Control of Phased Microcavity Laser Array Coherence

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Phased arrays of microcavity lasers exhibit novel optical properties as well as application as electronic beam steering and high brightness sources. The coherence and beam divergence of vertical cavity surface emitting laser (VCSEL) arrays are both related to the relative phase between the array elements, which in turn can be controlled by bias current. We have recently demonstrated that phased VCSEL arrays rely on a fundamentally different phase-shifting mechanism arising from temporal coherence [1]. Here we report the ability to tune virtually any array to coherence by insuring spectral overlap between the resonance of each element of the array.

A 2x1 phased VCSEL array is shown in Fig. 1 [2]. The coherent laterally coupled array is fabricated by combining a photonic crystal etched hole pattern with an ion implant-defined laser gain structure. The photonic crystal provides stable index guiding for array elements and greater optical loss for higher order modes [3]. This structure enables strong coupling between array elements and simultaneously enables independent current injection into either cavity.

Shown in Fig. 2 is the spatially resolved emission wavelength from the array and the far-field profile as a function of injection current. By preferential current injection to one element with respect to the other, we change the cavity refractive index for that element through ohmic heating and electronic suppression [2], thus varying its natural resonance, as confirmed by spatially resolved spectra measurements in Fig. 2(a). In effect, by varying the bias we can tune the resonance of each element as well as the phase relation and coherence of the array. For the array in Fig. 1, by electrically tuning elements 1 and 2, we obtain highly single-mode emission with an “out-of-phase” far-field mode throughout the coherent operation regime. With sufficient detuning two clearly defined spectral peaks with a single broad Gaussian far-field are apparent when Elements 1 and 2 become uncoupled and incoherent.

Also shown in Fig. 2 is a close up of the wavelength emission in this coherence regime; note that over a 100 µA injection current range, the array operates in a phase locked condition. We have found that virtually all similar arrays will operate coherently through similar resonance tuning, and that this phase-locked condition can occur at any injection current. Exploiting this latter behavior has enabled enhancement of the small signal modulation bandwidth to 37 GHz [4].

References