A cavity-microscope for micrometer-scale control of atom-photon interactions

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Cavity quantum-electrodynamics enables measurements of atoms with sensitivity limited by quantum backaction. Over the last decade, the possibility to observe and control the motion of few or individual atoms using cavity-enhanced light-matter coupling has been exploited to realize various quantum technological tasks, from quantum-enhanced metrology to quantum simulation of strongly-correlated matter. A principle limitation of these experiments lies in the mode structure of the cavity, which is hard-coded in the distance and geometry of the mirrors, effectively trading spatial resolution for enhanced sensitivity.

In this poster, I will present our cavity-microscope device allowing for spatio-temporal programming of the light-matter coupling of atoms in a high finesse cavity, which provides a spatial resolution an order-of-magnitude lower than the mode waist [1]. This is achieved through local Floquet engineering of the atomic structure, imprinting a corresponding light-matter coupling. We illustrate this capability by engineering micrometer-scale coupling, using cavity-assisted atomic measurements and optimization. Our system forms a single optical system with a single optical axis and has the same footprint and complexity as a standard Fabry-Perot cavities or confocal lens pairs, and can be used for any atomic species. This technique opens a wide range of perspectives from ultra-fast, cavity-enhanced mid-circuit readout to the quantum simulation of fully connected models of quantum matter such as the Sachdev-Ye-Kitaev model [2].

References

[1] D. Yang, C. Laflamme, D. V. Vasilyev, M. A. Baranov, and P. Zoller Phys. Rev. Lett. 120, 133601

[2] Philipp Uhrich, Soumik Bandyopadhyay, Nick Sauerwein, Julian Sonner, Jean-Philippe Bran- tut, Philipp Hauke. arXiv:2303.11343.

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