Rapid Switching and Modulation by Use of Coupled VCSELs

With proper design, coupled VCSELs oscillate at tens of gigahertz.

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Devices incorporating coupled vertical-cavity surface-emitting lasers (VCSELs) have been proposed as means to effect unprecedentedly rapid modulation and/or switching of light beams in advanced optical communication and information-processing systems. A basic device according to the proposal would comprise two or more VCSELs (1) positioned so close to each other that they are coupled and (2) connected to a current source that biases them at a steady current above the threshold current for lasing.

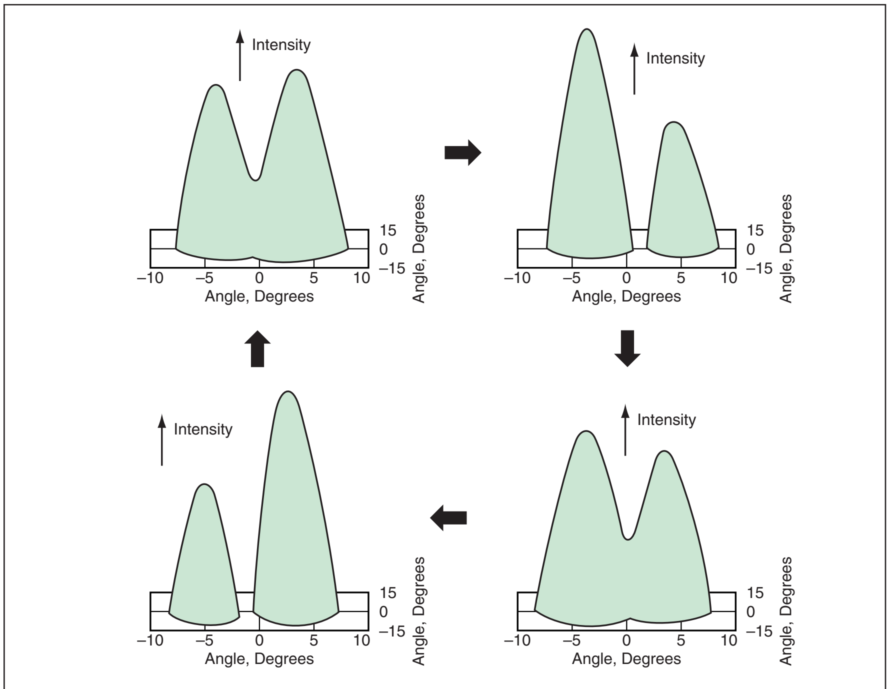

Figure 1. These **Plots of Intensity Versus Polar Angles**, generated by computational simulation, are snapshots at selected intervals of one cycle of oscillation of the beams from two coupled VCSELs.

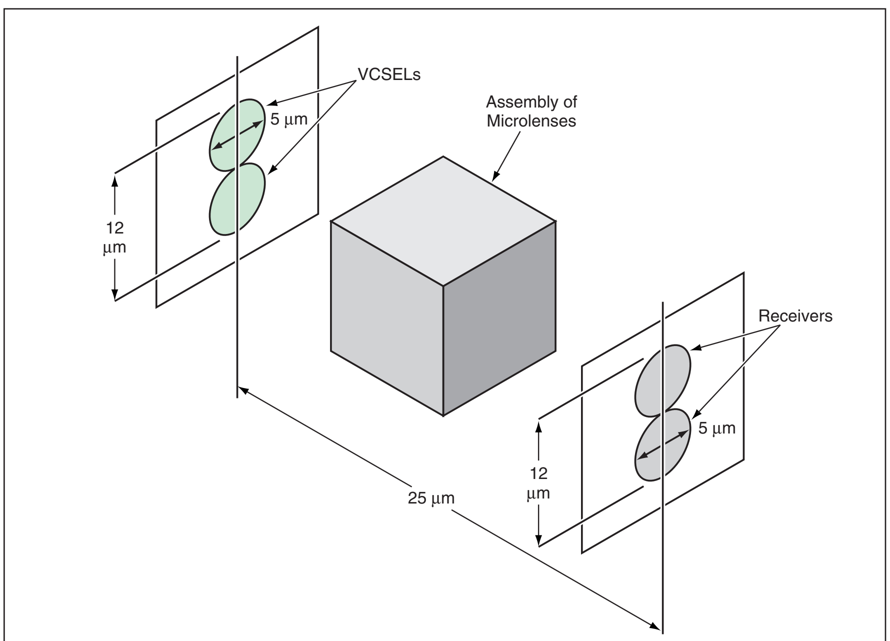

Figure 2. The **Assembly of Microlenses** would couple the oscillating beams from two coupled VCSELs to two receivers.

The operation of VCSELs under the conditions stated above has been simulated computationally with an algorithm that solves an approximation of the Maxwell-Bloch equations. (These are nonlinear coupled partial differential equations that model the relevant aspects of the physics of semiconductor lasers.) The results of the simulations show that the intensities of the beams oscillate, out of phase relative to each other, at a frequency that is typically of the order of tens of gigahertz.

In particular, one simulation was performed for two coupled VCSELs, each having a circular aperture 5.6 µm in diameter, operating at a wavelength of 980 nm. The results of the simulation showed that the intensities of the two beams oscillated in opposite phase (see Figure 1) at a frequency of 42 GHz. In the far field, the beams were found to be separated by an angle of ≈8°. The intensities of the beams were also found to oscillate in the near field, 90° out of phase with the oscillation in the far field. Figure 2 depicts a simple near-field switching device in which an assembly of microlenses would couple the two oscillating beams to two receivers.

Other simulations were performed to investigate the effects of VCSEL geometry and injection current on the oscillation frequency, relative brightness, and separation of the beams. In one simulation, for example, it was found that two VCSELs having square apertures would oscillate at 50 GHz with a beam pattern similar to that of two VCSELs having circular apertures. In another simulation, it was found that for three round VCSELs arranged around a ring, the far field would move in a circular pattern at a frequency of 31 GHz. In yet another simulation, the far-field pattern of four round VCSELs arranged in a square would comprise two circular-cross-section beams oscillating spatially in opposite directions at a frequency of 50 GHz.

This work was done by Peter M. Goorjian and Cun-Zhen Ning of **Ames Research Center**. *Further information is contained in a TSP (see page 1).*

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