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Quantum Sensor for detection of Dark Matter

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Introduction

The observable universe is composed of 26% dark matter. So, it is essential to understand dark matter to get a comprehensive description of the universe.

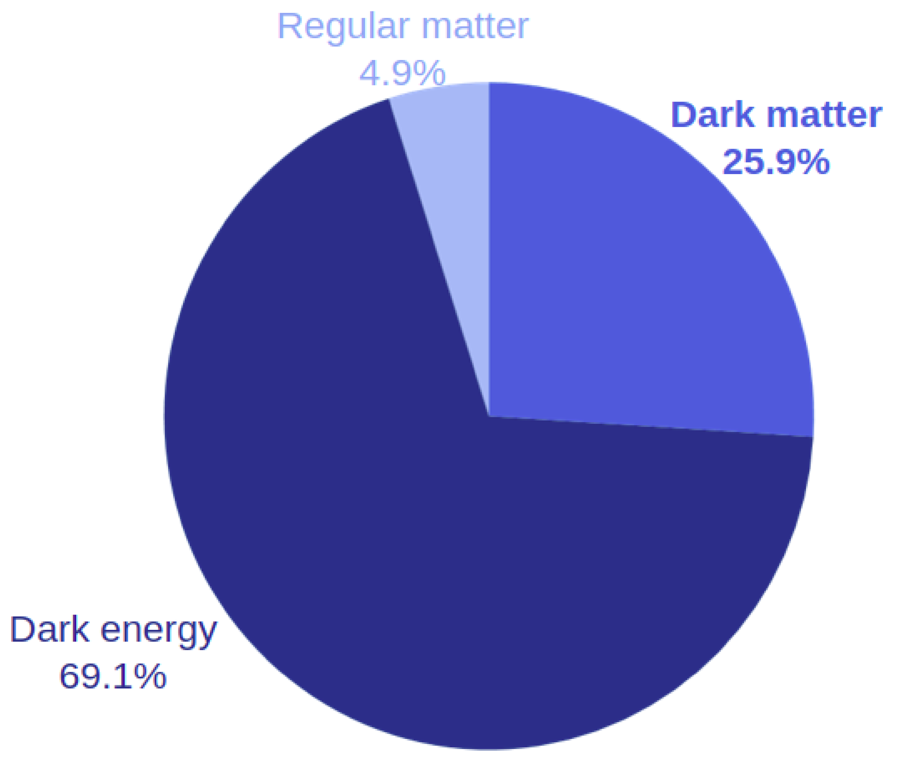

Fig 1 Composition of Observable

Dark Matter Search

It is very difficult to detect such matter since it only reacts through weakest known force. There has been numerous attempt to directly observe dark matter particle but the theoretical bounds for the supposed mass of dark matter is very large.

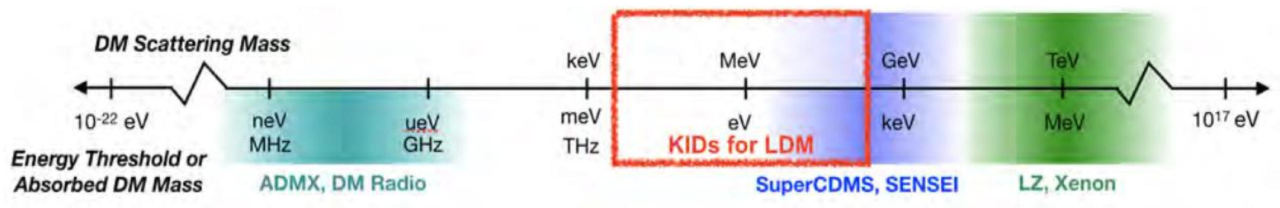

Fig 2. Range of mass of dark matter

This project aims to look for Light Dark Matter Particles (LDM) which has mass of order of few MeV. A quantum sensor is proposed to detect dark matter.

MKID (Microwave Kinetic Inductance Detector)

MKIDs, a kind of quantum sensor, work on the principle that incident energy changes the surface impedance of a superconductor through the kinetic inductance effect. This project aims to deploy the property of MKID to attempt to detect low energy dark matter particle. It is expected that when dark matter collides with silicon crystal substrate, it will deposit some fraction of its kinetic energy. Sometime this is enough to create electron-hole pair and shower of phonon.

