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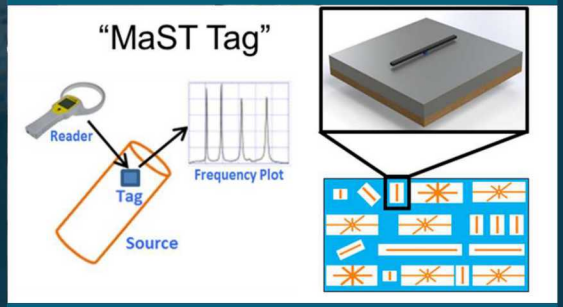
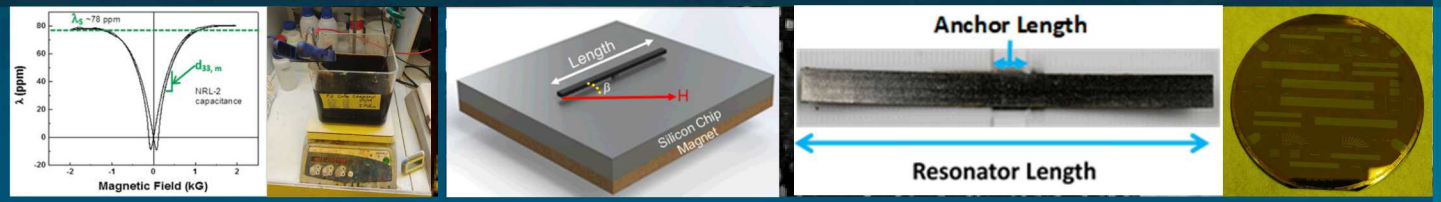
SAND2020-3523C

Magnetic Smart Tag (MaST) for Unique Identification





PRESENTED BY

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Goals and Objectives

Magnetic Smart Tag (MaST) for uniquely identifying nuclear materials and other high value assets, particularly for International Nuclear Safeguards and Arms Control regimes

- Primary need for unique identification (tags) is to prevent tampering and substitution of original component
- Passive (no battery required, zero standby power consumed)
- Wireless
- Distinctive, low frequency (< 10 MHz), magnetic signature
- Can be unobtrusively attached externally or intrinsically incorporated into the walls of new and existing nuclear fuel containers and equipment.

Identifier Uniqueness is achieved with random, multi-bit (i.e., multi-resonator) arrays

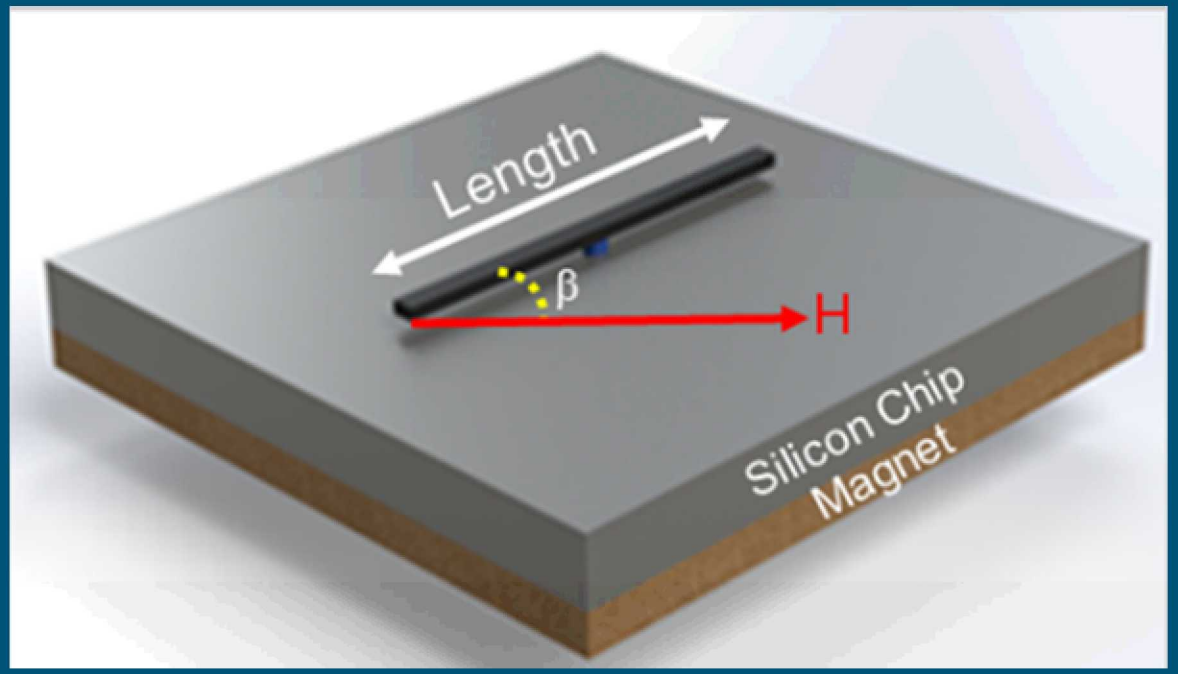
Anti-Counterfeit Properties making this technology nearly impossible to replicate:

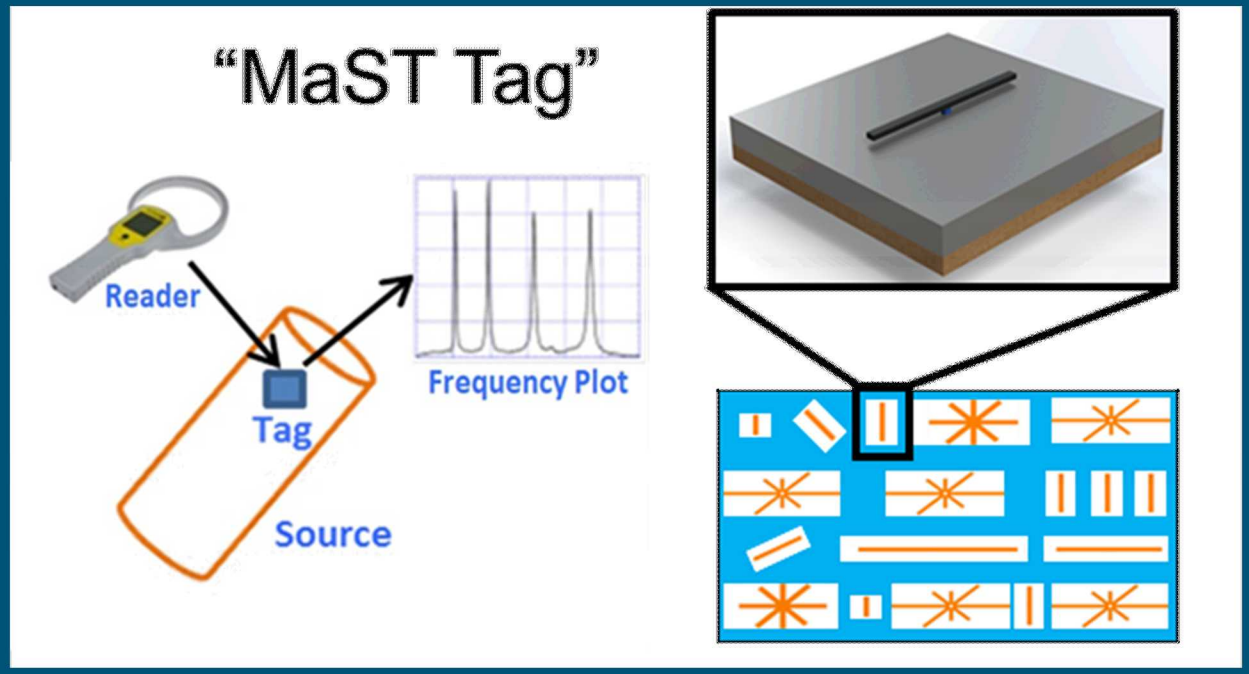
- Proprietary CoFe alloy electroplating
- Multi-bit arrays
- Unique array patterning
- Post-processing randomness (e.g., patterned thin film coatings)

Usage

MaST is comprised of an array of magnetic resonators and a bias magnet

- A periodic magnetic signal is imposed by a transceiver antenna
- The resonator undergoes mechanical oscillation due to Joule magnetostriction effect
- Resonator emits its own time-varying magnetic field via mechanical ring down detectable by the transceiver antenna
- Resonator frequency is proportional to resonator length and bias angle, β
- An electronically detected frequency spectrum from the resonator array comprises the MaST identity



