Eugene Wigner Colloquium

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"Coupled Nanofibre Fabry-Perot Cavity-QED"

Recently, experiments in the group of Takao Aoki at Waseda University in Japan have demonstrated coherent coupling of two nanofibre cavity-quantum electrodynamic (QED) systems (Figure 1) separated by a distance of more than a meter [1]. Transmission spectra show dressed states of the atoms in the two cavities with a normal mode of the cavity/coupling fibre/cavity system that is in fact dark in the coupling fibre, hence offering a robust, coherent channel between the two distant atom-cavity systems. Complementary to this, another experiment [2] has demonstrated the existence of a dressed state of the distant atoms with only the coupling fibre, i.e., a dressed state that is dark in the two cavity modes.

These phenomena are qualitatively well described by a relatively simple quantum optical model based upon treating the cavity and coupling fibre fields as single modes, with losses accounted for in a master equation approach. However, the long lengths of the cavities and the relatively low reflectivities of the (fibre Bragg grating (FBG)) mirrors mean that the single-mode picture can be limited in its applicability to this system. As an alternative, one can develop a travelling wave picture and transfer (or scattering) matrix approach that incorporates all modes of the fibre system, giving an improved model of the transmission properties [3]. However, a drawback of this approach is that it is linear and only appropriate for weak excitations. Hence, strong excitation of the atoms and uniquely quantum effects cannot be considered.

In order to have a fully quantum description, we have implemented a numerical method based on tensor-networks, which handles the two-way cascade represented by the connecting fibre in a similar fashion to a coherent time-delayed feedback system [4]. Considering a finite variable length of fibre enables us to study the intermediate regime between the short-fibre-length limit of coherent coupling and the long-fibre-length limit of a Markovian reservoir. This will enable us to, for example, examine super- or subradiant emission phenomena with atoms separated by distances such that retardation effects start to play a significant role. In this presentation I will sum up the experimental results and theoretical methods described above.

References: [1] S. Kato, N. Német, K. Senga, S. Mizukami, X. Huang, S. Parkins and T. Aoki, submitted (2018), [2] D. H. White, S. Kato, N. Német, S. Parkins and T. Aoki, in preparation (2018), [3] N. Német, D. H. White, S. Kato, S. Parkins and T. Aoki, in preparation (2018), [4] H. Pichler, and P. Zoller, PRL, 116, 093601 (2016), [5] P. Solano and P. Barberis-Blostein and F. K. Fatemi and L. A. Orozco and S. L. Rolston, Nat. Commun., 8, 1857 (2017)

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