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Powerful Laser Diode Matrixes for Active Vision Systems

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***Abstract*—**This article is deal with the experimental investigations of the laser diode matrixes (LDM) based on the AlGaAs/GaAs heterostructures (lasing wavelength 790-880 nm) to find optimal LDM parameters for active vision systems. In particular, the dependence of LDM radiation pulse power on the pulse duration and LDA active layer heating as well as the LDM radiation divergence are discussed.

***Keywords*—**Active vision systems, laser diode matrixes, thermal properties, radiation divergence.

I. Introduction

THE active vision systems (AVS) are widely used for visualization of object under bad visibility conditions (night, fog, smoke, snow, dust and so on) [1]-[4]. They are needed for safe operation of automobiles, railways, river transport, aircrafts, as well as for search and rescue operations, providing general security of sites, etc. The AVS operation is based on the following principle: the object being viewed is illuminated by short light pulses of duration substantially shorter than the time it takes light to propagate to the object and back. The receiver usually contains an electro-optical image converter which is opened for a short time in synchrony with the light pulses. When the delay between the opening of the image converter gate and the emission of the illuminating pulse is equal to the time required for the light to propagate to the object and back, the observer sees only the object and the layer of space immediately adjacent to it [3]. The system is mainly composed of high power near infrared pulsed laser transmitter, photoelectric receiving imaging module, range-gated synchronization control module, system control and image processing module [4].

Among the modern requirements to the active vision systems the compactness and low power consumption are the most significant. To satisfy all the requirements the laser diode matrixes (LDM) should be used. The aim of the report is experimental investigations of the LDM based on the AlGaAs/GaAs heterostructures with two quantum wells (lasing wavelength 790-880 nm) to find optimal parameters of the laser diode matrixes for the active vision systems.

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II. Experimental Investigations

The lasing wavelength range of 790-880 nm is chosen by the reason of satisfaction of the LDM radiation to the atmosphere transparency [5] and invisibility for human eye conditions. The most preferable lasing wavelength is 870 nm which correspond to the maximal atmosphere transparence in the range of 800-900 nm [5].

The LDM SLM-7-4 was produced by JSC "Inject" (Russia) [6]. Total optical output pulse power of the LDM is in the range of 2-4 kW. The LDM dimensions are 3.5 cm × 3 cm. An example of the lasing spectrum of the laser diode matrix at room temperature is shown in Fig. 1.

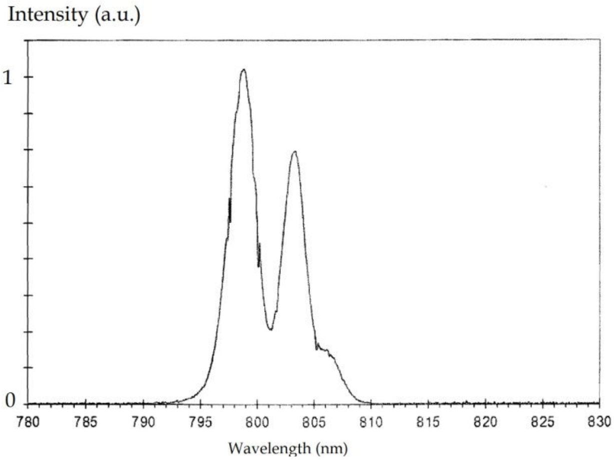
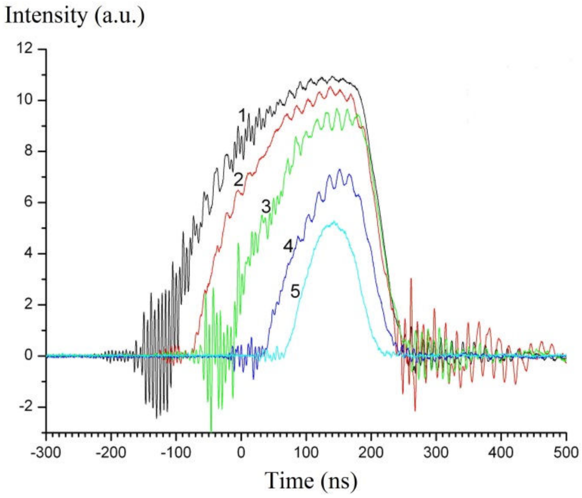


Fig. 1 The LDM lasing spectrum

The laser diode matrixes with the above mentioned parameters are widely used for solid-state laser pumping, e.g. for Nd:YAG lasers [7]. The typical LDM radiation pulse duration is about 250 μs for the solid-state laser pumping purpose.