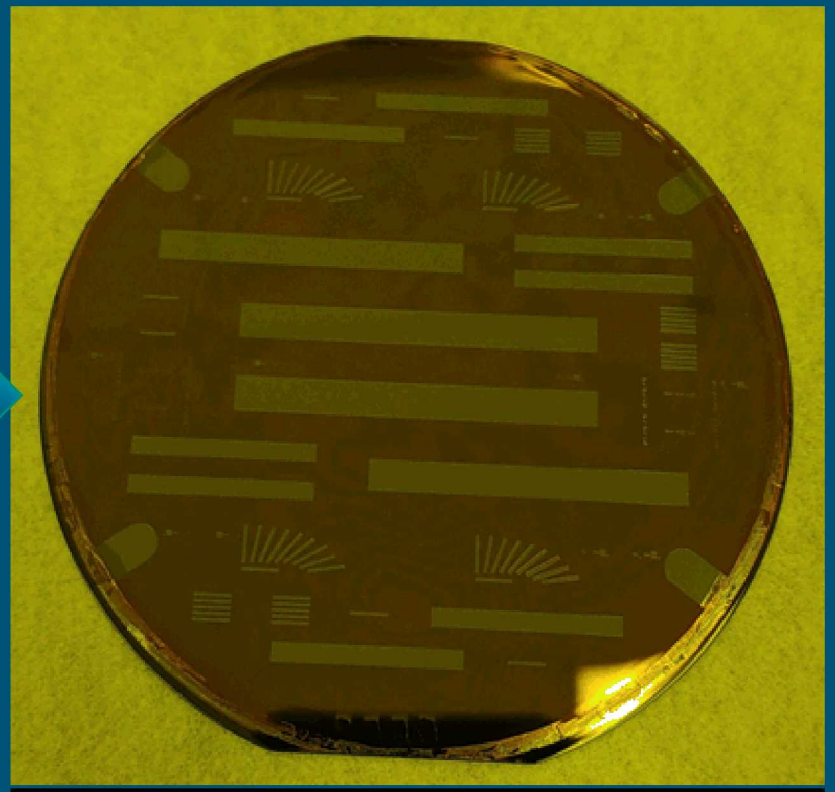


Fabrication

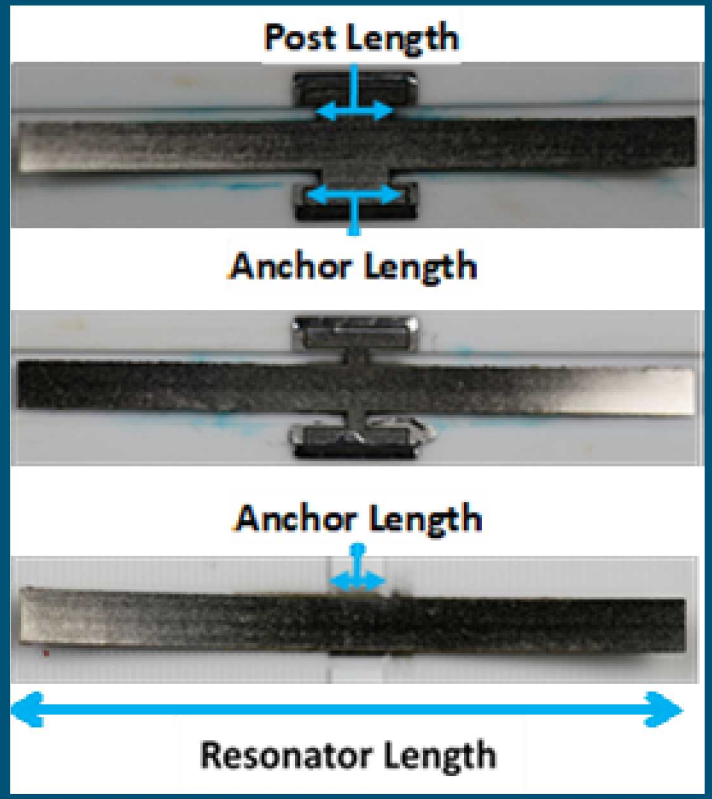
Two methods of magnetic resonator fabrication employed for MaST signature:

- CoFe-based magnetic resonators fabricated via electroforming (fabrication-friendly process!)
- Laser cut commercial USIII (Metglas) magnetic resonators solder attached to alumina substrates

Plating Setup



Resonator Wafer

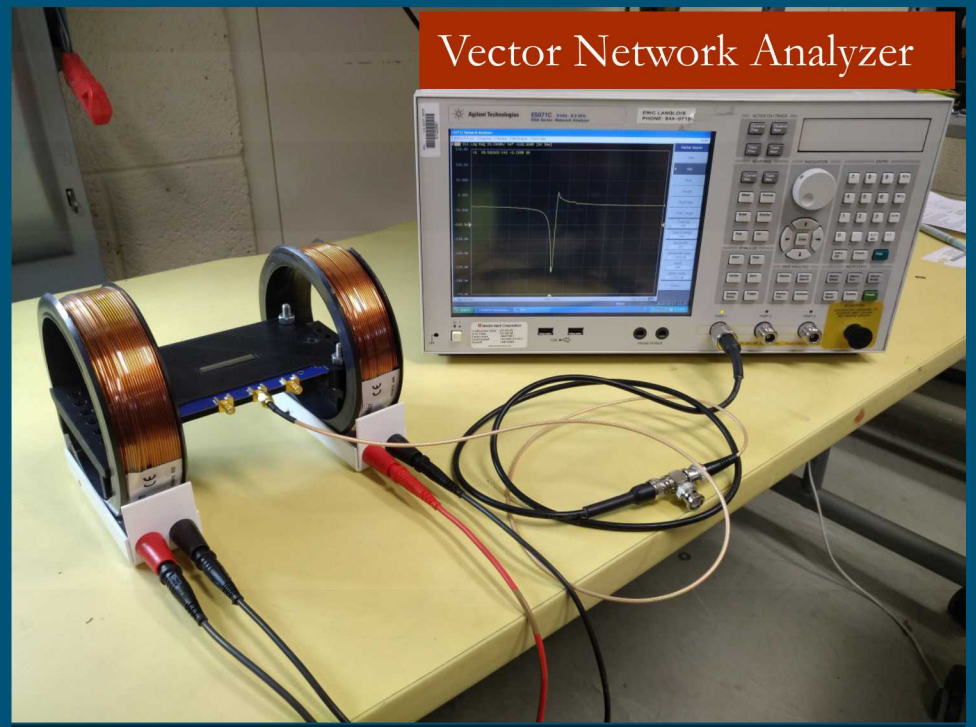


Laser Machined USIII

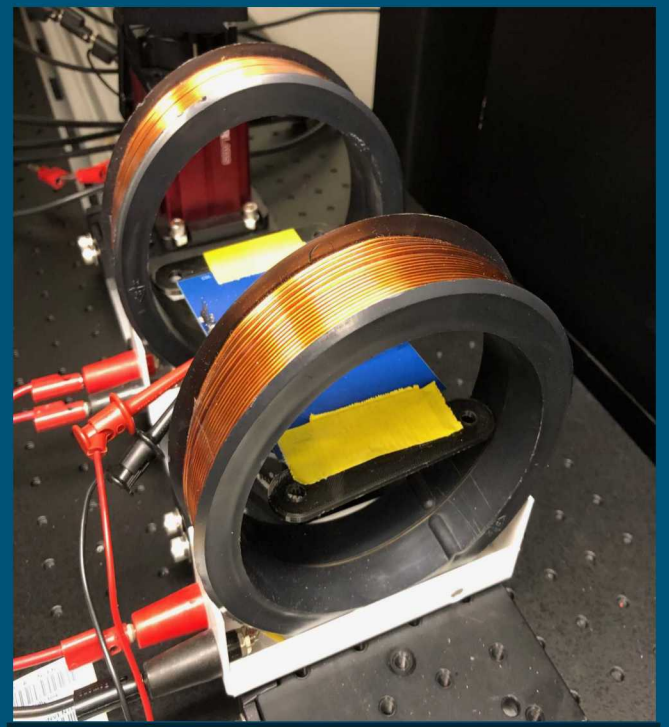
Bench Top Interrogation – Current State

MaST is currently interrogated by:

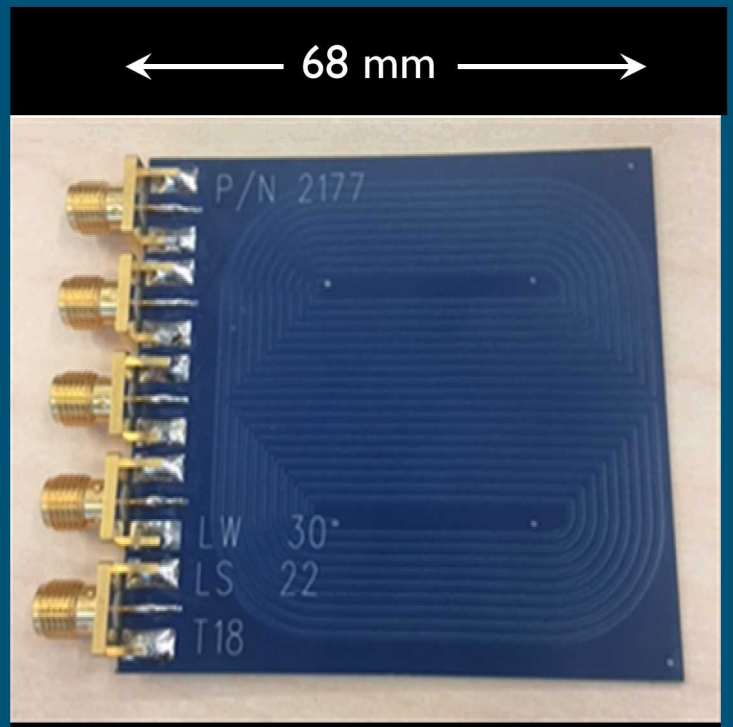
- DC bias supplied by a Helmholtz coil
- AC magnetic field supplied by a planar loop antenna transceivers
- Vector network analyzer (VNA)



Bench Setup



Bias Field Loop Antenna



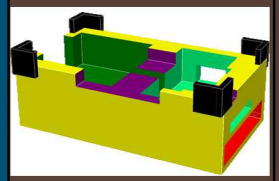
AC Field Planar Loop Antenna

Portable Interrogation – Future State

MaST will later be interrogated by:

- DC bias supplied by an attached thin film permanent magnet (Semivac-90, etc.)
- AC magnetic field supplied by a hand-held loop antenna and a FPGA-based transceiver

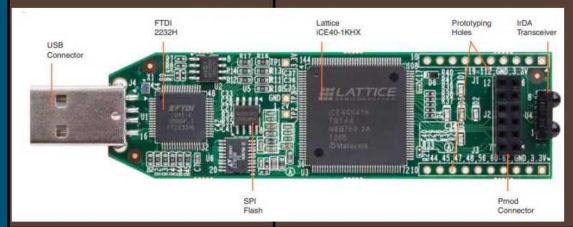
DAQ
VNA

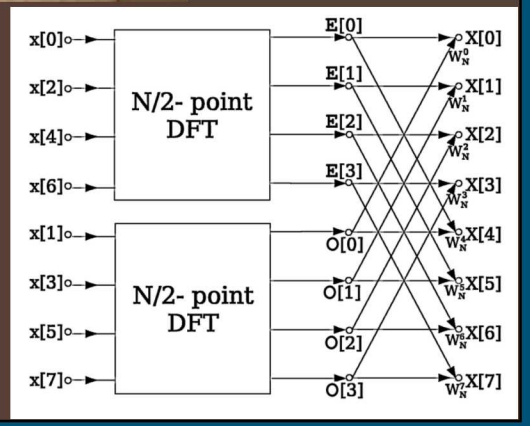


- Working handheld prototype
- DAQ + Battery + Raspberry Pi + Touchscreen

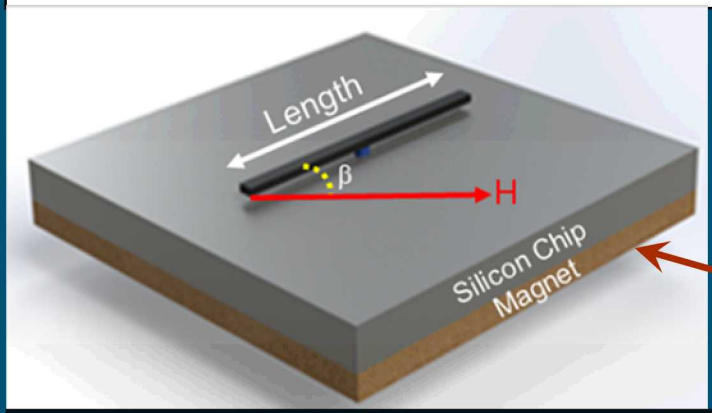
FPGA
Radix FFT

- Working FFT
- Need to add sweep capability





Necessary Features	Desirable Features
• Sweep through frequencies 50kHz → 5MHz • Detect absorption frequencies and magnitudes • <$10k • Handheld	• Smaller • Cheaper • Ergonomic • Quick detection



