Low energy calibration of novel dark matter detectors with a scanning laser device

Kelly Stifter, Cosmic Physics Center, Fermi National Accelerator Laboratory

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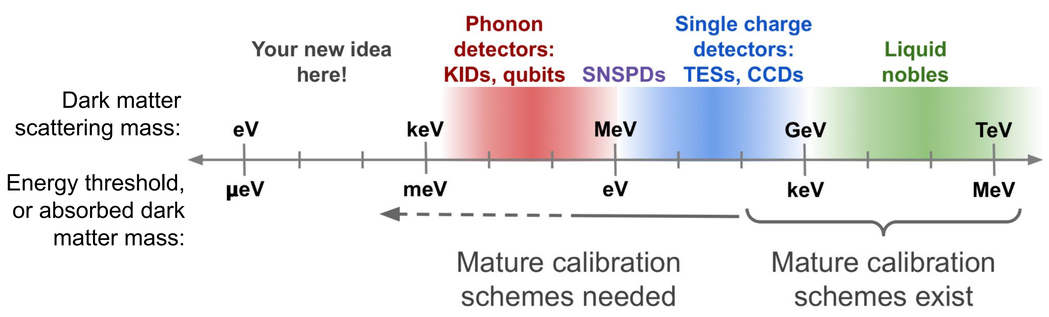
QUANTUM SCIENCE CENTER

Near-threshold calibration is required for novel dark matter detectors:

Motivation: Growing interest in low-mass dark matter requires novel, low-threshold detectors

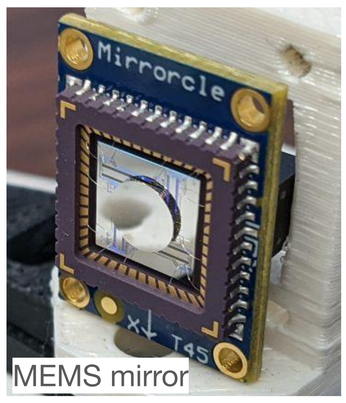


To enable discovery, we need to calibrate near threshold for this wide variety of devices.

Outcome: We have developed a calibration setup that

- Delivers photons over an energy range of 60meV - 5eV
- Scans over full area of device with <100μm precision
- Produces time-resolved, low-intensity pulses
- Operates *in situ* (cryogenic, no parasitic backgrounds)
- Is device independent, flexible, and modular
- Is relatively inexpensive

Careful design and technology choices allow for desired operating specifications:



MEMS mirror


Reflective collimator


Off-axis parabolic mirror

Challenge: cryogenic movement
Solution: modified MEMS mirrors for use at 10mK (upper left)

- Dissipates <nW of power on average

Challenge: small beam spot size at many wavelengths
Solution: homebrew reflective focusing mechanism

- Reflective collimator (center left) + off-axis parabolic mirror (lower left)

Target technical specifications:

- ~1.5” x 1.5” scanning area
- <100μm spot size
- ~10μm position resolution
- O(100)Hz scanning speed
- O(μs) pulse width
- Operating temperature as low as 10mK

Collaborators: Hannah Magoon (Tufts), Anthony Nunez (Stanford), Noah Kurinsky (SLAC), Israel Hernandez (IIT), Daniel Baxter (FNAL), Lauren Hsu (FNAL), Adam Anderson (FNAL)

