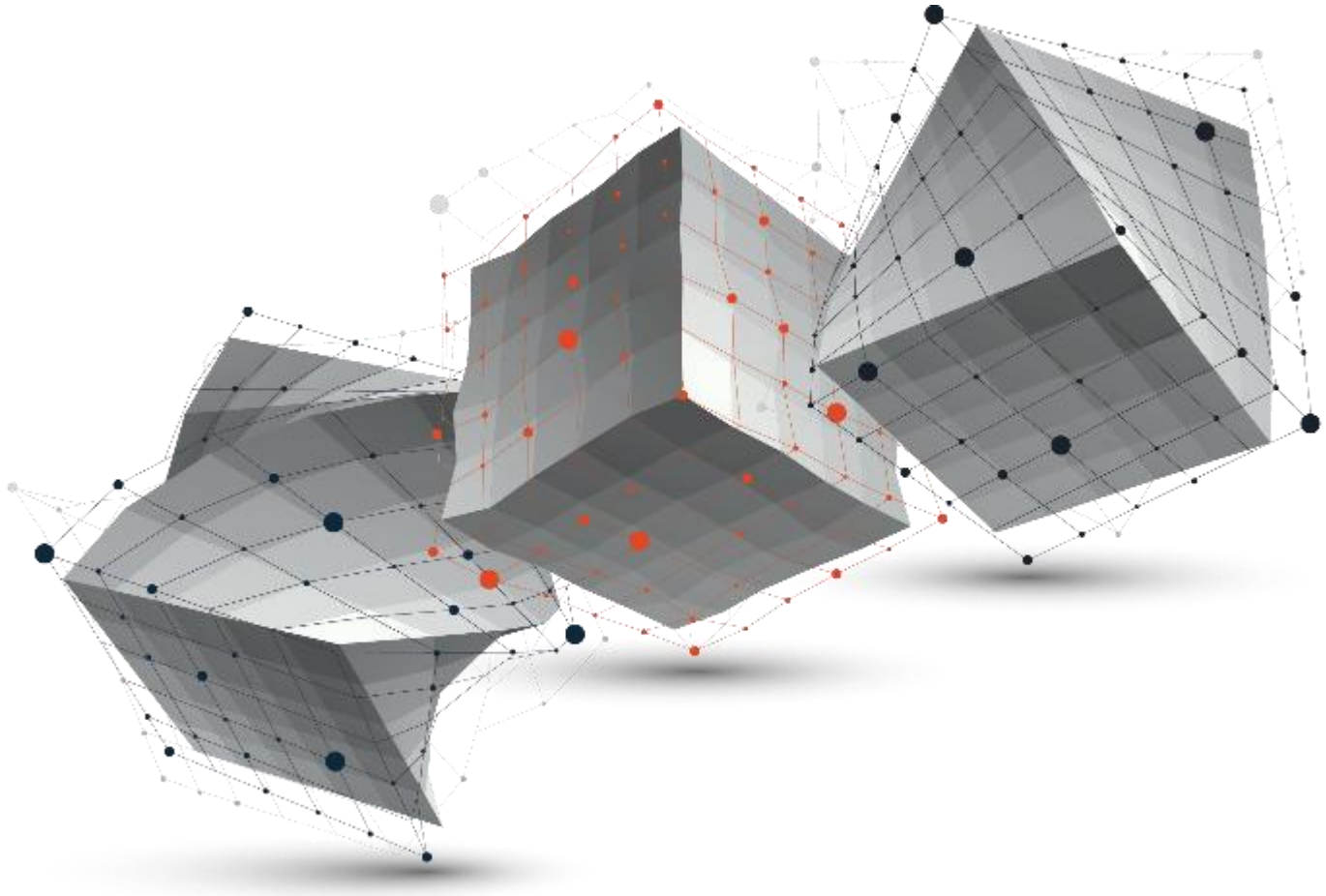
Archer Materials (ASX:AXE)
– ^{12}CQ Quantum Program

9th April 2025



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Spin Coherence in Carbon Nanospheres

