Scanning laser device for low-energy characterization of cryogenic devices

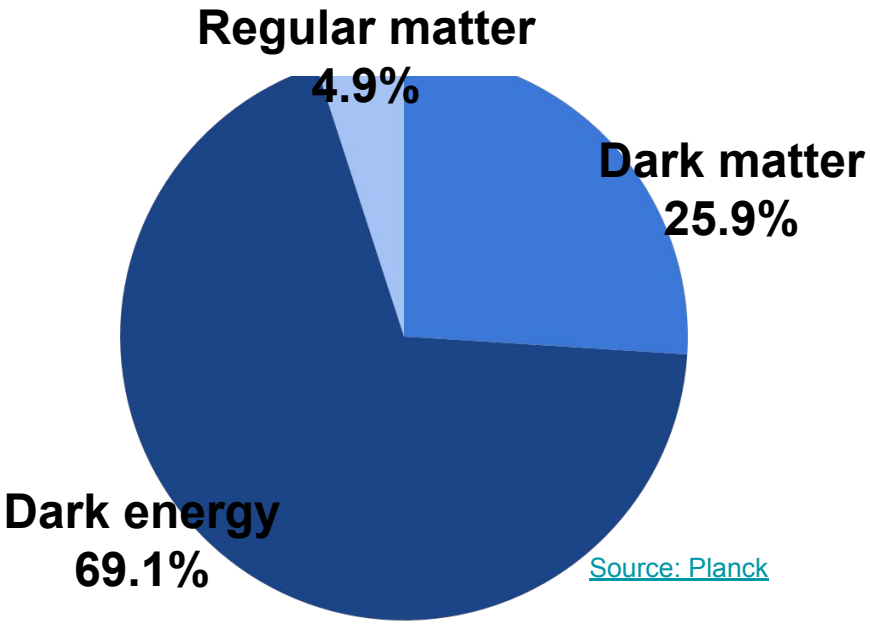
Hannah Magoon - Fermilab Cosmic Physics Center, Quantum Science Center

New Perspectives Conference

6/22/2022

SLIDES-22-072-AD-STUDENT

Dark Matter Background



Source: Planck

Fermilab

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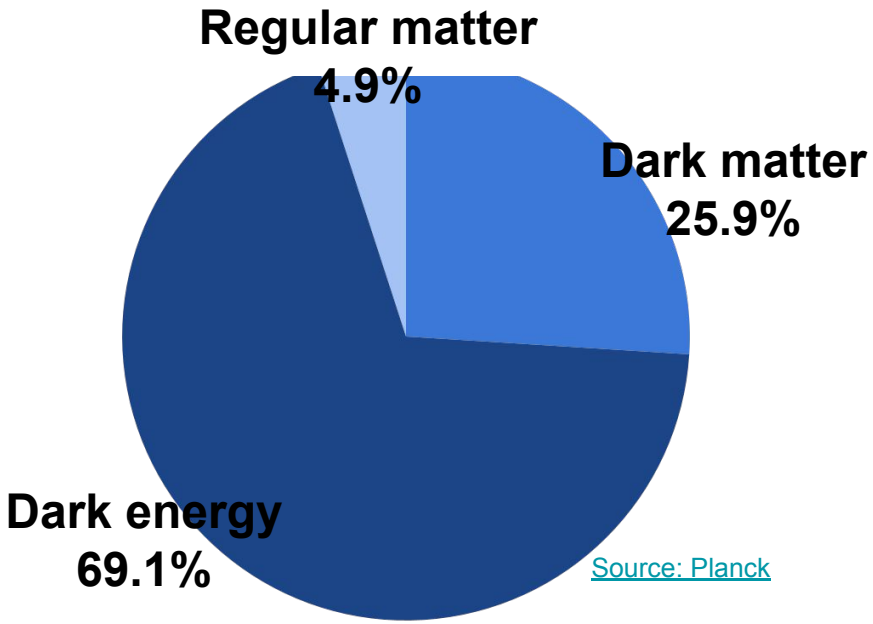

