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LeRoy Apker Award Talk: High Resolution Thermoreflectance Imaging of Thermal Coupling in Vertical Cavity Surface Emitting Laser Arrays

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Vertical cavity surface emitting laser (VCSEL) arrays have received increased attention over the past several years for use in telecommunications as high speed parallel data transmission devices, optical interconnects, and data storage devices. The increased packing density of the VCSELs in arrays has lead to undesirable thermal effects such as inter-element thermal crosstalk between individual lasers. Previous work has used a variety of techniques to measure the temperature of VCSELs; however, these techniques are usually single-point average measurements that lack sufficient spatial and thermal resolution. Instead, we present work utilizing high spatial (250nm) and thermal (10mK) resolution thermoreflectance microscopy to obtain two dimensional images of the surface temperature of VCSEL arrays. These temperature measurements show significant thermal coupling between VCSELs in the array, thermal lensing in the lasing VCSEL, and temperature gradients across adjacent lasers. In addition, thermoreflectance microscopy measurements reveal an offset between the optical mode and the hotspot for VCSELs in the array. The thermoreflectance results are used to calculate the radial thermal conductivity of the VCSEL array. A comparison of the thermoreflectance results to traditional wavelength shift measurements of the VCSEL temperature reveals an offset between the two techniques. We attribute this offset to the wavelength shift technique measuring the average cavity temperature of the VCSELs while thermoreflectance microscopy measures the surface temperature. Lastly, to better understand the speed of heat diffusion in the array, we use a time resolved temperature measurement technique to measure the thermal diffusivity of the complex VCSEL array structure. The thermal diffusivity value calculated is in good agreement with prior results on bulk and thin film structures of the same material.