CONTROL OF LASER RADIATION PARAMETERS

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Two-coordinate control of the radiation pattern of a chemical non-chain electric-discharge DF laser by using space – time light modulators

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Abstract**. The results of studies of radiation parameters of a chemical non-chain DF laser (emitting in the range from 3.5 to 4.1 μm) with an intracavity control of the radiation pattern with the help of spatiotemporal modulators based on PLZT electrooptic ceramics are presented.**

Keywords: *intracavity scanning of radiation, conjugate laser resonator, DF laser, space – time light modulator, PLZT electrooptic ceramics.*

1. Introduction

One of the ways to control the spatial radiation pattern of a laser beam iis the use of intracavity space – time light modulators (STLMs) of different types [1 – 4]. Electrically-controlled STLMs based on electrooptic PLZT ceramics [4], which is transparent in a broad spectral range (0.5 – 6.5 μm) [5], have the fastest response and radiation resistance.

We reported earlier [5] successful realisation of a DF laser with a one-coordinate intracavity electrically-controlled scanning of the propagation direction of laser radiation with the help of STLMs based on the electrooptic PLZT ceramics.

In this work we present the results of the study of radiation parameters of the DF laser with a two-coordinate scanning of a laser beam.

2. DF emitter and laser resonator

Radiation of the DF laser consists of about 15 spectral lines in the wavelength range from 3.5 to 4.1 μm at a pulse repetition rate of more than 1 kHz [6]. In this paper, experiments on the control of the radiation pattern were performed with an electric-discharge chemical closed-cycle DF laser [5]. The discharge-gap section was 14 (the spacing between electrodes) ×20 (the widths of electrodes) mm and the length of the discharge gap was 300 mm. The capacity of the storage capacitor charged to the voltage 24 kV was 8800 pF. The $D_2 : SF_6 = 1 : 5$ working mixture was used. The typical output energy in the laser with a planar short resonator was 50 – 55 mJ.

The experiments were performed with a linearly conjugate laser resonator [4]. Its main property is the reflection of the resonator mirrors by a system of lenses or mirrors to each other. The scheme of the laser is presented in Fig. 1. The broad linewidth of the laser complicates the use of the lens optics, which should be achromatic in a broad spectral range. Because of this, spherical mirrors covered by aluminum deposited on a glass substrate were used in the scheme. The focal lengths of these mirrors were 75 cm. The position of the axial resonator mode with respect to the cross section of the active medium is shown in the inset (Fig. 1). As in [5] we used a reflection polariser in the form of a stack of three plane – parallel plates of the PLTZ ceramics with the refractive index $n = 2.47$ in the visible spectral range. The plates were placed in a zigzagged manner to prevent radiation reflected from one plate to fall onto the adjacent plate (which decreases the polariser contrast). Such a polariser provided attenuation of s-polarised radiation by about 40 times per transit (measurements were performed at 1.064 μm).

As elements blocking lasing on non-switched pixels (generation direction) of the STLMs, quarter-wave phase plates of the zero order, which consisted of two plates with orthogonal directions of the z axis, were used. The plates were manufactured of a sapphire crystal and the difference of their thicknesses was equal to the thickness of the zero-order plate.

Space – time light modulators had control elements on one side of the plates. The spacing between the electrodes was 1 mm, the width of the electrode embedded into the substrate was 60 μm and 17 electrodes were used. Two STLMs were placed near a highly reflecting and an output resonator mirrors. STLMs had a one-layer AR coating for the central wavelength 3.8 μm. Control voltage 450-μs pulses with amplitude 1650 V were fed to electrodes of the modulators with the help of a computer program. For these modulators, the quarter-wave voltage for the radiation at 0.6328 μm was 860 V. For modulators with a quadratic electrooptic effect, the dependence of the radiation transmission on the voltage U between the electrodes is described by the expression [7]

$$F(U) = \sin^2\left[\pi m n^3 r \frac{l}{2\lambda}\left(\frac{U}{d}\right)^2\right],$$

where m is the number of round trips in the modulator ($m = 2$ for the modulator mounted in front of the mirror); n

