Mid-IR Optoelectronics: Materials and Devices
Room Lecture Hall, Nielsen Hall - Session MIOMD-TuA1

ICLs and LEDs

Moderator: Jerry Meyer, Naval Research Laboratory

1:30pm **MIOMD-TuA1-1 Interband Cascade Technology for Long Wavelength GaSb based Lasers and LEDs**, ***Robert Weih**, J. Nauschütz,* nanoplus Advanced Photonics Gerbrunn GmbH, Germany*; H. Knötig,* TU Wien, Austria*; N. Schäfer,* nanoplus Advanced Photonics Gerbrunn GmbH, Germany*; B. Schwarz,* TU Wien, Austria*; J. Koeth,* nanoplus Advanced Photonics Gerbrunn GmbH, Germany **INVITED**

Since the first demonstration of continuous wave operation [1] Interband Cascade Lasers (ICLs) have shown tremendous improvement in their performance. Not only cw operation up to a temperature of more than 100°C has been shown [2] but also the capability of the interband cascade concept to operate to wavelengths beyond 13µm [3]. Recently we demonstrated another design improvement which focusses on the mitigation of intervalence band absorption [4]. This in turn led to a significant improvement of laser performance in the wavelength region around 6 µm [5]. A spectrum and LIV characteristics of an epi down mounted laser are shown in Figure 1. Furthermore, the latest results on resonant cavity ICLEDs and long wavelength ICLEDs with emission um to 10.2µm will be shown.

2:00pm **MIOMD-TuA1-4 Metamorphic Growth of MWIR ICLED on Silicon**, ***Fatih Furkan Ince**, T. Rotter, M. Frost, G. Balakrishnan,* University of New Mexico*; M. McCartney, D. Smith,* Arizona State University*; C. Canedy, W. Bewley, S. Tomasulo, C. Kim,* U.S. Naval Research Laboratory*; M. Kim,* Jacobs Corporation*; I. Vurgaftman, J. Meyer,* U.S. Naval Research Laboratory

Interband cascade light emitting diodes (ICLEDs) grown on GaSb substrates have emerged as an effective continuous wave (CW) room temperature emitter technology in the 3 – 5 µm wavelength range [1,2]. The integration of ICLEDs directly on a silicon substrate can lead to significant benefits in manufacturability for applications including chemical sensing and IR scene projectors (IRSPs).

This presentation will discuss the growth at NRL of high performance ICLEDs on GaSb/Si buffers that were grown at UNM. The growths on GaSb *vs*. GaSb/Si are compared for crystallographic quality using cross section transmission electron microscopy (XTEM) and X-Ray reciprocal space maps (RSM). XTEM images show the presence of threading dislocations in the GaSb buffer grown on Si, with a higher density near the silicon substrate and reduced closer to the ICLED. We measure a range from 5 x 10^7 to 2 x 10^8 cm^2 in different samples. Individual threading dislocations in the GaSb buffer can reach the ICLED and multiply once they reach the active stages (figure 1). Another artifact of growth on silicon is an undulation in the ICLED layers. Our presentation will provide a detailed mechanism for both of these observations, and we will compare the results to those for an ICLED grown lattice-matched to a GaSb substrate (figure 2). We will also discuss possible strategies for improving the epitaxial quality and device performance.

2:20pm **MIOMD-TuA1-6 Production MBE Growth of QuiC SLED with Emission in the Longwave Infrared for Custom Gas Sensing Solutions**, ***Everett Fraser**, J. Shao, B. Barnes, P. Frensley, P. Pinsukanjana, Y. Kao,* Intelligent Epitaxy Technology, Inc.*; M. Miller,* Terahertz Device Corporation

We have demonstrated quantum interband cascaded superlattice light emitting diodes (QuiC SLED) operating in the longwave infrared for gas sensing applications. Production scale growth of strained layer superlattice (SLS) based materials presents challenges associated with volume material manufacturing and requires solutions for both uniformity and consistency of material output. We have developed a MBE growth methodology for routine production of SLS materials for focal plane array applications and applied these capabilities to growth of QuiC SLED materials for the gas sensing market. The QuiC SLED materials were developed based on Terahertz Device's Version 1.5 technology node architecture and produced by IntelliEPI on an Sb-equipped Riber MBE6000 multi-wafer production MBE system. The multi-wafer growth run was characterized for defect levels, uniformity of deposition and wafer warpage. The QuiC SLED materials were processed into surface emitting diodes based on standard photolithography and wet chemical etching. Electroluminescence emission was measured by FTIR spectrometer at various operating temperatures and show emission within the LWIR spectral band. The emission peak wavelength decreased with drive current from 10.6 µm to 10.2 µm.

2:40pm **MIOMD-TuA1-8 Interband Cascade Laser on Silicon for High-Speed Applications in the Mid-Infrared Domain**, ***Sara Zaminga**,* Mines-ParisTech, France

Quantum cascade structures are nowadays becoming mature solutions enabling mid-infrared (MIR) light-generation for diverse applications, such as free-space communications [1] and precision spectroscopy [2].

In the 3-6-µm transmission window, the interband cascade laser (ICL) is an excellent candidate over the quantum cascade laser (QCL) due to its low-threshold drive power [3]. Such reduced energy consumption meets the requirement for ultracompact devices and photonic integration: the utilization of epitaxial growth of III-V materials on silicon (Si) presents a compelling cost advantage compared to other material platforms [4]. The laser under study is a type-II Fabry-Perot (FP) ICL grown on Si, operating continuous-wave (CW) at room temperature (RT). Despite the high dislocations density and high non-radiative carrier recombination rates [5], the ICL still exhibits performances very similar to those grown on the native GaSb substrate. As shown in the light-intensity-voltage (LIV) characteristics in Figure 1a, the threshold current is 59 mA at 293 K; the maximum output power is around 11 mW per facet, the slope efficiency (per facet) is 0.12 W/A, and the external differential quantum efficiency (related to the two facets) is about 70\%. The frequency response in Figure 1b shows a sharp cut-off around 1 GHz, which is promising for multi-Gbit/s wireless transmissions. Ulterior results in this direction will be presented during the conference.

[1] Didier, P. et al.,Photonics Research11, 582-590 (2023).
[2] Sterczewski, L., et al.,Optical Engineering57, 011014 (2018).
[3] Meyer, J., et al.,Photonics7, 75 (2020).
[4] Liu, A. Y., et al.,IEEE Journal of Selected Topics in Quantum Electronics24, 6, 6000412 (2018).
[5] Cerutti, L., et al.,Optica8, 1397-1402 (2021).

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