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### High-efficiency interband cascade lasers

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The interband cascade laser (ICL) is a promising mid-IR (3-6  $\mu\text{m}$ ) coherent source that displays very low threshold current ( $\approx 130 \text{ A/cm}^2$ ) and power ( $\approx 300 \text{ W/cm}^2$ ) densities when operated at room-temperature in the spectral band  $\lambda \approx 3.1\text{-}3.8 \mu\text{m}$ . Most previous ICL designs have focused on minimizing the input power rather than maximizing the output power. However, in order to minimize the loss and thereby increase the efficiency and potential for high cw output power, we have modified the ICL waveguide by increasing the thickness of the low-doped GaSb separate-confinement layers and also increasing the number of stages from 5 to 7. Pulsed characterization of broad-area devices ( $150 \mu\text{m} \times 2 \text{ mm}$ ) shows that the external differential slope efficiencies (EDQEs) for the 7-stage ICLs are substantially higher (up to 56%) than for earlier 5-stage devices ( $\leq 43\%$ ). A 7-stage structure with 48% EDQE for the standard 2 mm cavity length yielded 64% when the cavity was shortened to 0.75 mm. The slope efficiency also falls off more gradually with temperature, e.g., up to 28% at 375 K. We also report the fabrication and testing of tapered-ridge ICLs ( $\lambda = 3.75 \mu\text{m}$ ) that emit up to 403 mW in cw mode at  $T = 25^\circ\text{C}$ , with near-diffraction-limited beam quality ( $M^2 = 2.3$ ). The highest power was obtained from a device with a single tapered section whose width increased linearly from 5  $\mu\text{m}$  at the high-reflection-coated back facet to 63  $\mu\text{m}$  at the anti-reflection-coated output facet.

### Biography

Igor Vurgaftman received PhD degree in Electrical Engineering from the University of Michigan in 1995. Since that time, he has been with the Naval Research Laboratory, Washington, DC, where he has investigated mid-infrared lasers based on interband and intersubband transitions, high-brightness semiconductor lasers, infrared photodetectors, and coherent sources of surface plasmons, among other topics. He is the author of more than 240 refereed articles in technical journals, cited more than 7600 times (h-index of 35), as well as 17 patents awarded and pending. He is a Fellow of OSA and APS.

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