# Phase-locked QCL arrays: Photonic crystals for watt-range, coherent mid-IR power generation

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Resonant leaky-wave coupling of antiguides[1] has been employed for phase-locking near-infrared-emitting lasers to high peak-pulsed (10 W) and cw (1.6 W)[2] near diffraction-limited (DL) powers (*i.e.*, beam-pattern lobewidths ≤ 2×DL). Since at and near resonance the structures are analogous to 2nd-order *lateral* distributed-feedback (DFB) structures,[3] they represent high-index-contrast (HC) ($\Delta n$ = 0.07–0.15) photonic-crystal (PC) structures that allow global coupling between array elements in an in-phase mode of uniform intensity profile. However, for resonant transmission between elements, the Bragg condition needs to be satisfied exactly[3] and the range in inter-element width over which the in-phase mode is favored to lase is proportional to the wavelength. Then, for near-infrared arrays the fabrication tolerance is rather small (~ 0.1 μm). In contrast, when resonant leaky-wave coupling was recently applied to phase-locking THz quantum cascade lasers (QCLs),[4] the fabrication tolerances significantly increased.

For mid-infrared QCLs, spatial coherence over large apertures has been reported from so-called PCDFB structures,[5] flared master-oscillator power-amplifier (MOPA) structures,[6] tree-type arrays and from evanescent-wave-coupled arrays. The PCDFB devices rely on diffraction gratings and hence inherently have low index contrast ($\Delta n$ ~ 0.008); they have shown near-DL single-lobe operation to only 10% above threshold and 0.5 W peak pulsed power.[5] Flared MOPAs, while demonstrating near-DL peak pulsed powers as high as 3.9 W,[6] have no built-in index steps; thus, they are vulnerable to thermal lensing in quasi-cw or cw operation.

We have implemented resonant leaky-wave coupling in 8.4 μm-emitting arrays of QCLs. Preliminary results are 5.5 W near-DL peak power from five-element arrays with 4.5 W emitted in the far-field beam pattern central lobe. Such HC-PC structures hold the potential for generating > 5 W quasi-cw coherent power in the 8–10 μm wavelength range and > 5 W cw coherent power in the 4–5 μm wavelength range. Furthermore, in combination with single-lobe-emitting, 2nd-order metal/semiconductor gratings,[7] such arrays hold potential to provide > 15 W cw surface-emitted, coherent power from 2D HC-PC mid-infrared QCLs.

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