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Interband cascade lasers

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It was long believed that interband mid-IR (λ=3-6 μm) diode lasers must inevitably perform poorly because the Auger nonradiative decay rate scales exponentially with wavelength while the internal loss scales as λ^2-λ^3. However, in 2008 an interband cascade laser (ICL) operated in continuous wave (cw) mode at room temperature (RT). By exploiting a semi-metallic interface that under bias provides an internal source of non-equilibrium electrons and holes, ICLs combine the conduction-to-valence band optical transitions of a conventional diode laser with the multiple active stages of a quantum cascade laser (QCL). Both electrons and holes are present in each stage of the ICL's active region, even though the contacts inject and remove only electrons. The ICL is especially advantageous in applications requiring low (e.g., ≤ 20 mW) single-mode output power at any wavelength in the λ ≈ 3-6 μm range, since it's extremely low threshold power requirement (29 mW reported) is ideal for small-footprint spectroscopic sensing systems driven by battery or solar power. Advances since 2008 include maximum cw operating temperature up to 118 °C, pulsed threshold current density as low as 100-130 A/cm^2, and RT cw operation to wavelengths as long as 5.7μm. When the number of stages was increased from 5 to 10, narrow ridge ICLs mounted epitaxial side down with HR/AR coatings on the back/front facets emitted RT cw powers up to 500 mW. Shorter cavities displayed wallplug efficiencies up to 18%. We also report interband cascade vertical-cavity surface-emitting lasers (ICVCSELs) that emit in pulsed mode at λ= 3.4 μm, with threshold current densities as low as 390 A/cm^2 at T = 25 °C and operation up to 70 °C.

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Short pulsed fiber laser pumped mid-IR optical parametric sources

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Tunable sources of short laser pulses in the mid-IR are useful for a number of spectroscopic and material processing applications due to the presence of characteristic vibrational absorptions of organic materials in this spectral region. Optical parametric processes offer an effective route for frequency down-conversion of readily available near-IR sources to longer mid-IR wavelengths. Advances in fiber laser technology have greatly extended the range of achievable output powers and energies, raising them to levels suitable for pumping parametric devices. Here, we report a high-energy picosecond optical parametric generator/amplifier (OPG/A) based on a MgO:PPLN crystal pumped by a fiber master-oscillator-power-amplifier employing direct amplification. An OPG tuning range of 1450-3615 nm is demonstrated with pulse energies as high as 2.6 μJ (signal) and 1.2 μJ (idler). When seeded with a narrow spectral bandwidth laser source, the output spectra are narrowed and maximum pulse energies of 3.8 μJ (signal) and 1.7 μJ (idler) are obtained at an overall conversion efficiency of 45%. We also demonstrate a compact high-energy, mid-IR, picosecond optical-parametric oscillator employing a high-harmonic-cavity. With a cavity that is just a small fraction of the length required to match the pump repetition rate, signal pulses with a repetition rate that is the 193rd harmonic of the 1-MHz pump repetition rate are realized. Pumped by 11-μJ, 150-ps pulses at 1035 nm idler output pulse energies as high as 1.5 μJ have been achieved. The overall photon conversion efficiency reaches 43%, and the idler wavelength can be tuned from 2300 to 3500 nm.

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