Simultaneous Optimization of Yield, Threshold, and Wavelength in Microring Lasers Using Bayesian Optimization

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The progress of Photonic Integrated Circuits (PICs) hinges on creating effective on-chip coherent light sources, but this continues to be a tough hurdle. Development is slowed by the complex relationship between material characteristics—like defect recombination, surface effects, and cavity behaviour—and the constraints of device design and efficiency [1]. InP/InAsP III-V multi-quantum-well (MQW) microring lasers have recently emerged as a promising solution, offering tunable emission in the telecommunication O-band with low-threshold lasing [2]. However, achieving high yield, minimal lasing thresholds, and precise wavelength calibration simultaneously remains a complex multi-objective optimization problem in quantum-confined heterostructures [3], further complicated by the expanding landscape of design and growth parameters.

We address this challenge by combining high-throughput experimental characterization of over 4,000 microring lasers with data-driven techniques, including Principal Component Analysis (PCA)-based Design of Experiments (DoE) and Multi-Objective Bayesian Optimization (MOBO). Our approach efficiently explores a large parameter space spanning 54 distinct growth and design variables—such as microring geometry and MOCVD growth conditions—enabling the identification of optimal subspaces that concurrently achieve high yield, low lasing thresholds, and long-wavelength emission, all crucial for practical PIC applications.

Our method resulted in a 65% reduction in lasing threshold for the best-performing devices, along with 100% yield, surpassing the lowest thresholds previously reported [2] for InP/InAsP MQW microring lasers while maintaining O-band emission. These results, achieved within a single growth cycle, highlight the transformative potential of data-driven optimization in accelerating PIC development, paving the way for scalable, high-performance on-chip light sources.

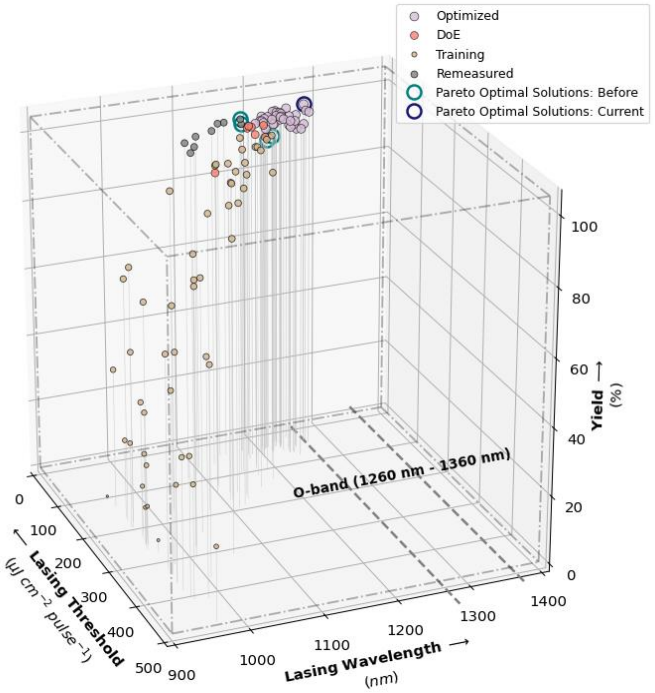

Fig. 1: Scatter plot visualizing three key performance metrics—median lasing threshold (μJ cm^{-2} $pulse^{-1}$), median lasing wavelength (nm), and yield (%)—across all characterized fields. Points are color-coded to distinguish pre-optimization (yellow) and post-optimization (purple) results, with the remeasured top-performing sample shown in grey and fields from the Design of Experiments (DoE) growth highlighted in red. Pareto-optimal solutions are marked with a bold outer circle. The optimized results exhibit clear advancements, shifting the Pareto front beyond previously identified optimal solutions.

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