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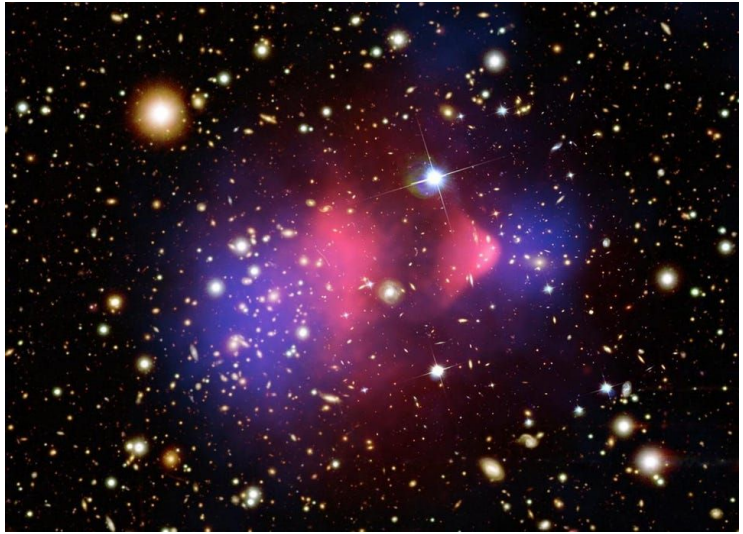

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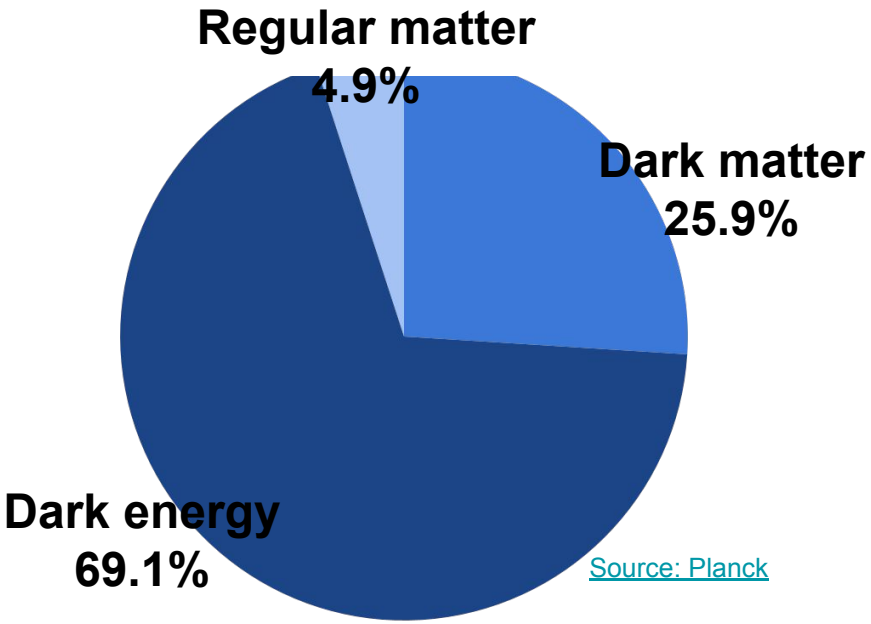

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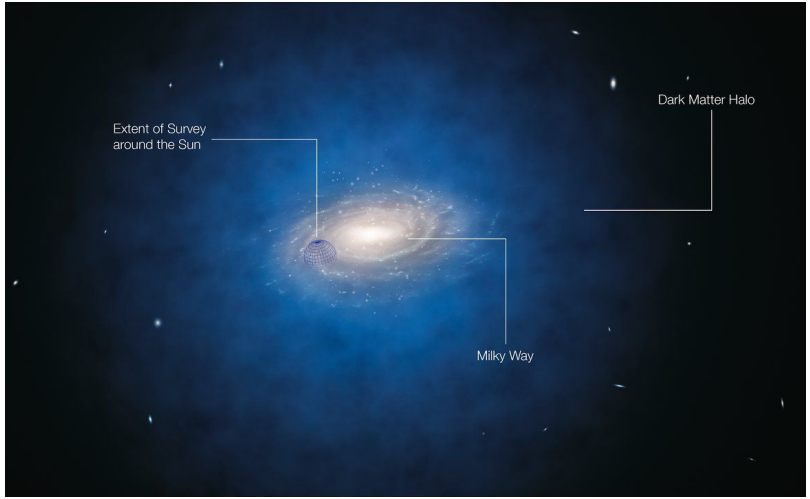
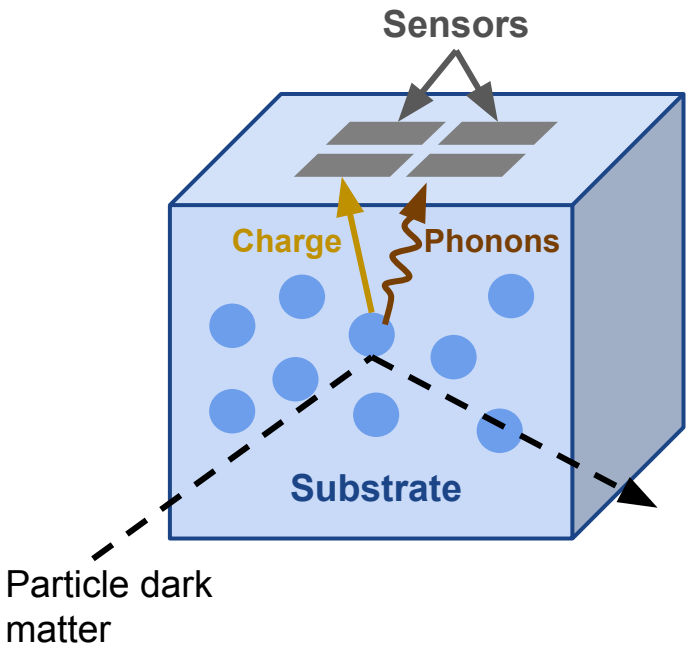


