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Resonant cavity enhanced InAs/GaAsSb SLS LEDs with a narrow spectral linewidth and a high-spectral intensity operating at 4.6 μm

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ABSTRACT

We investigated the design, growth, fabrication, and characterization of InAs/GaAsSb SLS resonant cavity light emitting diodes (RCLEDs) grown on InAs by molecular beam epitaxy. The structure consists of a 1λ-thick micro-cavity positioned between two lattice-matched AlAsSb/GaAsSb distributed Bragg reflector mirrors (DBRs). A 44-pair InAs/GaAsSb SLS active region is placed at the antinode of the electric field intensity in the center of the cavity. Electroluminescence emission spectra were recorded at room-temperature. Due to the resonant cavity effect, 400 μm-diameter SLS RCLEDs exhibited emission spectra peaked at 4.587 μm with a narrow spectral linewidth of 52 nm. A high-spectral intensity of >3 mW cm^{-2} nm^{-1} was achieved for the 400 μm SLS RCLED using 1% duty cycle to avoid Joule heating. Furthermore, temperature dependence of the emission spectra of the RCLED showed excellent temperature stability, with a rate of 0.34 nm/K. Compared to existing mid-infrared 5-stage InAs/GaAsSb SLS ICLEDs operating at ∼4.5 μm, the (400 μm-diameter) InAs/GaAsSb SLS RCLEDs exhibited 10.5× brighter spectral intensity, 14× narrower spectral linewidth, and 8× improvement in the temperature stability. Owing to these attractive features, our SLS RCLEDs could be used to develop the next generation CO gas instruments and active imaging.

There is a growing requirement for bright light emitting diodes (LEDs), which operate in the technologically important mid-infrared range, for applications such as environmental monitoring, industrial process control, and spectroscopy. Although extensive efforts have been devoted to developing mid-IR LEDs operating at room temperature and emitting at wavelengths of >4 μm,[1–8] the spectral intensity of these devices is relatively low due to the broad emission spectrum and to the low output power of a <10 μW. Interband cascade structures have been used to improve performance, including a variety of mid-infrared interband cascade light emitting diodes (ICLEDs) grown on GaAs, InAs, Si, and GaSb substrates.[9–14] At 300 K, these devices have generally been designed for the wavelengths of >4 μm, such as a 5-stage InAs/Ga(As)Sb SLS ICLED emitting at a wavelength of ∼4.5 μm[13] and a 16-stage InAs/GaSb SLS ICLED emitting at ∼4.6 μm.[14] Although these ICLEDs have high integrated output powers, their linewidths are still quite broad with a full width at half-maximum (FWHM) of >500 nm. Hence, the spectral intensity, important for spectroscopy, remains limited.

The resonant cavity (RC) enhanced LED is an attractive technology to enhance emission intensity and reduce linewidth, resulting in high spectral intensity. This is achieved using an active region at the electric field antinode inside a micro-cavity.[15] Typically, the cavity is positioned between two high-contrast distributed Bragg reflector (DBR) mirrors. The DBR reflectivity and the wavelength of the optical cavity mode can be controlled by varying the number of periods and the cavity thickness, respectively.[16] To date, most resonant cavity light emitting diodes (RCLEDs) operating in visible, near-, and mid-infrared wavelengths have been grown on GaAs, InP, and GaSb,[15,17–24] but no RCLEDs have been grown on InAs. Al(Ga)As/GaAs and AlAsSb/GaSb distributed Bragg reflectors (DBRs) were used as mirrors in the GaAs-based RCLEDs and GaSb-based RCLEDs, respectively. For wavelengths of >4 μm, there are a few reports of RCLEDs, including GaSb-based 4.3 μm bulk InAsSb RCLED with a spectral linewidth of ∼88 nm[23] and GaSb-based 4.5 μm AlInAs/InAsSb MQWs RCLED with a spectral linewidth of ∼70 nm.[24]