



A QUANTUM DEFTECH STARTUP'S PERSPECTIVE ON ACCELERATED MATERIALS DISCOVERY FOR SENSING

NRRAMD, ICTS-TIFR, BENGALURU

01/09/2026

**MALLIKARJUN KARRA
CO-FOUNDER**



Stats & Coordinates

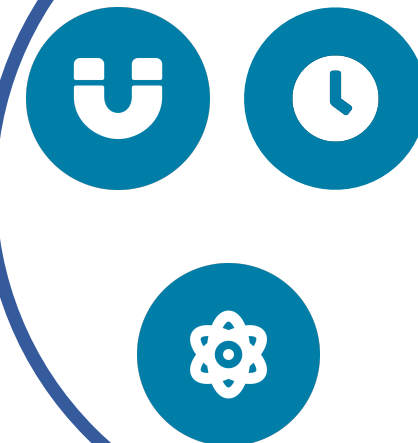
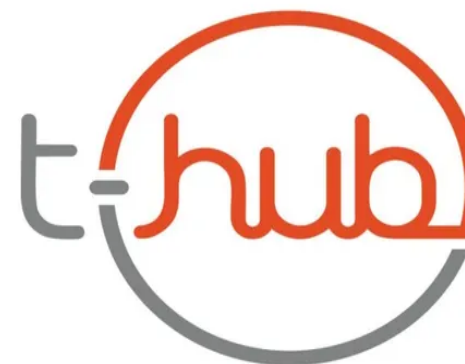


DEMO AT NATIONAL QUANTUM CONCLAVE, IIT B (2026)

- 100% INDIAN STARTUP (FUNDED)
- DEEP-SCI x DEEP-TECH
- 5+ ACADEMIC COLLABORATIONS
- ~50 EMPLOYEES
- 15% PHDs
- 20% FIELD ENGINEERS
- STRONG KNOW-HOW & IP



प्रतिष्ठित संस्थान
INSTITUTION OF EMINENCE
राष्ट्रीय अपेक्षाएँ, वैश्विक मानक
National Needs, Global Standards
हैदराबाद विश्वविद्यालय
UNIVERSITY OF HYDERABAD



Atomic Vapour Cells For Sensing

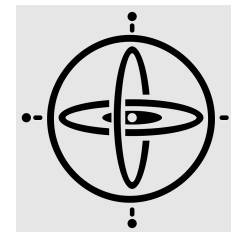
Strategic



Quantum Magnetometer
Sensors



Quantum Positioning
System

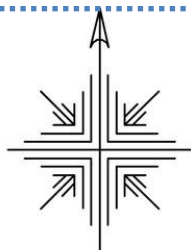


Quantum Gyroscope
(Co-magnetometer)