ARTICLE

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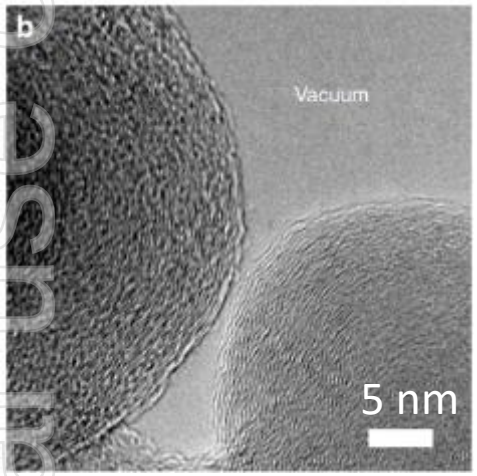
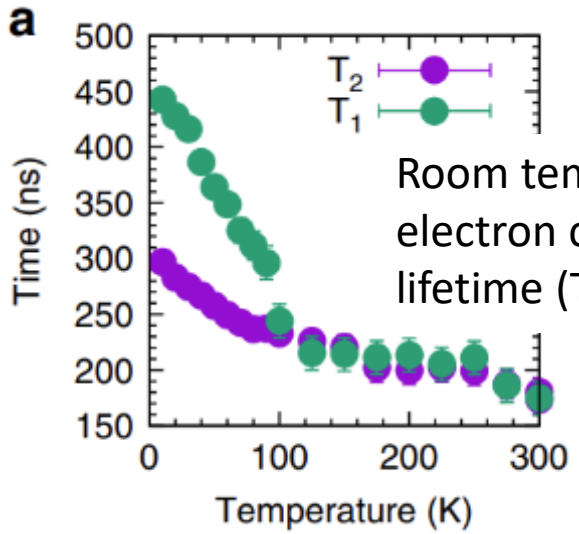
Room temperature manipulation of long lifetime spins in metallic-like carbon nanospheres

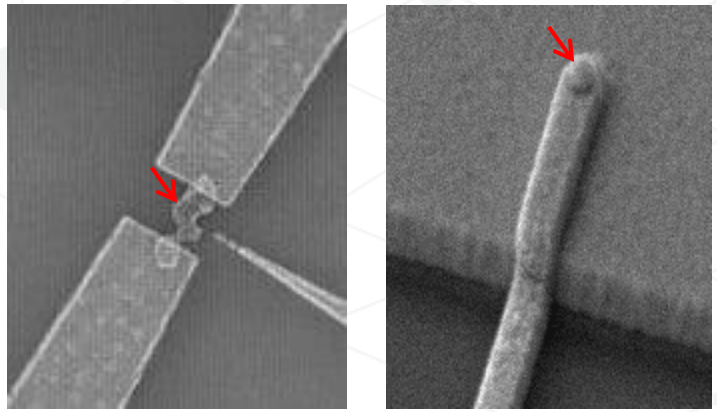
Bálint Náfrádi[1], Mohammad Choucair[2], Klaus-Peter Dinse[3] & László Forró[1]





Room temperature electron coherence spin lifetime (T_2) = 230 ns

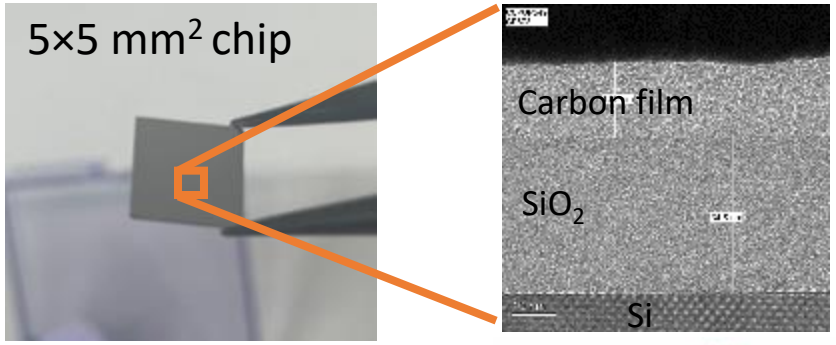
Advanced positioning and lithography for nanoscale device fabrication



Archer is developing novel carbon materials with long room temperature T_2 spin coherence lifetimes, useful for a wide range of quantum applications.