Source: ESO

Dark Matter Detection



Detection of sub GeV dark matter requires detectors sensitive to energy deposits of <1 keV

Novel calibration devices are required for the development and testing of these extremely sensitive detectors

Source: Kelly Stifter, QSC Summer School poster

Superconducting Detector Calibration

Goal: pulsed, steerable light source that can couple to a wide variety of cryogenic devices

Some phenomena that we can probe:

- Position sensitivity
- Quasiparticle poisoning
- Detection thresholds/readout efficiency
- Sensitivity to ionizing radiation
- Phonon propagation

Used to characterize devices:

- KIDs
- Qubits
- CCDs
- QCDs
- etc.

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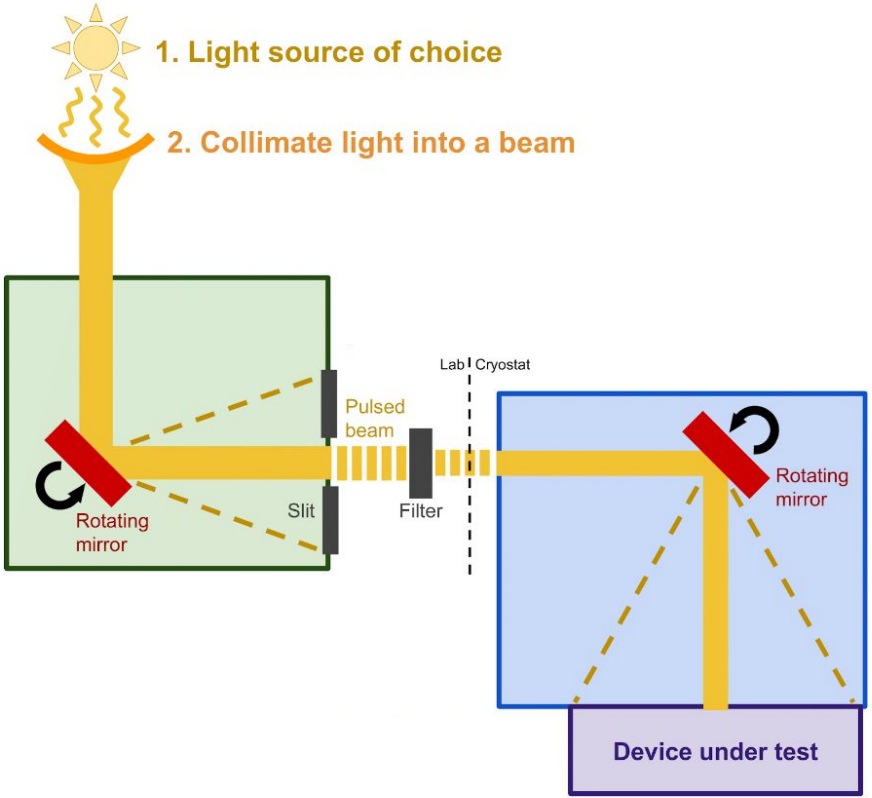
Calibration Device Overview

Goal: pulsed, steerable light source that can couple to a wide variety of cryogenic devices



