Radiation Hardened Opto-Atomic Magnetometer (RHOM)
Progress Update

DOE Funding Opportunity: DE-FOA-0001770
Grant Number: DE-SC0018586
Period of Performance: 05/28/20 to 03/27/20

DOE Program Manager: Dr. Michelle D. Shinn
Office of Science – DOE
Phone: (301) 903-8363

Principal Investigator: Jae Choi, Ph.D.
Hedgefog Research Inc.
San Pedro, CA 90731
August 2020

Company Overview

Introduction

Hedgefog Research (HFR) is a young, fast growing company; its team has expertise in the fields of optical engineering, optical metrology/sensing, spectroscopy, atom-based sensors, and mass spectrometry.

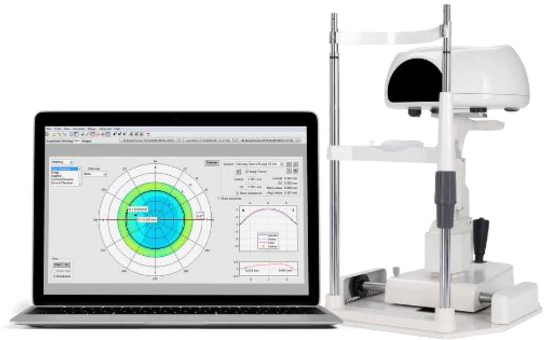
- **Optical system design** and **metrology/sensor development**.

- Manufacturer of **commercial corneo-scleral topographer.**

Team experience:

- Full-cycle product development.

- Proven track record of commercial device development - our corneo-scleral topographer is sold worldwide.



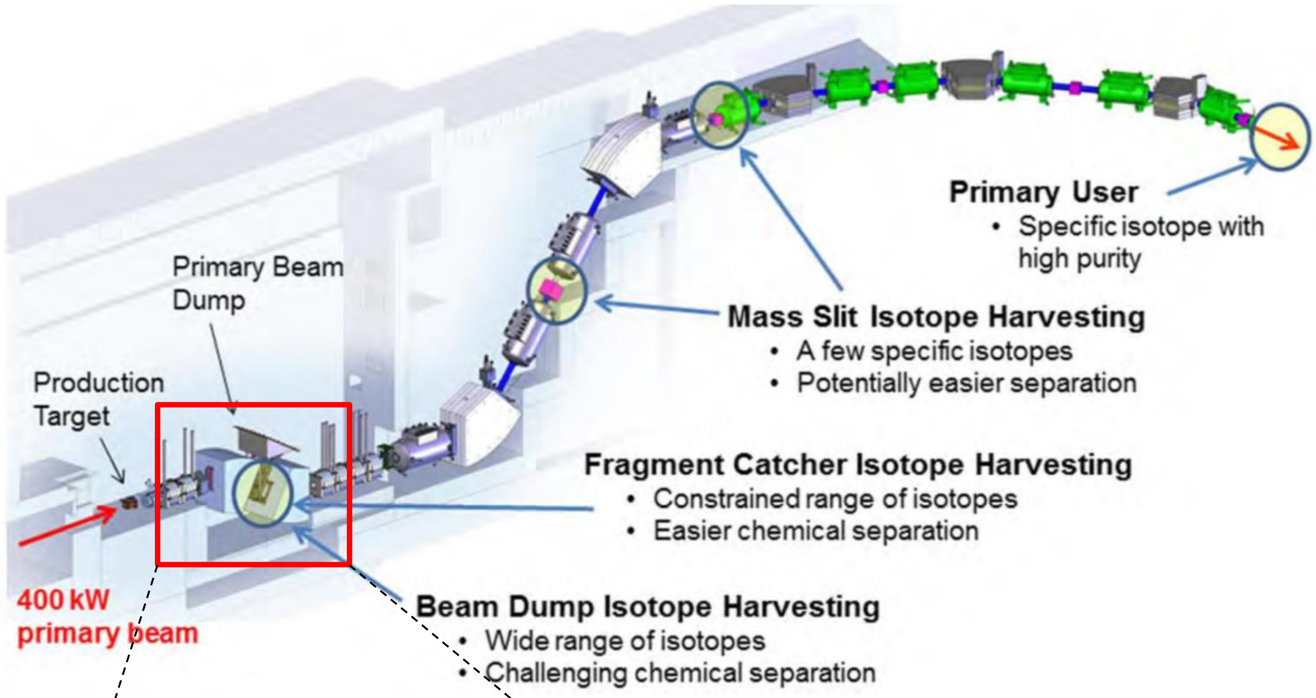
High-Power Target Facilities/Accelerators