Achievement of AVS's high efficiency is connected with a high average power of illumination, which along with peak optical power depends on the pulse duration and pulse repetition rate. In turn effective realization of the principle of range gated active night vision supposes usage of short light pulses. As contrasted to the laser pumping, the laser diode matrix radiation pulse duration must be about 10-300 ns for the application in the active vision systems which are used for the distances from 100 m up to 10 km [1]-[4].



1 – 280 ns, 2 – 235 ns, 3 – 190 ns, 4 – 128 ns, 5 – 90 ns

Fig. 2 The LDM radiation pulse amplitude dependence on the pulse duration

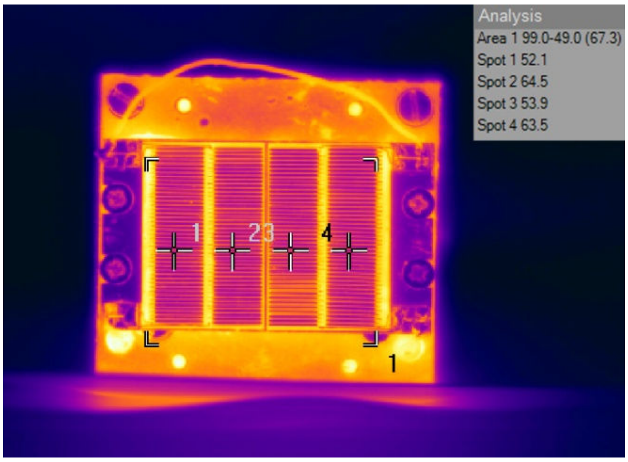
For the laser diode matrix under investigation the output radiation pulse duration was determined experimentally by using the Hamamatsu photomultiplier H6780-20 and Tektronix TDS 3032 B oscilloscope. The results of the output radiation pulse amplitude dependence on the pulse duration are presented in Fig. 2 for the following operation mode: injection current was of 50 A, operating voltage was of 160 V; injection current pulse repetition rate was of 10 kHz.

As seen in Fig. 2 the shorter pulse duration the lower output pulse power. An output pulse with high power is needed to the high AVS contrast and output pulse with short duration time is needed to high spatial resolution in the view zone along the view direction. So, to construct AVS with high contrast and spatial resolution one needs to find the optimal pulse duration value.

The pulse duration increasing together with the pulse power increasing leads to the LDM active layer (AL) heating. The active layer overheating is one of the main laser diode matrixes degradation factors. Thus, the AL heating is the additional limiting condition for the pulse duration increasing.

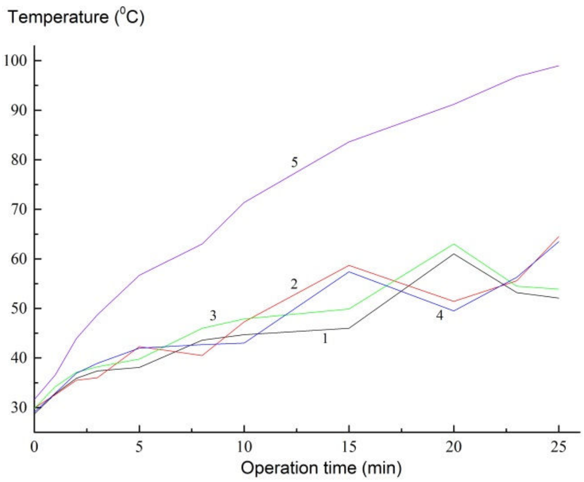
For the LDM heating investigation the infrared camera FLIR A655sc calibrated on the base of ambient temperature black body (Wahl instruments, Inc.) was used. The thermal view of the operating LDM is shown in Fig. 3 (the ambient temperature was of 23°C, injection current pulse duration was of 180 ns, the pulse repetition rate was of 10 kHz).