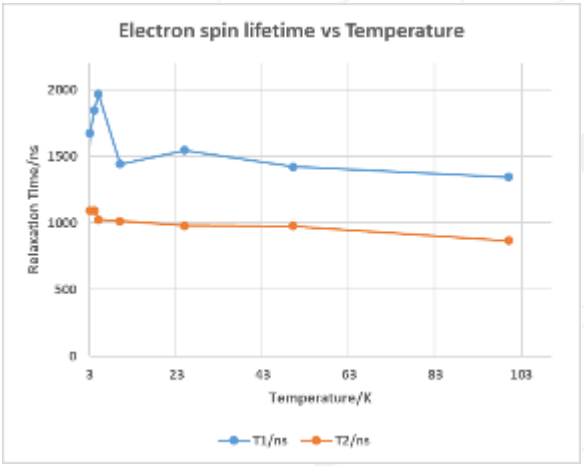
Archer's Quantum Carbon Film

Quantum film deposition



- Films are currently deposited using laboratory tools.
- Deposition is a CVD-based process. We expect scalability to full wafers.

Electron spin coherence time



$T_2 \approx 830$ ns

At room temperature

With development predicting a 2-3 times increase of T_2 – well beyond **1 *μs***

- We are exploiting the long spin lifetime for quantum device applications:
  - Primary focus: spin qubits.
  - Other: highly sensitive quantum magnetometers and magnetic microscopes.

Archer has developed a carbon film material with spin coherence lifetimes of ~1 *μs*.
The deposition process is compatible with full wafer scale manufacture.

See: ASX Announcement, 8 January 2025

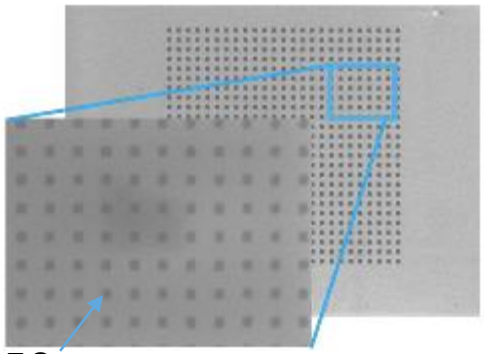
Film Processing and Device Fabrication

Carbon film deposited on a range of substrates, including silicon and SiO_2

- CVD-like process.
- Carbon-based precursors.
- Good run-to-run and chip-to-chip uniformity.
- Low impurity levels .

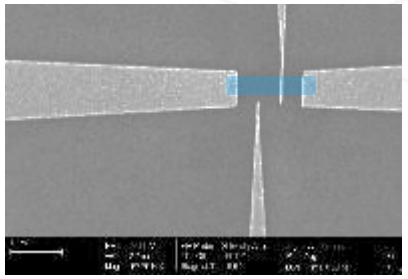
- Photo- or e-beam lithography.
- Standard RIE etching.

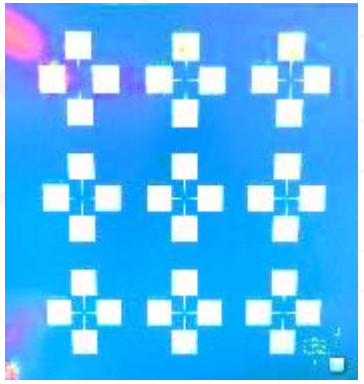
Spin confinement device



- Photo- or e-beam lithography.
- Standard RIE etching.
- Metallization.

