Electric-Field Tuning of a Superconducting Resonator via the Aharonov-Casher Effect

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The Aharonov-Casher effect describes the interference between two magnetic flux quanta which circulate around an electric charge in opposite directions. It is the dual of the well-known Aharonov-Bohm effect which can be observed in superconducting quantum interference devices (SQUIDs). The electrostatic dual of the SQUID is the charge quantum interference device (CQUID) [1], consisting of two superconducting nanowires in series, separated by a superconducting island. The capacitance of the CQUID can be modulated by an electric field, analogous to modulation of the SQUID inductance by a magnetic field.

Here we describe our experimental work on electric-field tuning of a superconducting NbN coplanar-waveguide microwave resonator which is short-circuit terminated at one end. At the other end it is short-circuited to ground via two NbN nanowires in a CQUID geometry. The resonant frequency depends upon the CQUID capacitance which in turn can be modulated via an electrostatic gate contact to the island between the nanowires. We observe tuning of the resonant frequency by more than 1 MHz (from around 3.5 GHz in zero d.c. electric-field). The response is periodic in an applied electric field. The periodicity is consistent with that which (given reasonable assumptions on the value of the relevant device parameters) changes the charge on the island by 2e.

Our results confirm that the Aharonov-Casher effect can be exploited in superconducting device applications. We will discuss routes to enable the tuneability to be optimized.

References

[1] de Graaf et al. Nature Physics 14 590-594 (2018)