The individual laser diode arrays and LDM mount heating dependence on the LDM operation time is presented in Fig. 3. As seen in Fig. 4 the forced cooling is necessary for the efficient LDM operation because the lasing wavelength thermal shift is about 1 nm/K for the LDM under investigation an pulse duration of 180 ns and repetition rate of 10 kHz. For lower pulse duration and/or pulse repetition rate the thermal stabilization of the LDM is not necessary. But low pulse repetition rate leads to the average power decreasing which in turns leads to the AVS effective distance decreasing.



In the right corner of the figure the temperature of individual laser diode array and the LDM mount is presented in Celcium degrees

Fig. 3 The thermal view of the operating LDM



1-4 - the laser diode arrays according to the Fig. 3, 5 - the LDM mount

Fig. 4 The laser diode array and heat sink heating dependence on the LDM operation time

One of the main tasks for active vision system efficiency is concluded in adjustment of the angle of AVS receiving objective with a divergence angle of light source illumination. This task is actual, especially by using laser diode matrix as a light source, since the initial radiation divergence angle of LDM's illumination attain 50 and more degree on fast axis (which correspond to the case of the LDM radiation propagation in the plane which is perpendicular to the p-n junction plane).

The AlGaAs/GaAs laser diode matrix output radiation divergence diagram is presented in Fig. 5. The divergence diagram was measured by using goniophotometer LEDGON 10C.

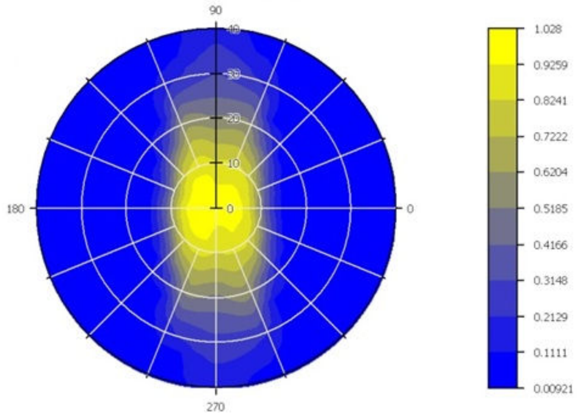
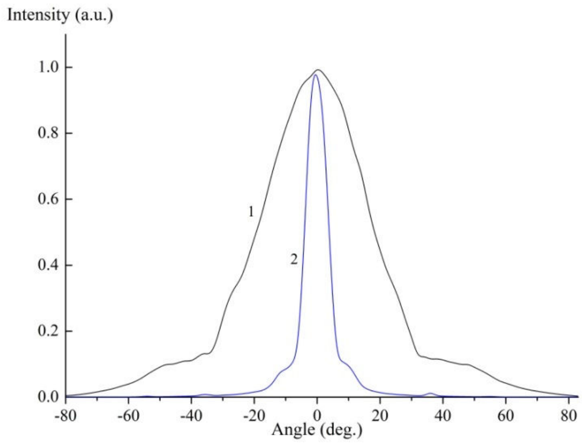


Fig. 5 The radiation divergence diagram from the point of view distant from the LDM at 80 mm

The LDM radiation divergence in the fast and slow (which correspond to the case of the laser diode matrix radiation propagation in the LDM p-n junction plane) axis is presented in Fig. 6 more detail.



1 – fast axis, 2 – slow axis

Fig. 6 The LDM radiation divergence

But in the real active vision systems divergence the angle of illumination of the order of 10 – 1 degree and less is required. To achieve such laser diode matrix divergence angle values the microoptical raster was used in present work. The raster photo is presented in Fig. 7. The raster is composed of groups of cylindrical microlenses. The focus length and the distance between microlenses are in concordance with the size of elementary light sources of the laser diode matrix.

The using of the microoptical raster leads to the divergence angle at FWHM decreasing from 40 to 20 degrees in the fast axis direction. There is possibility to reduce the divergence angle less than 20 degree by using the raster. But the divergence angle value of 20 deg. is sufficient to the AVS which are ussed for close distance (up to 2 km). This close distance active vision systems are used, e.g., in the headlight of dump trucks working in an open-cast mine or in the cameras for the perimeter security.