Nanoscale quantum transport device

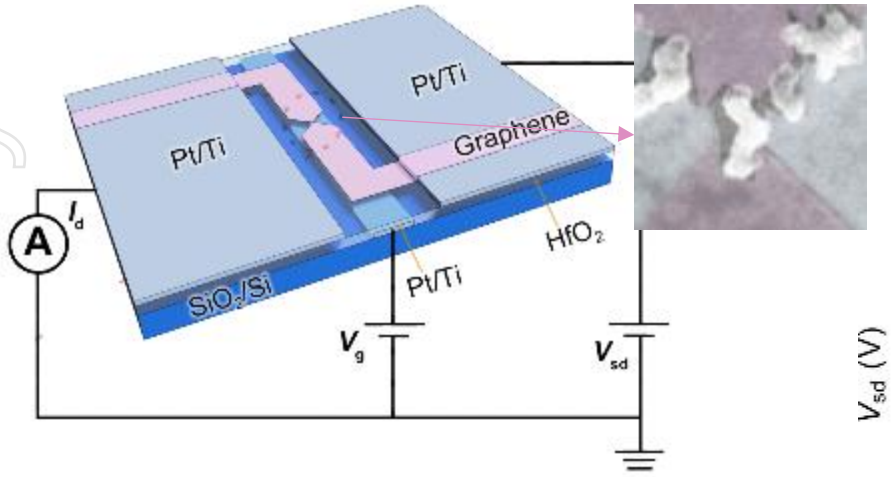


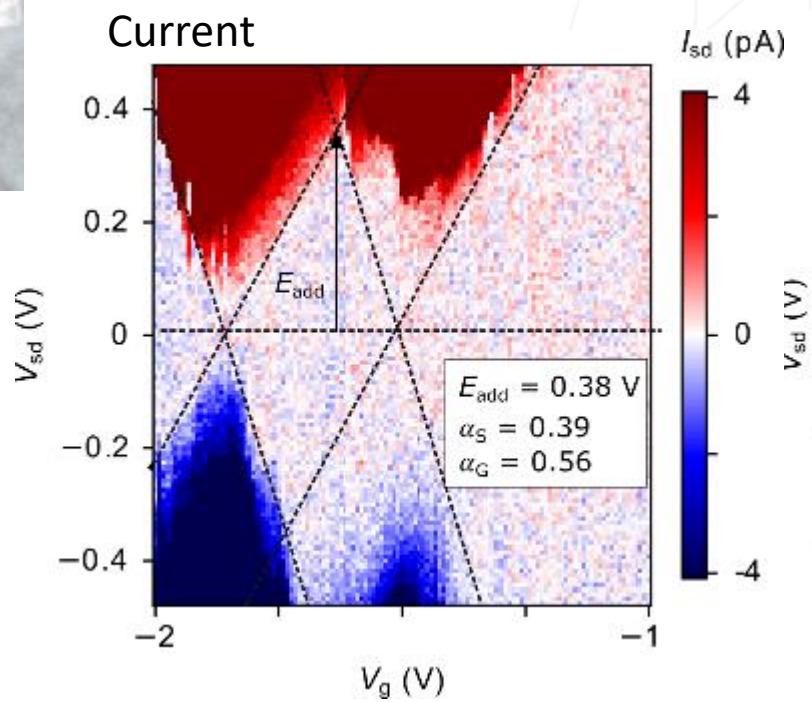


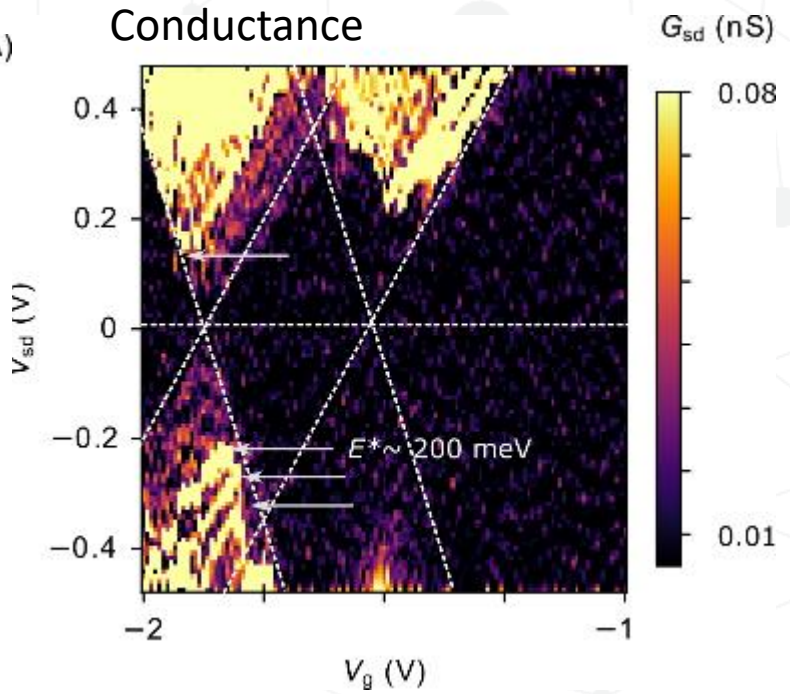
We are using traditional fab processing to fabricate nanoscale devices for development work and prototype devices.

