Micropillar-to-Fiber Mode-Matching for Improved Single-Photon Collection Efficiency

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Bright single-photon sources are a main requirement for the development of photonic quantum technologies. Semiconductor quantum dots embedded in distributed Bragg reflector (DBR) micropillars and directly coupled to optical fibers enable bright and scalable single-photon sources with the perspective of industrial applications [1]. Here we study the reflectivity of this micropillar-to-fiber system to determine the collection efficiency and how it limits the single-photon brightness. The collection efficiency depends on the rate of photon outcoupling through the micropillar top-DBR, and the mode-overlap between the optical spatial modes in the fiber and the micropillar (Fig 1 a). We adapt the cavity input-output-formalism [2] to our specific micropillar-fiber system to create a robust evaluation model of the micropillar reflectivity. With this we can retrieve the collection efficiency for micropillars with varying diameters and from different samples (Fig 1 b). This enables us to identify the micropillar diameter with maximum mode-overlap for the given fiber and compare the top-DBR outcoupling rate across different samples.

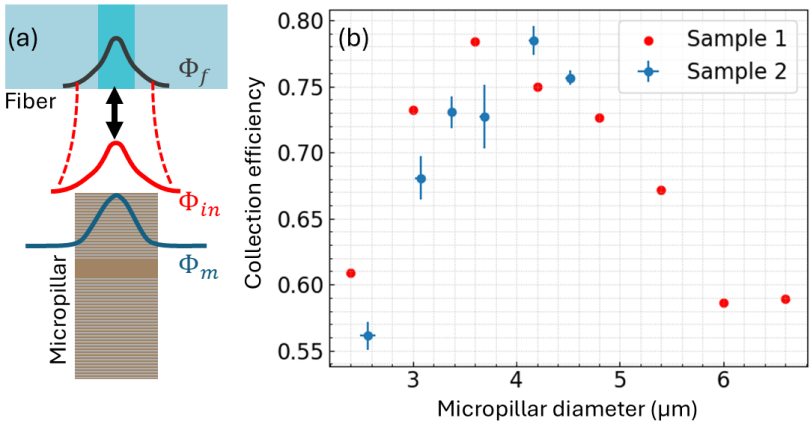

Fig. 1: (a) *Schematic of the setup with an optical fiber close to contact (<1μm) with a micropillar cavity. The spatial modes ϕ_f in the fiber, ϕ_{in} after propagating, and ϕ_m inside the micropillar determine the mode-overlap.* (b) *Comparison of the collection efficiency of micropillars with varying diameters between two samples.*

This evaluation model improves our understanding of the factors that limit the maximum brightness of direct fiber-coupled micropillar single-photon sources. Being directly dependent on the critical parameters related to quality of fabrication, this technique serves also as a precise characterization tool, enabling further sample fabrication improvements.

References

[1] Margaria, N. et al, Nat Comm. 16, 7553 (2025)

[2] Gardiner and Collet, Phys Rev A, 31, 6 (1985)