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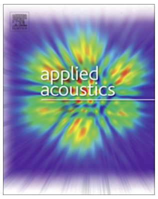

Control of laser pointer radiation by means of tunable acousto-optic filter

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ABSTRACT

We measured optical radiation parameters of commercial laser pointers controlled by stabilized external sources of electric power and also by autonomous built-in alkaline batteries slowly discharging during a continuous operation of the pointers. In particular, variations of optical intensity and wavelength of the radiation generated by the pointers at the wavelengths close to 405 nm and 650 nm were recorded by the acousto-optic method. We used for the purpose, a tunable acousto-optic filter based on tellurium dioxide single crystal. Light diffraction on ultrasound was provided in the crystal by a slow shear acoustic wave propagating at the angle 9° with respect to the axis $[110]$ in the $(1\bar{1}0)$ plane of the material. Dependences of the output intensity and the lasing wavelengths on time and driving voltage were recorded in the carried out experiments. We also examined drifts of the wavelengths and the intensities in case of stabilized external as well as discharging built-in sources of electrical power. When used with the built-in batteries, the violet pointer demonstrated drifts of the wavelengths up to 3.2 nm during the first 50 min of the laser operation. Similar measurements in the red pointer resulted in the drift about 0.35 nm. Advantages of the used acousto-optic method of the radiation control are briefly discussed in the paper.

1. Introduction

It is known that bulk acoustic waves propagating in liquids, glasses and crystals induce in the materials, optical phase gratings. These diffraction gratings are widely used in acousto-optic (AO) devices providing efficient control of parameters of optical radiation [1,2]. In particular, the AO devices regulate amplitude, phase, polarization, frequency, and propagation direction of optic waves [3]. Light diffraction by ultrasound, i.e., acousto-optic interaction is also actively applied for analysis of parameters of elastic waves generated in crystals, glasses and liquids [2–8].

The goal of this investigation is related to control of radiation generated by two commercial semiconductor laser pointers. We applied bulk acoustic waves carry out testing of the lasers. It is known that nowadays laser pointers are used not only in daily life but also in scientific research due to their low cost, reliability, small size and simple design. For example, in laboratory investigations, the pointers are often used in rough or preliminary adjustment of optical systems. The pointers are useful in fixing directions, determining distances, measuring angles, etc. In the present paper, we examined the laser pointers operating at the wavelengths of light near 405 nm and 650 nm. The laser devices were examined in two regimes of operation. In one of the regimes, the pointers radiated optic energy using electric power supplied by built-in alkaline AAA batteries. We noticed that these batteries were slowly discharging during a continuous operation of the lasers. In the other regime, we applied to the pointers, driving voltage provided by a stabilized external source of electric power. As found, basic parameters of the optic energy radiated by the lasers sufficiently differed in the two operation regimes.

The optic parameters under investigation were the wavelength of radiation and the output optical intensity. As known, there are traditional methods to carry out control of the laser radiation. Usually these methods are based on application of optical detectors together with spectral selectors such as interference filters or diffraction gratings. However, in this paper, the radiation was examined by means of the acousto-optic method [2,3]. We used for the purpose, bulk acoustic waves travelling in a tellurium dioxide single crystal (TeO_2) and generating in it, phase diffraction gratings [4–6]. The optical radiation emitted by the lasers was sent in the crystal at Bragg angle of light incidence. This radiation propagated in the crystalline medium and interacted with phase gratings induced in paratellurite by the acoustic waves.

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In the carried out experiments, the AO interaction was observed at acoustic frequencies dependent on the wavelengths of light. Recording the acoustic frequencies corresponding to the maximal intensities of the diffracted light, we easily determined particular magnitudes of the optic wavelengths radiated by the laser pointers [2–6]. Moreover, measurement of the diffracted light intensity at output of the used AO filter provided data on optical power of the lasers because the diffracted intensity was proportional to the intensity of the laser pointers. During the carried out research, we registered drifts of the optical wavelengths and variations of the optical intensity with time and driving electric voltage. In general, we experimentally proved that the spectral and amplitude parameters of the radiation emitted by the laser pointers were dependent on the driving electric voltage. It means that the radiation depended on type of source of electric power feeding the lasers.

2. Description of laser pointers and tunable acousto-optic filter

Photograph of the examined laser pointers and the acousto-optic filter may be seen in Fig. 1. The shorter pointer ("red pointer") in the figure radiated red light at the wavelength $\lambda \approx 650$ nm while the longer pointer ("violet pointer") emitted violet light at the wavelength of radiation $\lambda \approx 405$ nm. As mentioned, in order to drive the lasers, we used built-in commercial alkaline AAA batteries as well as stabilized external sources of electric energy. Basic parameters of the pointers were determined by means the paratellurite filter (AOTF) shown in Fig. 1 to the left of the pointers. Usually it is expected that radiation of a laser pointer is characterized by stable color and constant intensity [5]. However, we registered drift of the laser parameters even if the devices operated during a relatively short period of time.