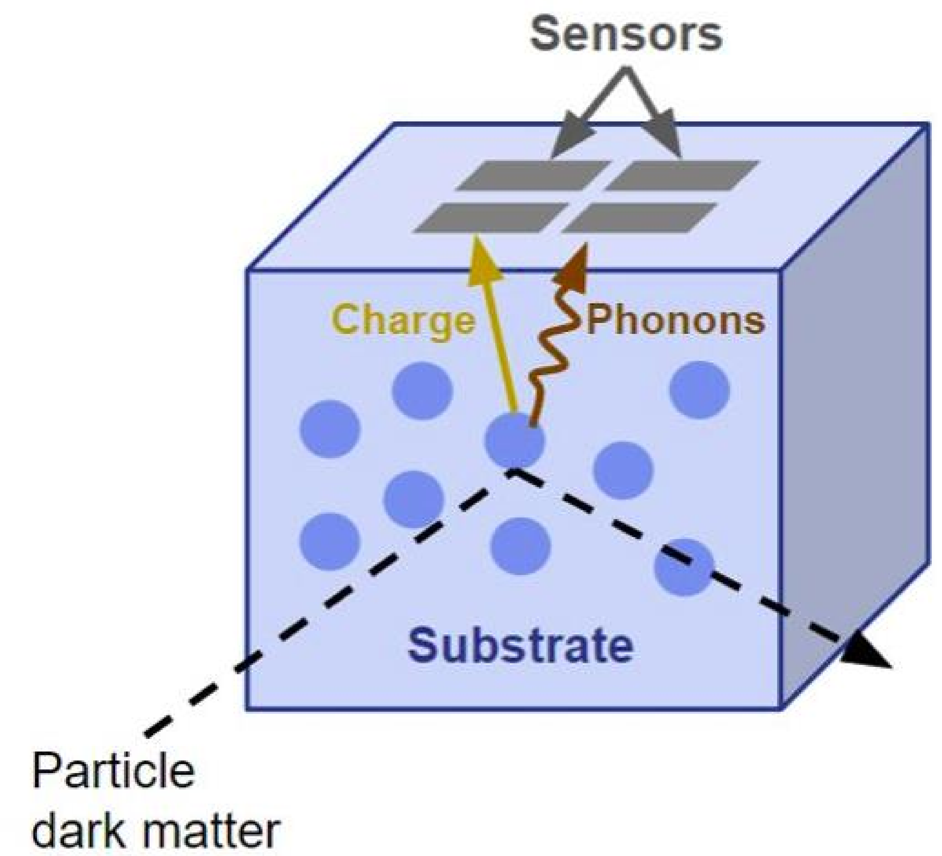

Fig 3. Operation of the detector

In this project, we aim to use MKID (Microwave Kinetic Inductance Detector) to detect these low energy phonons. Kinetic Inductance Detectors (KIDs) are superconducting film on top of semiconductor substrate constructed as a resonator. The Cooper pairs in the superconductor have low binding energy. When the phonon from the interaction hits these cooper pair, they break the pair. The breaking of Cooper pairs within the film changes their surface inductance — an effect that can be measured via an RF tone.

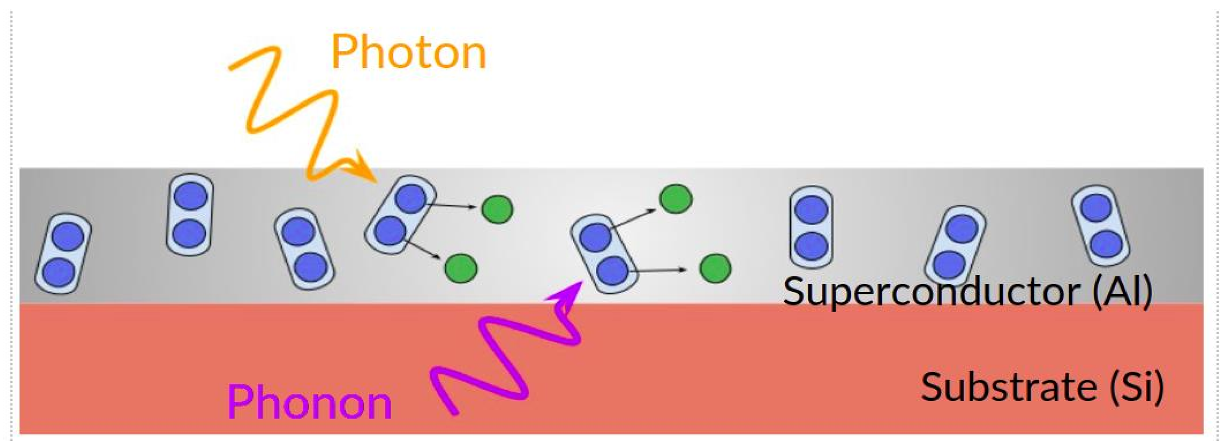

Fig 4. Microwave Kinetic Inductance Detector (MKID)

Simulating the Detector

Geant4, a simulation software, was used to create and simulate the detector. G4CMP, a library toolkit built on top of Geant4, allows to simulate passage of phonons through silicon crystal. The substrate and a layer of superconductor is modelled to simulate the behaviour of detector.