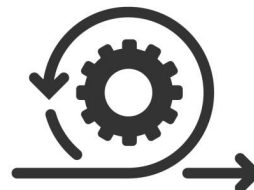


Precision Target
Detection System

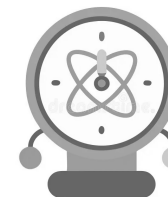
Dual-Use



High Resolution
Magnetic Maps



AI/ ML based Sensor
Data Fusion Software

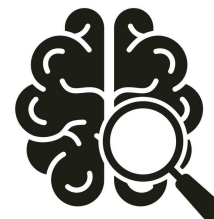


Atomic Clocks



Rydberg Electrometry
For broadband RF

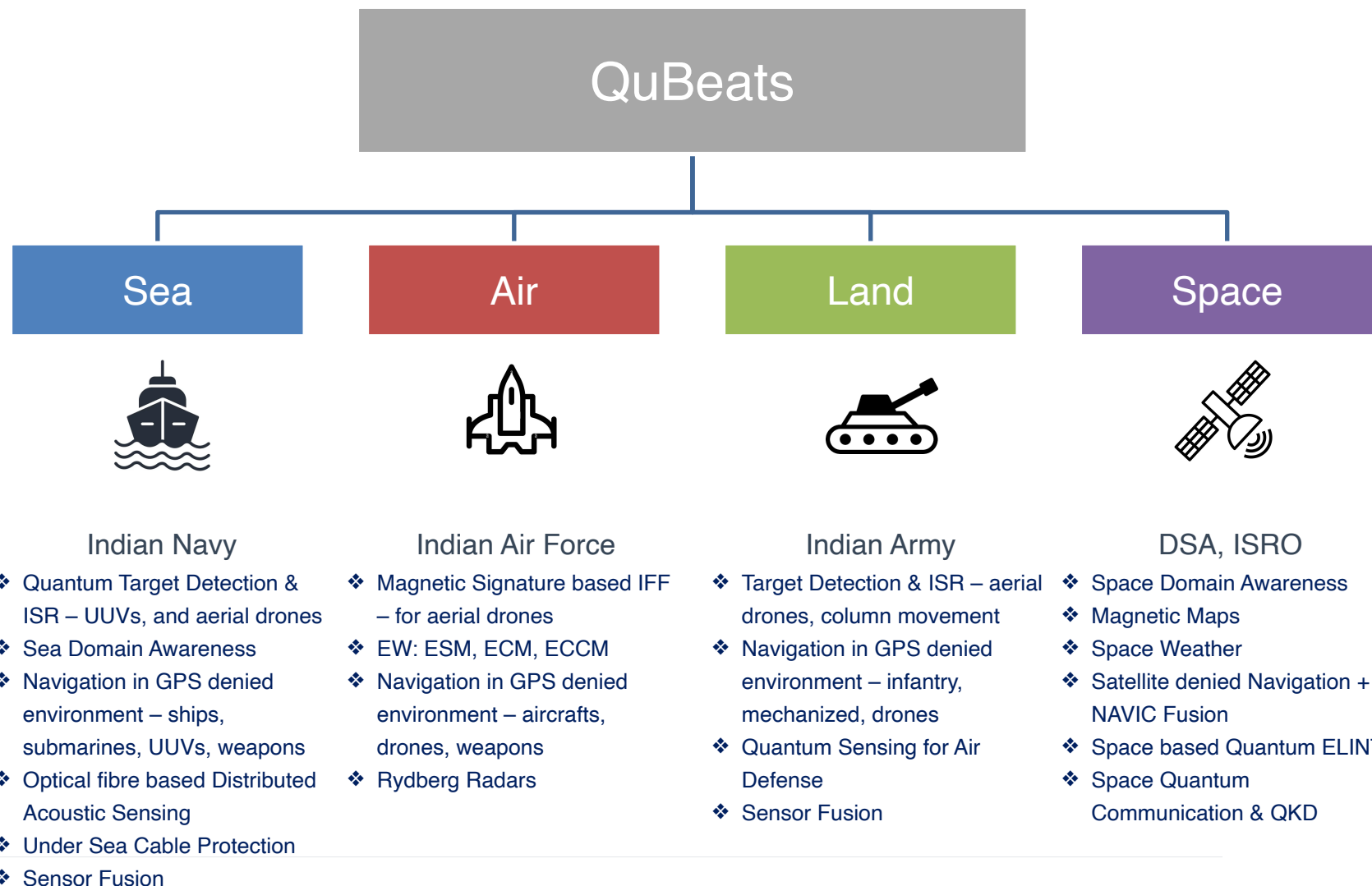
Civilian



Quantum MEG/MCG*



Our Vision: Quantum Sensing For Defence





Themes For Today

WHAT WE DO

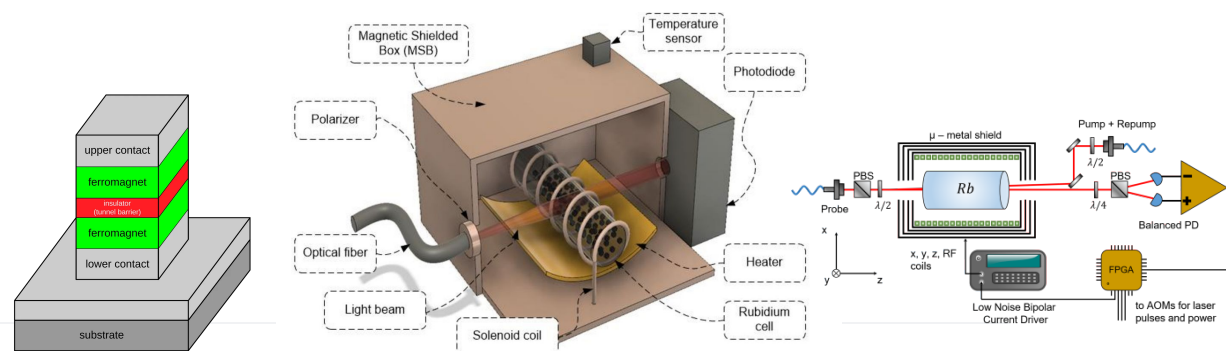
1. ALT-PNT: MAGNETOMETERS & CLOCKS
2. OTHER APPLICATIONS
3. RYDBERG RF RECEIVERS & LASERS

WHAT WE'D LIKE TO DO WITH INTERESTED PARTIES HERE

1. COLLABORATE ON WELL-POSED PROBLEMS THAT MATTER TO US
2. CONTRIBUTE TO & HELP EXECUTE ASYMMETRIC STRATEGIES
3. DISRUPT EXISTING PLAYERS & BRING GLOBAL CUSTOMERS TO THE TABLE



We are interested in shockingly disruptive
devices that get built —
VERY CHEAP. VERY FAST.



Classical

INS (Classical)

- Always-on, unjammable, but bias drift grows t^2/t^3
- Tactical IMU alone: ~10–20 nmi/h drift classically

Vision/Terrain-aided Nav (TERCOM/scene matching)

- Excellent terminal accuracy; needs maps & visibility
- Vulnerable over ocean/cloud/smoke

Anti-jam GNSS upgrades

- CRPA antennas, null-steering
- M-code / encrypted signals + vector tracking

Signals of Opportunity (SoOP)

- Uses ambient RF (cell, TV, LEO sats)
- Great in urban/littoral, weaker in deep ocean/desert

Celestial/Nav from stars

- Passive and global; works best above cloud + at night

eLoran / pseudolites / local beacons

- High-power terrestrial time-PNT backup
- Regional coverage, tens-of-meters accuracy

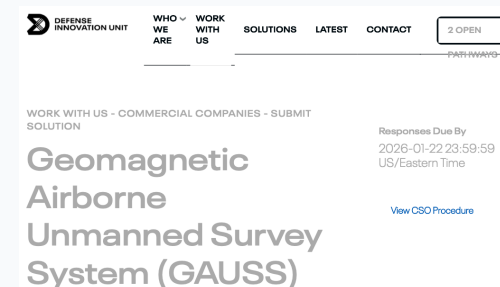
Quantum Assured

Portable atomic clocks

- CSAC / mini-Rb greatly improve **holdover & fusion observability**
- Extends GPS-denied window **2–6× at system level** (not IMU-only)

Quantum assured navigation

- MagNav
- GravNav
- Quantum IMUs



Layered Stack

- NavIC/GNSS when available
- Tactical INS always
- CSAC/Rb holdover
- MagNav as primary GPS-denied absolute aid
- Vision/Terrain for terminal phase



Suggested Roadmap

- Surveys & sovereign high-res maps of priority corridors
- Trials on IA/IAF/IN platforms
- Indigenous NavIC/GNSS + CSAC/Rb + INS + MagNav fusion modules
- Transition path to weapon-grade guidance

Strategy — posture, doctrine, mission/operational scenario dependence

What is the operational scenario? What are my objectives? What's my budget? What is the required accuracy? What trade-offs can I live with?

When GNSS is denied, time signal is the biggest issue



Airborne

Jamming & spoofing over contested corridors; EW denial can persist for entire sorties. INS drifts freely without aiding.



Maritime / subsea

Ships face regional spoofing; submarines & UUVs are physically GNSS-denied for days to weeks once submerged.



Timing is the hidden dependency

GNSS position is really a time measurement: pseudoranges are time-of-flight. Every receiver solves x , y , z and clock bias.

TIMING ERROR TO DISTANCE ERROR CONVERSION

1 ns of clock error $\approx$ 30 cm

1 μ s of clock error $\approx$ 300 m of ranging error — a quartz TCXO drifts by milliseconds per day; that is why it cannot anchor a navigation solution.

The CSAC: an atomic frequency reference in a matchbox

A chip-scale atomic clock locks a quartz oscillator to a microwave hyperfine transition of caesium or rubidium atoms in a MEMS vapour cell (coherent population trapping). It delivers atomic stability at the size, weight and power of an OCXO — the class benchmark is Microchip's SA.45s / SA65 (fielded in >138,000 units).

