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Mid-infrared resonant cavity light emitting diodes operating at 4.5 µm

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Abstract: We report on a mid-infrared resonant cavity light emitting diode (RCLED) operating at the wavelength of 4.5 µm with a narrow spectral linewidth at room temperature. Compared to a reference LED without a resonant cavity, our RCLED exhibits (85x) higher peak intensity, (13x) higher integrated output power, (16x) narrower spectral linewidth and (7x) superior temperature stability. The device consists of a one-wavelength thick micro-cavity containing an $Al_{0.12}In_{0.88}As/InAs_{0.85}Sb_{0.15}$ quantum well active region sandwiched between two high contrast $AlAs_{0.08}Sb_{0.92}/GaSb$ distributed Bragg reflector mirrors, grown lattice–matched on GaSb by molecular beam epitaxy. The high spectral brightness, narrow linewidth and superior temperature stability are attractive features, enabling these devices to be used for detection of N_2O at 4.5 µm. We show that with only minor adjustments the gases CO_2 (4.2 µm) and CO (4.6 µm) are also readily accessible.

1. Introduction

There is a growing requirement for light emitting diodes operating in the technologically important mid-infrared spectral range, for applications such as gas and chemical sensing, infrared scene projection, industrial process control and spectroscopy. For example, mid-infrared absorption spectroscopy is an attractive technique for monitoring greenhouse gases such as CH_4 (3.3 µm), CO_2 (4.2 µm) and N_2O (4.5 µm) because they have strong fingerprint absorptions in this spectral range, enabling gas specific detection and remote sensing. Consequently, there is an increasing demand for mid-infrared light sources and detectors at these key wavelengths. Compared with thermal sources LEDs are more robust and can be operated at high modulation rates, with low power consumption, making them better suited to portable instruments. Mid-infrared LEDs also provide a more attractive, cost-effective alternative to cascade lasers especially for widespread distributed sensing applications requiring many point sensors. A variety of prototype LEDs on InAs and GaSb substrates, have already been demonstrated for some of the target wavelengths [1–6]. There has also been significant interest in developing mid-infrared LEDs on less expensive GaAs substrates, using various buffer layer schemes to accommodate the large inherent lattice mismatch with respect to active regions of alloys and heterostructures having suitable band gaps [7]. This resulted in devices of some complexity ranging from LEDs with bulk active regions in small arrays [8–11], to multispectral mid-infrared multiple quantum well (MQW) emitters [12]. Sources with sufficiently narrow linewidth and high enough spectral intensity could also be integrated with Si/Ge waveguides [13–16]. However, due to insufficient power in the absorption band of interest (low spectral intensity), there are still relatively few examples of LED based instruments or widespread technology uptake [17]. More recently, high emittance interband cascade LEDs (ICLEDs) have been demonstrated at $\lambda \approx 3.2$ µm [18], 3.7 µm [19] and 4.1 µm