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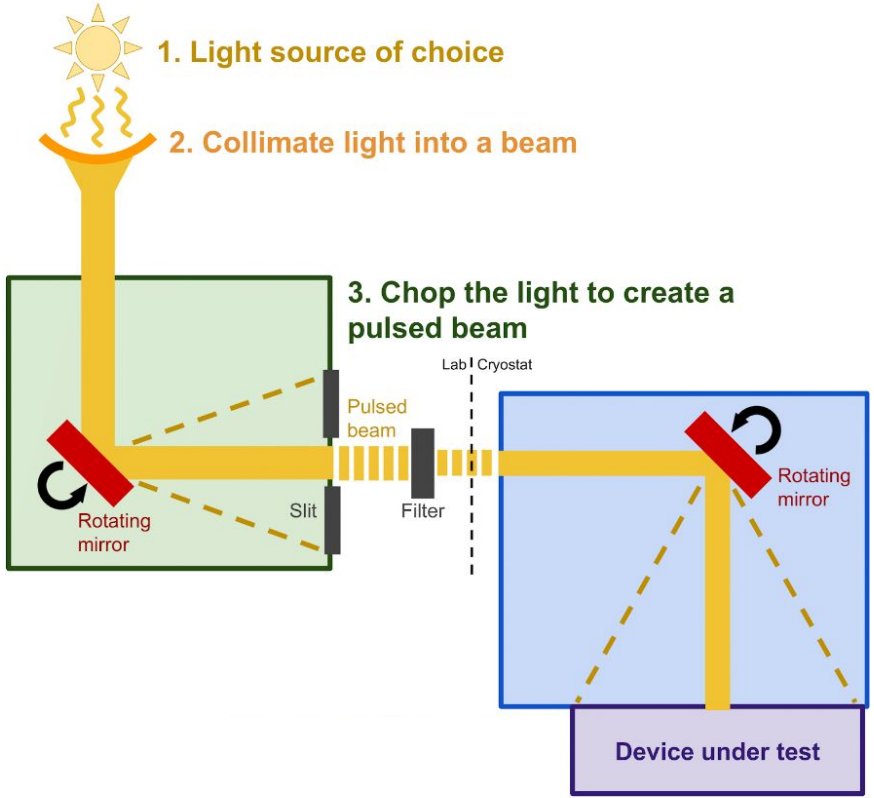

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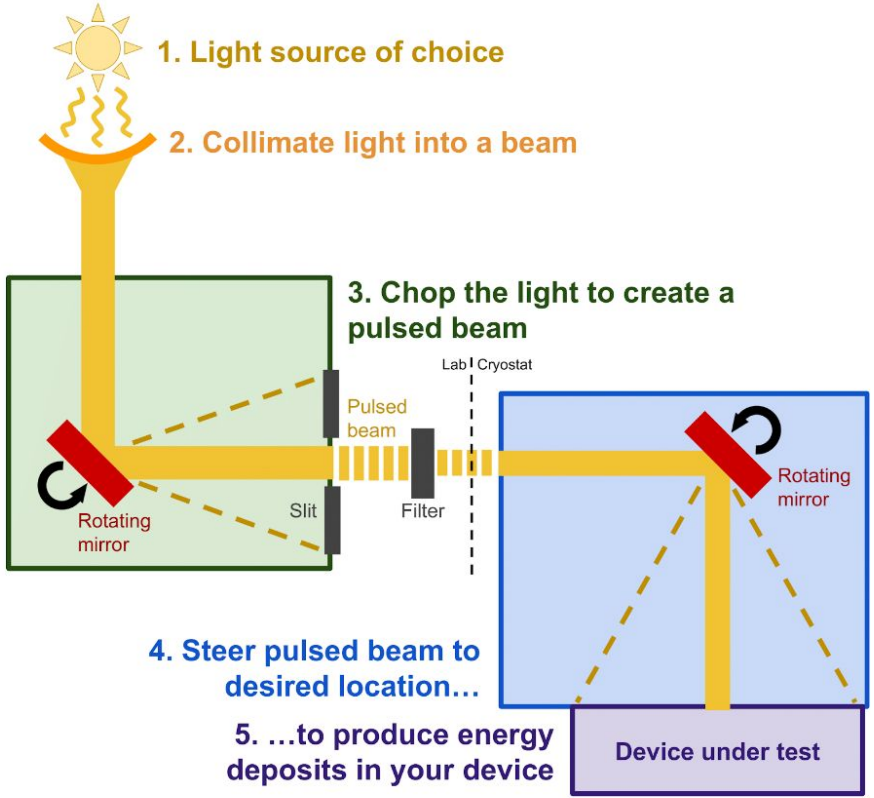