$\approx 17 \text{ cm}^3 / 35 \text{ g}$

volume & mass

$\approx 120 \text{ mW}$

steady-state power

$3 \times 10^{-10} @ 1 \text{ s}$

Allan deviation ($\tau=1 \text{ s}$)

$\approx 3 \times 10^{-11} @ 100 \text{ s}$

Allan deviation ($\tau=100 \text{ s}$)

$\approx 9 \times 10^{-10} / \text{month}$

aging rate (typical)

$-40 \text{ to } +80 \text{ }^\circ\text{C}$

operating range (SA65)

WHERE IT SITS ON THE OSCILLATOR LADDER

TCXO — *quartz, temp-compensated*

$\approx 10^{-6}$ frequency accuracy

OCXO — *quartz, ovenised*

$\approx 10^{-8}$ – 10^{-9} ; watts of heater power

CSAC — *Cs/Rb CPT vapour cell*

$\approx 10^{-10}$ – 10^{-11} ; 120 mW

Mini rubidium (MAC / mRO-50) — *lamp-pumped Rb*

$\approx 10^{-11}$ – 10^{-12} ; a few W

Optical clock (Tiqker class) — *optical transition + frequency comb*

maser-like stability; rack-mount

Demonstrated Earth-field Quantum Magnetometry

A rubidium optically-pumped magnetometer with frequency modulated nonlinear magneto-optical rotation (FM-NMOR) readout, operating unshielded in the ambient geomagnetic field.

$\leq 600 \text{ fT}/\sqrt{\text{Hz}}$

Sensitivity in Earth field

$30 \mu\text{T} - 80 \mu\text{T}$

Unshielded operation

DC – 500 kHz

AC detection frequency

1000 mL

Packaged prototype

TRL 5

Field-demonstrated

WHY IT MATTERS



Unshielded

Runs directly in Earth's field — no magnetic shielding required.



Absolute & SI-traceable

Outputs I_B and B_I from the Rb gyromagnetic ratio — no calibration coil.



Field-proven

200 mL unit flown on a hexacopter UAS; found inert mines buried 10–20 cm.

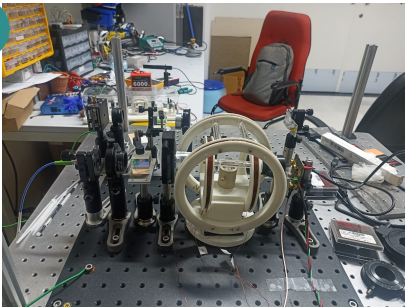


Clear roadmap

$\leq 10 \text{ fT}/\sqrt{\text{Hz}}$ in a 20 mL deployable package within 24 months.

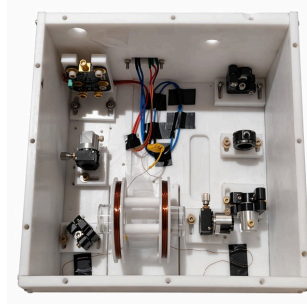
FROM BENCHTOP TO A FIELD-DEPLOYABLE MAGNETOMETER

1



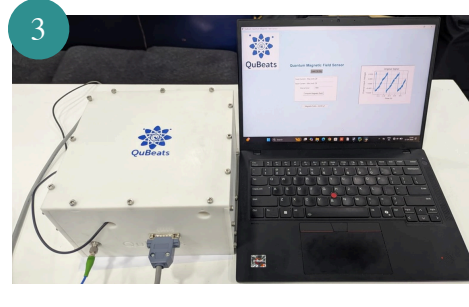
Free-space lab bench

2



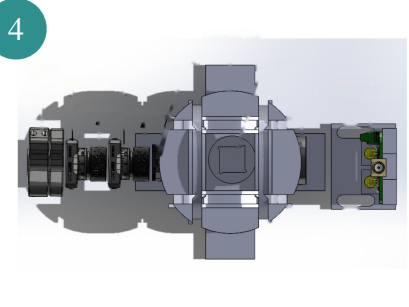
Compact optical design

3



Sealed unit + readout software

4



Field deployable prototype



Quantum FM-NMOR Magnetometer



SENSING PERFORMANCE

SENSITIVITY

$\leq 500 \text{ fT}/\sqrt{\text{Hz}}$

BANDWIDTH (–3 DB)

DC – 5 kHz

DYNAMIC RANGE

$\pm 100,000 \text{ nT}$

ABSOLUTE ACCURACY

$\pm 0.3 \text{ nT}$

LONG-TERM DRIFT

$< 0.05 \text{ nT} / \text{month}$



PHYSICS PACKAGE

SENSOR CELL

Rb-87 vapor, paraffin coat

CELL DIMENSIONS

$12 \times 12 \times 12 \text{ mm}$

PUMP / PROBE LASER

DFB, 795 nm (D1 line)

MODULATION SCHEME

FM-NMOR

CELL TEMPERATURE

$39 \text{ }^\circ\text{C} \pm 0.05 \text{ }^\circ\text{C}$



PHYSICAL & ENVIRONMENTAL

SENSOR HEAD SIZE

$75 \times 75 \times 35 \text{ mm}$

SENSOR HEAD MASS

185 g

ELECTRONICS UNIT

$120 \times 80 \times 35 \text{ mm}$, 1.4 kg

OPERATING TEMPERATURE

$-10 \text{ }^\circ\text{C}$ to $+45 \text{ }^\circ\text{C}$

WARM-UP TO SPEC

$< 3 \text{ minutes}$



POWER & INTERFACE

POWER CONSUMPTION

5 W steady-state

SUPPLY VOLTAGE

9 – 28 VDC

DATA OUTPUT

USB-C / RS-422

SYNCHRONIZATION

Local clock

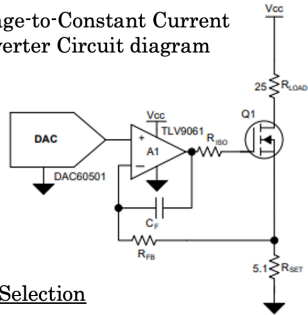
REQUIRED SHIELDING

No mu-metal shield required

Design and Development of FM-NMOR

Electronics Miniaturization Strategy (Low noise current driver)

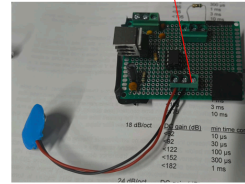
Voltage-to-Constant Current Converter Circuit diagram



