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Iodine photodissociation laser with an intracavity space–time light modulator

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***Abstract.* A scheme of an iodine laser with two different intracavity space–time modulators based on electrooptic PLZT ceramics is experimentally studied. It is shown that lasing can occur in different angular directions with the use of both modulators. The output laser energy is 10 mJ with a pulse duration of 200 μs and a beam divergence of 6.3×10^{-4} rad. The laser field of view (5.1×10^{-3} rad) consists of a discrete set of 8×8 directions.**

Keywords: *intracavity radiation pattern control, iodine photodissociation laser, space–time light modulators, electrooptic PLZT ceramics, phase-conjugate resonator, spatial contrast of radiation.*

1. Introduction

The control of laser radiation pattern is an important problem in different laser application fields. The methods of intracavity scanning are effectively used to solve this problem [1, 2]. Advantages of this approach are the high rates of radiation pattern switching and the possibility of digital or analogous control of the device in the automatic regime [3].

A laser with intracavity scanning must have a phase-conjugate resonator, which has not one but a great number of equivalent optical axes filling the entire laser field of view, and a space–time light modulator (STLM) responsible for the optical axis selection [4, 5]. A specific feature of a phase-conjugate resonator is that, after a roundtrip, each point of its focal plane returns to itself without magnification. The laser beam direction is traditionally selected using STLMs [6].

The use of STLMs based on electrooptic PLZT ceramics (lanthanum-doped lead titanate–zirconate) in phase-conjugate resonators of Nd:YAG lasers was proposed and realised in [4, 7].

In the present work, we achieved intracavity control of the radiation pattern of an iodine photodissociation laser using such a modulator. The characteristic time of electro-optic switching of the modulator cell did not exceed 5 μs.

2. Radiation-pattern-control unit based on an STLM

In this work, we study two schemes of intracavity units controlling the radiation pattern of an iodine photodissociation laser, which are based on STLMs made of electrooptic PLZT ceramics. To use these devices in iodine lasers operating at a wavelength of 1.315 μm, it is necessary to apply a higher control voltage to the STLM cells than in the case of visible radiation. This may lead to electrical breakdown at the modulator surfaces.

In the first device [5] (Fig. 1a), the STLM had a form of two orthogonal one-dimensional matrix plates (*3*) and (*4*) of PLZT ceramics (each operating at a quarter-wave voltage) separated by a crystalline quartz plate (*7*) rotating the polarisation plane by 90°. This device was installed between two polarisers (*1*) with identical transmission azimuths. The advantages of this scheme are the absence of surface electrical breakdown (which disrupts the oscillation) owing to the quarter-wave voltage (2.33±0.07 V) applied to the electrooptic ceramic plates and the low optical losses. A drawback of this scheme is a low contrast, $\gamma = 4$ [6]. The contrast is determined as the intensity ratio of radiation passed through the switched-on STLM cell to the radiation passed through all the switched-off cells.

In the second device (Fig. 1b), the STLM had the form of two orthogonal one-dimensional matrix plates (*5*) and (*6*) operating at a half-wave control voltage. Each plate was positioned between crossed polarisers (*1*) and (*2*). The advantage of this scheme is a high optical contrast ($\gamma \approx 1000$ [6]), and its

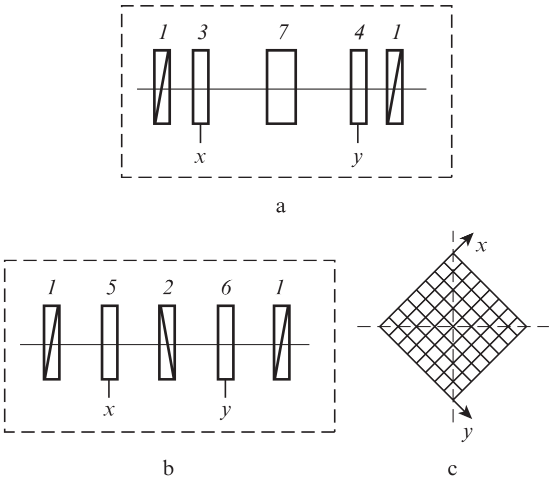

Figure 1. Principal schemes of radiation-pattern-control devices based on STLMs with a rotating quartz plate (a) and two half-wave Q-switches (b), as well as scheme of disposition of STLM cells:
(*1*) polariser with a vertical transmission axis; (*2*) polariser with a horizontal transmission axis; (*3*) and (*4*) STLM plates for *x* and *y* coordinates (quarter-wave control voltage); (*5*) and (*6*) STLM plates for *x* and *y* coordinates (half-wave control voltage); (*7*) quartz crystal plate rotating the polarisation plane by 90° [5].

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drawbacks are a long length and the probability of surface electrical breakdown due to the half-wave voltage (3.3±0.1 kV) applied to the plates, which is 1.4 times higher than in the first device.