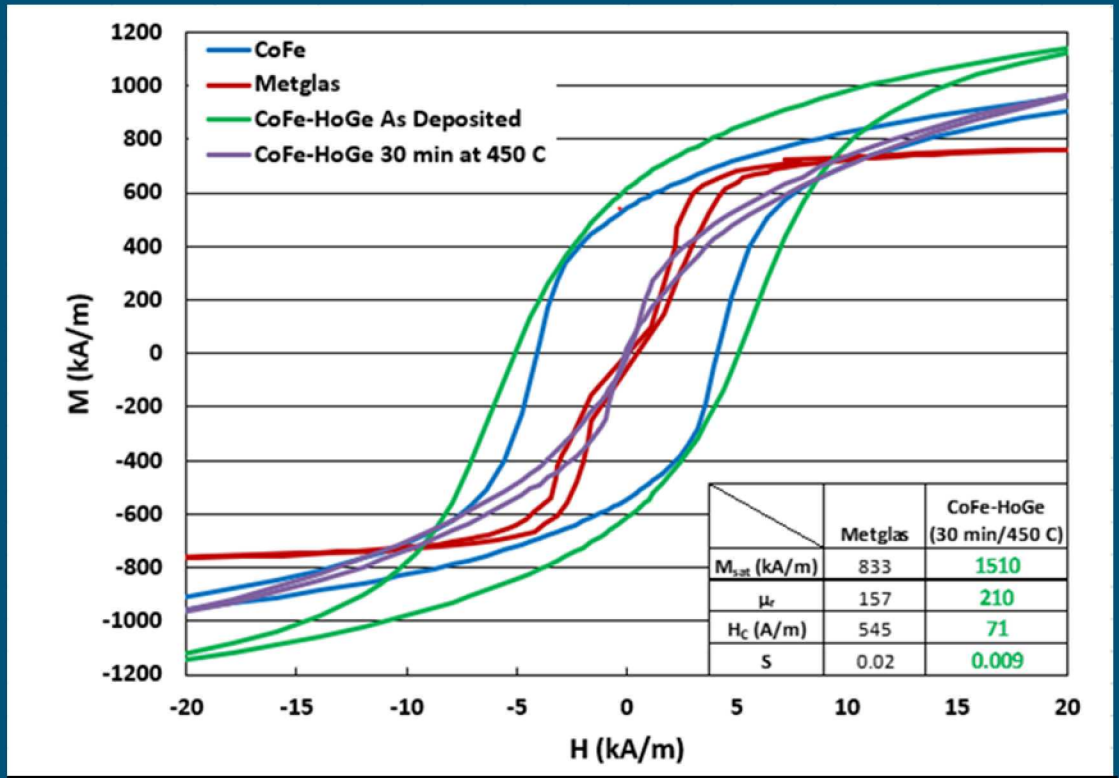
Bias Field Magnet

Semivac-90 or other thin film magnet to replace coils for DC biasing.

Magnetic Testing

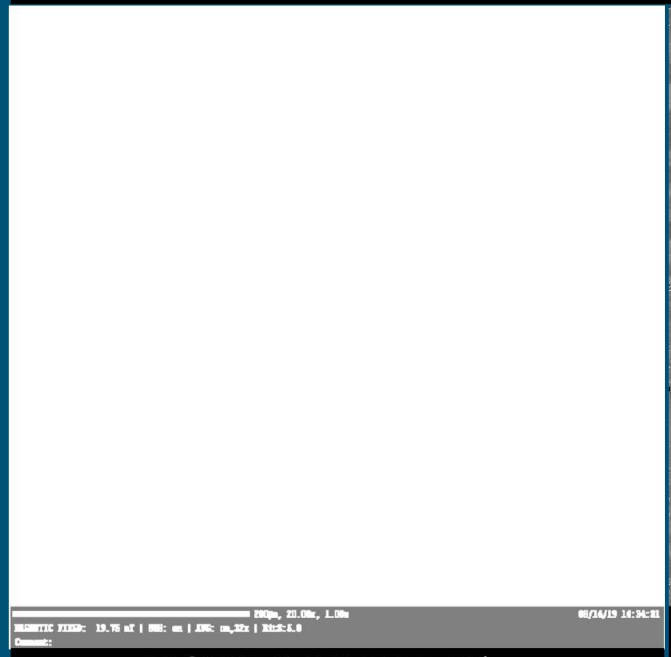
Magnetic testing is critical towards understanding and optimizing MaST resonator performance

- Magnetization (M) vs. magnetic field (H) curves generated by SQUID magnetometry
- Magneto-Optical Kerr Effect (MOKE) used for domain imaging

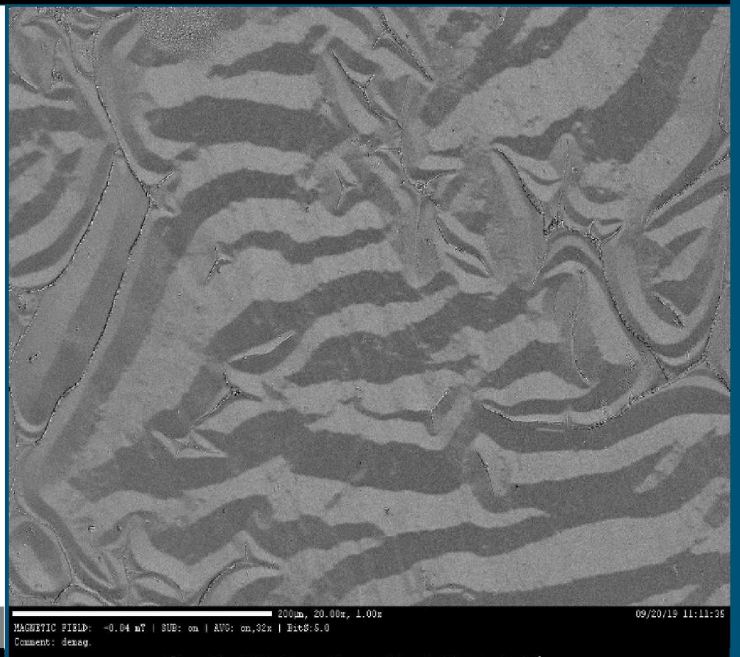


CoFe M vs. H Plot

Stripe domains characteristic of amorphous ribbons observed on USIII and electroplated CoNiFe!



