Radiation Hardened Opto-Atomic Magnetometer (RHOM)

Progress Update

DOE Funding Opportunity: DE-FOA-0001770
Grant Number: DE-SC0018586
Period of Performance: 4/4/22 – 10/03/2024

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Hedgefog Research Inc.
San Pedro, CA 90731
8/13/2024

Hedgefog Research Inc.

Areas of Expertise

- Laser systems
- Atomic interferometry sensors
- Custom optical sensors
- Dust mitigation and filtering
- Fluid dynamics sensing and simulations
- Vision testing
- Magnetic sensing
- Software development
- Machine learning

Manufacturing Capabilities

- Large area flex circuits
- Eye care devices

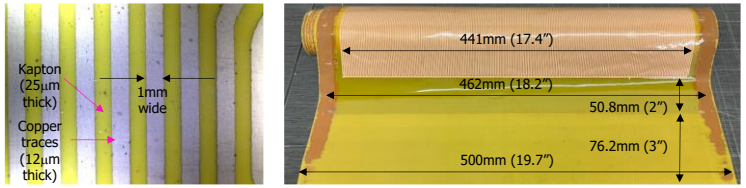
Certifications

- ISO 13485:2016

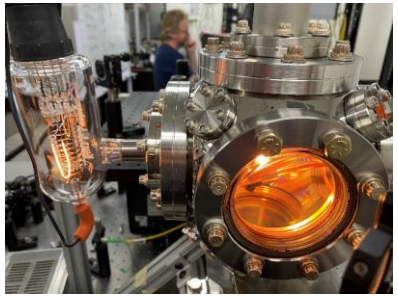
Our customers:

USAF, US Army, US Navy, NASA, DTRA, DLA, DoE

Automated Vision Tester presented at the 2022 Military Health Research Symposium



Large area flex circuit manufactured at HFR



HFR's state-of-the- art optics and vacuum lab

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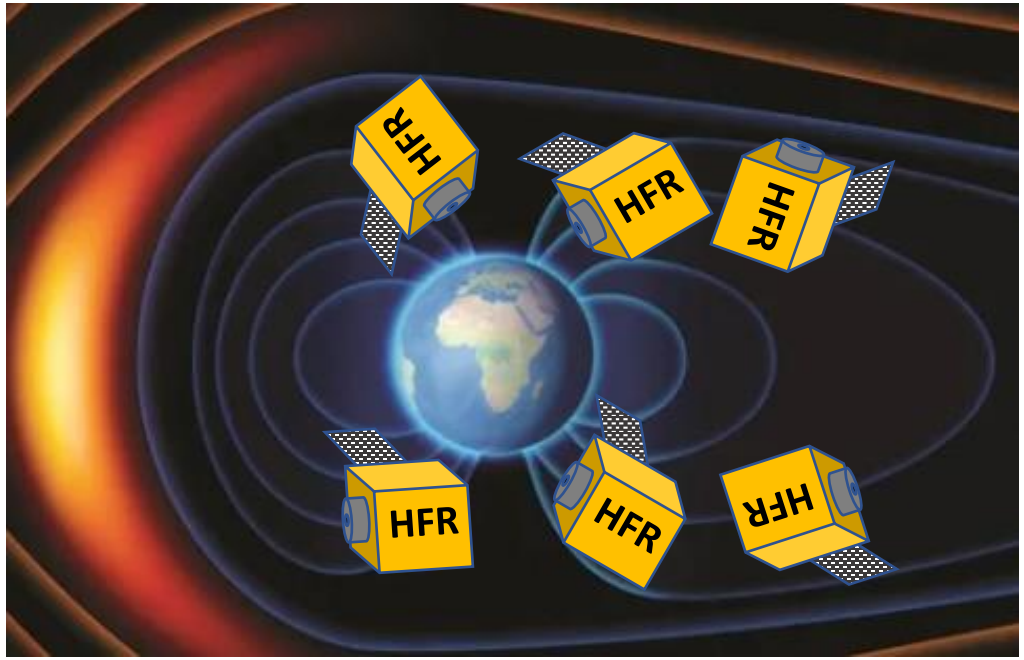

Space Weather Sensing (conceptual)

