

Experimental Study of Coherent Summation of Radiation from Two Widely Aperture Pulsed CO₂-lasers

V.E. Rogalin^{1,2}, I.A. Kaplunov^{2,*}, I.K. Babaev¹, Yu.M. Vaskovsky¹, M.I. Zhavoronkov¹,
V.M. Ivanov¹, A.S. Korenev¹

¹ Open Joint Stock Company «National Center of Laser Systems and Complexes «Astrophysica»,
95, Volokolamskoe Sh., 125424 Moscow, Russia

² Tver State University, 33, Zhelyabova Str., 170100 Tver, Russia

(Received 19 May 2014; published online 15 July 2014)

Emission of two high-power pulsed CO₂-lasers with a transverse discharge at atmospheric pressure in the active medium and the output beam aperture 100 × 100 mm, united by a joint unstable telescopic resonator, was coherently summarized under conditions of real ground-level track on the screen surface, which was remote from output mirror of the laser at a distance of 263 m. Output Brewster windows of laser cuvettes were manufactured from single-crystal plates of sodium chloride which had a diameter of 300 mm. Mirrors for resonator and optical circuit were manufactured from oxygen-free copper. Active medium - a mixture of gases: CO₂: N₂: He in the ratio 1 : 2 : 3. Laser pulse duration is 5 microseconds. During the experiment, when summing on the screen 2-laser beams at the lowest possible convergence angle of rays, the interference pattern was registered.

Keywords: Coherent radiation, Summation of radiation, Pulsed lasers, CO₂ lasers, Laser active medium, Laser energy.

PACS number: 42.60.Jf

1. INTRODUCTION

Pulsed CO₂-lasers of high pressure can operate at pressures of the active medium about 1 atmosphere and more and also have significant advantage – high efficiency factor under very high specific output parameters. They are widely used to stimulate chemical reactions, in laser thermonuclear fusion, for isotope separation, in laser technology, etc. [1-4]. Coherent summation of the radiation of laser beams is one of the most actively developed directions of laser physics, aimed primarily on creating on the object to be processed, the laser radiation of high power density. This direction is intensively developed also for other types of lasers, such as fiber lasers, which are successfully used in various fields of science, technology, medicine [5-7].

The aim of the study was an experimental study of the possibility of coherent summation of radiation of two powerful four-section of CO₂-lasers with an aperture of ~ 100 × 100 mm and length of the active medium to 160 cm.

2. MATERIALS AND METHODS

Exterior view of the experimental apparatus is shown in figures 1 and 2. Structural features of lasers, optical resistance of used transparent materials, structure and optical properties of copper mirrors are considered in [8-10]. Figure 3 shows the optical scheme of coherency laser beams whose axes are in the horizontal plane. Scheme allows us to summarize radiation of even number wide-aperture lasers. We used two laser cuvettes, united by collective modal and active volumes by means of telescopic unstable resonator with a converging beam. Radiation from the cuvettes was extract-

ed through Brewster windows of NaCl single crystals with a diameter of 300 mm. Distances $d_{1,5} = d_{7,12}$ were 50 cm and $d_{6,14} = 16$ cm, optical path length of the resonator $L_{1,5} = L_{7,12} = 825$ cm the angles $\alpha_1 = \alpha_2 = 11^\circ$, magnification factor $M = 1.7$; α_3 – the smallest possible angle of convergence of rays on the screen.

At simultaneous inclusion of all sections of the two lasers, united by this scheme, the total energy was 200 J in the pulse (peak power up to 2×10^8 W, beam divergence ~ 10^{-3} rad). Two beams with a spherical wave front, summarized on the screen by system of copper mirrors (Fig. 3) went out of resonator.

We measured the parameters of operating generator, overlapping any one of the two channels by an opaque screen. Energies of summated beams were measured by thermocouple calorimeters – TPI 2-5 and maintained the same. The time shift between pulses from separated sections of lasers was controlled by photodetector effect of photon entrainment holes in germanium, signal from which was registered with oscilloscope.

Optical scheme of the track for study of coherent summation includes two sections: the first is a scheme of summation two wide-aperture laser beams, the second-system of transporting and mixing of two beams in the far zone. Radiation from the laser was directed by two almost parallel beams on the mirrors of the second block.

The second block consists of 8 flat copper mirrors with diameter of 200 mm, mounted on the adjustment tables, which are fixed on supports. The accuracy and rigidity of the used adjusting mechanisms provided an opportunity for summation on the screen two light beams with dimensions of 100 × 100 mm (at the output of the laser cuvette) at a distance of 263 m with an accuracy of ~ 1 mm.

* Ivan.Kaplunov@tversu.ru



Fig. 1 – General view of the experimental apparatus



Fig. 2 – Laser cuvettes with Brewster windows of NaCl single crystals having a diameter of 300 mm

At full beam divergence $\sim 10^{-3}$ rad in the distance of 263 m, the focal constriction size is ~ 0.26 m, thus the distance between the interference peaks (or interference step) will be:

$$h \approx \frac{\lambda L}{\sigma} \approx 0,5 \text{ cm} \quad (1)$$

where λ – wavelength in cm;
 L – distance between the mirrors 5, 12 and screen 20 (Fig. 2) in cm;
 σ – the distance between the centers of the beams on the mirrors 6 and 14.