The photograph of an individual STLM plate for one of the coordinates is shown in Fig. 2. Operation of each STLM plate is based on the formation of a line scan due to the transverse electrooptic effect in the PLZT ceramics of the composition 9.75 : 65 : 35 [4].

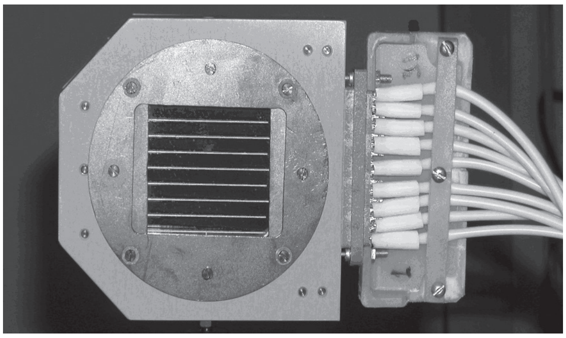


Figure 2. Photograph of an STLM plate for one of the coordinates.

3. Optical scheme of the laser

The optical scheme of an iodine photodissociation laser with an intracavity unit controlling the radiation pattern is shown in Fig. 3. We used a linear phase-conjugate resonator, which consisted of two plane mirrors (*1*) placed in the focal planes of confocal lenses (*3*) and (*7*). The radiation was coupled out of the resonator by a semitransparent mirror (*6*). The elementary cell of the radiation-pattern-control unit was 3×3 mm in size. The active medium was a heptafluoroiodopropane(n-C_3F_7I) : argon (1:10) mixture with the total pressure 15–20 Torr, which filled a quartz tube 0.5 mm long with an inner diameter of 20 mm. The active medium was pumped by two IFP-800 pulsed xenon lamps in an aluminum reflector.

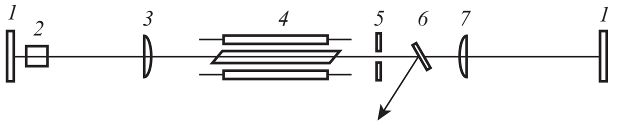


Figure 3. Optical scheme of the iodine photodissociation laser: (*1*) resonator mirrors; (*2*) radiation-pattern-control unit based on an STLM; (*3*) and (*7*) lenses of the phase-conjugate resonator with focal lengths of 4.7 and 1.6 m, respectively; (*4*) tube with the active medium and pump lamps; (*5*) aperture diaphragm 12 mm in diameter; (*6*) semitransparent mirror ($R = 50\%$).

The principle distinction of this scheme from the schemes described in [3, 4, 7] is that the STLM was placed near one of the resonator mirrors in the focal plane of the lens of the angle selector.

4. Experiment

Placing the first device (Fig. 1a) with the elementary cell 3×3 mm in size and with a rotating quartz plate into the resonator of an iodine photodissociation laser, we experimentally obtained scanning of the beam direction along two angular coordinates in the field of 8×8 directions. The laser operated in the free-running regime. The beam divergence was 8×10^{-4} rad. The output laser energy averaged over 35 measurements was $E = 12\pm1$ mJ. A laser pulse oscillogram is given in Fig. 4.

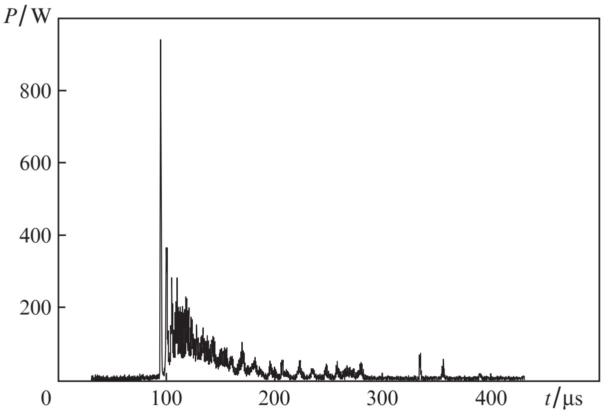


Figure 4. Oscillogram of a pulse of the laser with a radiation-pattern-control device based on a rotating quartz plate.

To demonstrate lasing in several angular directions, three cells were switched on one by one. The far- and near-field-zone intensity distributions for this case are presented in Fig. 5. In the far-field zone, one can clearly see spots of cells neighbouring the switched-on cell of the radiation-pattern-control unit. This is explained by the device design, which ensures a low ($\gamma = 4$ [6]) contrast in the multimode lasing regime.