Contact Information
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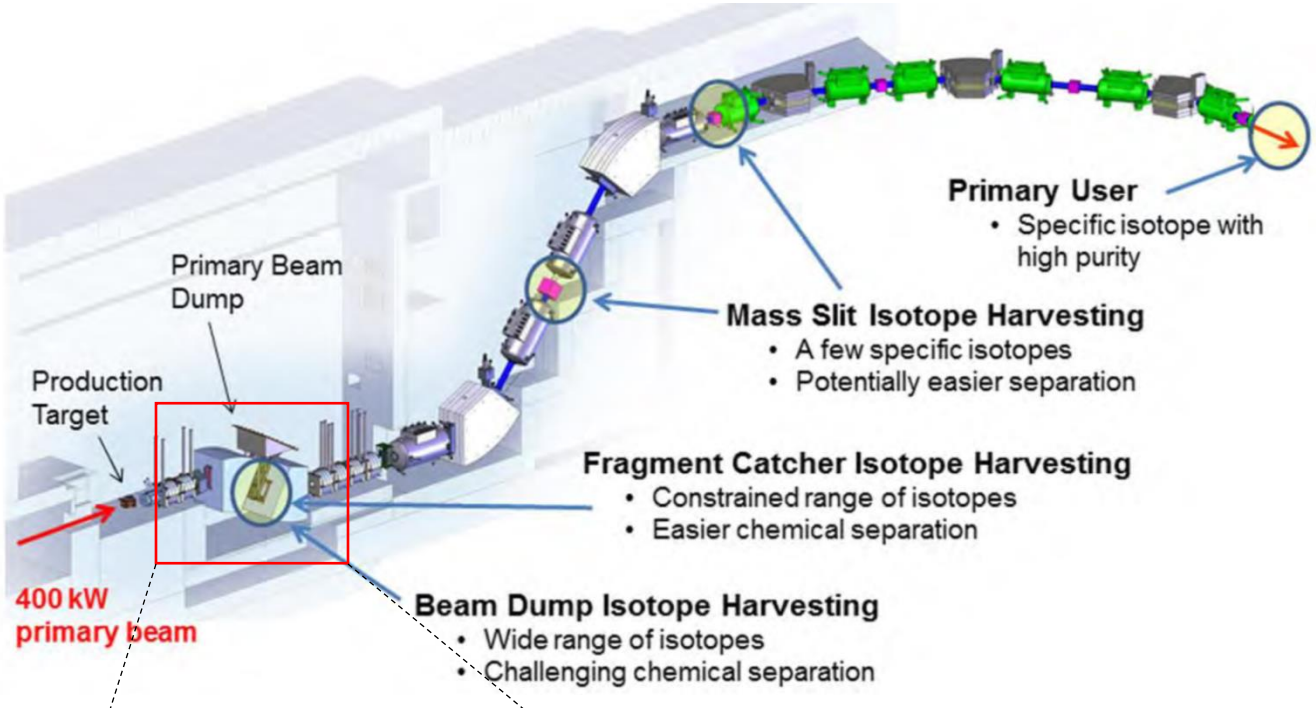
Accelerator Facilities for Nuclear Science

- In rare isotope beam (RIB) facilities, **production and manipulation of the reaction products**, including ionization, purification, acceleration, and transport, need to be optimized individually to achieve maximum production rate of target nuclei.
- **Precise electromagnetic manipulation of reaction products** is needed to deliver intense rare-isotope beams with good ion optical quality and desired timing/energy characteristics.
- **Magnetic-field probing** is one of the diagnostic tools routinely used in the operation of RIB facilities.
- Nuclear magnetic resonance (NMR) probes commonly used in these applications have **limited lifetime** (~ weeks) due to radiation-induced damage. This results in facility downtime and increased operation cost.