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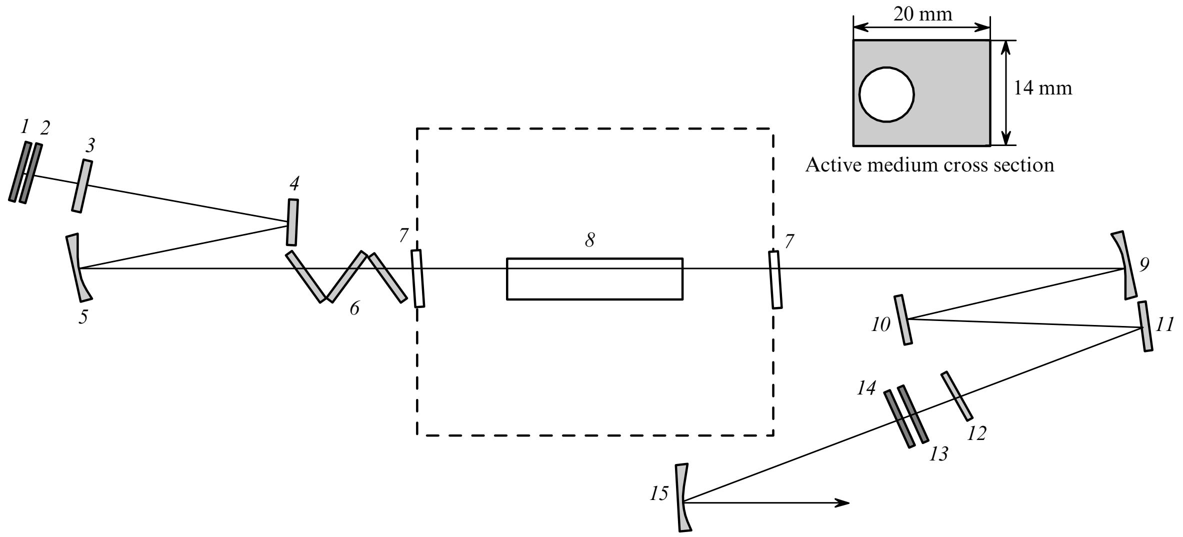


Figure 1. Scheme of the conjugate resonator of the DF laser and the beam position with respect to the cross section of the active medium (inset): (*1*) multilayer dielectric highly reflecting resonator mirror (the reflection coefficient is $R = 99\,\%$); (*2*, *13*) STLM plates; (*3*, *12*) sapphire quarter-wave plates; (*4*, *10*, *11*) plane fold mirrors; (*5*, *9*) spherical resonator mirrors with the focal distance of 750 mm ($R = 100\,\%$); (*6*) STLM plates mounted at the Brewster angle; (*7*) fluorite windows of the discharge chamber; (*8*) discharge gap of size 14×20 mm with the active medium; (*14*) output resonator mirror (plane–parallel PLZT plate); (*15*) spherical intracavity mirror with the focal distance of 1200 mm.

is the refractive index of ceramics ($n = 2.47$); r is the electrooptic coefficient; l is the thickness of the modulator in the direction of the radiation propagation; d is the spacing between the electrodes; λ is the radiation wavelength. It follows from this expression that the transmission of each of the STLM plates is 0.7 per two transits for $U = 1650$ V. The quarter-wave voltage for $\lambda = 3.8$ μm is approximately equal to 2 kV but because of the danger of the electric breakdown between the electrodes, the voltage of 1650 V was applied.

3. Results

Before mounting the STLM into the resonator, the conjugate condition of this resonator was verified by moving a diaphragm with diameter 1.2 mm near mirror (*1*). Lasing was observed for a broad range of diaphragm positions along the mirror. Figure 2 shows the photographs of imprints on a thermosensitive paper at the output of the DF laser for different positions of the diaphragm. The output energy in the case of mounting quarter-wave plates and polarisers in the open position was ~20 mJ. Then, the STLM plates were placed into the resonator and the quarter-wave plates were in the closed position. The STLM pixels were switched on 100 μs prior to the discharge onset in the laser. The switching on of the discharge lead to pulse generation in the direction specified by the position of the STLM pixel. Figure 3 presents the imprints of the radiation intensity distributions in the far field on the exposed photographic paper, which was located near resonator output mirror (*14*) (Fig. 1).