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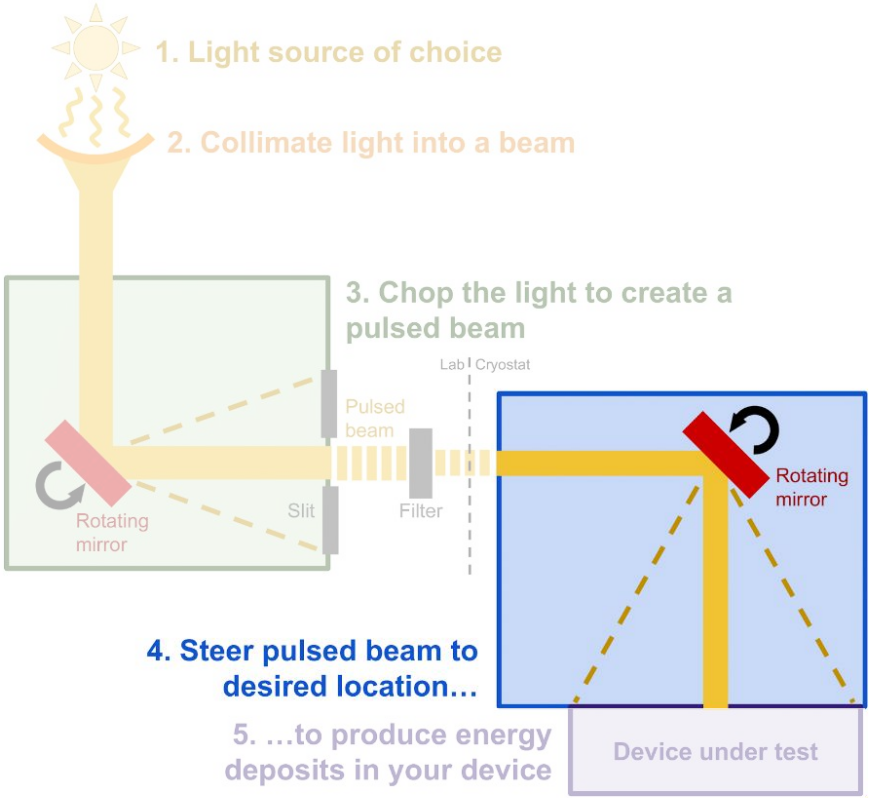
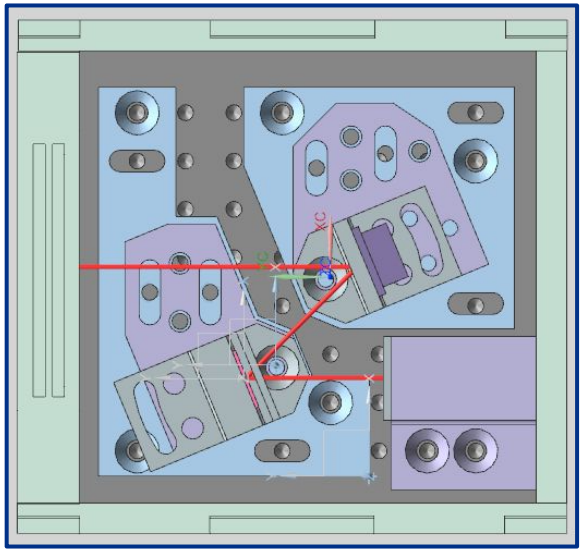
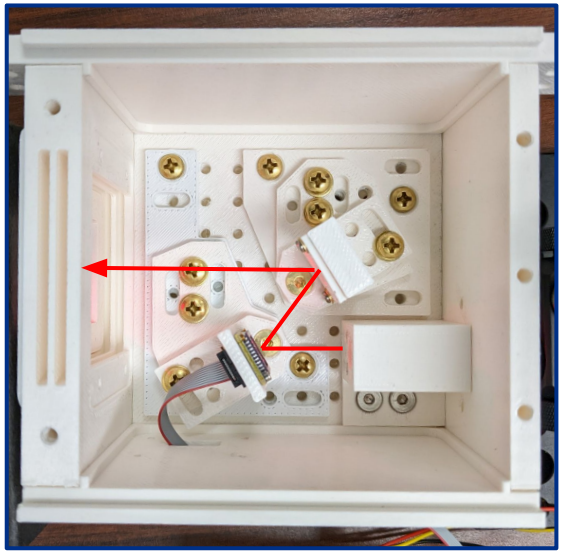


Source: Kelly Stifter, QSC Summer School poster

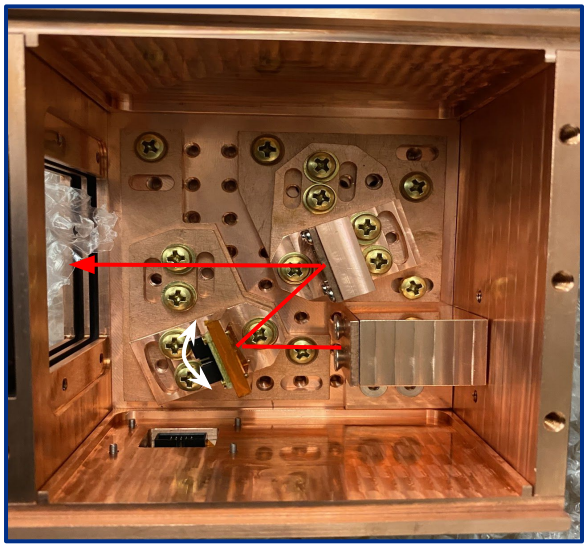
Calibration Device Design Progression



CAD model of enclosure



3D print prototype
(April 2022)