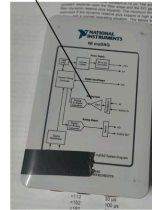
Component Selection

- Op-Amp: High slew rate precision amplifier
- MOSFET: N-channel power transistor (e.g., IRF540)
- Sense Resistor: Low-value precision resistor (0.1-1Ω)
- Power Supply: Dual-rail battery-powered supply

Voltage-to-Constant Current Converter Circuit



PC-Controlled Digital-to-Analog Converter (DAC) Circuit

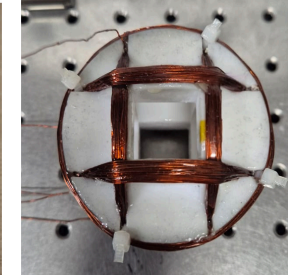
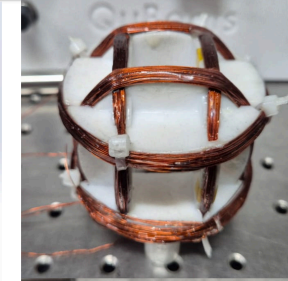
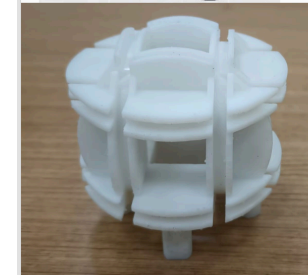
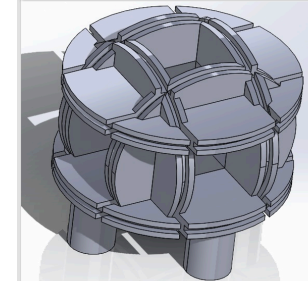


- A constant current source is required to generate a stable magnetic field using the Helmholtz coil.

Operating Principle:

- Op-amp drives MOSFET gate such that $V_{ref} = I \times R_{sense}$
- MOSFET operates in linear region, acting as voltage-controlled current source. Negative feedback ensures output current tracks reference voltage.

Compact 3-axis Helmholtz Coil Design and realization

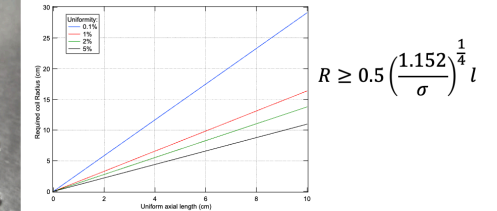


$$\begin{aligned} D_1 &= 30 \text{ mm} & N_1 &= 50 \\ D_2 &= 30 \text{ mm} & N_2 &= 50 \\ D_3 &= 35 \text{ mm} & N_3 &= 58 \end{aligned}$$

Coil thickness = 0.3mm (30 SWG)

- Field uniformity range : 1 cm.
- Gradient constraints $\leq 0.01 B_0 / \text{cm}$,
- B_0 : Field at centre

Analytical expression for optimum design of coil:



Multifunctional Instruments using Red Pitaya

Developed UI for 2 input 2 output port with multi functionality instruments using Red Pitaya where we can control and access the multifunction instruments all together at a place.

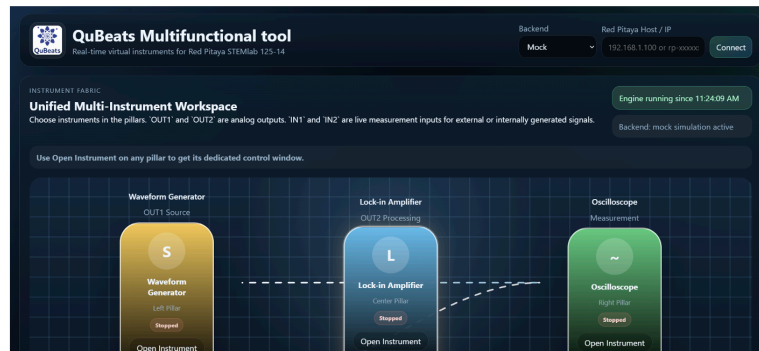
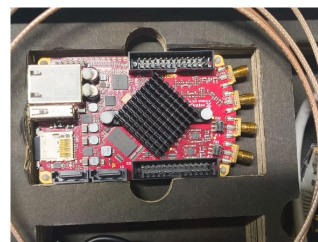


Fig-1 – Dashboard using UI with Redpitaya

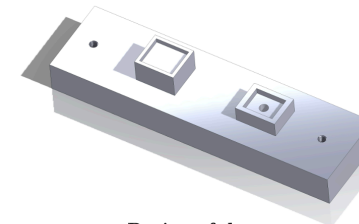
Hardware



Packaging design for optics

All optical elements should be mounted with the Rb-cell in a same platform.

The platformed will be placed centre of the Helmholtz coil.