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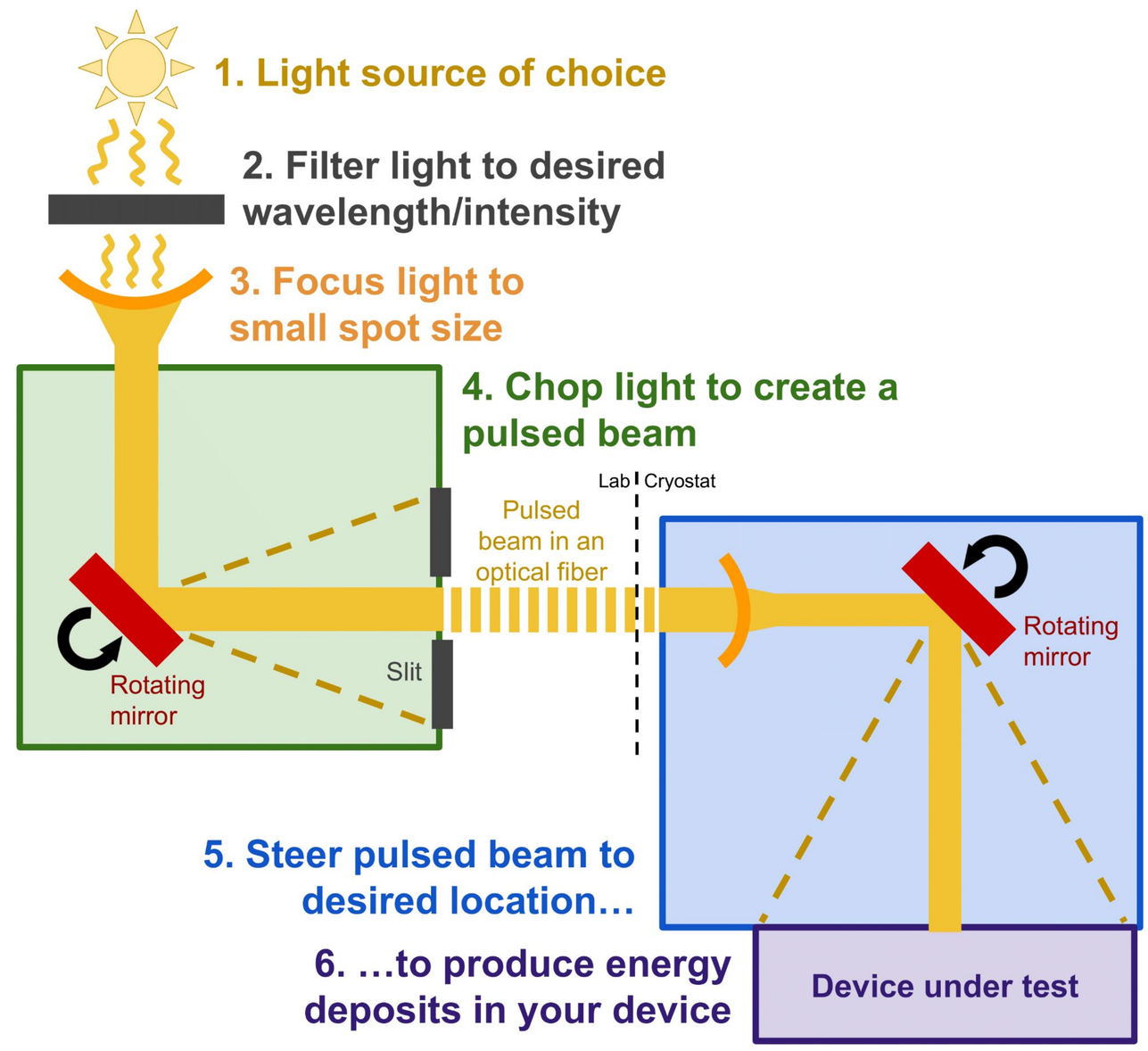
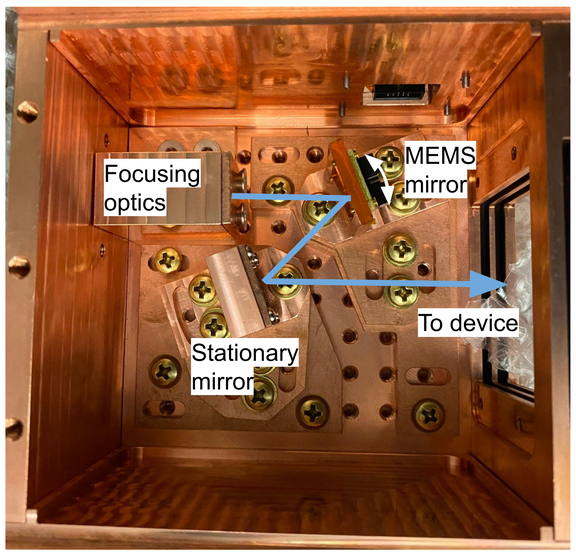
Pulsed, scanning laser device concept:



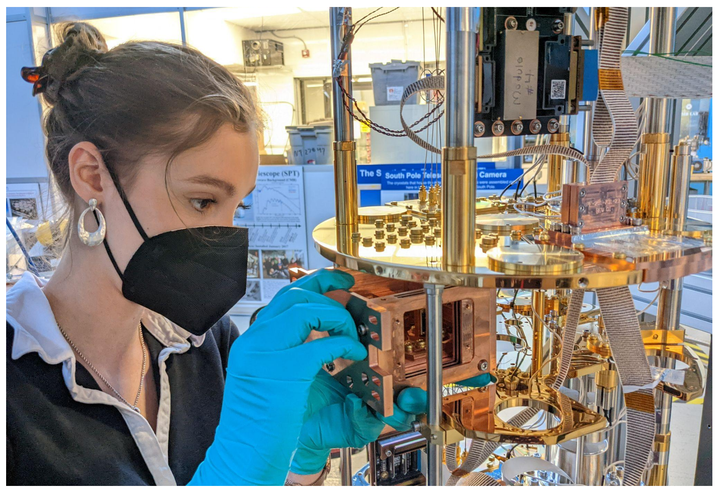
Current status: First 100mK scanning test imminent



Upper left: Final design of scanning device, machined in copper

Lower left: Full ~1.5” x 1.5” scanning area can be targeted with arbitrary pattern of laser light

Below: H. Magoon installing scanning device into dilution refrigerator



Early science goals of testing program:

- Functionality demonstration of modified MEMS mirrors at 100mK
- Investigation of MKID detector position sensitivity
- Measurement of phonon transport and collection to inform simulations of variety of quantum devices and detectors
- Study of quasiparticle poisoning in qubits