DOE Needs

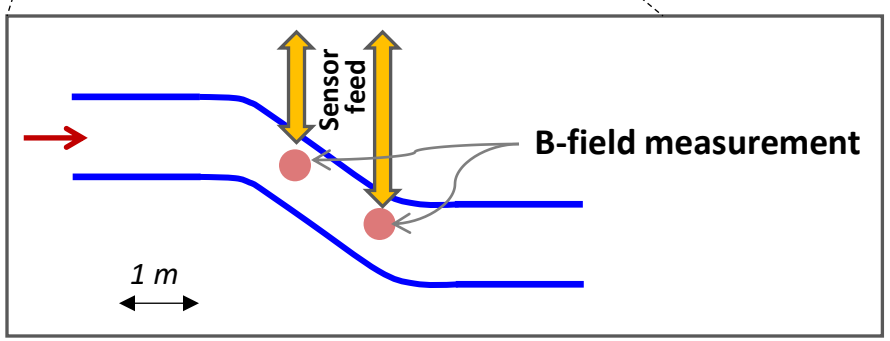
- Magnetic-field sensing in high-radiation environments (gamma ray and **neutron**, **0.1 ~ 10 MGy/yr**), replacing NMR probes
- Target operation lifetime **> 1 year**
- Field range: **0.2 ~ 3 T**
- Precision (ΔB/B) better than 10^{-4}, **10^{-5} desired**
- Field gradient (in one direction): 10^{-4} cm^{-1}
- Rep. rate: higher than 1 min^{-1}, **1 Hz desired**

Isotope Harvesting at FRIB



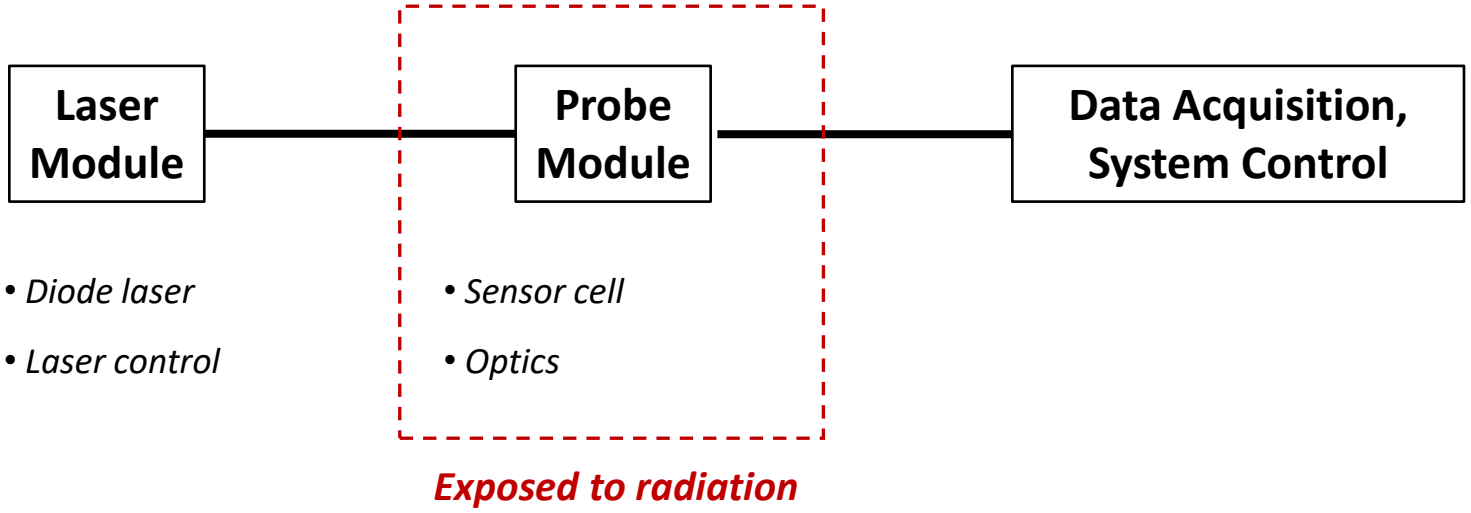
**** FRIB: Opening New Frontiers in Nuclear Science***
August 2012