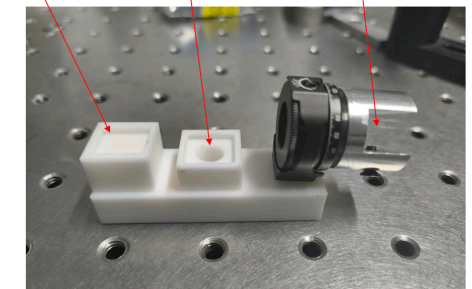


Design of the platform

Dedicated Slot for Glan-Taylor Polarizer Integration



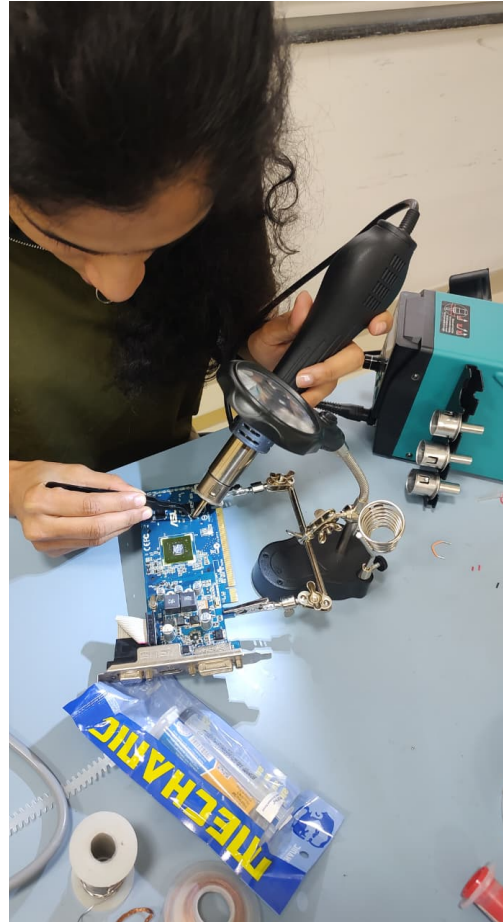
Slot for Wollaston-prism



Design and Development of FM-NMOR

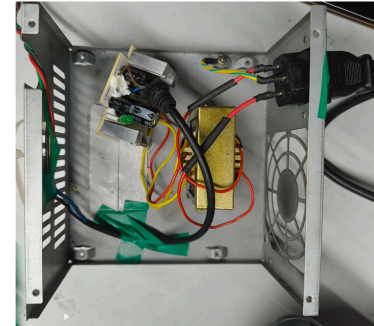


QuBeats

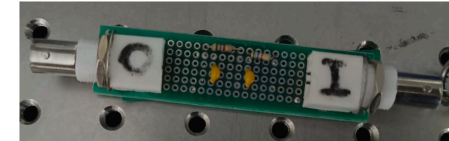


Power supply for Photodetectors

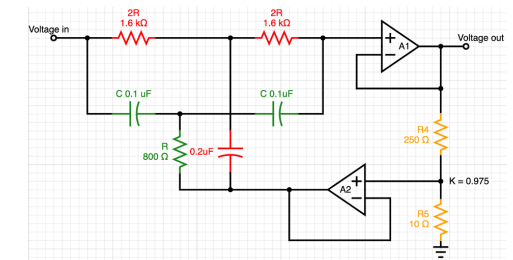
Home-made low noise power supply



Home-made Low-pass Filter



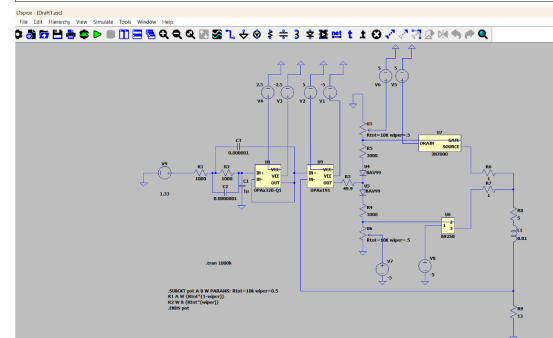
RC circuit



An Active two op-amp notch filter for a 20dB notch depth

Constant Current source- Bidirectional

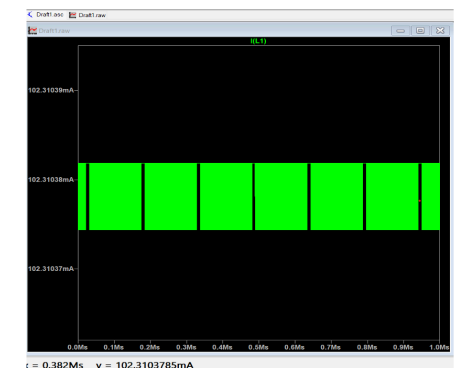
Schematic diagram for the Constant current source for the bi-directional using Op-amp and P-Channel and N-Channel MOSFET.



Specification:

Maximum current: 100 mA
Current resolution: 50 uA

Simulation for the Constant Current Source



Using the LTspice we did the transient analysis for the million second for the 13 Ohm sense resistance with the voltage source reference of 1.33V. $I_{out} = 1.33/13 = 102.3 \text{ mA}$

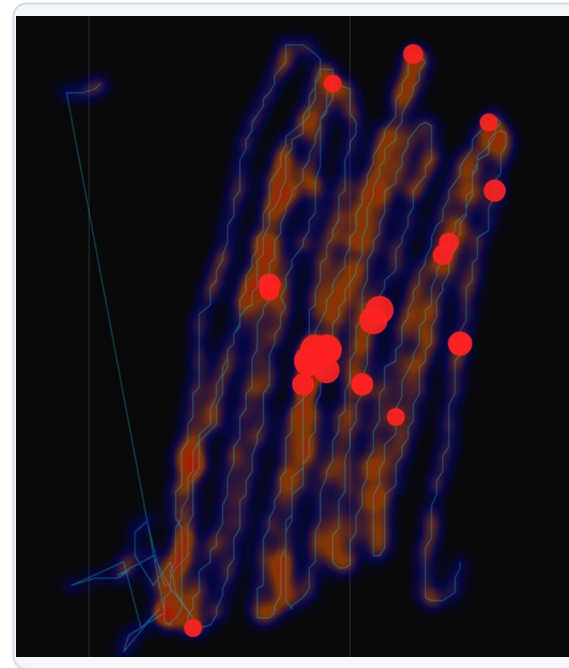
Magnetometer flown on UAS to detect and geolocate buried landmines



Hexacopter UAS with QuBeats sensor payload and boom-mounted vector magnetometers



Survey flight with suspended sensor boom (video available)