See: ASX Announcement, 8 January 2025

Single Electron Transistors – Coulomb Blockade





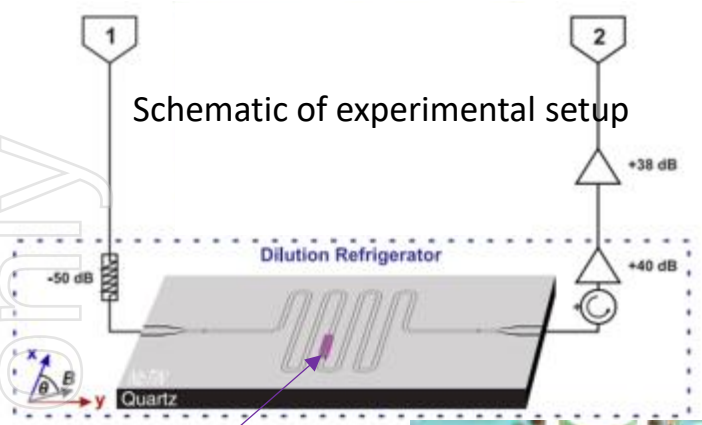


- Addition energy (E_{add}) of ~400 meV – matching a temperature of 80 Kelvin.
- Excited states (E *), result of C=C bond stretching:
  - Coupling of ~200 meV.
  - Suggests very strong electron-vibrational mode coupling.

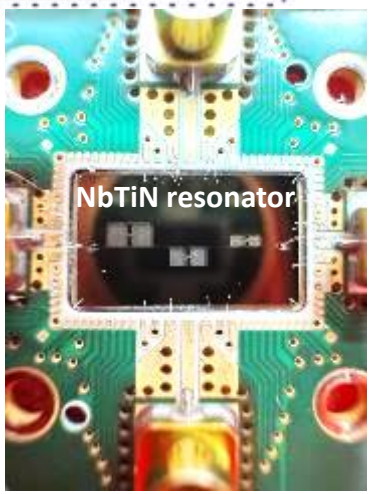
Building devices around nanoscale islands of our carbon film has allowed demonstration of Coulomb blockade and the first part of a spin readout structure.

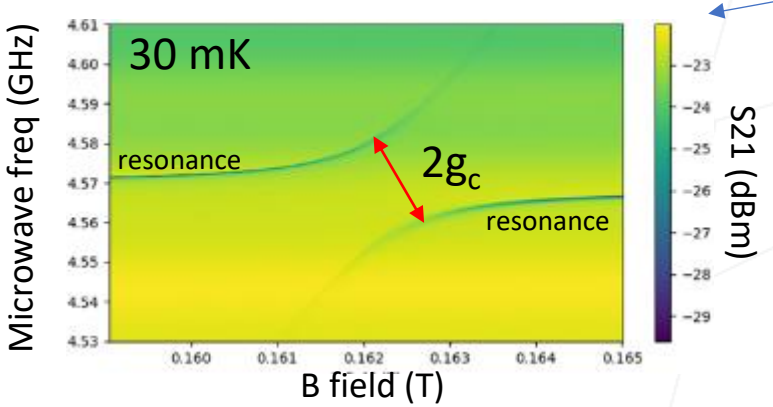
See ASX Announcement, 30 Oct 2024

Micro-resonators – Spin Detection and Control



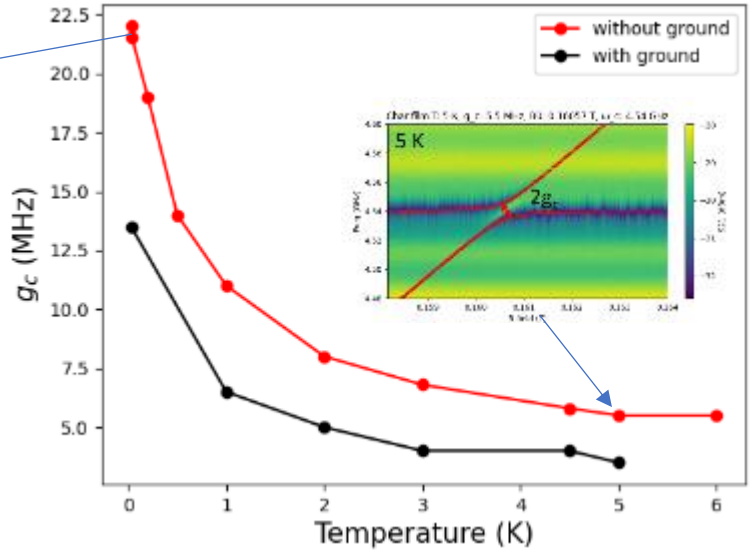
Carbon spin material





Avoided-crossing → quantum hybridization when resonator frequency is close to the spin transition frequency

Effective coupling vs temperature



Decrease in spin polarisation with increasing temperature

Clarity of observed signal indicates high electron spin densities.
Micro-resonator coupling, as demonstrated, will provide a mechanism for spin control.

