Optical properties of L-threonine Nonlinear Crystals


Instituto de Física de São Carlos - USP - São Carlos, SP, Brazil
misoguti@if.sc.usp.br

Abstract

This works reports on the linear and nonlinear optical properties of L-threonine crystals. Linear properties such as absorption spectra and dispersion of the refractive index are presented. Through second harmonic generation measurements we characterized the phase-matching loci for this sample, which presents conversion efficiency equivalent to that of KDP. The nonlinear refractive index $n_2$, measured through the Z-scan technique is of the order of $10^{-20} \text{m}^2/\text{W}$. These characteristics indicate L-threonine crystals as good materials for the construction of nonlinear devices, such as frequency doublers and optical parametric amplifiers.

Introduction

The search for new optical materials is of paramount importance, because of the practical applications in optical modulation, switching and other signal processing devices [1,2]. Amino acids is a family of organic materials that has been considered for photonic applications. L-Arginine Phosphatated (LAP), for example, have shown promising results as an efficient second harmonic generator (SHG) and are being applied in devices such as optical parametric amplifiers [3]. The complete understanding of the LAP optical properties, as well as other organic crystals, still requires more information. In this work, we reported the absorption spectrum, refractive index, thermooptic coefficient, second-harmonic generation and nonlinear refractive index of the L-threonine crystal.

Results and Discussions

The crystals used in our measurements were grown by the slow cooling method, which enable to grow crystals 3 cm long with about 1 cm$^2$ cross-section. L-threonine crystals present an orthorhombic structure, belonging to the space group of symmetry $P2_12_12_1$. The dimensions of the unit cell are: $a=13.611 \text{Å}$, $b=7.738 \text{Å}$ and $c=5.144 \text{Å}$ [4]. To perform optical measurements, such as refractive index and absorption spectra, it is necessary crystals with the appropriated orientation, which can be performed by optical axes determination through the optical conoscopic technique. After determination of the $xyz$-axes, crystals of L-threonine were cut, lapped and polished with the appropriate shape.

We have measured the absorption spectra of L-threonine from 250 to 1650 nm with polarized light in the three axes, x, y and z. The absorbance is quite low in the spectral range from 250 up to 1500 nm, and small peaks are present at 1200 and 1400 nm. The spectra are similar to those observed to L-arginine [3] and L-alanine [5]. It should be pointed out that L-threonine presents a good optical transparency at the wavelengths of sources commonly used in SHG devices, such as Nd:YAG (1064-532 nm), InGaAsP (1200-1550 nm) and GaAs (820-850 nm). The dispersion of the refractive indices of L-threonine crystals was measured with a Pulfrich refractometer at room temperature. We observed (results not shown here) a smaller difference between the values of $n_x$ and $n_y$ than that between $n_y$ and $n_z$, indicating the negative biaxial crystalline characteristic of L-threonine. The thermooptic coefficients $(dn/dT)$ at 546.1 nm are $-3x10^{-5}$ °C$^{-1}$, $-4x10^{-5}$ °C$^{-1}$ and $-6x10^{-5}$ °C$^{-1}$ for the x, y and z axes respectively.

Prior to the SHG efficiency measurements, the phase-matching loci for SHG with incident light at 1064 nm were found. To accomplish this task, the sample, inside a glass cell, was immersed in an index-matching fluid and placed in a $\theta$-$\phi$ positioning mount. After this first step, the absolute value of the effective nonlinear coupling coefficient for the L-threonine crystal was determined by comparison with the well know KDP crystal [6]. By choosing the angle of maximum conversion efficiency for both samples we were able to determine that the efficiency for the L-threonine crystal is about the same as the KDP crystal. This result suggests the use of L-
threonine crystals as a practical SHG. However, in the regime of ultrashort pulses most nonlinear devices, such as SHG, can present a third order nonlinear effect that disturbs the pulse propagation, and consequently the device operation. In this way, third-order nonlinearities in the L-threonine samples were investigated through the Z-scan technique [7,8]. In order to improve the Z-scan sensitivity, once the nonlinearities we are measuring are quite small, we employed the fastscan method [9], which allows high sensitivity measurements.

Our Z-scan experiment used laser pulses at 775 nm, delivered by a commercial Ti:sapphire chirped pulse amplified (CPA) system CPA-2001 from Clark-MXR Inc., operating at a 1 kHz repetition rate. The typical pulse energy used in our experiments was 0.12 µJ. The FWHM pulse duration was 190 fs, and the spatial profile of the laser beam presented an nearly Gaussian distribution. The beam waist size and pulse irradiance were determined by performing Z-scan measurements in fused silica (1.2 mm) [10]. The laser beam waist at the focus was measured to be 14 µm.

Figure 1 shows Z-scan measurements in a L-threonine crystal for light polarized along their three principal axes. The transmittance change observed as a function of the sample position Z has a peak to valley configuration that is characteristic of a self-focusing medium (positive nonlinearity). The $n_2$ values were determined with the usual procedure, being in the order of $1\times10^{-20}$ m$^2$/W, and no two-photon absorption process or white light generation was observed. Similar $n_2$ values were measured for other inorganic nonlinear optical crystal, such as, for example KTP, LBO and BBO [11].

![Figure 1 – Closed aperture Z-scan measurements on the 1 mm thick L-threonine crystal with the laser polarization along the three optical axes directions. The solid lines are drawn to guide the eye.](image)

The smaller variation observed the Z-scan measurements with the beam polarization directions (Fig. 1) indicates the anisotropy of the third order nonlinearity of this crystal. As can be seen in Figure 2, the dependence of the nonlinear refractive index follow the same trend observed for the linear one, as expected for biaxial orthorhombic crystal.
Figure 2 – Linear (left axes) and nonlinear (right axes) index of refraction measured for the L-threonine crystal with light polarized along its optical axes. The solid lines are draw just to guide the eye.

Conclusions
We reported here the optical properties of L-threonine crystals. The second harmonic conversion efficiency was measured to be quite good, being comparable to the one observed for KDP crystals (frequently used in commercial devices). Z-scan measurements, performed with 775 nm femtosecond laser pulses, revealed that the nonlinear refractive index in this crystal is in the range of $10^{-20} \text{m}^2/\text{W}$. In addition, the experimental results show that nonlinear refraction is dependent on the laser beam polarization, as expected. In general, the good second harmonic generation efficiency and the low third order nonlinearity measured, indicates the use of L-threonine crystals for application in nonlinear optical devices.

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