- 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 lengthy – and costly – facility downtime.

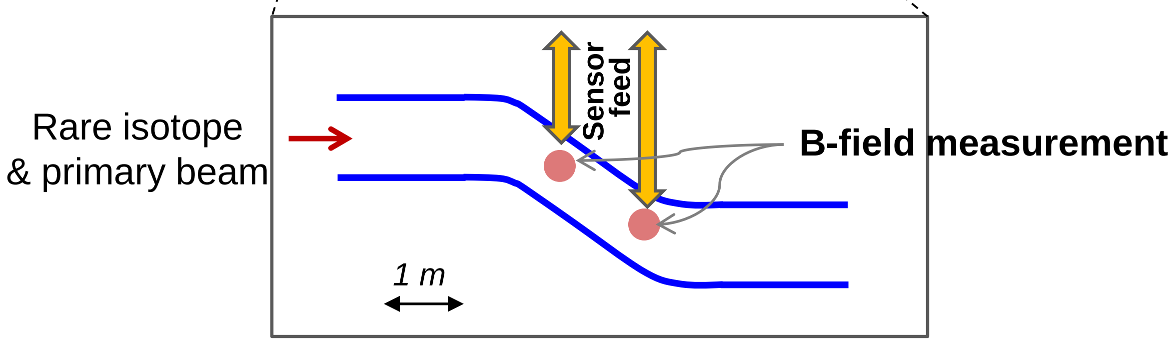
DOE Needs

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

Isotope Harvesting at FRIB

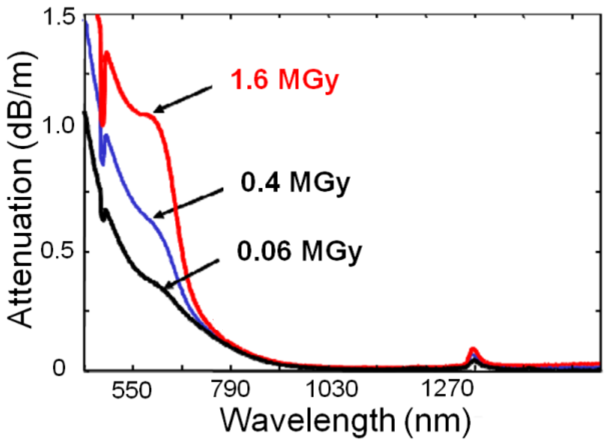


*** FRIB: Opening New Frontiers in Nuclear Science**
August 2012



Radiation Hardening

- "***If in doubt, leave it out***"
  The fewer components exposed to radiation, the better.
- **Electronic, electrical, and mechanical** components could be susceptible to radiation damage
  (example: capacitors have a damage threshold level of 10^2 ~ 10^5 Gy)
- Synthetic organic materials are among the most radiation-sensitive materials, while **ceramics** are more resistant. **Metals** are often the most radiation-resistant.
- Radiation may reduce light transmission by **darkening optical materials**. Transmission in visible tends to be worse than in **NIR**.