See ASX Announcement, 13 Feb 2025

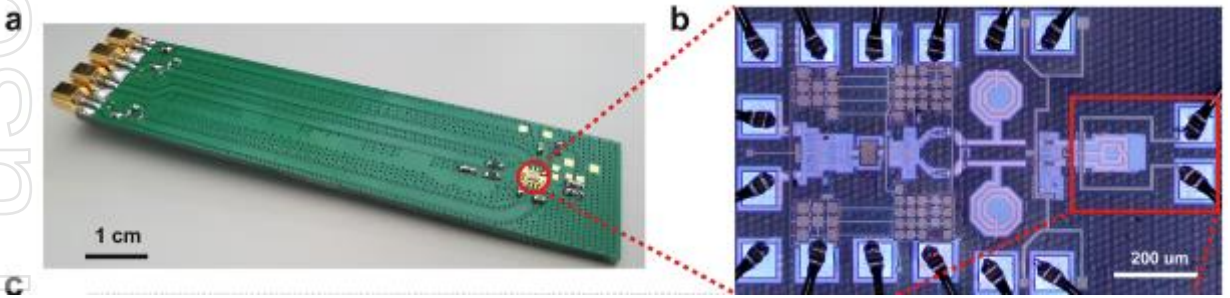
Chip-based Spin Detection

X-Band Single Chip Integrated Pulsed Electron Spin Resonance Microsystem

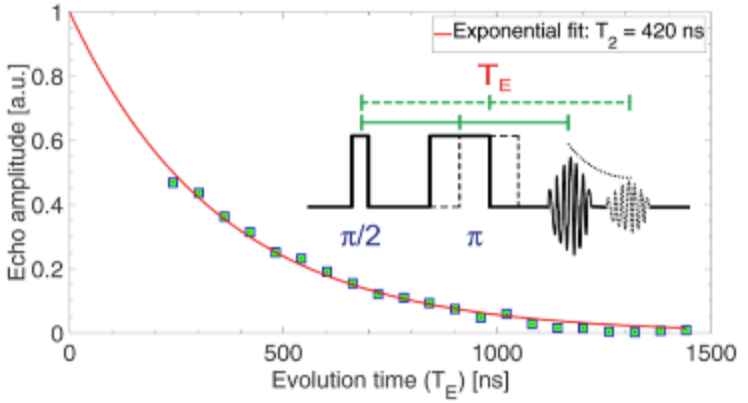
Reza Farsi,* Nergiz Sahin Solmaz,* Mattéo Maury, and Giovanni Boero

Cite This: *Anal. Chem.* 2024, 96, 14516−14523 Read Online

Chip design has been manufactured on SiGe BiCMOS, HEMT and standard CMOS technology platforms



Pulsed electron spin resonance allow direct measurements of electron spin lifetime

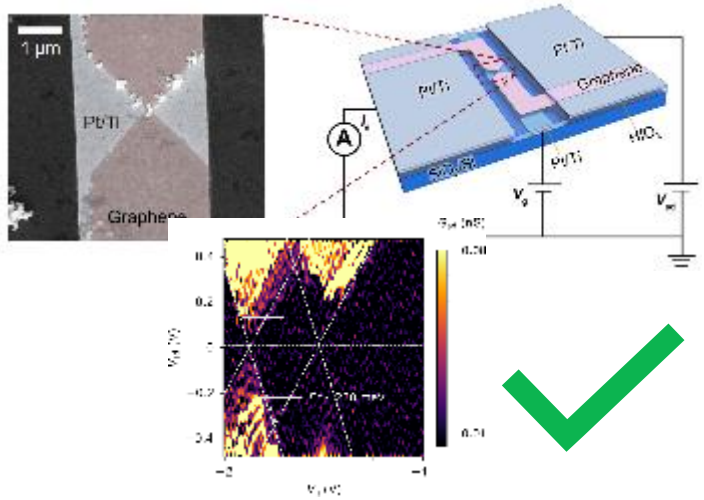


Archer has developed chip-based ESR microsystem demonstrating efficient detection of ~10^7 spins, within its carbon spin material.