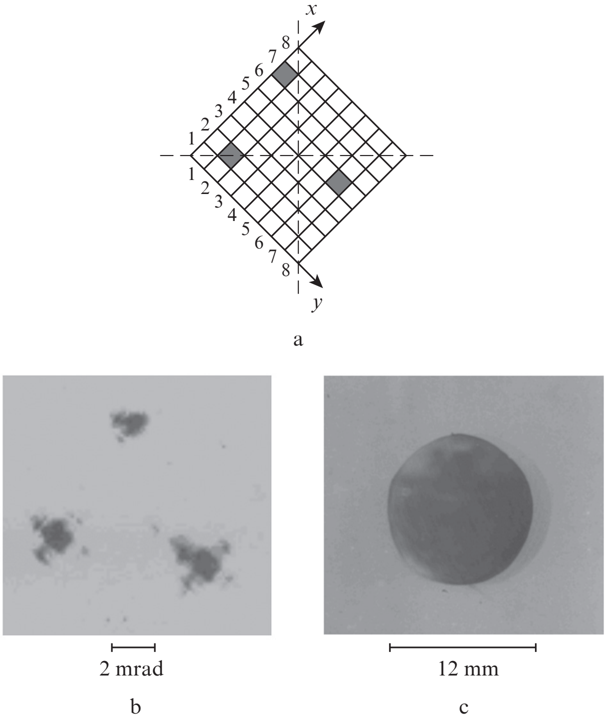
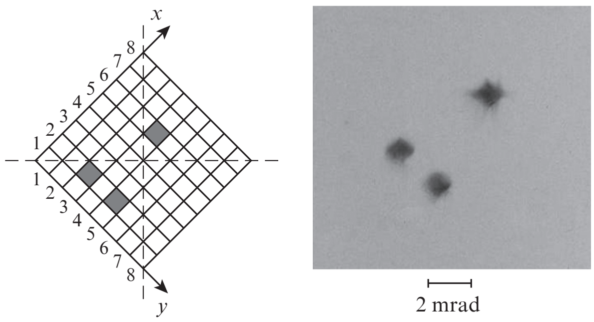


Figure 5. Scheme of switching on of the cells of the radiation-pattern-control device (a), as well as intensity distribution patterns in the far- (b) and near-field (c) zones.

To determine the contrast in the single-mode regime, we performed a series of experiments using a neodymium laser with pulsed lamp pumping. The experiments showed that the device based on a rotating quartz plate allows one to obtain a high ($\gamma > 500$) contrast in the far-field zone in the case of diffraction matching of the laser emitting aperture with the angular size of the STLM cell. In this case, the output laser energy is two times lower than in the multimode regime.

The radiation-pattern-control unit with a rotating quartz plate in a laser with diffraction-mismatched sizes of the emitting aperture and the STLM cell does not allow one in principle to obtain high-contrast lasing in one elementary cell. However, this can be useful in some laser applications.

To obtain high-contrast beam intensity distribution in the far-field zone, we placed into the resonator the second radiation-pattern-control device based on two orthogonal half-wave Q-switches (Fig. 1b). In the course of experiments, the radiation pattern of the iodine laser was controlled in the entire working field. As a result of increased losses in the resonator, the laser energy decreased to 10±1 mJ, while the pulse duration was 200 μs. The beam divergence was 6.3×10^{-4} rad, which is explained by the high contrast. The laser pulse oscillogram in this case is similar to the oscillogram shown in Fig. 4. The scheme of switching of STLM cells and the beam intensity distribution pattern in the far-field zone after switching on of three cells are shown in Fig. 6.



a b

Figure 6. Scheme of switching on of the cells of a radiation-pattern-control device (a), as well as intensity distribution pattern in the far-field zone (b).

It is necessary to note that, at the edges of the working field, the laser energy decreases by 15% in comparison with the laser energy in the axial direction due to vignetting in the tube with the active medium.

The experimental results show that the scheme with two orthogonal half-wave Q-switches allows one to obtain lasing in selected directions within the laser field of view with a high-contrast intensity distribution in the far-field zone.

5. Conclusions

Thus, the operation of an iodine photodissociation laser in the free-running regime with intracavity control of the radiation pattern using different STLM-based units is demonstrated for the first time.

The output laser energy amounted to 12 mJ when the radiation-pattern-control device was based on a rotating quartz plate and decreased by 17% for the device based on two orthogonal half-wave Q-switches, the pulse duration was 200 μs, and the beam divergence was $(6-8)\times10^{-4}$ rad.

It is shown that the use of radiation-pattern-control devices based on two orthogonal half-wave Q-switches allows one to obtain a high-contrast intensity distribution in the far-field zone even at the diffraction-mismatched sizes of the STLM cell and the laser emitting aperture. To obtain similar high-contrast distribution in the scheme with the unit based on a rotating quartz plate, one must ensure diffraction matching of the laser emitting aperture with the size of the elementary STLM cell.

The radiation-pattern-control device with a rotating quartz plane is preferable for application in resonators of lasers operating at a slight excess over the lasing threshold. In lasers with higher powers, it is better to use the high-contrast device based on two orthogonal half-wave Q-switches.

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