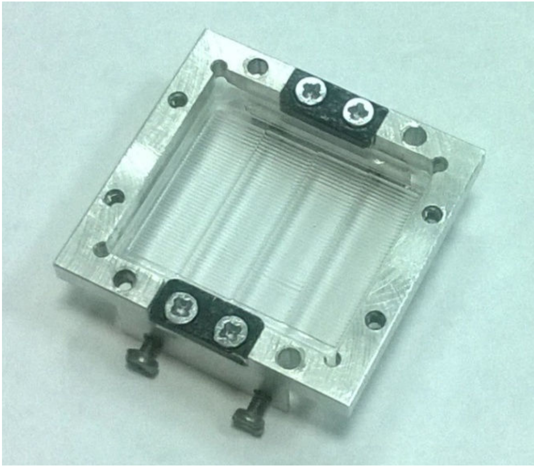


Fig. 7 The raster for the LDM

It is necessary to use the power supply which reduces the negative influence of the laser diode matrix inductance on the output radiation pulse duration.

The optimized illumination module based on the laser diode matrix for close distance active vision system with power supply is presented in Fig. 8. The illumination module dimensions are 112 mm × 51 mm × 40 mm.

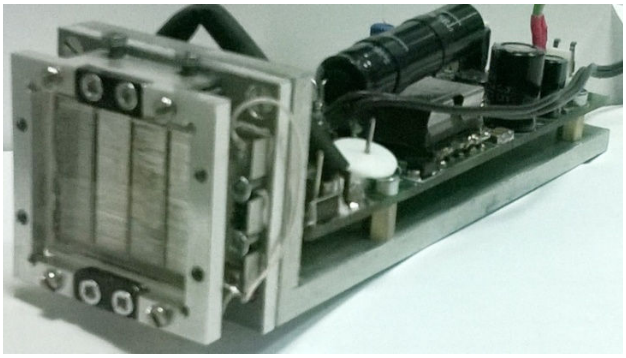


Fig. 8 The AVS illumination source based on the LDM with power supply

III. Conclusion

According to our investigations for the active vision systems acting up to 10 km the optimal LDM pulse duration is about 70 ns. To reduce the power decreasing with pulse duration decreasing the power supplier which operates stably with laser diode matrix inductance should be used.

To achieve low laser diode matrix divergence angle values the microoptical raster was used. The using of the microoptical raster leads to the divergence angle decreasing from 40 to 20 degrees or less.

REFERENCES

[1] O. David, N. S. Kopeika, and B. Weizer, "Range gated active night vision system for automobiles," *Appl. Optics*, vol. 45, no.28, pp. 7248–7254, October 2006.

[2] R. S. Espinola, E. L. Jacobs, C. E Halford, R. Vollmerhausen, and D. H. Tofsted, "Modeling the target acquisition performance of active imaging systems," *Optics Express*, vol. 15, no.7, pp. 3816–3832, April 2007.

[3] V. A. Gorobetz, V. V. Kabanov, V. M. Kabashnikov, B. F. Kuntsevich, N. S. Metelskaya, and D. V. Shabrov, "Active pulse vision systems and algorithms for determining distances to objects," *J. Appl. Spectroscopy*, vol. 81, pp. 279–287, March-April 2014.

[4] Li Yang, Zhigang Gai, Mengde Liu, Jianbin Ba, Jie Zhao, Shibo Chu, Junxian Yang, Chengjie Lu, Yang Zhao, "Experimental study of all-weather NIR laser active imaging system," *Proc. SPIE*, vol. 8912, pp. 891203-1–4, 2013.

[5] https://almascience.nrao.edu/about-alma/weather/atmosphere-model.

[6] www.inject-laser.ru

[7] T. V. Bezyazychnaya, M. V. Bogdanovich, A. V. Grigor'ev, V. V. Kabanov, O.E. Kostik, Y. V. Lebiadok, K. V. Lepchenkov, V. V. Mashko, A.G. Ryabtsev, G. I. Ryabtsev, M. A. Shchemelev, and L .L. Teplyashin, "Transversally diode-pumped Q-switched Nd:YAG laser with improved power and spatial characteristics," *Opt. Comm.*, vol. 308, pp. 26–29, 2013.