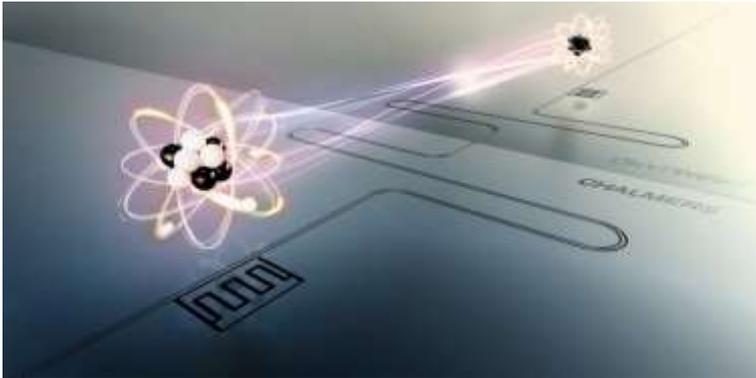


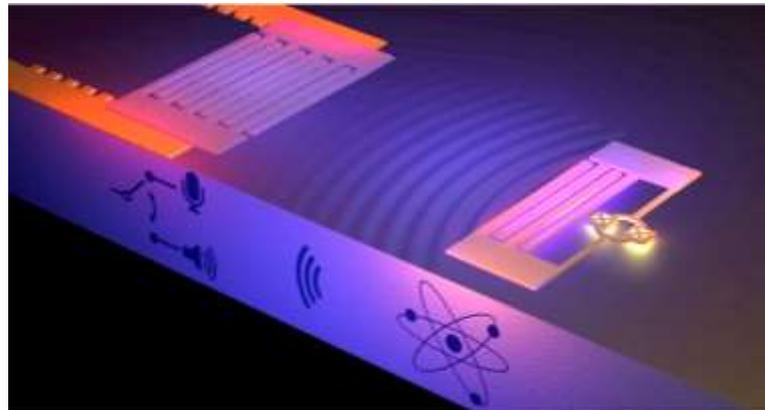
## Coupling artificial atoms to light and sound

Artificial atoms made from superconducting circuits can be coupled both to light and to sound. Of special interest is when this is done in the quantum regime such that the modes that the atom couples to are free from excitations, i.e. the atom couples to the quantum vacuum of the modes. Both the electromagnetic quantum vacuum and the phononic quantum vacuum can be studied. Here we will describe two different experiments carried out at mK-temperatures and at microwave frequencies.

*An atom in front of a mirror*



In the first experiment, we embed an artificial atom in the form of a superconducting transmon qubit at a distance from the shorted end of a transmission line, which acts as a mirror [1]. By tuning the wavelength of the atom, we effectively change the distance between the atom and the mirror. We probe the strength of vacuum fluctuations by measuring spontaneous emission rate of the atom and show that we can cancel the vacuum fluctuations seen by the atom, and extend the life time of the atom by an order of magnitude.



### *The sound of an atom*

In the second experiment, we couple an artificial atom to sound in the form of Surface Acoustic Waves (SAW) by placing it on a piezoelectric surface [2]. This coupling is frequency dependent, and on lithium niobate it can be made very strong. The frequency dependent coupling to the phononic vacuum results in a strong Lamb shift which is the Hilbert transform of the coupling. Using spectroscopy, we can observe this large Lamb shift which is due to the phononic vacuum [3].

### References

- [1] I.-C. Hoi *et al.*, Nature Physics, 11, 1045 (2015)
- [2] M. Gustafsson *et al.*, Science 346, 207 (2014)
- [3] T. Aref *et al.*, In preparation (2017)