InAs(Sb) LEDs and negative luminescent devices for dynamic scene simulation in the first atmospheric window (3-5 μm)

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We report on the test results of 3 to 5 um wavelength light-emitting diodes (LEDs), which simulate highest apparent temperature (T_a) values for photonic emitters yet, reported. Points of our concern are maximum power emitted in both positive and negative modes, uniformity of light pattern in micro scale (current crowding effect), and possible effect of a structure base overheating on a device performance.

The 3.3-3.4 μm LEDs were grown as lattice matched InAsSbP/InAs double heterostructures (DHs) by the LPE process onto heavy doped and therefore practically transparent for emitting wavelength InAs substrate**.** The DH consisted of 1-1.5 μm thick wide-gap n-$InAs_{1-x-y}Sb_xP_y$ (0.08<x<0.09, 0.15<y<0.19) confining layer, 0.5-1 μm thick n-InAs active region and 2-3μm thick wide-gap p-$InAs_{1-x-y}Sb_xP_y$(Zn) (0.08<x<0.09, 0.15<y<0.19) emitter. The n-InAs active region was grown from the melt with gadolinium ions as a gettering agent; this type melt purification process reduces the concentration of non-radiative recombination centers and therefore increases quantum efficiency of the structure. The epilayers for the 4-4.7 μm LEDs have been grown as 25÷60 μm thick InAsSbP graded band gap structures. The layers were characterized by low dislocation density (10^4 cm^{-2}) due to lattice match conditions at heterojunction and smooth increase of lattice parameter to the surface which make possible “inverse defect formation”. The samples were curved with R=10÷15 cm and were characterized by an increase of antimony and the decrease of phosphorus concentrations towards the epilayer surface

The wafers were processed by a wet photolithography into circular (D=300 μm) mesa chips. Ohmic contacts (central circular anode of d=150 μm and peripheral 'U-shaped' cathode) were formed by thermal evaporation of Au. Both chip contacts were soldered to contact area of a 1.5x1.7x0.4 mm^3 semi insulating Si submount. Next, the Si submounts with LED chip were soldered onto a TO-39 header in substrate up manner. Some LEDs were equipped with immersion lens made from CdSb and attached to the LED surface by a chalcogenide glass. The full width at half-maximum of the collimated beam escaping the structure through substrate and lens was less then 25^0.

The IR micro mapping system we developed consists of reflective-type IR microscope co-axially attached to scanning IR thermal imaging camera operated in the 3-5 μm spectral range with HgCdTe cooled photo detector. This system permits scene spatial resolution better than 20 μm, the 10 μs minimum time-resolved interval, and temperature resolution of about 0.1^0C. In addition, the system is capable of operating in external triggering mode with noise reduction by image averaging[1].

Operating in extreme modes (50 usec pulse duration, 25 Hz repetition rate, I=1 A) and recorded by 3 to 5 μm infrared microscope, the devices are capable of simulating dynamic apparent temperature ΔT = 300 K at room temperature and $\Delta T \geq$ 500 K when cooled down to T=200 K (positive contrast devices). We show that the results achieved are due to charge carrier confinement, intended structure doping by rare-earth metals, improved heat sink and internal beam focusing in a transparent substrate-up mesa structure. We show also that the most effective room temperature negative contrast devices are 4.4 μm-emitting structures. By comparing these LEDs to the conventional edge-emitting diode lasers, we show that conventional non-resonant IR LEDs are becoming an important candidate to form the basis for IR (3 to 5 μm) dynamic scene simulation devices.

Shown in Fig.1 are some results of high-resolution mapping (28 ms frame duration) of radiation emitted by InAs (λ=3.3 μm, top) and InAsSb (λ=4.3 μm, bottom) mesa down LEDs. Being spatially uniform at low forward bias the light spatial distribution suffer of current crowding, that results in concentration of light over central circular contact (conventional electroluminescence mode). That is not the case for reverse bias mode (negative luminescence) [2,3].

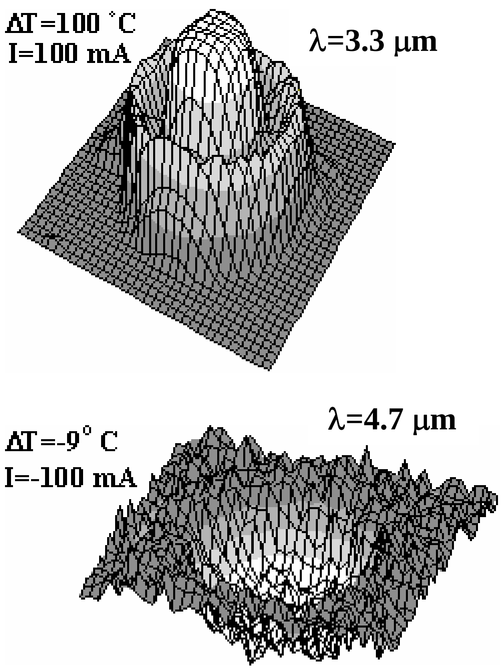

Fig.1 Two-dimensional distribution of the apparent temperature over the surface of the activated LEDs as detected by thermal camera

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