Mid-IR Optoelectronics: Materials and Devices
Room Lecture Hall, Nielsen Hall - Session MIOMD-MoM2

Interband Cascade and Diode Lasers

Moderator: Benedikt Schwarz, TU Wien, Austria

10:30am **MIOMD-MoM2-14 Recent Advances in Interband Cascade Lasers for Mid-Wave Infrared Free-Space Optical Communications***, **Frederic Grillot**,* Telecom Paris, France **INVITED**

Free-space laser communications constitute a promising alternative for transmitting high bandwidth data when fiber optic cable is neither practical nor feasible. This technology has emerged as a strong candidate with a large potential of applications from daily-basis broadband internet to satellite links. Although the availability of high-quality transmitters and detectors operating in the near-infrared window makes the 1.55 microns optical wavelength a natural choice for free-space optical systems, two other wavelength ranges can also be considered. First, the mid-wave infrared (MWIR) window between 3 and 5 microns, and second, the long-wave infrared (LWIR) window between 8 and 12 microns. Both are well known for their superior transmission performance through adverse atmospheric phenomena, such as fog, clouds, and dust. In order to develop free-space laser communications in the MWIR, interband cascade lasers (ICL) are currently emerging as very serious candidates. In this presentation, we will review our recent progress in the physics and applications of interband cascaded devices. We will discuss their intensity noise and modulation properties and reveal the existence of the oscillation relaxation frequency that is of paramount importance to achieve very fast modulation rates. In summary, these novel findings in interband cascade devices provide clear scientific guidelines that will be very useful to researchers and engineers in the design and deployment of future free-space MWIR laser communication systems.

11:00am **MIOMD-MoM2-17 Continuous Wave Room Temperature Operation of the Epitaxially Regrown GaSb-Based Diode PCSELs***, **Leon Shterengas**,* Stony Brook University **INVITED**

Photonic crystal surface emitting laser (PCSEL) device architecture can dramatically improve brightness of semiconductor laser sources. The development of the PCSELs within nitride [1], arsenide [2], phosphide [3], and antimonide [4] material systems is subject of active research to enable high power high brightness surface emitting diode laser operation from UV to mid-infrared. One of the key technological challenges associated with PCSEL development is integration of the high-index-contrast photonic crystal layer into laser heterostructure. The air-pocket-retaining epitaxial regrowth [5] was shown to be effective technique which yielded high-power diode PCSELs. The air-pocket-retaining regrowth within antimonide material system was explored by our research group.

We report on the continuous wave (CW) room temperature operation of epitaxially regrown monolithic GaSb-based ~2 µm diode PCSELs. The devices are based on laser heterostructure containing carrier stopper layer designed to inhibit electron carrier leakage into buried photonic-crystal section. Atomic hydrogen cleaning of the nanopatterned surface followed by optimized epitaxial step resulted in highly uniform air-pocket-retaining regrowth. The laser heterostructure with buried high-index-contrast photonic crystal layer generated about 10 mW of power near 2 µm in CW regime and tens of mW in 5% duty cycle at 20 oC.

[1] K. Emoto, et al, Commun Mater 3, 72 (2022).

[2] K. Hirose, et al, Nat. Phot. 8, 406 (2014).

[3] Y. Itoh, et al, Opt. Exp. 30, 29539 (2022).

[4] L. Shterengas, et al, Phys. Status Solidi RRL 16, 2100425 (2022).

[5] M. Nishimoto, et al, Appl. Phys. Exp. 6, 042002 (2013).

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11:30am **MIOMD-MoM2-20 Single-Mode Tunable Interband Cascade Lasers with a Wide Tuning Range***, J. Gong, Z. Wang, J. He,* Zhejiang University, China*; **Rui Yang**,* University of Oklahoma

Type-II interband cascade lasers (ICLs) [1,2] are efficient and compact mid-infrared light sources with many applications such as gas sensing and environmental monitoring. Here, we report the demonstration of single-mode tunable ICLs with a wide tuning range based on V-coupled cavity [3,4]. By optimizing the coupling coefficient and the cavity structure design, the tuning range of V-coupled cavity single-mode ICLs is significantly extended with a side mode suppression ratio (SMSR) exceeding 37 dB in continuous wave operation near 3.4 µm. At a fixed temperature, a tuning range of up to 97 nm has been demonstrated. By combining two temperatures at 82K and 100K, a total tuning range of about 150 nm has been achieved, as shown in Fig. 1. The total tuning range exceeded 150 nm when operation temperature extended to 110K. More details and updated results will be presented at the conference.

11:50am **MIOMD-MoM2-22 Expanding the Frontiers of Long Wavelength Interband Cascade Lasers using Innovative Quantum Well Active Regions***, **Yixuan Shen**, J. Massengale, R. Yang,* University of Oklahoma*; S. Hawkins, A. Muhowski,* Sandia National Laboratories, USA

Interband cascade lasers (ICLs) [1-2] based on type-II quantum wells (QWs) are an efficient mid-infrared light source for many practical applications due in large part to their low power consumption. High performance operation of ICLs has been demonstrated at room temperature across a wavelength range from 2.7 µm to about 6 µm [2-4]. However, extending the operation of ICLs to longer wavelengths with similar performance as their short wavelength counterparts is challenging due to factors such as the reduced wavefunction overlap in the type-II QW and the increased free-carrier absorption loss. In this work, we report significant progress in long wavelength ICLs from newly designed and grown ICL wafers by employing an innovative QW active region containing strained InAsP layers [5]. These ICLs were able to operate at wavelengths near 14.3 µm, the longest ever demonstrated for III-V interband lasers, suggesting great potential of ICLs to cover an even wider wavelength range. Devices from another wafer were able to lase at a low threshold current density (*e.g.*, 15 A/cm^2 at 80 K) and at temperatures up to 210 K near 12.3 µm. Detailed results will be presented at the conference.

Author Index

Bold page numbers indicate presenter