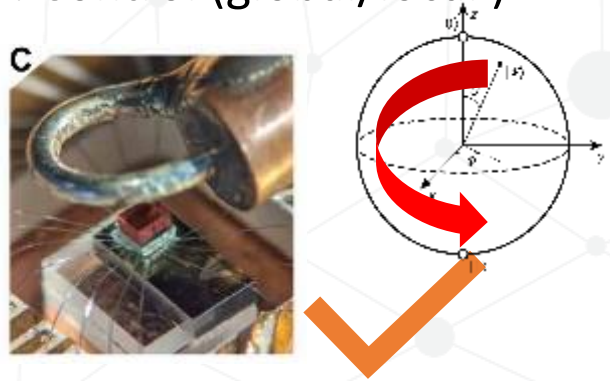
Qubit Roadmap

Qubit components

1. Confinement (CNO device)

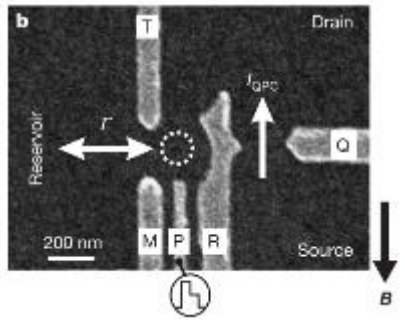


2. Control (global/local)

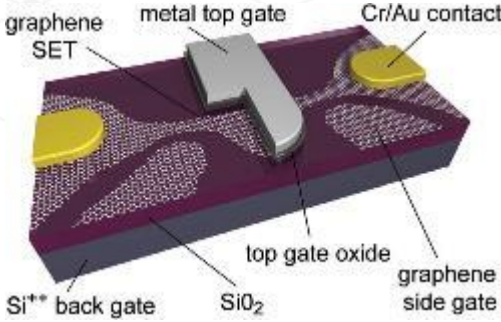


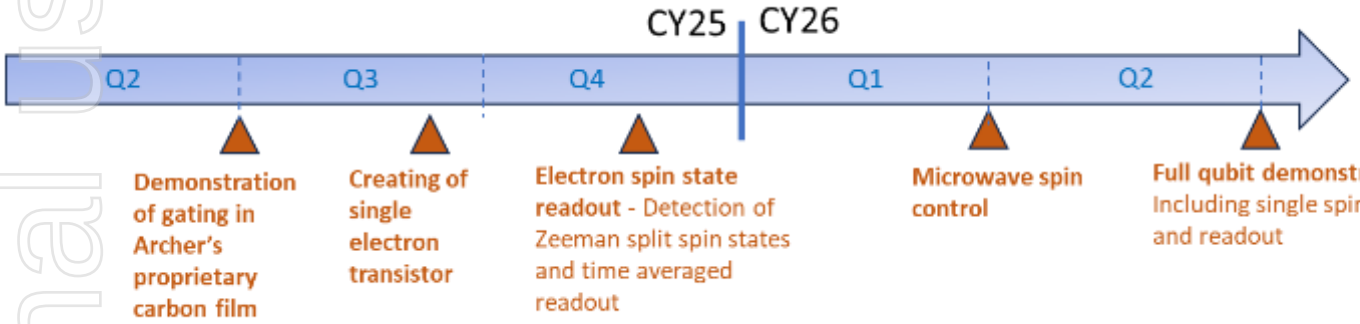
3. Readout (graphene SET)

Elzerman et al, Nature 430 (2004)



