Probing the Local Temperature Distribution in Electrically Pumped Broad-Area VCSELs

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Bose-Einstein condensation of photons in an optical microcavity filled with rhodamine 6G has been reported [1]. The following recent study showed that a photon gas in a state of thermal equilibrium with its surroundings trapped in semiconductor optical microcavity can display signatures of Bose-Einstein condensation [2]. However, the effects of ununiform local temperature on Bose-Einstein distribution in semiconductor lasers have not been examined yet.

The emission spectrum of semiconductor electrically pumped vertical-cavity surface-emitting lasers (VCSELs) is directly influenced by the local temperature and current density distribution. The effective inhomogeneous confining potential is the reflection of the effective local width changes in the cavity. This inhomogeneity effect changes the density of states function and influences extracted values of the Bose-Einstein distribution. The assumption that the density of states is purely 2D and has a fixed value over the whole VCSEL resonator may be an insufficient approximation. The most commonly used measurement method to characterize the thermally induced shift in the lasing wavelength provides only information on the average temperature distribution across the entire microcavity surface [3]. Here, we present a novel technique for measuring local spectral temperature distribution in wide aperture oxide-confined VCSELs by locally fitting the Boltzmann distribution to the high-energy tail of the spontaneous emission spectrum. Furthermore, we characterized the local potential change of the microresonator, measuring the local fundamental mode energy by filtering the spontaneous emission in the wavevector space close to the normal incidence $k_{\parallel} \approx 0$. The resulting data can be compared to theoretical simulations of the influence of current and temperature on the local potential shape.

Studies on the thermalised boson gas of trapped photons in electrically pumped VCSEL microresonators is a new promising direction in Bose-Einstein room-temperature condensation. Therefore, understanding the details of wide aperture semiconductor VCSELs may provide devices that act as Bose-Einstein condensate of photons, allowing for new research on Bose-Einstein photon condensation physics.

[1] J. Klaers et al., Nature 468, 545 (2010)
[2] S. Barland et al., Opt. Express 29, 8368 (2021)
[3] M. Farzaneh et al., IEEE Photon. Technol. Lett., vol. 19, no. 8, pp. 601-603, (2007)