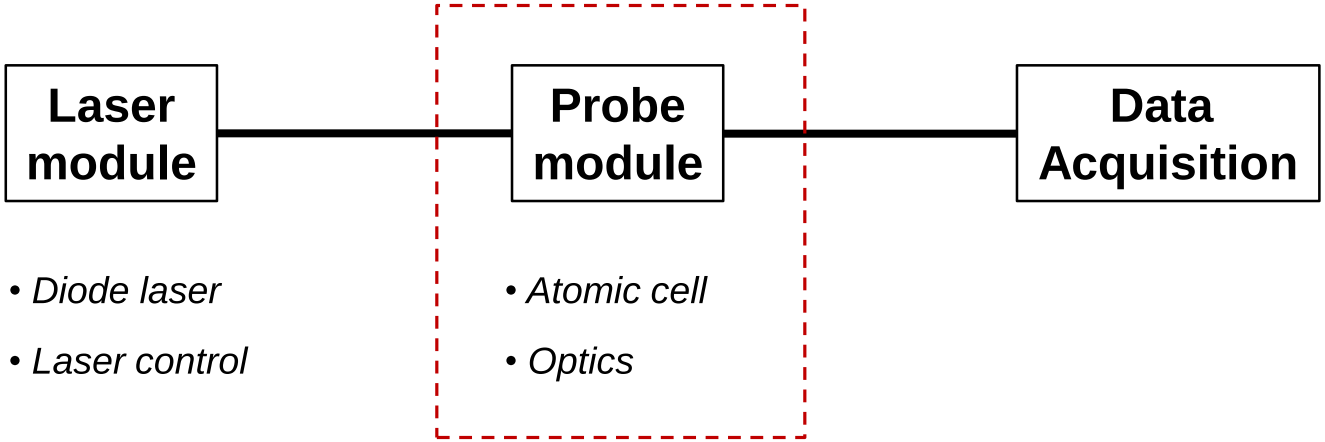


** Optical fiber in radiation from fusion reactor tested up to 1.6 MGy*

Brichard, et.al. Journal of Non-Crystalline Solids, 353, pp.466-472, 2007

Radiation Hardened Opto-Atomic Magnetometer (RHOM)

- Contains **minimal number of probe components** exposed to radiation (atomic cell, mirror, fiber, mechanical housing)
- **Traceable**
- Sensitivity ~ **10^{-5} T** or better
- Relative precision **($\Delta B/B$) ~ 10^{-5}**
- **>1 Hz** sampling rate

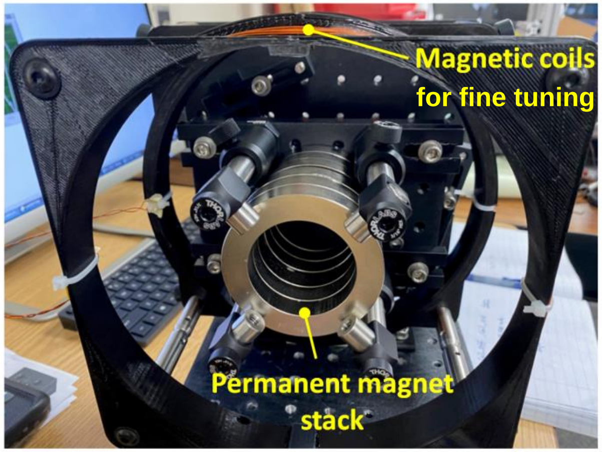


Exposed to ionizing radiation

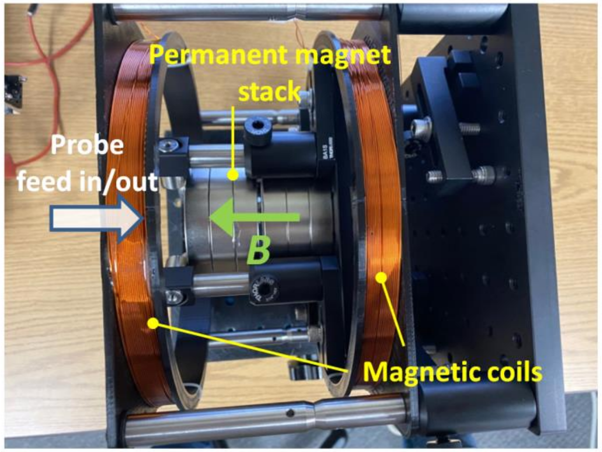
Progress Summary (Aug 2020)