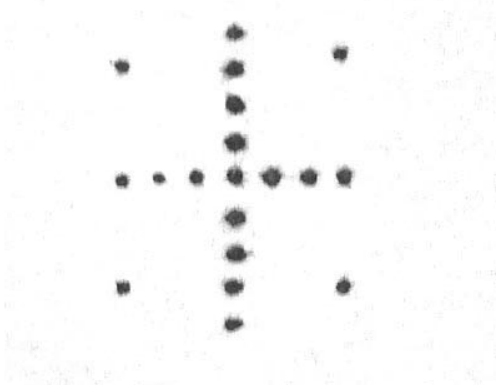
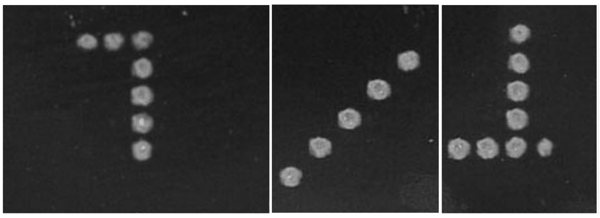


Figure 2. Imprints of beam profiles on a thermosensitive paper placed near the output resonator mirror, which were obtained by moving the intracavity diaphragm. The spacing between adjacent beams in the 'cross' is 2 mm.



a b c

Figure 3. Imprints of beam profiles in the far field on black photographic paper obtained by switching on the STLM pixels upon scanning along the vertical (a), diagonal (b) and horizontal (c) lines.

When this resonator scheme was used, the pulse energy of 6–8 mJ was obtained upon scanning the radiation pattern of the laser. To increase the energy to ~20 mJ, it is necessary to apply the quarter-wave voltage to the STLM plates (for the central oscillation wavelength), which requires improvement in their design to exclude the voltage breakdown. Note that the sapphire quarter-wave plates and the fluorite windows of the discharge chamber did not have AR coatings, which also provides a potential for increasing the output energy. To increase the output energy, the output pulse was directed to the active medium with the help of mirrors (see inset in Fig. 1). In this scheme the increase in

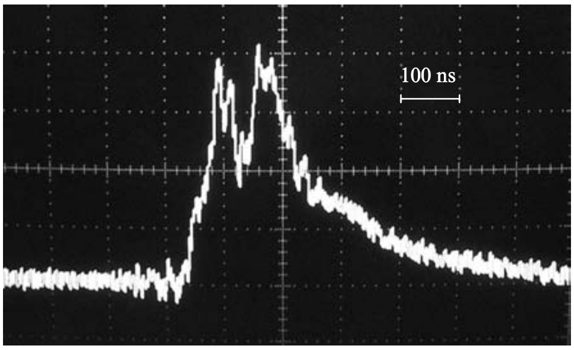


Figure 4. Temporal pulse shape of radiation from the DF laser.

the pulse energy to 18 – 20 mJ was obtained only for the case when the amplified beam did not intersect the volume in the active medium in which lasing occurred.

Figure 4 shows the oscillogram of a laser pulse obtained with a detector with the temporal resolution of 7 ns and a broadband oscilloscope (500-MHz band). The oscillogram is characterised by the presence of two humps, the first of which probably determines the short-lived emission lines and the second – emission lines with a longer life time.

4. Conclusions

The possibility of intracavity two-coordinate control of the radiation pattern of a chemical non-chain DF laser with the help of an electrically controlled STLM has been shown experimentally for the first time.

The pulse energy of 6 – 8 mJ has been obtained upon scanning the laser radiation pattern with the divergence close to the diffraction limit. The increase in the energy is possible due to applying AR coatings on the surfaces of quarter-wave plates and windows of the chamber as well as due to supply of a higher voltage to the modulators. The amplification of output pulses is also possible but this requires an active medium with a large cross section.

The laser under study can find applications in ecological monitoring of the environment and in medicine. Upon scanning the laser radiation in the angular space of several degrees, an optical and mechanical system to deflect the beam is not required.

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