Quantum Light-Matter Interfaces with Tweezer Atomic Arrays

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Tweezer atomic arrays are quickly emerging as one of the most dominant platforms of quantum science and technology. This makes their efficient coupling to light a pressing issue for diverse applications, from state-readout and quantum networks to the generation of entangled states of light. Nevertheless, such efficient interfacing is severely limited in typical tweezer arrays due to large scattering losses to non-paraxial lattice diffraction orders. I will describe our progress in solving this basic problem by using the collective physics of radiation as a resource. First, we derive a general formalism, showing that the quantum interface efficiency of the atom array is universally given by its reflectivity to light [1]. We then apply this principle to develop methods for efficient interfacing: (i) designing a multibeam mode that naturally couples to the array [2]; (ii) eliminating the scattering losses by destructive interference between different array layers [3]; (iii) enhancing the coupling by using a cavity [4]. For all these solutions, we derive analytical theories and design principles, showing favorable scalings with the number of array atoms.

References

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