Rare isotope & primary beam

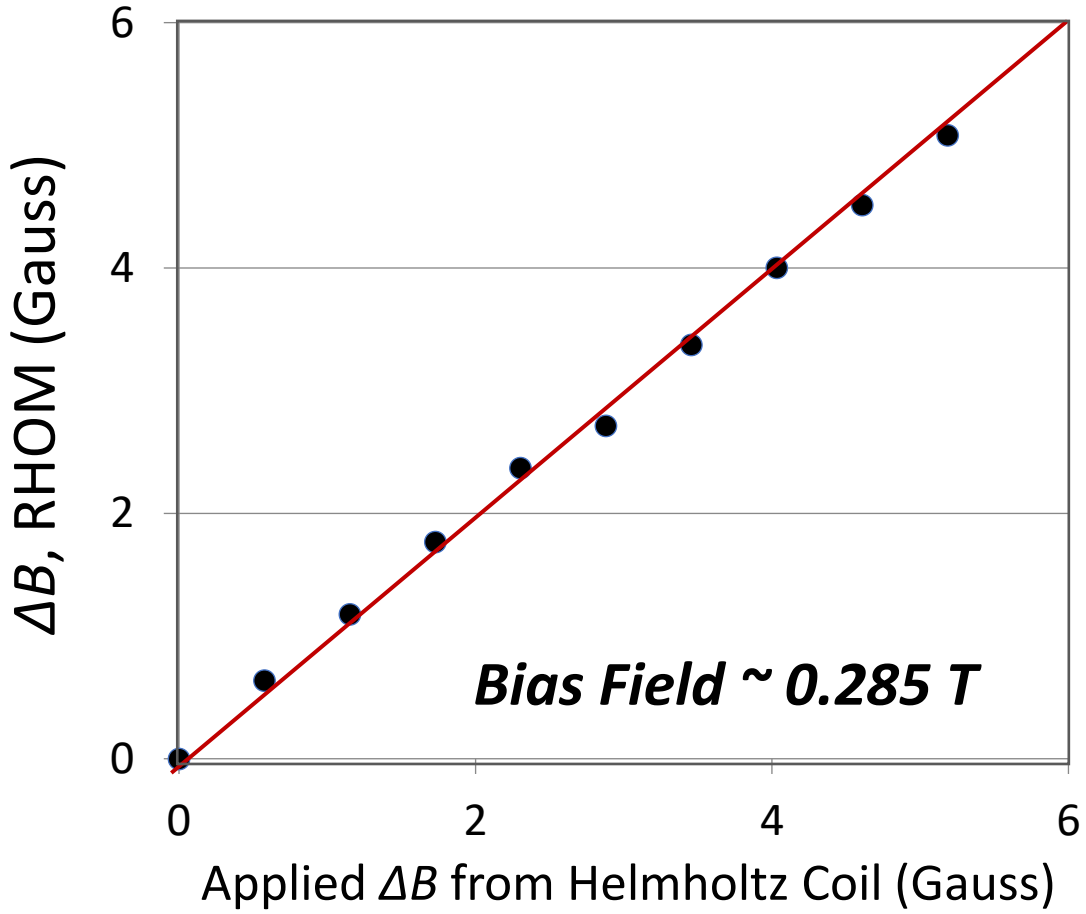


Radiation Hardened Opto-Atomic Magnetometer

- Contains **minimal number of radiation-hard components** exposed to radiation
- RHOM accuracy guaranteed by quantum mechanics; **no need for device calibration**
- Sensitivity better than **10^{-5} T**
- Relative precision **($\Delta B/B$) better than 10^{-5} at 1 T** (**~ 1 Hz** sampling rate)



Magnetic Field Measurement

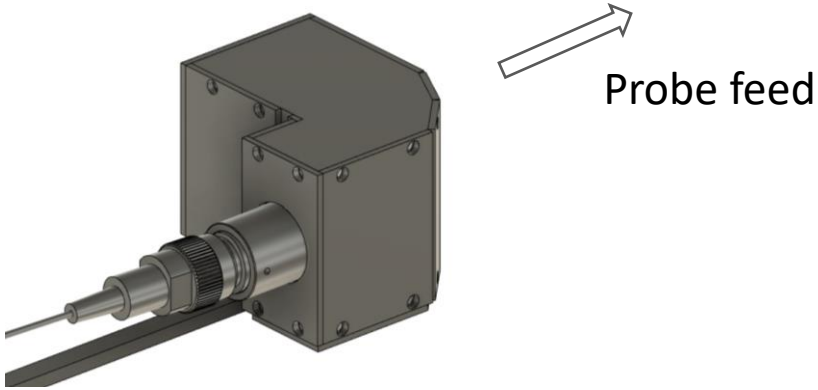


SI-traceable, calibration-free determination of magnetic field

Phase IIA Progress Summary (Aug 2024)

