Dark matter search with single-photon resolution Quantum Capacitance Detectors (QCDs)

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What is Quantum Capacitance Detector (QCD)?

- A superconducting quantum detector based on charge qubit
- Fabricated by JPL/NASA for far-infrared spectroscopic mission
- The most sensitive far-infrared (1.5THz) single photon detector.
- Has low Noise Equivalent Power:

\[ NEP < 10^{-20} \text{W/Hz}^{1/2} \]

- See Pierre’s Echternach’s Poster (id#52)
Projected sensitivity to dark matter using QCD

How does QCD work?

Schematic of a QCD circuit

Simulated quantum capacitance trace

QCD Readout

- Sweep the gate voltage that spans a few quantum capacitance peaks.
- Counting the missing peaks (tunneling event)
- Missing peak rate shows that the dark count rate is high at this point
Landau Zener transition
Detector Assembly
Designed and fabricated at Fermilab

- Using a Josephson radiator as photon sources
- QMC filter with 0.1THz passband around 1.5THz
- Enclosure made up of OFHC copper

Design with filters and emitter
Assembly inside QuantiSED fridge
Josephson radiator is

- A photon source

- Using AC Josephson effect as a current source

\[ I = I_c \sin(\omega t) \quad \omega = K_JV_{DC} \]

- The structure has a radiation impedance that matches with the junction impedance to emit photons at frequency \( \omega \).
The black body source will be mounted on 4K stage since it will be heated up to 27K.

The first IR filter will be placed in 4K stage to see a higher cooling power. Filter is also required on 900mK stage so it will block most unwanted radiation from 4K.

This design is using copper tube to transfer photons in free space.
Projected sensitivity to dark matter using QCD

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