LASER BEAM DIVERGENCE METER

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We have developed a beam angular divergence meter with a CCD camera intended for testing beam quality of UV excimer lasers. Maximum diameter of the laser beam is 110 mm. *The resolution of the instrument corresponds to the diffraction limit. The wavelength region is within the range from* 200 *to* 1100 nm. *Preliminary testing of the meter has been carried out using a commercial repetitively pulsed nitrogen laser of ILGI-503 type and a cw He-Ne laser of LGN-105 type. Operation of the instrument was demonstrated to be satisfactory for both cw and pulsed operating modes.*

Output beam divergence is one of the main laser parameters. Check of a beam divergence is sometimes necessary not only during laser operation but also when adjusting laser systems.[1] To obtain a laser beam of a high quality at the output of a laser system, it is necessary to achieve high quality of the output beam formed in a laser unit and to obtain the lowest (ideally, diffraction limited) divergence at its output. Hence, a divergence meter is a tool for permanent control used at the stages of modeling and testing of lasers and laser systems.

We have developed a divergence meter of laser radiation that is intended for use in UV excimer laser systems. The operation of instrument is based on the analysis of spatial distribution of the illumination measured in the focal plane of a long-focus objective. This analysis characterizes angular spectrum of laser beam. It is performed using a CCD camera and a system of information processing based on IBM PC/AT.

Laser beam is reflected by the front surface of plates *2* (see Fig. 1), passes through the objective *3*, and is focused onto the photosensitive area of a CCD. Wedge-shaped quartz plates perform two functions : they provide measurement of the beam divergence in parallel with the normal operation of laser system inspected and reduce pulsed power of laser beam irradiating the detector. Additional attenuation of laser radiation was provided by a filter *4* placed in front of a photodetector. Focal length of the objective (lens) *3* of a diffraction quality was approximately equal to 10 m. Video signal from the CCD enters a computer *7* through an interface adapter *6*. Digital processing of input data is performed by a computer and the results are presented on the display or printed out.

Photosensitive device with charge coupling of FPPZ-7L type including two lines of photodetectors exhibits a wide range of spectral sensitivity with its lower boundary lying in the UV at 200 nm. Functional diagram of video camera with a CCD is presented in Fig. 2.

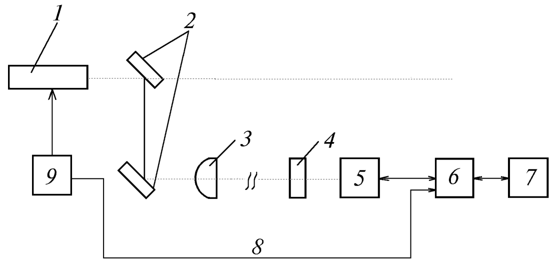

FIG. 1. Block diagram of the meter: laser under control 1, wedge-shaped plates 2, an objective 3 a filter 4, a video camera 5, an interface adapter 6, a computer 7, the line of synchronization 8, and a laser triggering device 9.

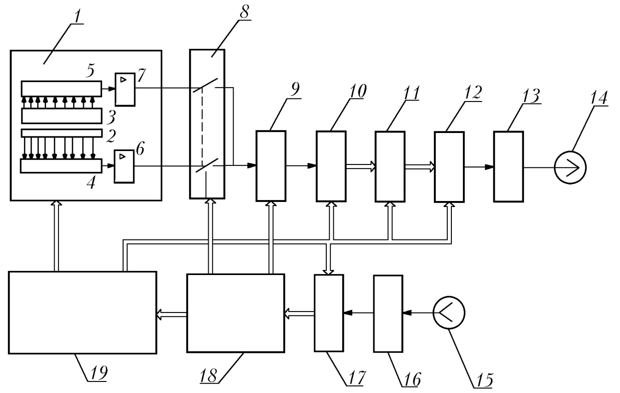

FIG. 2. Functional diagram of the video camera with a CCD: a photodetector 1, a narrow line 2, a wide line 3, analog registers 4 and 5, amplifiers 6 and 7, a multiplexer 8, an amplifier 9 with a variable amplification factor, an analog-to-digital converter 10, RAM 11, a serial register 12, a transmitter 13, the output connector 14, the input connector 15, a detector 16, a shift register 17, a scheme of parameter assignment 18, and a multi-step generator 19.

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The card of the interface adapter (see Fig. 3) is mounted in the computer system unit. Output cascades of the adapter and video camera (detectors/transmitters) provide reliable delivery of information at a distance up to 50 m. This is achieved due to absolute electrical decoupling of power circuits of video camera and computer.