- Developed a new probe module design (1.5 in. × 1.3 in. × 1.5 in.)
- Devised and successfully tested a new optical system scheme
- Developed data acquisition and signal processing software, which, combined together, will provide a fully automated real-time magnetic-field sensing.
- Procured all system components
- Evaluated system performance with final components
- Currently finalizing the prototype assembly for delivery to FRIB in September 2024

RHOM Probe



- Probe housing constructed from aluminum
- Will be located outside the vacuum chamber
- Sensing zone ~ 1 mm
  - determines the field-probing cross-section
  - can be adjusted if needed
- Optical fiber is the only component potentially susceptible to radiation damage; Single-mode fiber to be used in RHOM

Remaining Phase II Tasks

- System assembly and delivery

  RHOM system to be delivered to DOE will contain

  - two 19-in. rack-mountable modules (Controller & Laser)
  - one RHOM probe
  - optical fiber (connecting the Probe and Laser module)
  - user interface
  - user manual

Thank you!

Thank you! Questions?

Areas of Expertise

- Lunar in-situ Resource Utilization (ISRU)
- Atomic interferometry sensors
- Custom optical sensors
- Dust mitigation and filtering
- Fluid dynamics sensing and simulations
- Vision testing
- Magnetic sensing
- Nuclear Forensics

Manufacturing Capabilities

- Large area flex circuits
- Eye care devices
- Medical Devices

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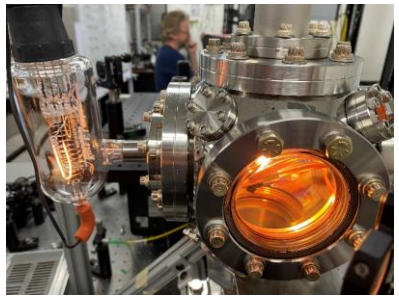

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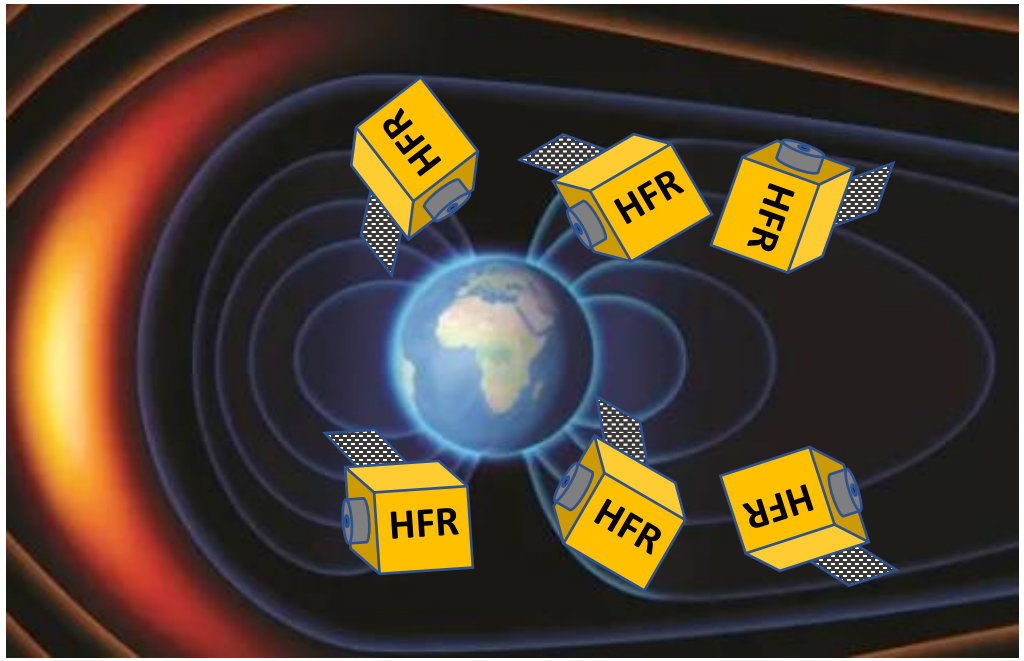

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