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Short Communication

HIGH POWER LONG PULSE WIDTH QCW LASER DIODE BARS FOR OPTICAL PUMPING OF YB-ER GLASS SOLID STATE LASERS

N. I. Katsavets[1], V. A. Buchenkov[2] and A. L. Ter-Martirosyan[1]
[1]ATC-Semiconductor Devices Joint-Stock Company, St. Petesburg, Russia
[2]Jenoptik Components Company, St. Petersburg, Russia

ABSTRACT

This publication is devoted to development of 100 W quasi-continues wave 950 nm long pulse width (5 ms) laser diode bars. Results on optical output power and degradations characteristics within wide temperature range (from -40^{0}C to +85^{0}C) are presented. Developed LDBs are based on advanced single quantum well separate confinement heterostructures with index-graded waveguide design optimized for generation wavelength 950 nm at +25^{0}C, low threshold current density (70 A/sm^2), high characteristic threshold current temperature (T_0=150 K) and good slope efficiency (1,1 W/A).

Estimated LDB lifetime in long pulse width regime is more than 10^9 and 10^8 pulses at heat-sink temperature +25^{0}C and +85^{0}C, respectively.

These laser diode bars are developed for effective pumping of Yb-Er glass solid state lasers (SSLs) with generation within the “eye-safe” spectral range (1.54 μm). Design of Yb-Er glass SSLs using for optical pumping two 950 nm laser diode bars was developed. Such SSLs have the pulse energy up to 8mJ at multimode regime, the pulse width 20 ns and repetition rate up to 20 Hz.

Solid state lasers (SSLs) are widely used for science and technical applications. Significant interest is attracted to SSLs which generate radiation in the “eye-safe” optical range (1.5 μm ÷ 2.0 μm) [1-3]. Radiation of Yb^{3+}- Er^{3+} (Yb-Er) doped glass SSLs is in this range. Optical radiation in 940÷970 nm spectral range effectively pumps of ions Yb. Absorption energy is then non-radiatively transferred to the “pump” level of ions Er with generation spectral line at 1.54 μm [1]. Due to durable lifetime of the metastable lasing manifold of ions Er (about 5 ms) Yb-Er glass SSLs have possibility to generate high-energy optical pulses at relatively low optical pumping density.

High power laser diode bars (LDBs) with generation wavelength 940÷970 nm can be successfully used for effective optical pumping of Yb-Er doped glass SSLs. However, long pulse width regime results in significant thermo-cycle stress in the LDB crystal [4] and makes additional demands to laser heterostructure post-growth processing and crystal bonding technologies.

In this publicity results of development of high power quasi-continues wave (QCW) 950 nm LDBs operated in long pulse width (up to 5 ms) regime are presented. They have high efficiency and can reliably operate in the wide temperature range (from -40^0C to $+85^0$C). The publication also presents SSLs based on Yb-Er glass with optical pumping by developed LDBs.

Original design of laser wafers based on single quantum well $Al_xGa_{1-x}As/In_yGa_{1-y}As$ /GaAs heterostructures with separate electronic and optical confinement having the index-graded waveguide [5] was developed. This heterostructure design was optimized for generation wavelength 950 nm at $+25^0$C, low threshold current density, high characteristic threshold current temperature and good slope efficiency [6].

Figure 1 shows the composition diagram X(d), Y(d) of grown heterostructures as well as calculated distribution of optical intensity I(d) in the waveguide (d – distance from the active region). The calculation was made using the SiLENSe program [7] adapted to cubic III-V compounds. The calculation gives the optical confinement factor Γ = 0,034 and a full width of half maximum (FWHM) of fast axis far-field laser radiation distribution (in the direction perpendicular to the p-n junction) $\Theta_{\perp} = 40^0$ which agrees well with calculated value. Such laser wafers were grown by MBE technique. Technology installation features were presented in [8]. Measuring threshold current as well as quantum efficiency of laser diodes made from the grown laser wafer versus cavity length gives transparency threshold current density 70 A/sm^2, intrerior quantum efficiency about 100% and interior optical losses 1,5 sm^{-1}.

