and 25 mW respectively. While the nonlinear absorption coefficient was measured using the open aperture z-scan method were 2.71 x10$^{-3}$ cm/mW at1064nm with power 35mW and 4.32 x10$^{-3}$, 4.37 x10$^{-3}$ cm/mW at the Nd: YAG frequency doubler 532nm with powers 80mW and 25mW respectively.

| $\lambda$ (nm) | Power of laser (mW) | $\Delta T_{p-v}$ (cm$^2$/mW) | $n_2 \times 10^{-14}$ (cm$^2$/mW) | $B \times 10^{-4}$ (cm/mW) | $|\chi^{(3)}| \times 10^{-3}$ (esu) |
|----------------|---------------------|------------------------------|-------------------------------|--------------------------|---------------------------|
| 1064           | 35                  | 9.8                          | 3.59                         | 2.71                     | 2.55                      |
| 532            | 80                  | 7                            | 3.67                         | 4.32                     | 2.28                      |
| 25             | 2                   | 3.35                         | 4.37                         | 2.32                     |                           |

In this study we made a study to optical power limiter for Potassium Titanyl Phosphate KTP crystal by the use z-scan technique and Nd: YAG laser CW at frequency doubler 532 nm with power rang (10-85). The figure (2) represent the optical power limiter. It is observed from this figure that KTP crystal occurs a good optical power limiter.
Figure (2) The Optical Limiting for KTiOPO$_3$ crystal.

In figure (2) shows the input power is in the range (10-20-30-40-50 -60-65-70-75-80-85) mw. the output beam power increases with increases input beam power for KTP crystal, up to 60 mw the output beam power is constant, because its nonlinear absorption coefficient increases with increases in the incident irradiance. The volume of limiting threshold for KTiOPO$_3$ crystal is found 60 mw. Result that KTP crystal is good for Optical Limiter. To obtain on other representation for optical power limiter, we draw transmittance laser beam (output power/ input power) on the expense input laser beam power to crystal, as it is shown in the following figure (3).

Figure (3) the transmittance curve via input power for KTiOPO$_3$ crystal.

The values optical limiter for KTiOPO$_3$ crystal listed in table (1).

Table (1) the value of the power-limiting threshold.

<table>
<thead>
<tr>
<th>crystal</th>
<th>$\lambda$ (nm)</th>
<th>Power Limiting Threshold $L_m$ (mw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KTP</td>
<td>532</td>
<td>60</td>
</tr>
</tbody>
</table>

5. Conclusion

We have investigated the optical power behavior for KTP crystal by using scan beam laser. good optical limiting action with relatively low limiting threshold. Our results show that the KTP crystal is promising matter for applications in optical devices. At the study of the power limiting, it is found that KTP crystal possesses a limiting threshold values.

Acknowledgement:

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Reference


[3]-Daniela Marciu,"Optical Limiting and Degenerate Four – Wave Mixing in Novel


الخلاصة

في هذه الدراسة تم بحث سلوك محدد القدرة البصري لبلورة KTiOPO₃ باستخدام حزمة الليزر بطريقة المسح وليزر الموجة المستمرة نيديموم ياك وبالتردد المزدوج 532 نانو ملم وبقدرة متغيرة (10-85) ملي واط وكذلك قوة العتبة التي كانت 60 ملي واط واظهرت نتائج الدراسة ان بلورة KTP كانت جيدة الاستجابة ويمكن استخدامها كمادة قوية في اجهزة التطبيقات البصرية.