Copper enclosure
(June 2022)

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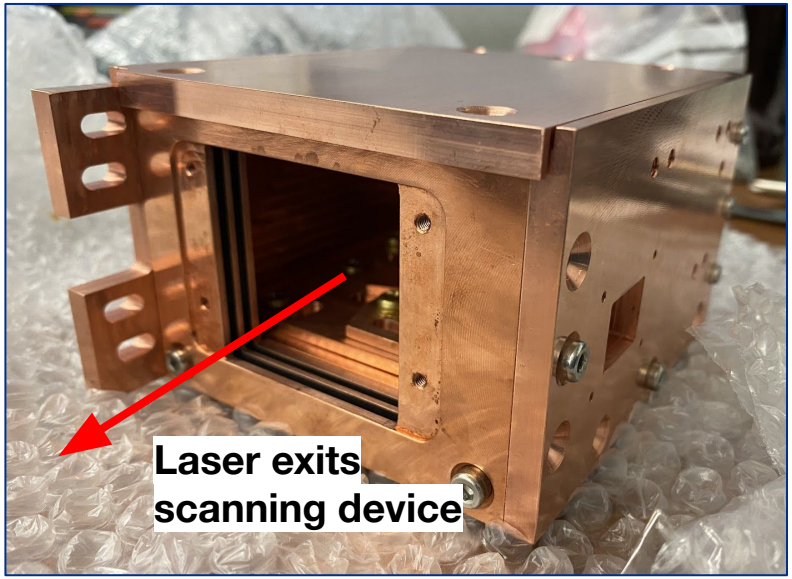
Scanning Unit Requirements

Suitable for use in cryostat:

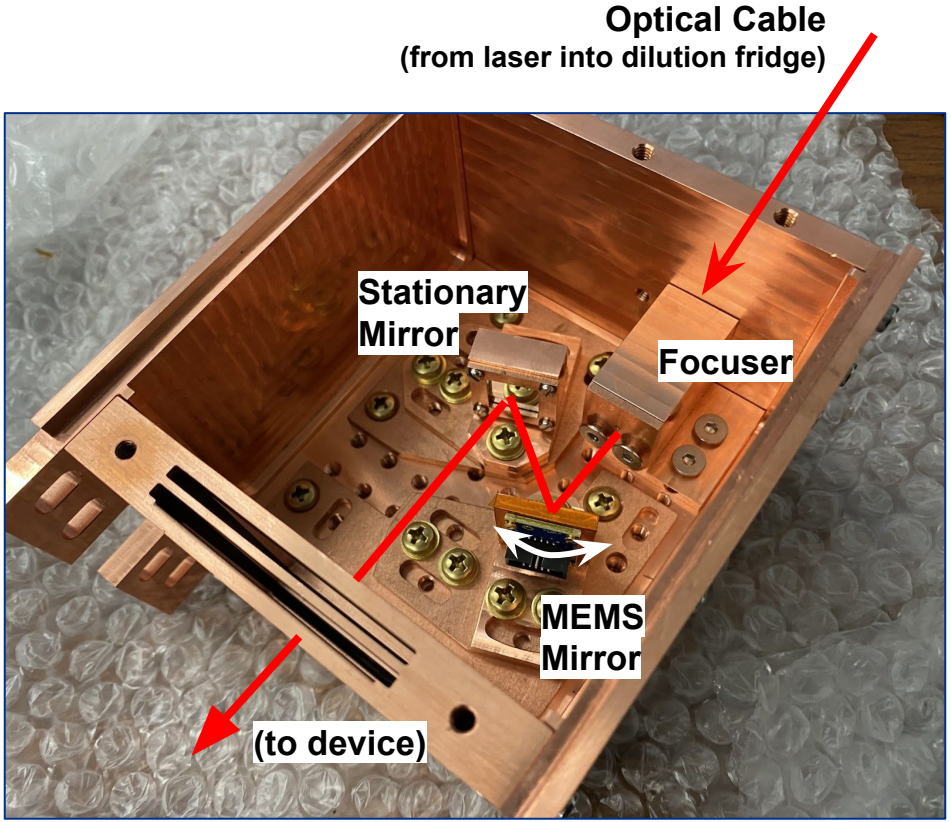
- Control hardware must function at 10mK (Dissipates μW of power during operation)
- Compatible with long/high impedance control cabling
- Unit must be light-tight

Modular design:

- Can interface with a wide variety of detectors
- Easy to swap source and filters to adjust energy range



Scanning Unit Design

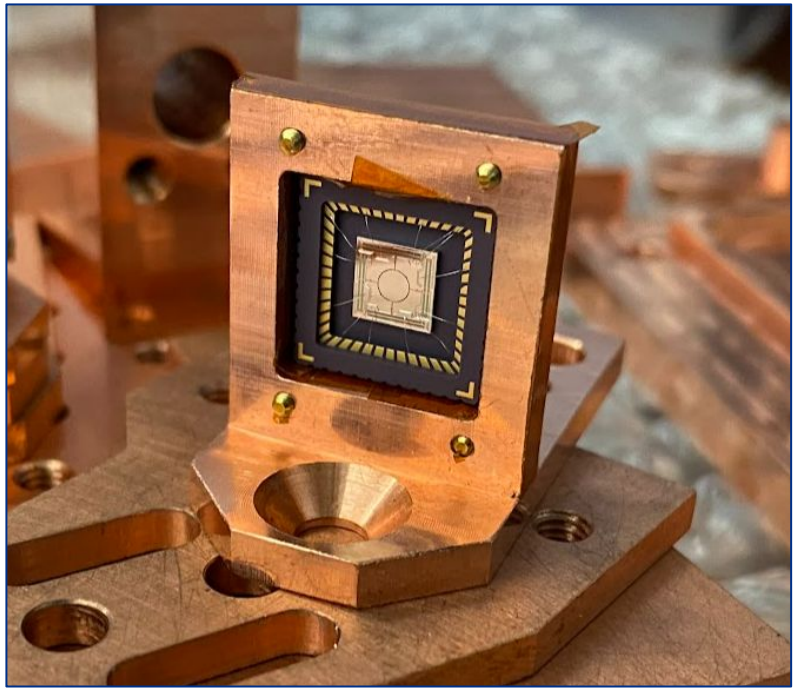


Controllable Scanning Mirror

mirrorcle TECHNOLOGIES, INC.

MEMS mirror used to steer laser beam

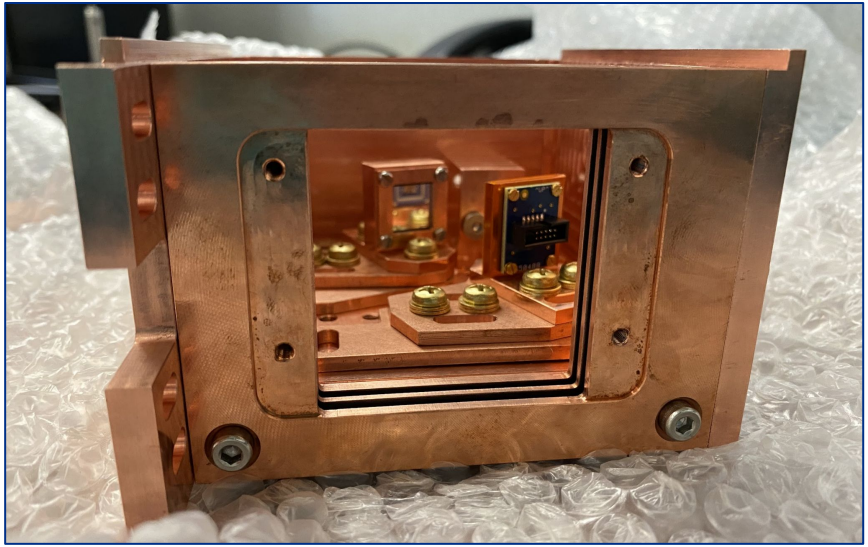
- No power dissipation while stationary
- Modified control lines to function at cryogenic temperatures (>10mK)
- Large deflection angles (> ±5°)
- High deflection resolution (<0.001°)
- High broadband reflectance



Scanning Unit Design

Anticipated Functionality

- 3cm x 3cm scanning area
- <100μm spot size
- ~10μm position resolution
- O(100)Hz scanning speed
- O(μs) pulse width
- >10mK operating temperature



Light directed by the MEMS mirror exits the steering unit through a filter window

