Linewidth narrowing in self-injection-locked, on-chip lasers

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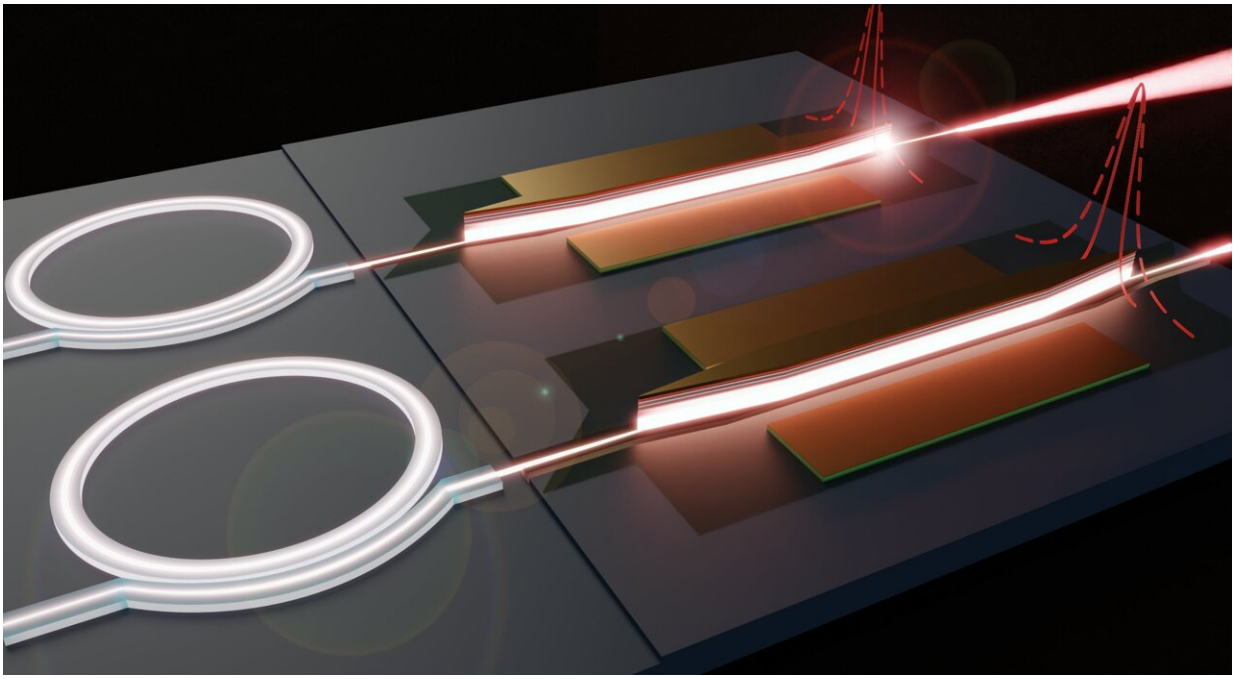


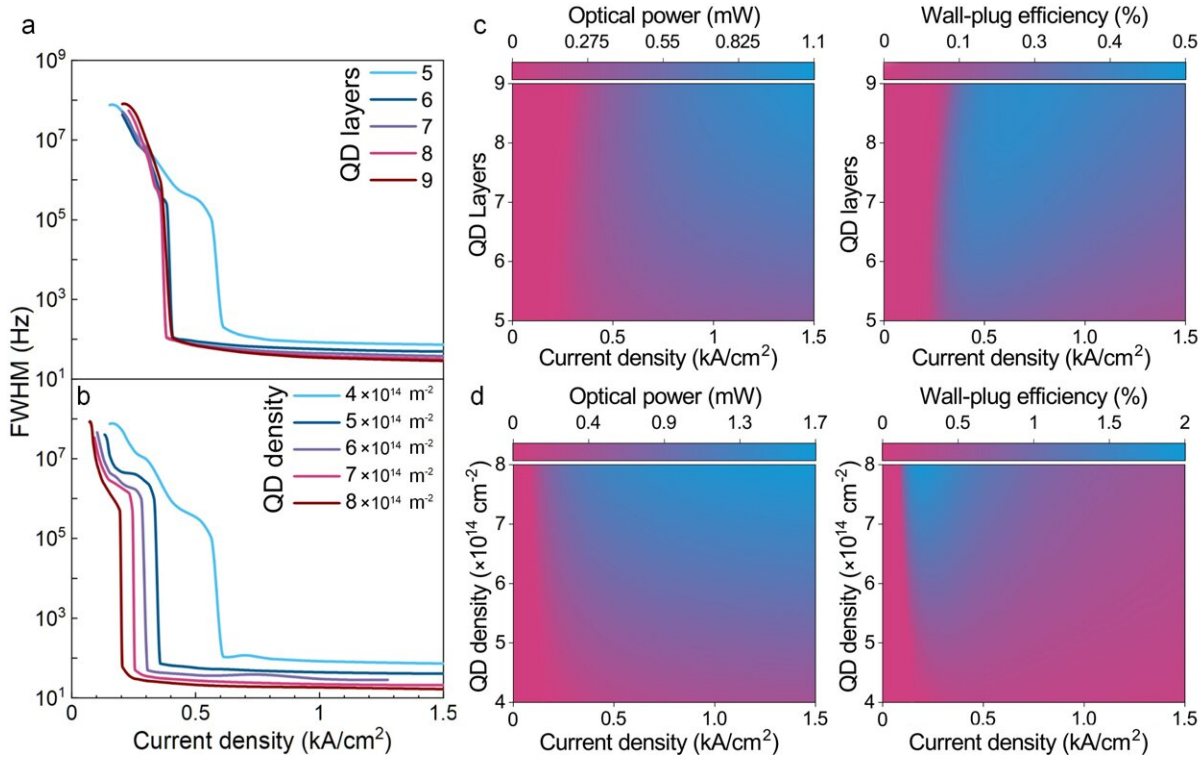
III-V QW/QD DFB lasers and SiN microring resonators. Credit: Emad Alkhazraji, Weng W. Chow, Frédéric Grillot, John E. Bowers, and Yating Wan

