UNIVERSITÄT DUISBURG ESSEN

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Quantum Physics with Levitated Systems: from Atoms to Nano-Particles

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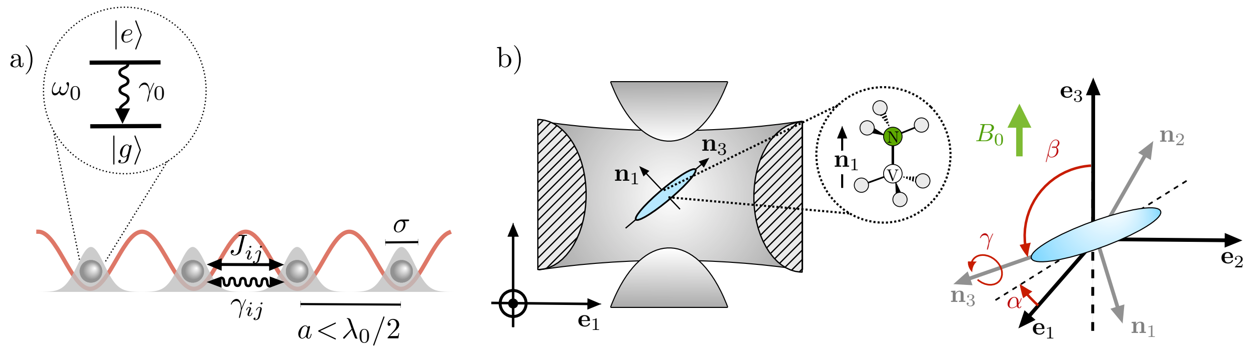

Fig.1. a) Schematic illustration of a subwavelength array of two-level atoms. At subwavelength inter-atomic separation strong dissipative and coherent dipolar interaction dominates the optical response of the system. b) Electrically levitated nano diamond with embedded NV centre. The applied magnetic field couples the NV spin to the rotation of the particle.

Throughout its history, Quantum Optics has approached the study of quantum system following a simple paradigm: understand, control and use quantum degrees of freedom in nature. In this talk I will show how this successful approach, which traditionally has been applied to the case of atom-photon interactions, extends nowadays to more exotic systems comprising, for instance, the dynamics of levitated mesoscopic particles in the quantum regime.

I will focus on two examples to show how this very same approach can be applied successfully to two very different situations.
First, I will talk about subwavelength atomic arrays, i.e. ordered ensembles of atoms placed at a subwavelength interatomic separation. These systems exhibit strong collective response to light stemming from the dipole-dipole interactions between the atoms. I discuss how such a strong collective response can be harnessed both for studying light-matter interaction in non-conventional regimes and as a platform for quantum science and technology [1,2].
Second, I will consider levitated mesoscopic particles and discuss their role for fundamental and applied quantum physics. In particular, I focus on a particular examples of a levitated diamond with embedded NV centers. I show how by controlling the internal dynamics of the NVs it is possible to generate a superposition state of the mesoscopic particle being in two orientations at once [3].

[1] C.C. Rusconi, T. Shi, and J. I. Cirac, PRA **104**, 033718 (2021).
[2] D. Castell-Graells, D. Malz, C. C. Rusconi , and J. I. Cirac, PRA **104**, 063707 (2021).
[3] C.C. Rusconi, M. Perdriat, G. Hetet, O. Romero-Isart, and B. Stickler arXiv2203.11717.