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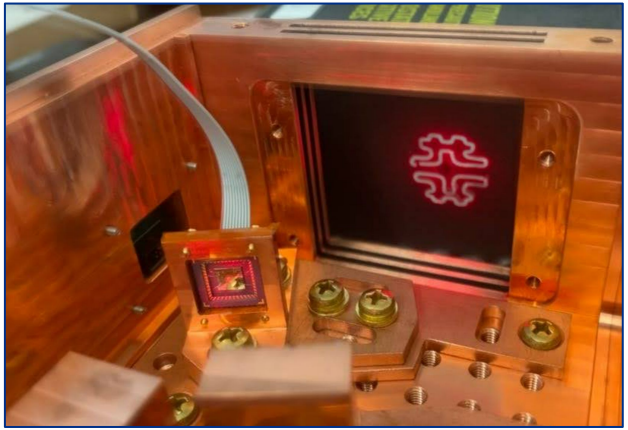
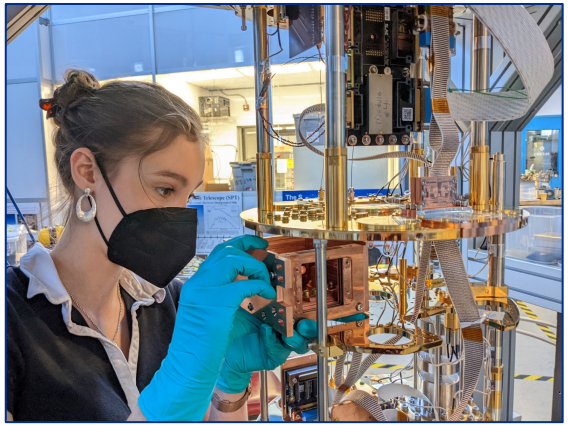
Next Steps

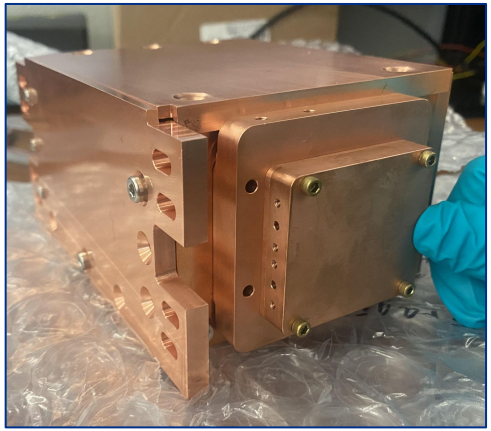
- Continue warm characterization tests
- Demonstrate functionality in dilution fridge
- Measure position sensitivity of KID devices



Warm characterization using a visible laser beam



Copper enclosure being fit to cryostat cold plate



KID device housing attached to steering unit

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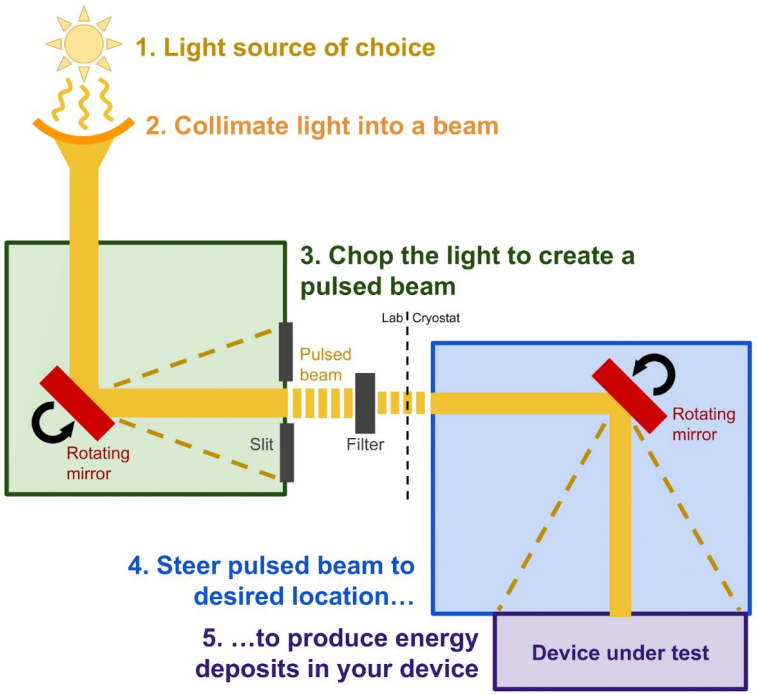
Summary

1. Our design provides a pulsed, steerable light source that can be used to calibrate a wide variety of low energy detectors
2. The design is modular, making it easy to swap bandwidth, intensity, and pulse characteristics
3. We are nearing the end of the development phase, and will soon begin testing in a dilution fridge



Source: Kelly Stifter, QSC Summer School poster

Thanks to:

Scanner team:
Kelly Stifter (Lederman Fellow)
Israel Hernandez (IIT grad)
Hannah Magoon (Tufts undergrad)

Fermilab QSC group:
Dan Baxter (Scientist)
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Dylan Temples (Lederman Fellow)

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Slide from Kelly Stifter (EXCESS2022 Workshop)