Work in progress

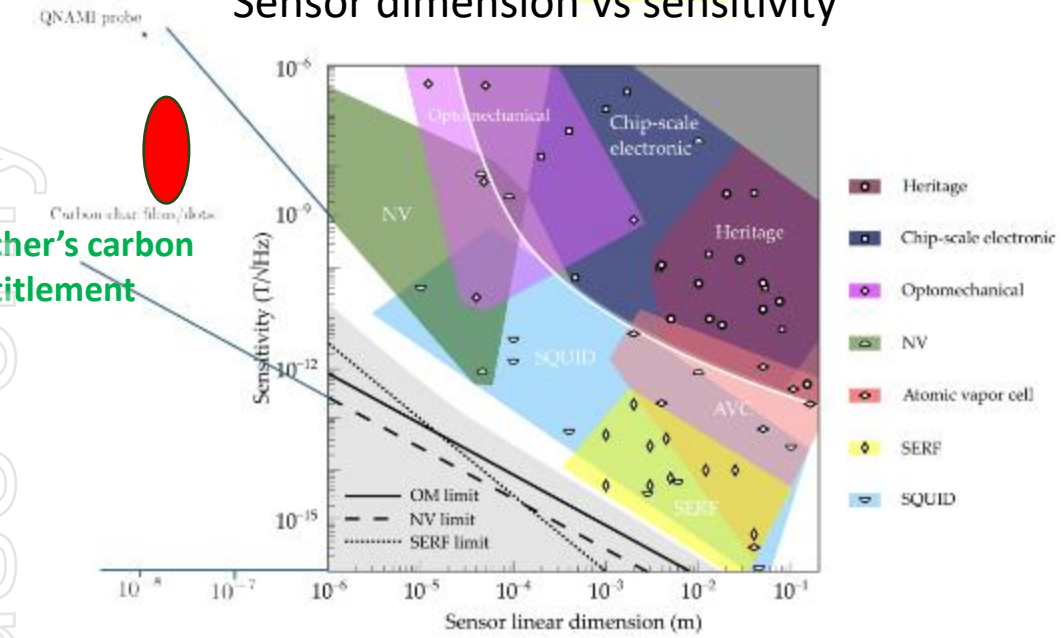




Work will be extended on devices built around nanodots of carbon.
Targeting an Elzerman qubit architecture demonstration in 2026.

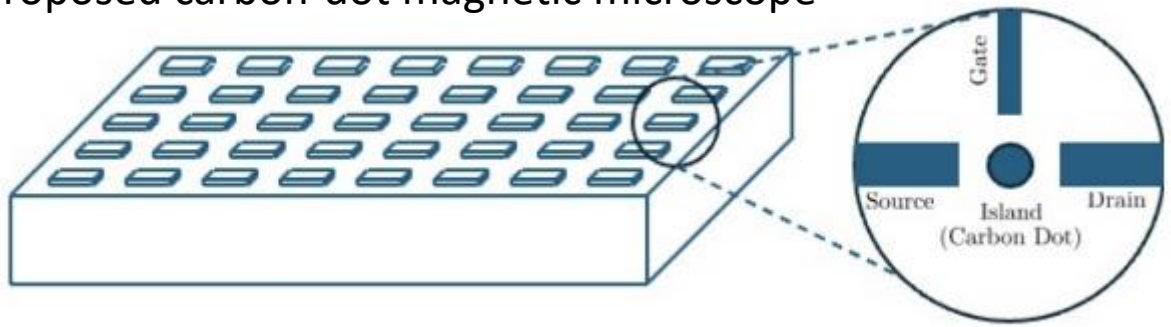
Sensing Applications - Magnetometry

Sensor dimension vs sensitivity



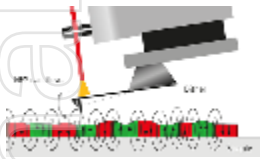
Archer's carbon entitlement

Proposed carbon-dot magnetic microscope

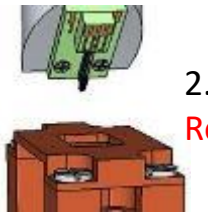


Array of lithographically defined spin single electron transistors (SSETs) would allow an extremely sensitive, high spatial resolution magnetic microscope

Incumbent technologies

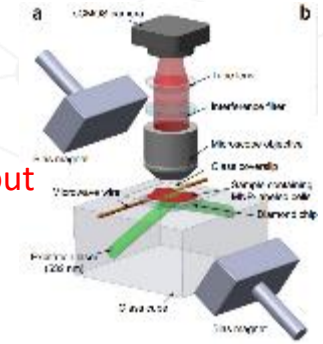


1. Magnetic Force Microscopy – Can only scan surfaces



2. Scanning SQUID microscopy – Requires cryogenic temperature

3. Nitrogen-vacancy in diamond – Requires optical excitation and readout



Archer's carbon films could be used for a differentiated magnetic microscope → non-destructive, high throughput, room temperature.

Archer Materials – Quantum Program

- We are developing quantum technology in differentiated carbon-based materials that have attractive quantum properties even at elevated temperatures.
  - Our focus is qubit technology for quantum computing.
  - There is the possibility to develop quantum sensors e.g. highly sensitive room-temperature magnetometers.
- Our long electron spin lifetime carbon materials can be deposited as films via a fab-friendly CVD-like process.
- Targeting qubit demonstration by mid-2026.
  - Demonstrated quantum transport through single electron device structure.
  - Demonstrated coupling to micro resonators for control.
- We are seeking external partnerships and opportunities for industry and academic research organizations to support this work.

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