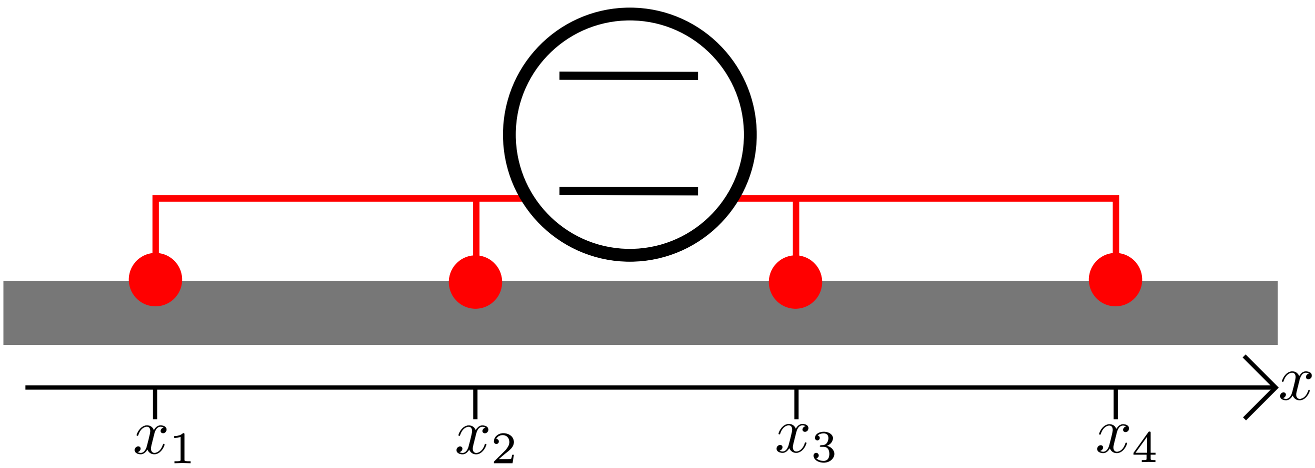
Chiral giant atoms

In quantum optics, the interaction between light and matter is studied at the level of individual photons and atoms. In this project, we will explore the consequences of violating a common assumption in quantum optics: that atoms are small compared to the wavelength of the light they interact with. We call systems that violate this assumption *giant atoms*. The reason that the assumption about atoms being small is so prevalent in quantum optics is simply that, until recently, most experimental systems were firmly in this regime. For example, natural atoms have a radius r ~ 10^-10 m and interact with optical light, which has wavelengths in the range ~ 10^-6 — 10^-7 m.

It is only recently, in an experiment performed here at Chalmers in 2014, that the giant-atom regime was reached. In that experiment, an artificial atom (a superconducting quantum bit) was coupled to propagating sound waves, realizing a setup like that shown in the figure below: the atom was coupled at multiple points, separated by wavelength distances, to a one-dimensional waveguide. In initial theoretical investigations of such setups with one [1] and multiple [2] giant atoms, we have explored how the multiple coupling points give rise to useful interference effects.

In this project, we will go beyond previous work by calculating the behaviour of giant atoms in a chiral waveguide, i.e., a waveguide with unidirectional propagation. This may change the interference effects that we found in [1,2].

[1] A. F. Kockum, P. Delsing, G. Johansson, ”Designing frequency-dependent relaxation rates and Lamb shifts for a giant artificial atoms”, Physical Review A 90, 013837 (2014)
[2] A. F. Kockum, G. Johansson, F. Nori, ”Decoherence-free interaction between giant atoms in waveguide quantum electrodynamics”, Physical Review Letters 120, 140404 (2018)



A sketch of a giant atom. A two-level atom (dark circle) couples at multiple discrete points (red; coordinates x_n to a one-dimensional waveguide (grey). The distance between coupling points is *not* negligibly smaller than the wavelength of the light (or sound) that propagates in the waveguide at the frequency corresponding to the atomic transition. For comparison, a small atom would be an atom with only a single coupling point to the waveguide, which is a common setup in quantum-optics experiments.

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