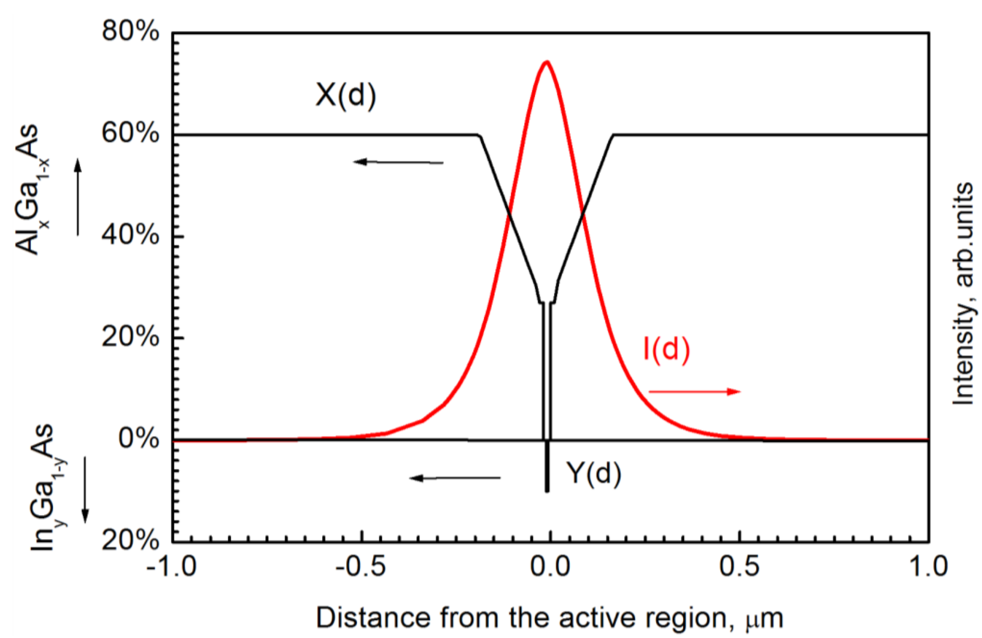


Figure 1.

LDB crystal (chip) design was the array (50 units) of optically isolated broad-area laser diodes (LDs) with stripe-width 160 µm, period of 200 µm and cavity length 1000 µm. High reflection (95%) and antireflection (5%) coating were deposited on the laser chip mirrors with electron beam vacuum technique after surface passivation treatment.

Special equipment was used for bonding of laser chips on the heat-sink with placement accuracy plus/minus one micron. Chips were bonded p-side down with the In-containing solder on the Cu-W submounts placed onto the Cu heatsinks. Solder thickness and temperature regime were optimized for minimum mechanical stress appearing after bonding.

For output optical power measurement the laser power meter “LASERMATE” was used. Spectral parameters are measured with the spectrometer “MDR-23”.

Typical output optical power dependencies versus pumping current of LDB operated at different pulse width (300 µs and 5 ms) at duty factor (10%) are presented in the figure 2.