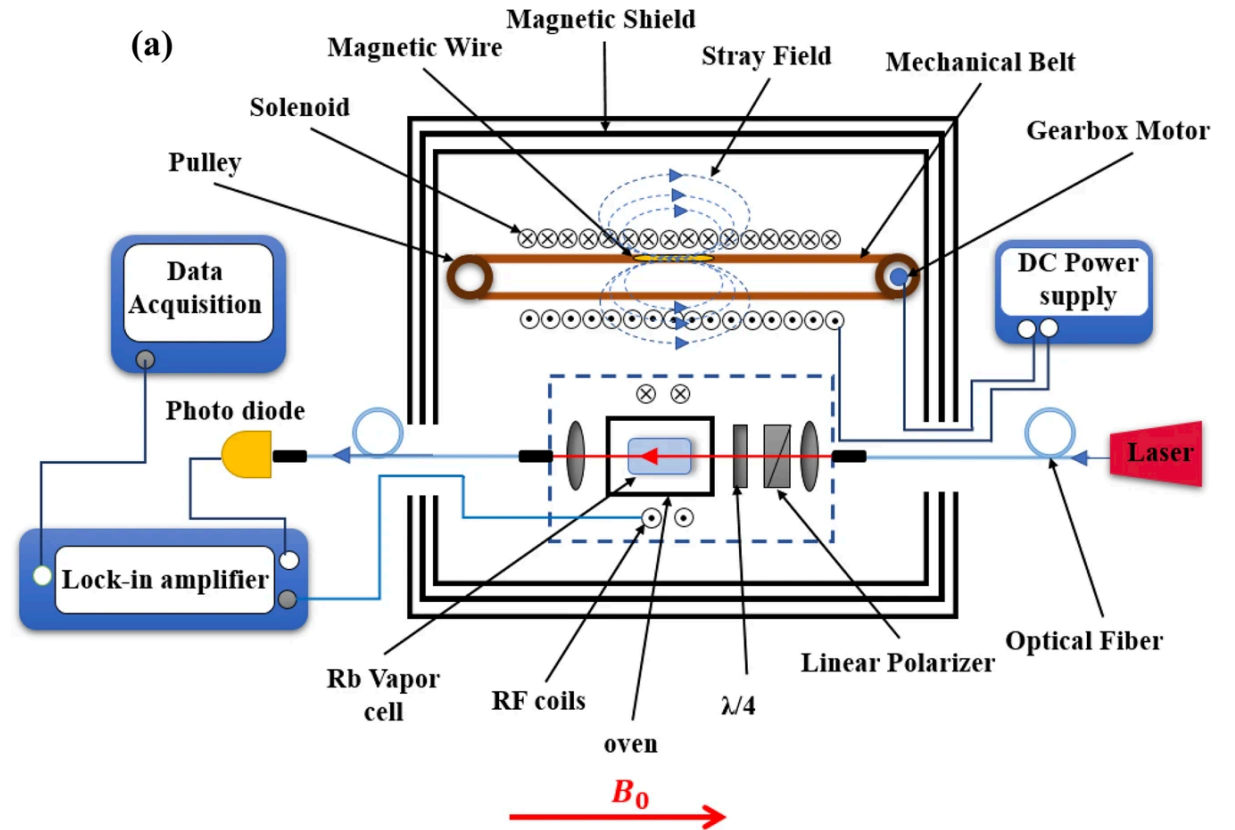
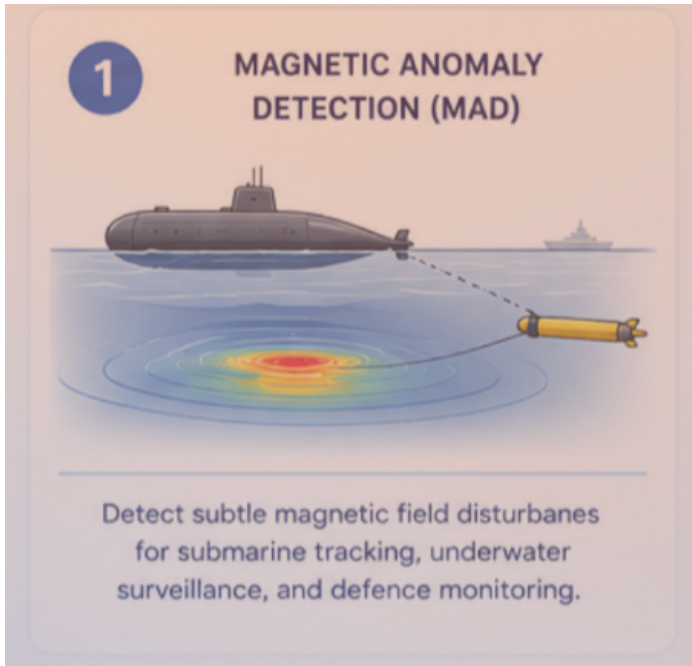
Anomaly map: survey lines + detections (red) over target field



Georeferenced detections overlaid on satellite imagery

Inert mines buried 15–30 cm underground were detected and geolocated by the UXO detection prototype flying a programmed survey grid on a hexacopter UAS — full sensor-to-map pipeline demonstrated in the field (May 2026).

Proposed field trials for omnidirectional submarine detection from pontoons, buoys, tow-boats, and AUVs

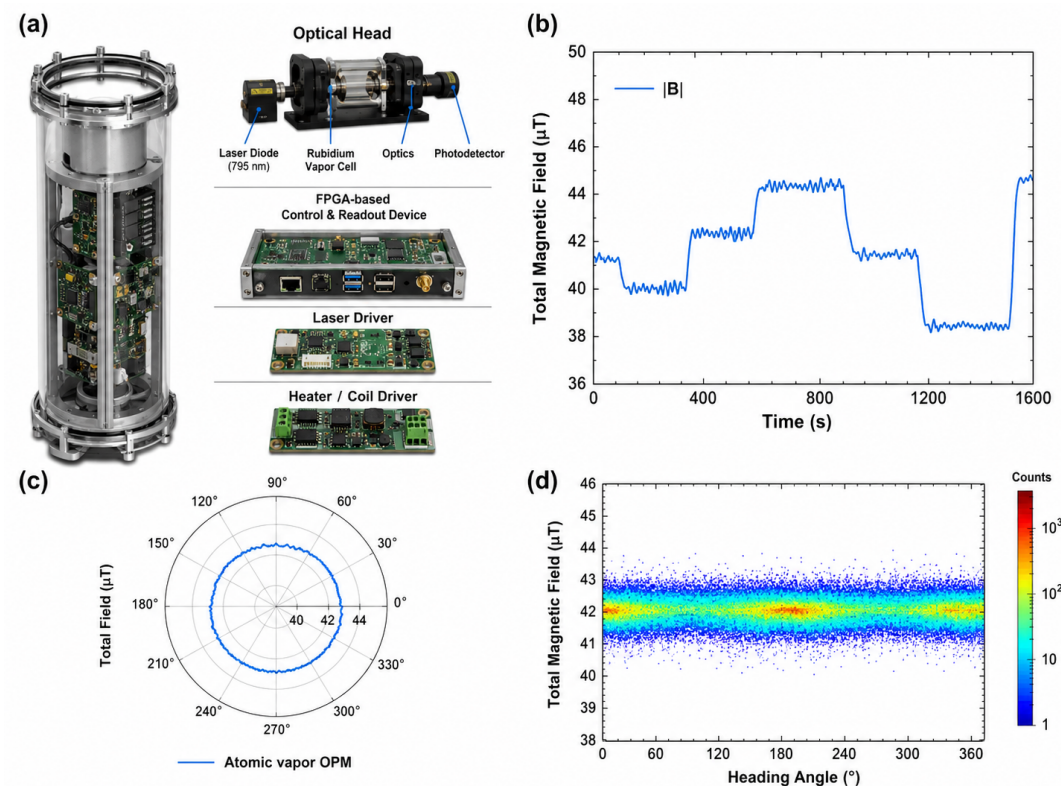
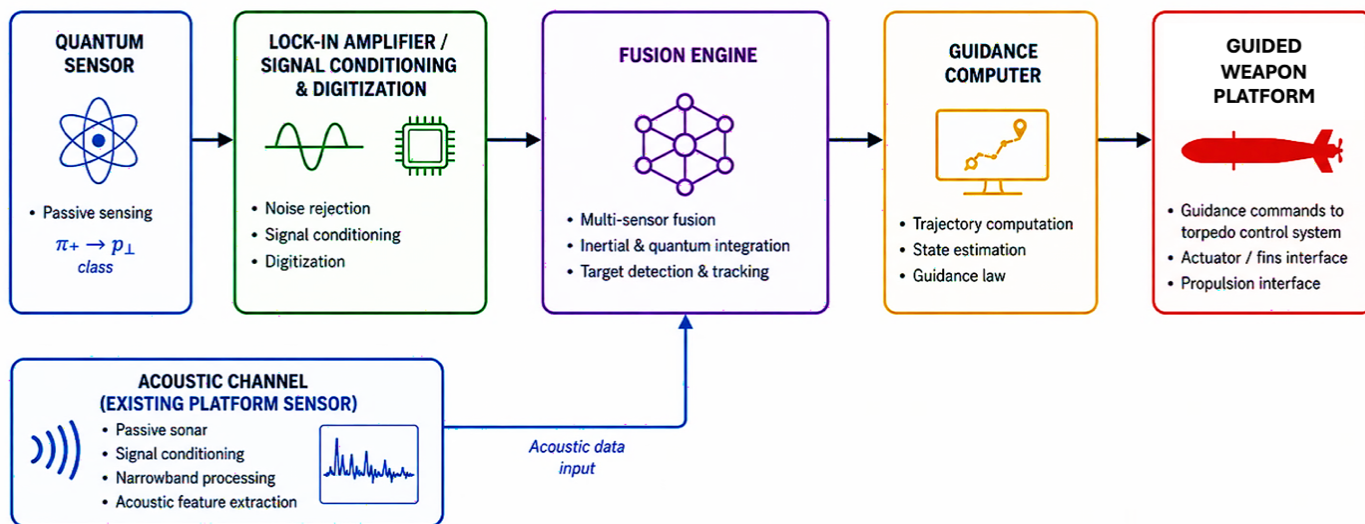