USIII MOKE Plot

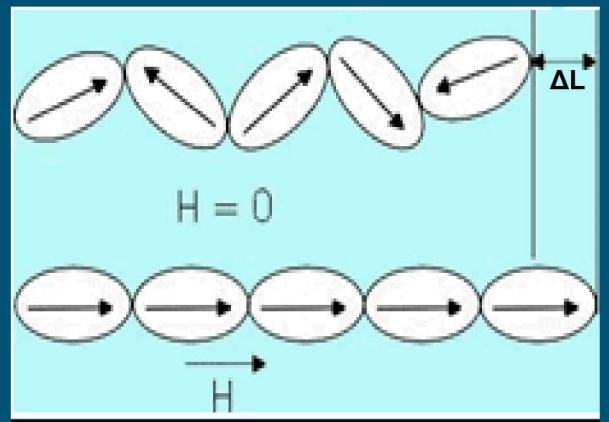


CoNiFe MOKE Plot

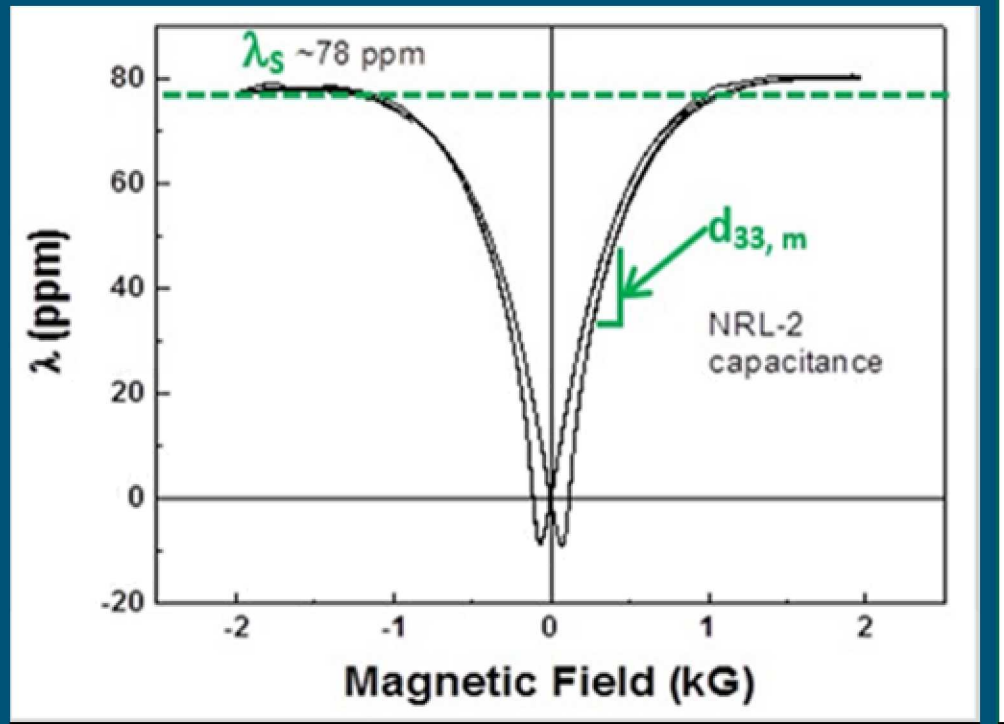
Magnetostriction Testing – Current State

Magnetostriction testing also critical towards understanding and optimizing MaST resonator performance