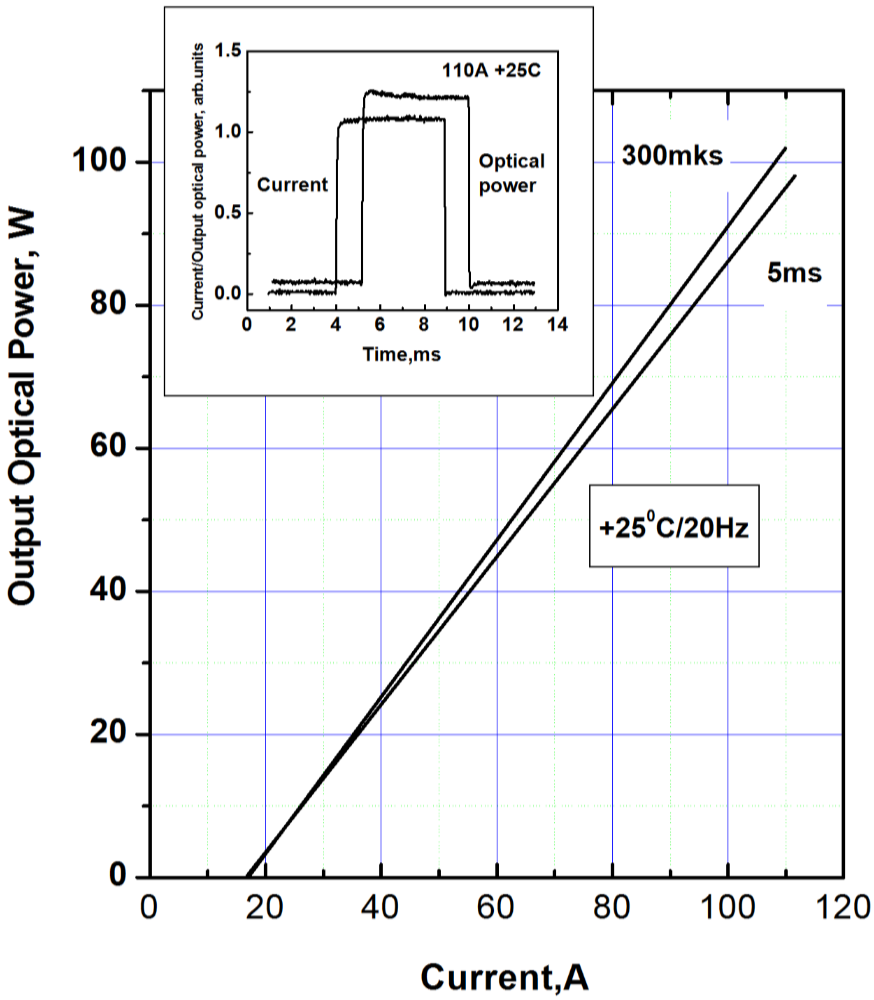


Figure 2.

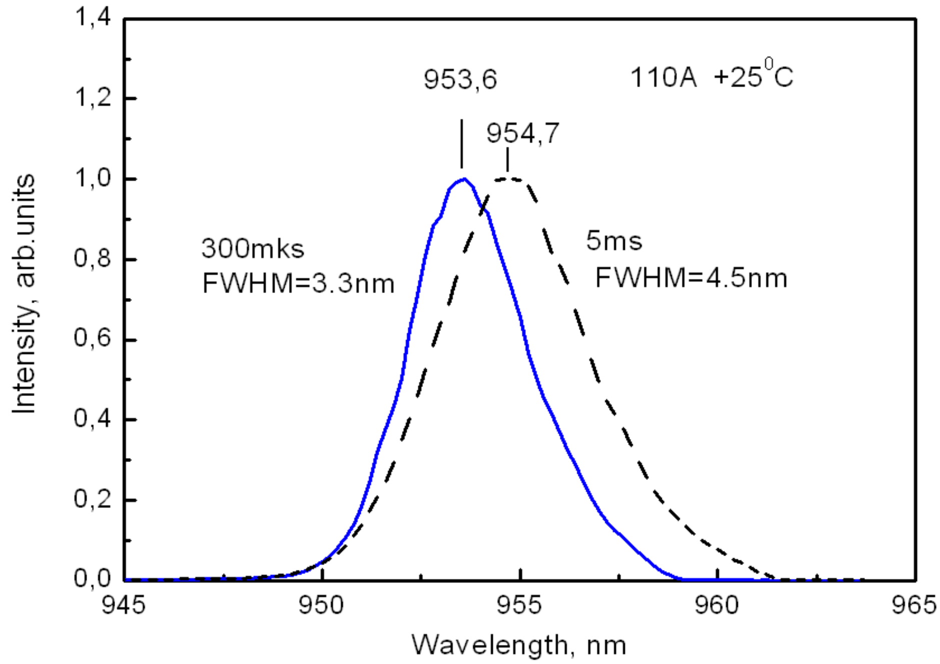


Figure 3.