Solution for acoustically quiet submarines lying low near to our coast.

Proposed to be integrated onto a Torpedo for accurate terminal homing

QUANTUM-FUSED HOMING SYSTEM — SIGNAL PROCESSING & DATA FLOW

“Secure Navigation Through Quantum + Inertial + Fusion + AI Guidance”



- (a) Integration of QuBeats' OPM on torpedo buoyancy ring
- (b) Total magnetic field during operation
- (c) Uniform field sampling
- (d) Heading angle sampling

The RF Stack Has Hit Physics Limits

Semiconductor receivers suffer from noise, congestion, power draw, and detectability.



THE SHIFT

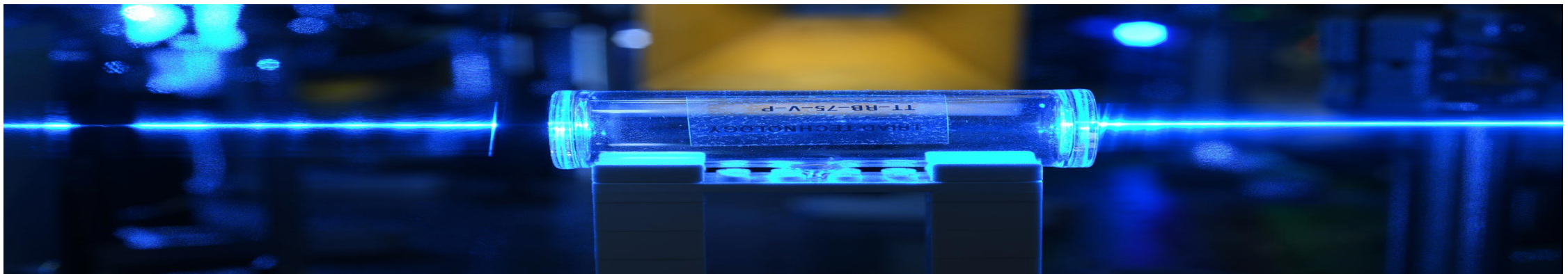
From Copper to Atoms

- Fundamental noise floors – classical receivers are approaching physical limits that no semiconductor improvement can overcome
- Spectrum congestion – explosive growth in 5G, IoT, and radar is rendering narrowband legacy architectures obsolete
- Electronic warfare gap – modern battlefields demand passive, zero-signature reception that antennas simply cannot provide

Rydberg

**22 - 33 dB SNR
gain**

**Potential signal-to-
noise improvement
over conventional
dipole systems**



Quantum sensing (and other technologies) are a useful stress test for this roadmap

Small volumes. Extreme specifications. Near-total import dependence. If a national capability in accelerated materials discovery works here, it will work almost anywhere.

1

Low volume, high leverage

Component demand is measured in hundreds of units, not tonnes — but a single unavailable part stalls an entire sensing platform.

2

Specifications are unforgiving

Linewidth, coherence time, loss and damage threshold are set by the physics of the measurement, not by a market preference.

3

Almost everything is imported

Cells, coatings, crystals, gain media, shielding alloys. Lead times and export controls, not science, set our schedule.

We are reimagining some of the old, solved problems; solved abroad, but not in India. Because it is a race against time.

The component bottleneck



Alkali vapour cells & anti-relaxation coatings

Coherence lifetime varies cell to cell; coating chemistry is largely empirical.



Narrow-linewidth gain media

Linewidth, drift and mode stability; no domestic source at instrument grade.



Nonlinear & electro-optic crystals

Phase-matching range, damage threshold, availability at usable aperture.



Low-loss, high-LIDT optical coatings

Loss budget and damage threshold decide whether a design closes at all.



Magnetic shielding alloys

Shielding factor after forming and annealing; reproducibility across batches.



Colour-centre hosts (diamond, SiC)

Defect density and placement control; charge-state stability over lifetime.

Each has a measurable target property and a known failure mode making them tractable.

The component bottleneck



Alkali vapour cells & anti-relaxation coatings

Coherence lifetime varies cell to cell; coating chemistry is largely empirical.