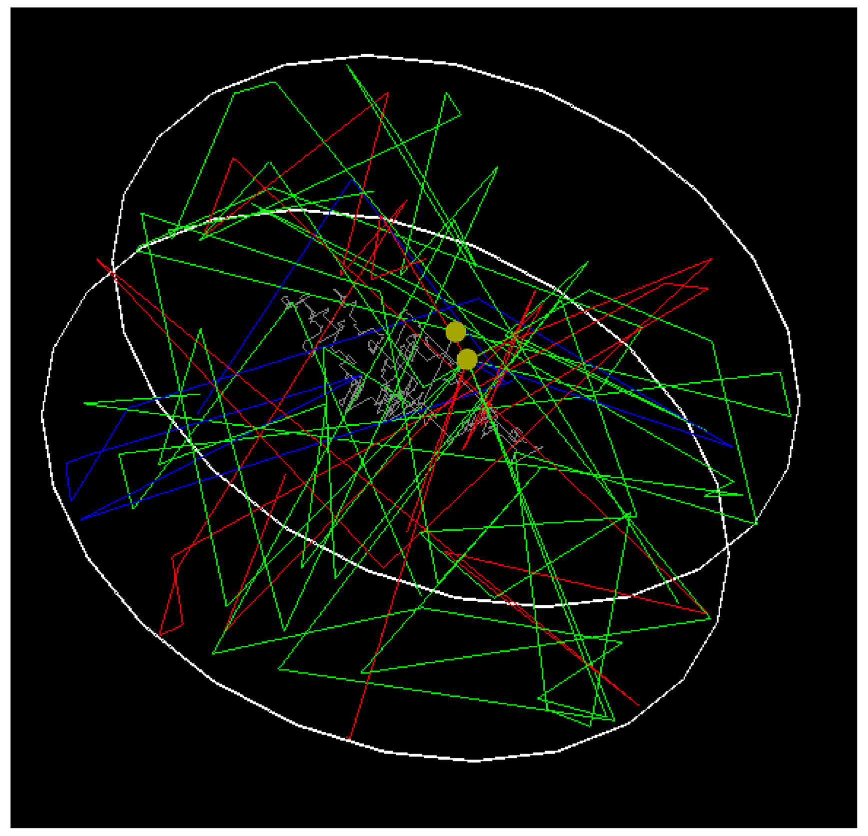

Fig 5. Generation of phonons

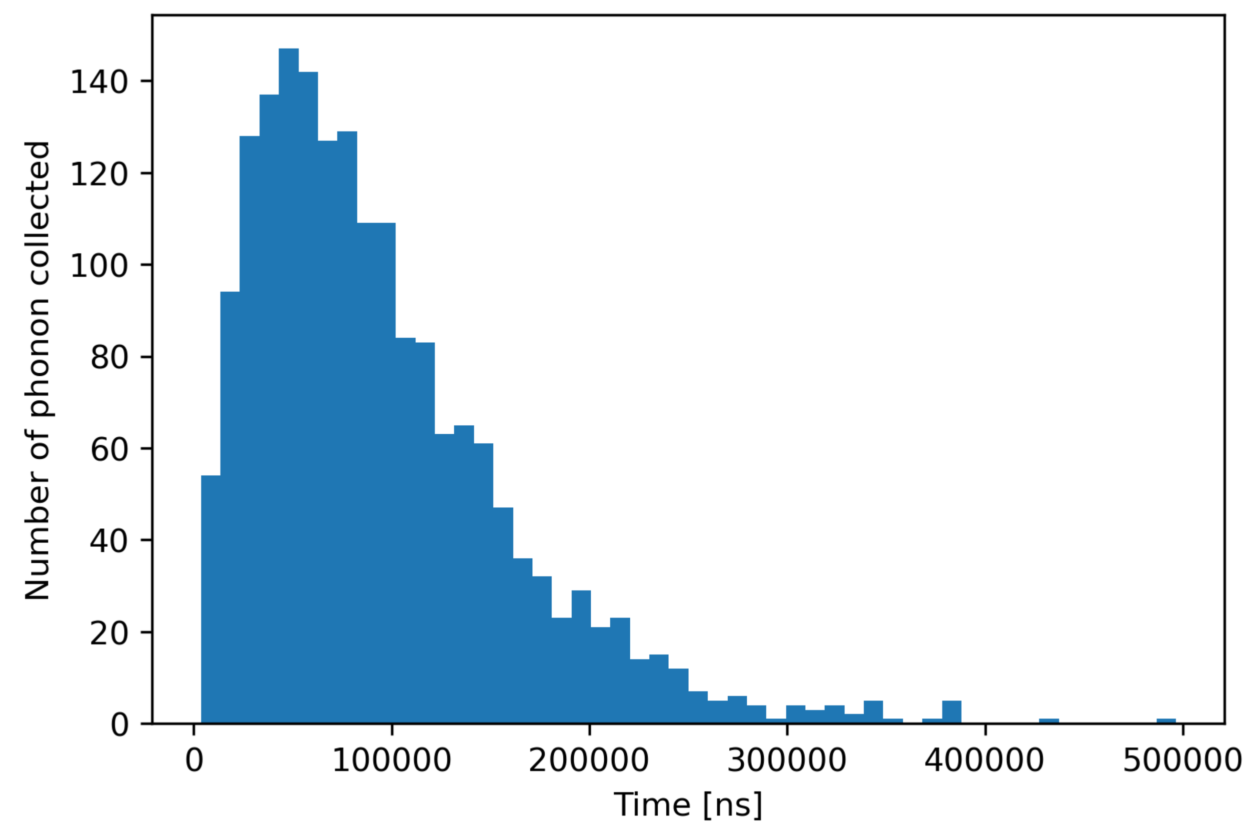

Fig 6. Phonon Collection

Acknowledgment

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