Slope efficiency is slightly (from 1.1 W/A to 1.05 W/A) decreased at long pulse width operating regime. The inset in the figure 2 shows the typical oscilloscope image of the output optical pulse measured at a pumping current of 110 A. As can be seen, the decay of the output optical power during the 5 ms pulse does not exceed 5%. This fact says about low LDB active region overheating at long pulse width regime. On the other hand, low active region overheating is confirmed also by not-significant red shift and small broadening of generation spectrum (figure 3).

Figure 4 shows typical output optical power as well as power conversion efficiency versus pumping current of LDB at different heat-sink temperature (T). As can be seen, from the figure, output optical power riches to 100W (80W at $+85^0$C) without any bend with power conversion efficiency from 60% (T= -40^0C) to 40% (T= $+85^0$C). Analysis of LDB threshold current I_{th}(T) versus heat-sink temperature using expression

$$I_{th}(T) = I_{th}(0) * \exp(T/T_0)$$

gives the characteristic temperature [4] T_0=150 K.

Figure 5 shows typical spectral characteristics of LDBs at different temperature. FWHM spectral generation line increases from 3.5 nm to 5.6 nm at heat-sink temperature rise from -40^0C to $+85^0$C. Shift temperature coefficient of spectrum line maximum is 0.35 nm/degree.

Developed LDBs were exposed to long-term test at $+25^0$C and $+85^0$C of heat-sink temperature in the constant pumping current (100A) regime and pulse width 5 ms for $5*10^7$ pulses. Estimation of LDB lifetime defined as pulse quantity for 20% decreasing of initial output optical power gives the value 10^9 pulses at $+25^0$C and more than 10^8 pulses at $+85^0$C.

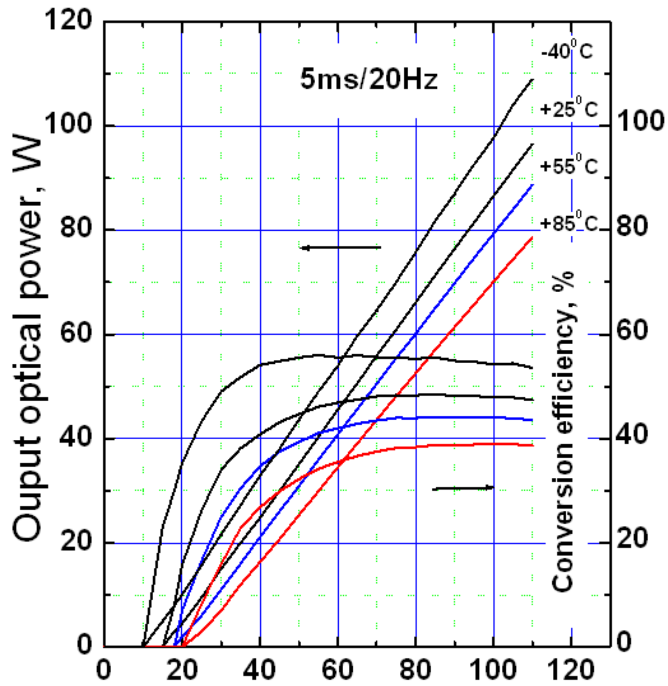


Figure 4.