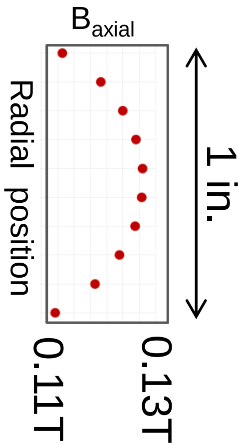
- Constructed a compact probe prototype (ϕ1″×L1″)
- Constructed a test setup to check B-field sensitivity

Axial



Side



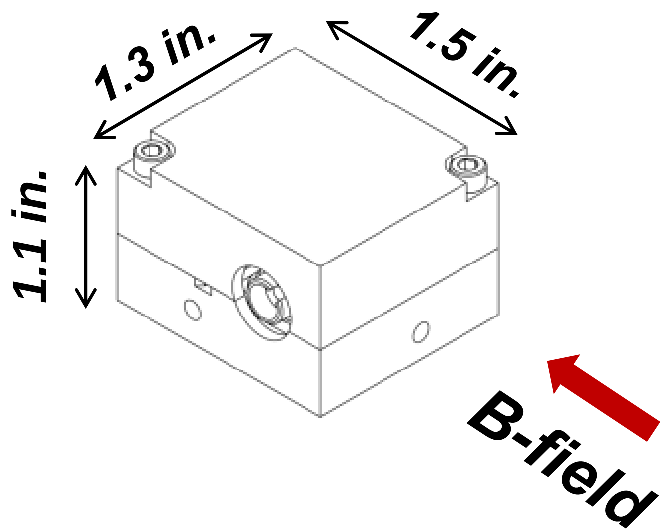


Y1 testing setup

- Verified B-field sensitivity suitable for the DOE application
- Laser control/stabilization development is underway

Progress Summary (Aug 2020)

- Radiation hardness of probe components to be tested at Argonne National Laboratory (ANL) in 2020 (Oct ~ Dec)
- Mechanical design for magnetic-field probe is being finalized



** non-magnetic construction*

Phase II Performance Schedule

Task	Task Description	Year 1: 1	2	3	4	5	6	7	8	9	10	11	12	Year 2: 1	2	3	4	5	6	7	8	9	10	11	12
1	Define Operation Environments and Develop System Requirements																								
2	Develop System Architecture and Design of the Phase II Prototype																								
3	Select and Acquire System Components																								
4	Design, Build and Test Custom System Components																								
5	Develop and Test Probe Module																								
6	Assemble Phase II Prototypes																								
7	Test Phase II Prototype in laboratory settings																								
8	Ruggedize Phase II Prototype																								
9	Perform On-site Testing of Phase II Prototype																								
10	Enhance Phase II Prototype Based on Site Testing Results																								
11	Preparing for *Transition to Production*																								
12	Plan Commercialization																								
13	Manage Program and Submit Reports																								
	Milestones					①							②									③			

Milestone 1. Finalizing Phase II prototype design
Milestone 2. Assembly of Phase II prototype
Milestone 3. Performance of on-site testing and further system ruggedization

Phase II Development

- Full feasibility of the technology will be demonstrated.
- By end of Phase II, probe design will be nearly production-ready.
- Preliminary layout of support system (controller, DAQ module) will be developed.

HFR
Hedgefog Research Inc.

Technology Transition (Post-Phase II)

- Full system design (probe & support system) to be finalized.
- User interface to be developed and tested.
- Manufacturing plan to be established.

  HFR will take advantage of existing manufacturing base and quality control (ISO 13485).

ISO
13485:2016

Thank you!