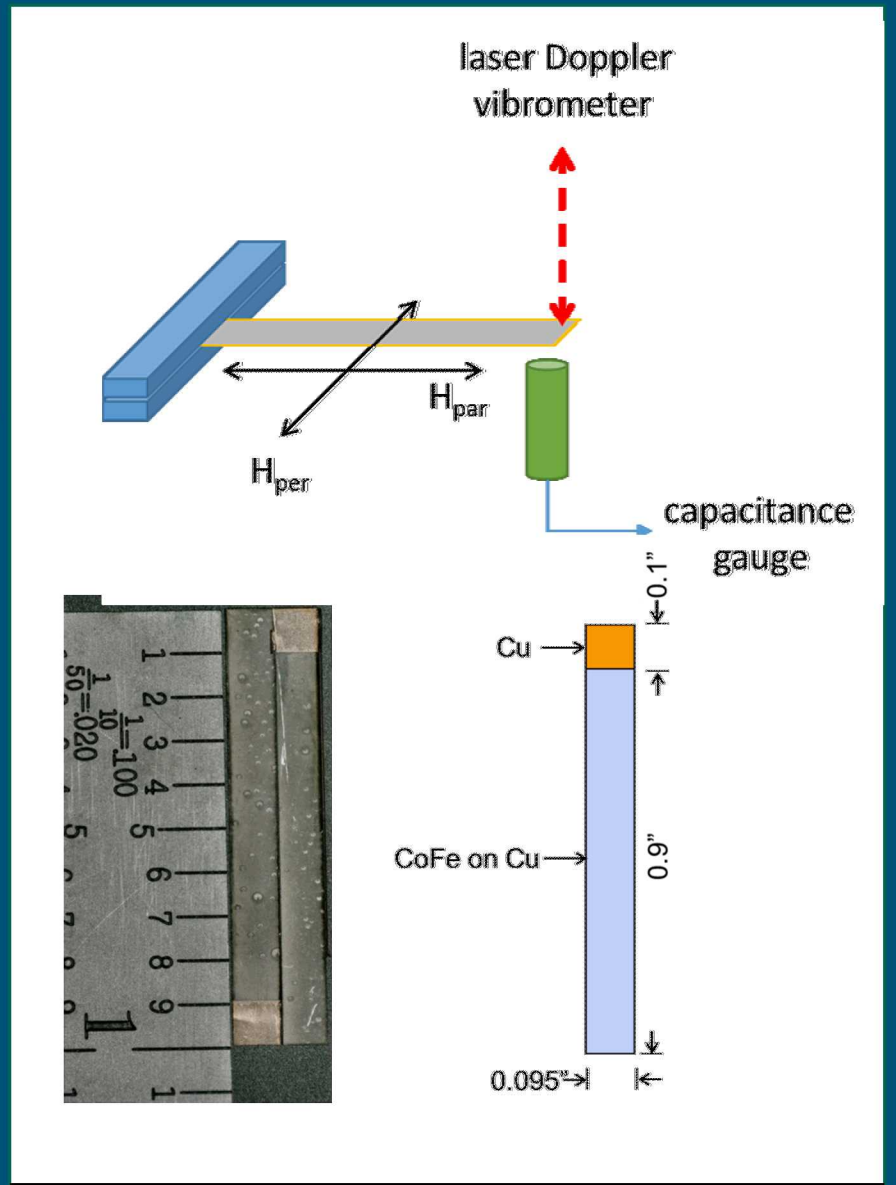
- Optical and capacitive deflection of bimorph cantilevers (CoFe coated Cu) under parallel and perpendicular magnetic fields measured
- Measurement data provided by Naval Research Labs (NRL)



