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Freedom from band-gap slavery: from diode lasers to quantum cascade lasers

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Semiconductor heterostructure lasers, for which Alferov and Kromer received part of the Nobel Prize in Physics in 2000, are the workhorse of technologies such as optical communications, optical recording, supermarket scanners, laser printers and fax machines. They exhibit high performance in the visible and near infrared and rely for their operation on electrons and holes emitting photons across the semiconductor bandgap. This mechanism turns into a curse at longer wavelengths (mid-infrared) because as the bandgap, shrinks laser operation becomes much more sensitive to temperature, material defects and processing. Quantum Cascade Laser (QCL), invented in 1994, rely on a radically different process for light emission. QCLs are unipolar devices in which electrons undergo transitions between quantum well energy levels and are recycled through many stages emitting a cascade of photons. Thus by suitable tailoring of the layers' thickness, using the same heterostructure material, they can lase across the molecular fingerprint region from 3 to 25 microns and beyond into the far-infrared and submillimeter wave spectrum. High power cw room temperature QCLs and QCLs with large continuous single mode tuning range have found many applications (infrared countermeasures, spectroscopy, trace gas analysis and atmospheric chemistry) and are commercially available.