



PIMS/AMI/Chemistry/Engineering Seminar

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2:30 p.m.

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“Investigation of a Broad-Area Quantum Cascade Laser with External Cavity Feedback”

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Abstract

Broad area Quantum Cascade Lasers (BA-QCLs) tend to oscillate on fewer transverse modes than the number which can be supported by the waveguide. In cases lasing is dominantly if not totally on a single high-order transverse mode, it leads to a well defined two-lobed far-field radiation pattern [1]. As a dynamical system, feedback of light and injection of external light back into the cavity has been investigated in QCLs but *only* for single transverse mode emitters [2]. QCLs possess very fast time scales and a near zero linewidth enhancement factor. These traits strongly alter their dynamical behaviour over the traditionally studied quantum well laser. This motivates us to explore how external cavity feedback affects the lasing operation of a BA-QCL and can the feedback be used as a control parameter.

Our observations point to three principal regimes of dynamics. The first is a regime of stability that is characterized by a pulse shape similar to the free-running case although different in amplitude. Significantly, very small amounts of feedback, $\square I/I < 1\%$, are sufficient to alter the modal intensity. No high frequency oscillations or large amounts of noise are observed. This occurs most typically with feedback as observed in Figs. 2(a) and 2(c). With feedback above a few percent, the laser beam can be effectively *steered in the far-field using the mirror as the control parameter*. In a second regime, very strong mode competition occurs that is manifested by large and erratically occurring power jumps and drop-outs within the pulse envelope. This occurs under conditions observed in Fig 2(b). Adjacent peaks with equal intensity compete for dominance causing the far-field beam to fluctuate rapidly with large bursts of power. The last (third) regime shows strong evidence of small amplitude external cavity oscillations that arise from the round-trip time delay of the feedback. The time-series show a very distinct signature that occurs nearly identically on every pulse. The laser is stable near threshold and a bifurcation occurs with increasing power exciting these external cavity oscillations. These are observed up to the maximum injection current which is 3x threshold. To this point, the external cavity mode oscillation is excited but the amplitude relative to the power in the pulse remains small.

These initial results open the door for further investigation both in experiment and modeling. Future research will investigate coherent phase-locking of linear arrays of QCLs in a Talbot and Self-Fourier cavity. The results are promising for creating a bright infrared source with Watt-level power.

In a second part of the talk, I will summarize other QCL research being undertaken at the Air Force Research Laboratory. We have investigated 4.6 μm QCLs being operated at cryogenic temperatures for improved laser performance, and we are building arrays for 9 μm QCLs for infrared applications.