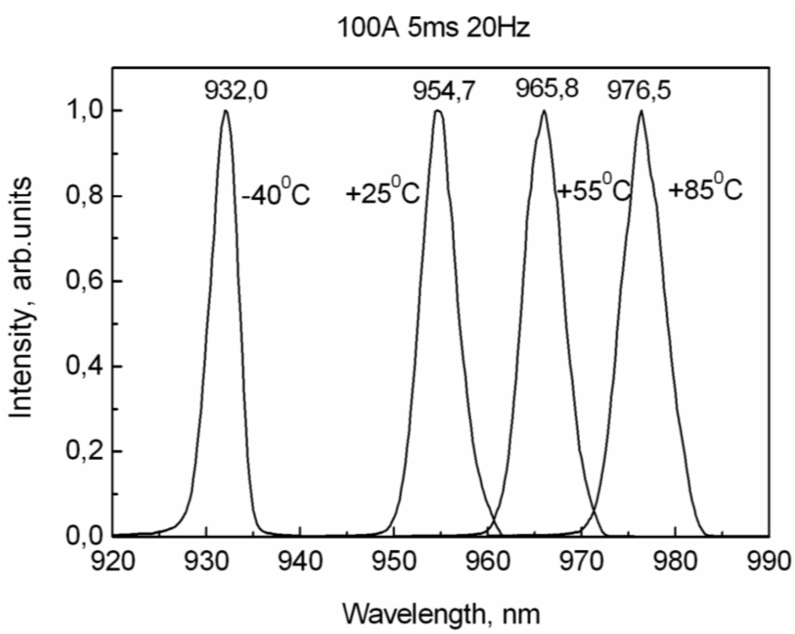
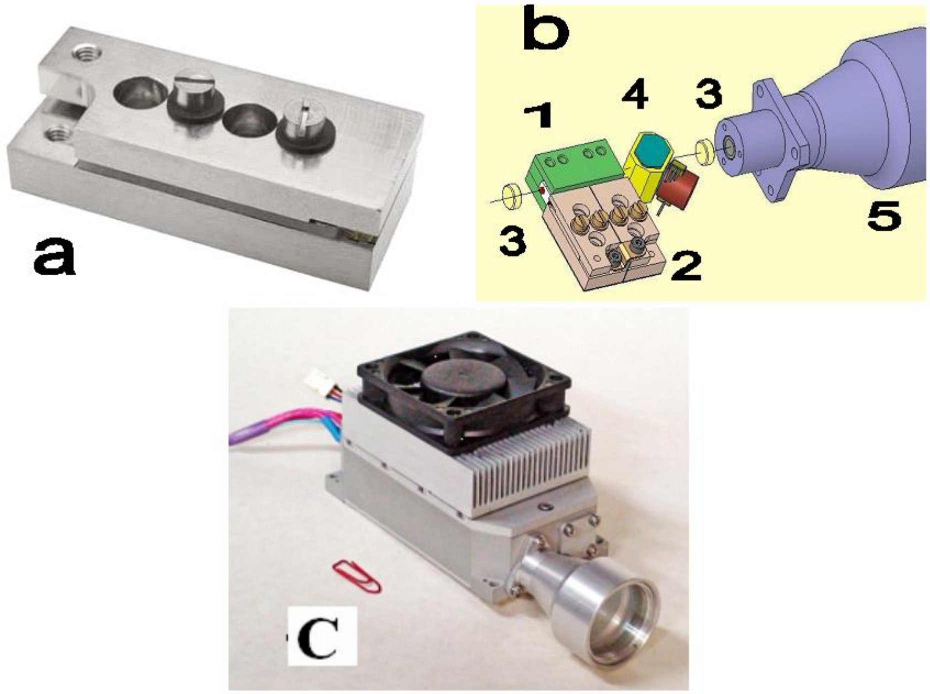


Figure 5.



a) the exterior view of the LDB;
b) the simple schema of Yb-Er glass SSL (1 – the resonator with theYb-Er active crystal, 2 - two LDBs, 3 - mirrors, 4 – the active optical shutter, 5 – the telescope);
c) the exterior view of Yb-Er SSL.

Figure 6.

Reliable operation of developed LDBs at wide temperature range (from -40 to +85^{0}C) and a broad shoulder in the Yb absorption spectrum [3] gives opportunity to create Yb-Er SSL without thermo-stabilization of pumping system. Such SSL design results in low energy consumption, construction simplicity and high reliability.

Yb-Er glass SSLs with optical pumping based on developed LDBs were created. Such SSLs use two LDBs and operate in “eye-safe” range (1,54µm) with energy 8 mJ at multimode operation, pulse width 20ns and frequency up to 20Hz. The exterior views of developed LDBs and SSLs with simple optical pumping schema are presented in the figure 6.

In conclusion, high power long pulse width QCW 950nm LDBs operating in wide temperature range were developed. They are successfully used as optical pumping in SSLs based on Yb-Er glass.

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