Since the central zone of laser beams should have divergence 2×10^{-4} rad, the maximum radiation density in the center of the interference pattern should not ex-

ceed the optical breakdown threshold on the screen, even at the output radiation energies up to 300 J. Really:

$$\rho \approx \frac{4E^* T_{tr}}{\alpha_D^2 L_{tr}^2 \tau^*} \approx 0,5 \times 10^7 \text{ Watt} \cdot \text{cm}^{-2} \quad (2)$$

Where: E^* – the energy in the central zone of the pulses in one of the beams;

T_{tr} – transmission coefficient of the track;

α_D – the diffraction angle;

L_{tr} – length of the track;

τ^* – laser pulse duration ($\sim 5 \times 10^{-6}$ s).

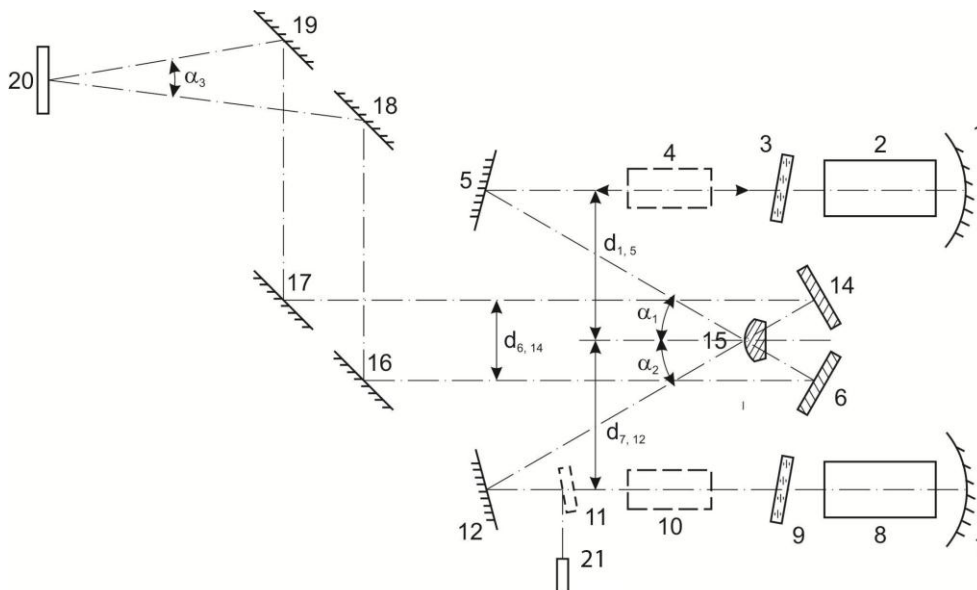


Fig. 3 – Scheme of the experiment to obtain coherency of two pulse CO₂-lasers with large aperture and high power output: 1, 7 - resonator copper concave mirror with a radius of $R \sim 4 \times 10^3$ cm; 3, 9 - the windows of NaCl at Brewster angle; 15 - square (6×6 cm) copper output mirror with a radius of $Rz \sim 2.35 \times 10^3$ cm; 5, 6, 12, 14, 16 - 19 - turning flat mirrors for part radiation output (diameter ~ 200 mm); 2, 8 - 4-section laser cuvettes, the length of the active medium changes discretely from 40 to 160 cm; 4, 10, 21 - adjustment semiconductor lasers; 11 - plane-parallel plate of single crystal BaF₂

3. RESULT AND DISCUSSION

During this experiment we detected the interference under summation 2 beams of pulsed CO₂-lasers with minimal convergence angle rays (Fig. 4).

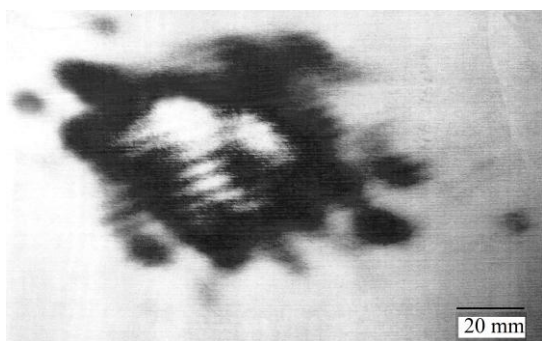


Fig. 4 – The imprint on thermal paper of the interference pattern, obtained under the summation two beams of pulsed CO₂ laser

Sharpness of the interference pattern increases with decreasing energy of radiation. That is caused by dynam-

ic range of sensitivity of the thermal paper used for registration. Interference pattern and the size of the central zone of radiation beams were well reproduced in different experiments. Due to the small dynamic range of thermal paper in a bright part of the central zone of radiation beams, blurring of the interference pattern was observed; interference phenomenon due to 2 times increase of energy density in the maximum of the band allows to fix the sub threshold levels of laser energy density for the given thermal paper.

4. CONCLUSIONS

The imprint on thermal paper of the interference pattern, was obtained under the summation two beams of pulsed CO₂ laser.

ACKNOWLEDGEMENTS

This work was financially supported by the Ministry of Education of the Russian Federation within the framework of the performance of public works in the field of scientific activity.

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