It is evident that we could visually register changes in the lasing intensity only qualitatively. Usually we observed decrease of the laser intensity when a battery was discharging. However, we were practically not able to detect changes in the wavelengths of the laser radiation if these changes were limited to a few nanometers or tens of nanometers. Moreover, it was difficult to notice visually the decrease of the intensity by tens of percent especially if the radiation was intensive so that saturation of sensitivity in our eyes took place. However, these changes in the optic characteristics could easily be registered by the modern acousto-optic instrument, i.e., the AO tunable filter [4–6].

As mentioned, in the carried out experimental investigation of the laser pointers, we used a wide-angle acousto-optic tunable filter based on the crystal tellurium dioxide [4]. The slow shear acoustic waves were generated in the crystal by a piezoelectric transducer fabricated of X-cut crystal lithium niobate. The waves were propagating in the plane $(1\bar{1}0)$ of the crystal at the angle $\alpha = 9°$ with respect to the axis [110]. Fundamental frequency of the transducer was equal to $f_0 = 130$ MHz. Electrical parameters of the transducer were matched with a driving electric generator in the frequency range $f = 85–200$ MHz, evaluated at the -3 dB level.

Fig. 1. Photo of the acousto-optic filter together with the "red" (short) and "violet" (long) laser pointers.

We calculated tuning curve of the AOTF using the following equation describing dependence of the selected optical wavelength λ on the frequency of ultrasound f and the angle of light incidence θ_i [4–6]:

$$\lambda = (\Delta n V / f)[\sin^2(\theta_i + \alpha) / \sin\theta_i]. \tag{1}$$

In the above equation, V is the phase velocity of ultrasound and Δn is the birefringence of the crystal. We carried out our calculations on base of Eq. (1) and obtained the tuning curve λ (f) presented in Fig. 2. We used the following parameters of the crystal in our calculations: the birefringence was equal to $\Delta n = 0.15$ at the wavelength $\lambda = 650$ nm and $\Delta n = 0.18$ at $\lambda = 405$ nm. As for the parameters of the acoustic wave, they were as follows: the angle of acousticpropagation $\alpha = 9°$ and the velocity of sound $V = 685$ m/s. The optical Bragg angle of light incidence for the extraordinary polarized radiation was limited to $\theta_i = 9.3°$.

According to Eq. (1), the frequency of Bragg matching at the red wavelength $\lambda = 650$ nm was equal to about $f = 99$ MHz. Correspondingly, the acoustic frequency $f = 199$ MHz related to the violet optic wavelength $\lambda = 405$ nm. The calculation based on Eq. (1) also predicted that variations of the acoustic frequency in the range $f = 85–200$ MHz provided tuning of the filter in the domain of optic wavelengths $\lambda = 400–810$ nm, i.e., all over the visible light.

We found that the optical bandwidth of the filter $\Delta\lambda$ was practically not dependent on divergence of the incident optical radiation. This passband was as narrow as $\Delta\lambda = 4.0$ nm at the wavelength $\lambda = 650$ nm. The passband was mainly determined by the length of the piezoelectric transducer along light propagation direction $l = 0.6$ cm. As usual, the spectral bandwidth of the AOTF $\Delta\lambda$ depended on the wavelength as $\Delta\lambda \sim 1/\lambda^2$. That is why, at shorter optical wavelengths, the filter bandwidth was narrower than $\Delta\lambda = 4.0$ nm. In particular, we measured $\Delta\lambda = 1.6$ nm at the wavelength $\lambda = 405$ nm. As for the transmission coefficient T of the filter, it depended on the length $l = 0.6$ cm and the width $d = 0.4$ cm of the acoustic column in the crystal. This coefficient was as high as $T = 85\%$ at the wavelength $\lambda = 650$ nm and at the driving electrical power $P = 400$ mW applied to the AOTF. Correspondingly, at the wavelength of light $\lambda = 405$ nm, practically the same value of the coefficient $T = 80\%$ was registered at the driving power $P = 160$ mW. Therefore, the basic operation characteristics

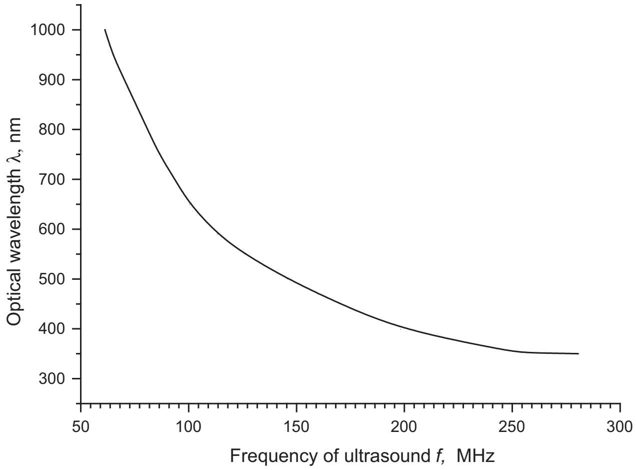

Fig. 2. Tuning curve of the acousto-optic filter.