On-chip laser diodes based on quantum well (QW) and quantum dot (QD) semiconductor materials have become the primary technology for several applications due to their excellent characteristics, including high power efficiency, high-temperature operation, and small form-factors. Although QWs have been extensively used in commercial products, QDs

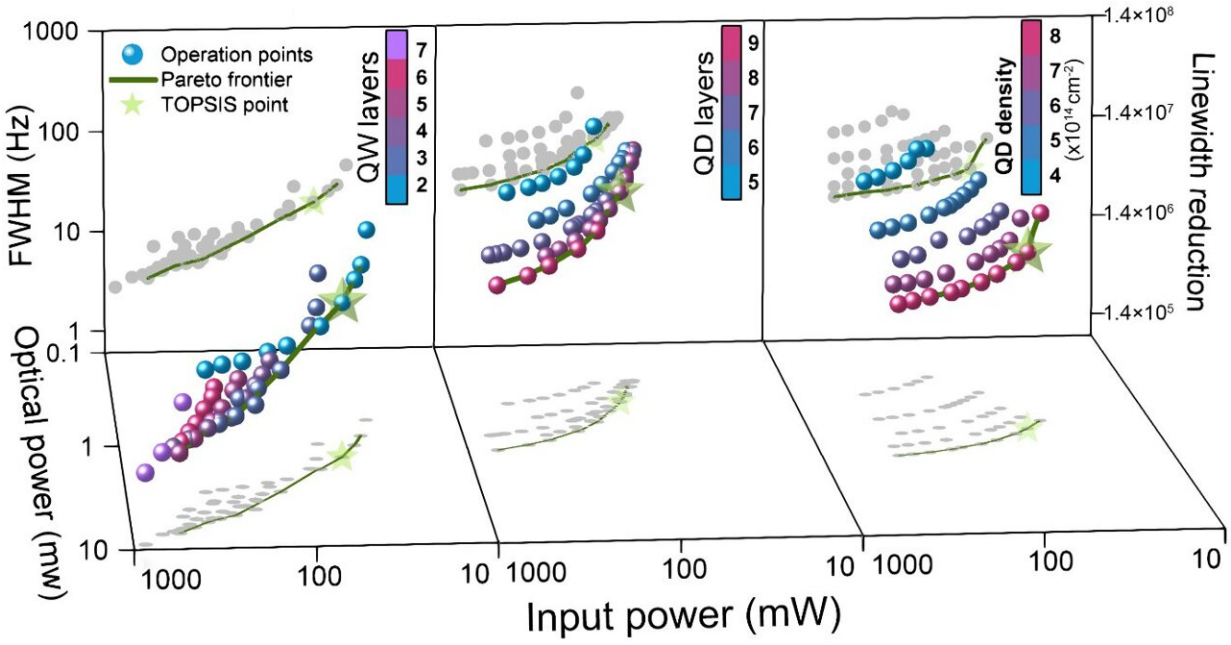
have emerged as an attractive alternative due to their unique zero-dimensional density of states and atom-like degeneracy.

Heterogeneous integration of III-V lasers with SiN microresonators, aided by self-injection locking, not only provides intrinsic advantages of compactness and high-volume production, but also enhances stability. This technology enables the realization of superior performance in terms of linewidth narrowing compared to that of III-V lasers grown on native platforms.

A new study published in *Light: Science & Applications* is a parametric investigation of the design of active medium of composite cavity lasers. The team of researchers, led by Professor Yating Wan from the Integrated Photonics Lab at King Abdullah University of Science and Technology (KAUST), Saudi Arabia, Dr. Weng W. Chow from Sandia National Laboratories, Albuquerque, U.S., Prof. Frédéric Grillot from LTCI, Télécom Paris, Institut Polytechnique de Paris, France, and Prof. John Bowers from the University of California Santa Barbara, U.S., focused on the effects of carrier quantum confinement on the dynamic and spectral characteristics of the locked composite cavity device.



a,b Linewidth FWHM of the III-V/SiN QD laser as a function of the injection current density for different QD layers (a) and QD densities (b). c,d Colormaps of the output power (left) and wall-plug efficiency (right) as functions of the QD layers (c) and QD density (d). Credit: Emad Alkhazraji, Weng W. Chow, Frédéric Grillot, John E. Bowers, and Yating Wan



The 4D design space and the optimal points for each device. Credit: Emad Alkhazraji, Weng W. Chow, Frédéric Grillot, John E. Bowers, and Yating Wan

Specifically, they examined the attainable emission spectral refinement, or linewidth narrowing, of integrating III-V QW or QD distributed feedback (DFB) lasers with SiN microring resonators. "When properly tuned and locked to one or more of the microring's whispering gallery modes, optical feedback in the form of Rayleigh backscattering can enable drastic reductions in the lasing linewidth of a laser diode to the Hz-level," says Emad Alkhazraji, the first author of the paper.

The parametric investigation was concluded with a multi-objective design-operation optimization analysis of both QW and QD devices via a genetic algorithm. A multi-decision algorithm was then employed to identify the optimal design-operation points for each optimization variable. "These findings provide guidance for more comprehensive parametric studies that can produce timely results for engineering design

," concludes Professor Yating Wan.

More information: Emad Alkhazraji et al, Linewidth narrowing in self-injection-locked on-chip lasers, *Light: Science & Applications* (2023). DOI: 10.1038/s41377-023-01172-9