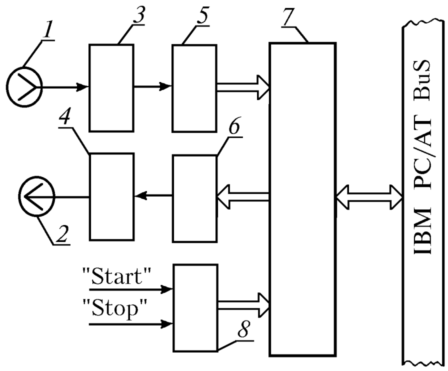

FIG. 3. Functional diagram of the interface adapter: an input connector 1, an output connector 2, a detector 3, a transmitter 4, the shift register of detector 5, the shift register of transmitter 6, the scheme of input and output 7, and the scheme of single initiation 8.

Video camera can operate in two modes, specifically, in modes of single trigger and of periodical trigger. Selection of the operating mode and assignment of a number of its parameters are performed from a computer keyboard. Program works in an interactive mode, and input parameters are assigned responding to computer inquiry. The operating mode of the video camera, exposure time, delay of laser trigger, amplification factor of the amplifier of the video signal, the number of line and the number of measurements serve as input data. After storage of the picture, one can assign any level of intensity with respect to its maximum and obtain the angle of divergence based on corresponding level.

Construction of the video camera unit allows one to rotate CCD within 180° with indication of the angular position on a limb with the scale of 1° per division. This allows one to obtain a two-dimensional angular spectrum of radiation if several pictures are successively fixed at different angles of orientation of the CCD.

Divergence meter can be used for measurement of beam divergence of both pulsed and cw lasers. Testing of operation of the instrument with a cw laser was performed using a commercial He-Ne laser of LGN-105 type. Since laser beam diameter did not exceed 2 mm, the conventional objective was replaced by an objective with focal length of about 1.5 m. An example of output data from one line is presented in Fig. 4. Reproducibility of the value of beam divergence measured by successive fixation of the line during 30 minutes was not worse than 2%.

Tests of operation of the instrument with pulsed radiation was performed using a commercial nitrogen laser of ILGI-503 type. Pulse repetition frequency was 30 Hz at a pulse duration of 10 ns. An objective with a shorter focus (about 300 mm) was used since beam divergence was extremely high. Reliable operation of the instrument with a pulsed laser was demonstrated. The divergence of the central core measured was $2.8 \cdot 10^{-3}$ rad.

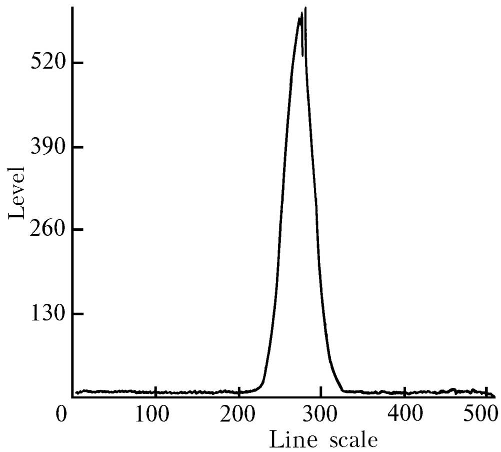

FIG. 4. Angular distribution of the beam intensity of a He-Ne laser in a fixed cross section.

Spectral region of sensitivity was determined using a Hitachi-330 spectrophotometer made in Japan. The curve of spectral sensitivity of the video camera is presented in Fig. 5. It is seen that spectral region of the sensitivity of the instrument is from 200 to 1100 nm.

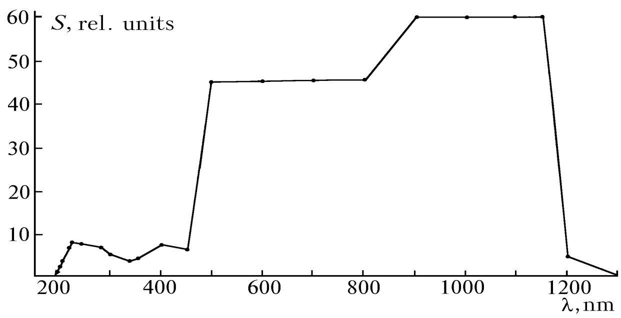

FIG. 5. Sensitivity of the CCD versus wavelength (unequal spectral response of spectrophotometer was neglected).

Thus, a laser beam divergence meter has been developed which can be used for the beam quality control of both cw and pulsed radiation in the wide range of wavelengths.

REFERENCES

1. S.E. Kovalenko and V.F. Losev, Kvant. Elektron. **19**, No. 3, 219–221 (1992).