Narrow-linewidth gain media

Linewidth, drift and mode stability; no domestic source at instrument grade.



Nonlinear & electro-optic crystals

Phase-matching range, damage threshold, availability at usable aperture.



Low-loss, high-LIDT optical coatings

Loss budget and damage threshold decide whether a design closes at all.



Colour-centre hosts (diamond, SiC)

Defect density and placement control; charge-state stability over lifetime.



1:37 AM



Dear

I would advise against personally exporting these items. We are required to ensure that export regulations are followed.



↩ Reply

↩↩ Reply all

➦ Forward

Each has a measurable target property and a known failure mode making them tractable.

What breaks between a promising material and a product

RESEARCH PAPER

One good sample

Measured on a bench

Fresh, in a lab

Bare material

Cost not considered

WHAT PRODUCTISATION DEMANDS



Batch-to-batch reproducibility across suppliers and years



Traceable calibration and a qualification protocol someone will accept



Lifetime, thermal cycling, vibration, humidity, field deployment



Hermetic packaging and interfaces that survive the same environment



A cost floor that closes at hundreds of units, not millions

Use AI to accelerate well-posed problems (only, by and large!)

WE CAN CONTRIBUTE

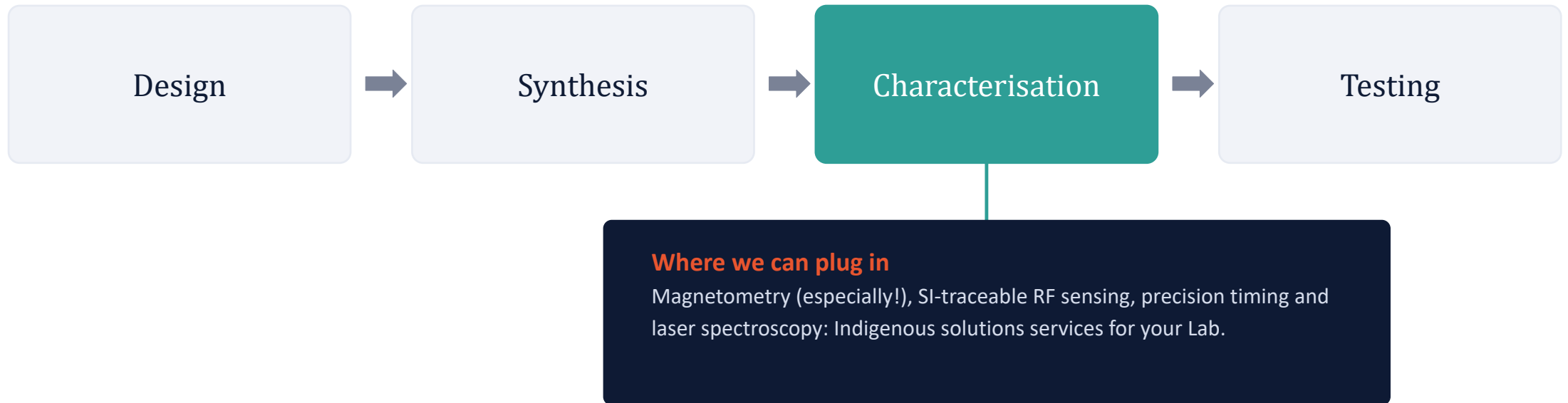
- Instrumentation, services, and custom design of infrastructure: quantum magnetometers, Rydberg RF setups, precision timing and laser spectroscopy as in-situ readout on a shared platform
- Sponsored problem statements especially in the domain of TMR magnetometry and/or 2D materials based sensing
- Characterisation-as-a-service on bench for academic partners. Thin-film magnetic properties with TIFR-H.
- Process and qualification data, including failed runs, under agreed terms
- Internships/jobs

WE NEED

- Startup-eligible access to national synthesis and characterisation facilities, with published rates and turnaround
- A shared autonomous synthesis platform for coatings, cells and crystals that industry can queue jobs on
- Standard IP and data-sharing templates so each collaboration does not restart the legal negotiation
- Co-funded engineer positions that sit across the institute and the company (?)

Quantum sensors are also instruments for the self-driving lab

The same technologies that need better materials can serve as the measurement layer of a closed loop — non-destructive, high-bandwidth and in-situ, complementing the diffraction and microscopy routes discussed elsewhere in this meeting.



On a national materials archive, including failed experiments

Industry holds a large share of the negative results the archive would most benefit from. Whether it reaches the archive is a terms question, not a willingness question. **How about anonymisation of results?**

WHAT WOULD MAKE IT POSSIBLE

- A defined embargo window before deposited data becomes open
- Field-level control: release process parameters and outcomes, withhold supplier identity and formulation
- A schema agreed with contributors, so deposition is not a bespoke data-cleaning project each time
- Clarity on downstream IP if a model trained on deposited data produces a commercial result

Bottlenecks we would co-invest against

1 AI-driven synthesis for thin films and coatings
Shared, queue-based, open to industry jobs.

WE PUT IN

Manpower and consumables

2 A domestic qualification and calibration route
Traceable measurement for optical and magnetic components, run as a service.

WE PUT IN

Sell (custom built) reference sensor systems and protocol development

3 Compute and model access at a startup-viable price
Viable RoI on Generative Design is highly important for a startup.

WE PUT IN

Problem statements and validation data

What helps our bottomline

1

Focus on asymmetric ideas

Adapt strategy to Indian realities and constraints. Agility. Quick iteration cycles.

2

Access shared platforms

Published rates, defined turnaround, eligibility rules that a company under five years old can actually meet.

3

Tackling non-scientific barriers together

Fast-tracked MoUs for collaboration and data sharing, and standard IP templates cost little and unblock a lot.

4

Completely new ways of doing age-old things that India has still not caught up with

End-to-end AI-driven experiments for small, well-defined problems might throw up interesting surprises...

5

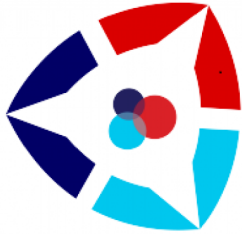
Integrate well with other AI-driven programs

Orchestration models + small, task-specific models

Happy to be a test case. Small volumes, hard specifications, short decision cycles = a fast way to iterate the Roadmap.



We gratefully
acknowledge support
from



iDEX



(Via QMET-TECH, IIT B)



arjun@qubeats.com



+91 9630196249



www.qubeats.com

Thank you!