Joule Magnetostriction



CoFe Magnetostriction "Butterfly" Curve

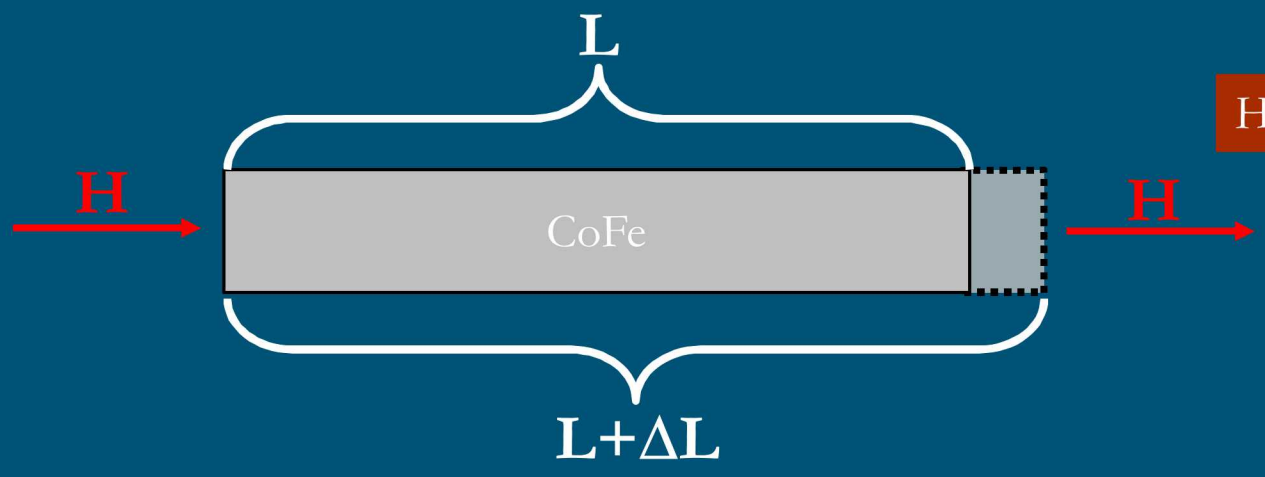


Small CoFe Coated Cu Tine

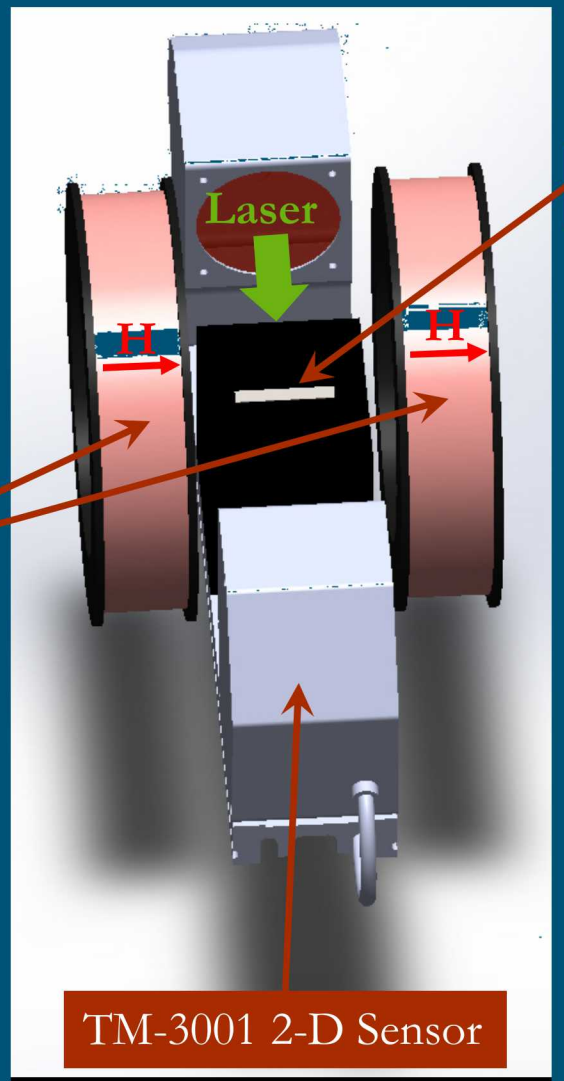
Magnetostriction Testing – Future State

Magnetostriction testing in-house

- Purchase a TM-3001 high-speed 2-D measurement sensor and couple it with a Helmholtz coil
- Provides a novel, direct, and rapid measurement of alloy magnetostriction that can be performed here at Sandia



Direct Measurement of Ribbon Elongation, ΔL, Under A Ramped Magnetic Field, H



Magnetostriction Setup

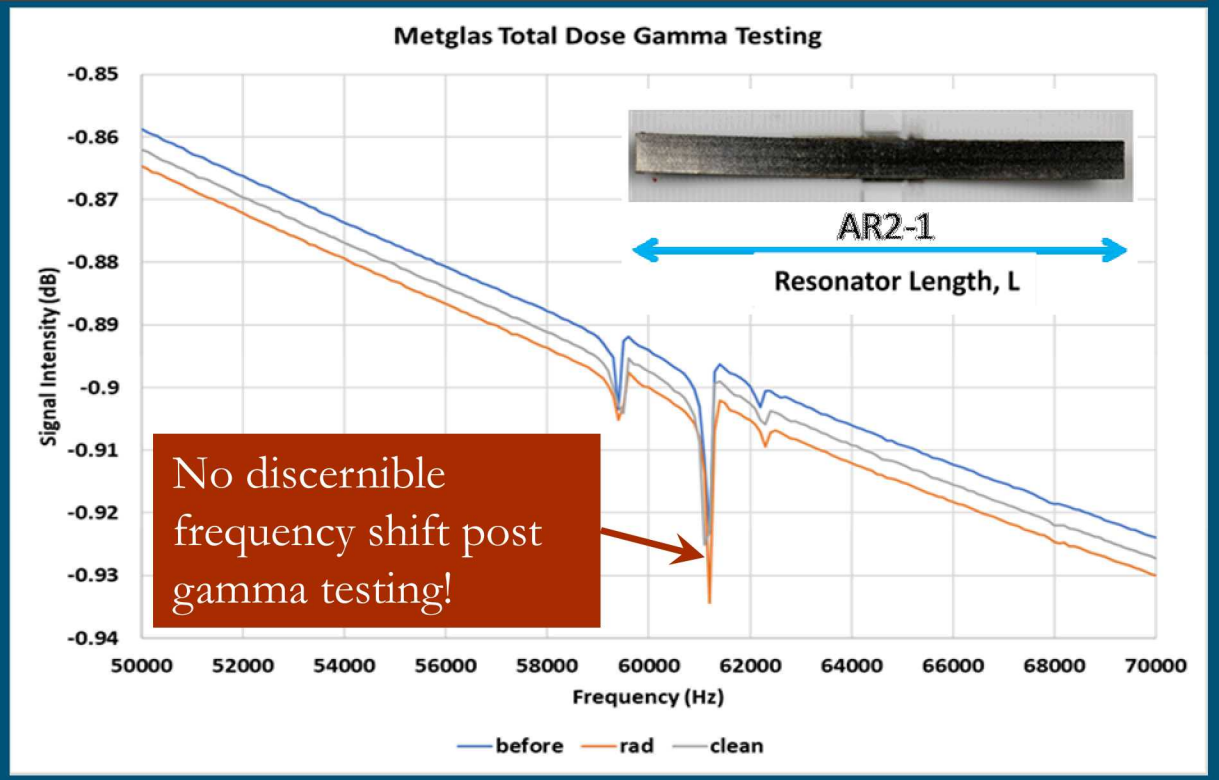
Radiation Testing

Gamma Testing

- Testing performed at Sandia's Gamma Irradiation Facility (GIF)
- 4 bottom anchored laser cut commercial USIII ribbon resonators used
- 0.2 Grads total dose (1krads/s dose rate) for 2 days – approximates 10 years of total dose (IAEA Qualification Test)
- No discernible frequency shift detected post gamma testing!
- Future testing planned using high energy particles (alpha particles, neutrons, etc.)

Gamma Irradiation Facility (GIF) and Co-60 Sources

For 100 years of gamma exposure, a 20 day exposure at GIF or 1 day exposure to 2.8 MeV H+ in the Ion Beam Lab (IBL)



Summary, Future Work, and Acknowledgments

- Goal is to create a Magnetic Smart Tag (MaST) for uniquely identifying nuclear materials and other high value assets (passive, wireless, distinctive, etc.)
- Identifier Uniqueness is achieved with random, multi-bit (i.e., multi-resonator) arrays
- Possesses anti-counterfeit properties (proprietary CoFe alloy electroplating, multi-bit arrays, unique array patterning, post-processing randomness) making this technology nearly impossible to replicate
- Novel electroplated CoFe-based alloys will provide a fabrication-friendly means for creating MaST with future optimization planned
- Magnetic and magnetostriction testing are critical towards understanding and providing feedback for our microfabrication efforts in order to optimize MaST resonator performance
- Portable transceiver development for MaST interrogation is underway
- MaST proven to be radiation hard against gamma rays with high energy particle testing planned

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