Towards axion searches using superconducting qubits

Sep 16, 2024

The University of Tokyo / ICEPP　Tatsumi Nitta

@ Patras 2024

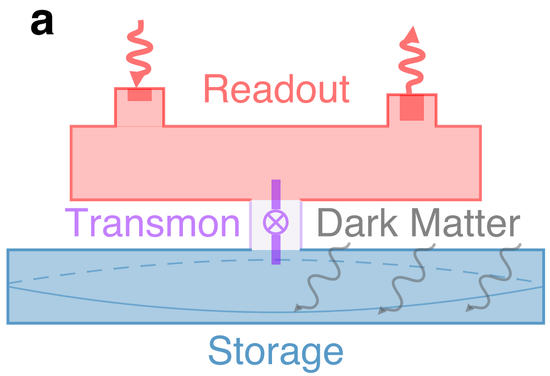
Motivation

Direct excitation

Moroi et.al. Phys. Rev. Lett. 131, 211001

Check Posters by K. Watanabe & S. Chen

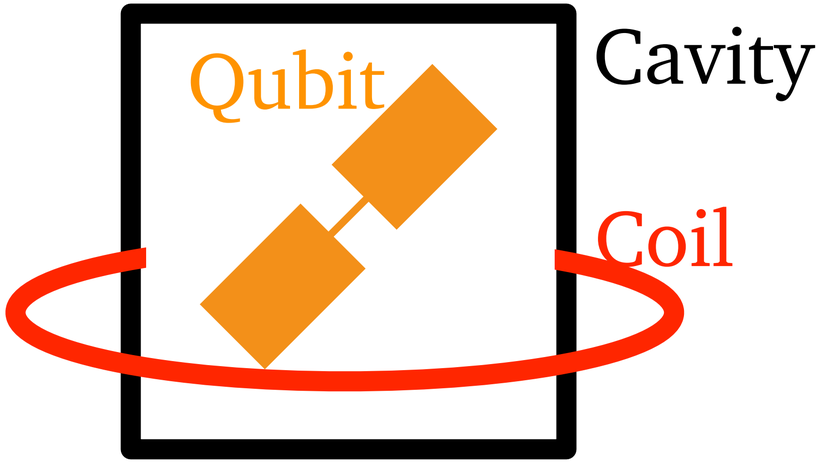
Single photon counting



Aaron et.al.

PRL 126 141302 (2021)

Cavity tuning with qubit



Talk by Kan Nakazono on Wed.

Qubits improves dark photon searches

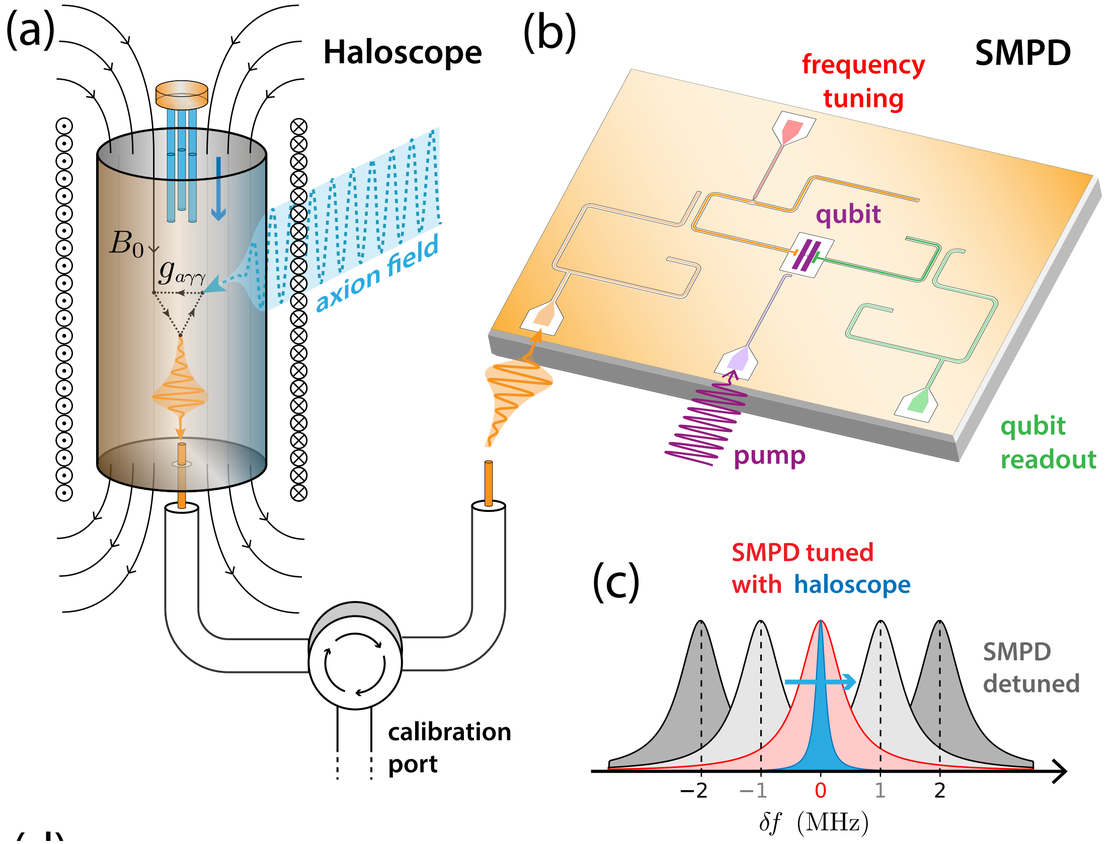
→ **Magnetic field makes these axion searches**

Ways to introduce B-field

This poster

Photon transfer

Pros: Easer, Cons: Potentially lossy

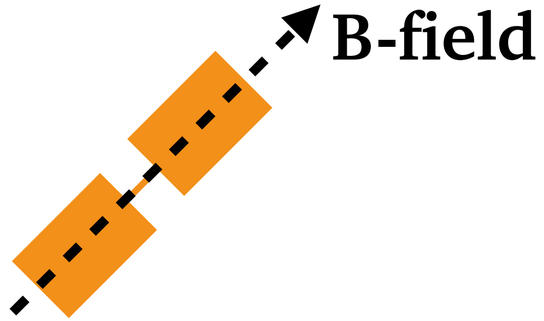


arXiv:2403.02321

B-field tolerant qubits

Pros: No loss

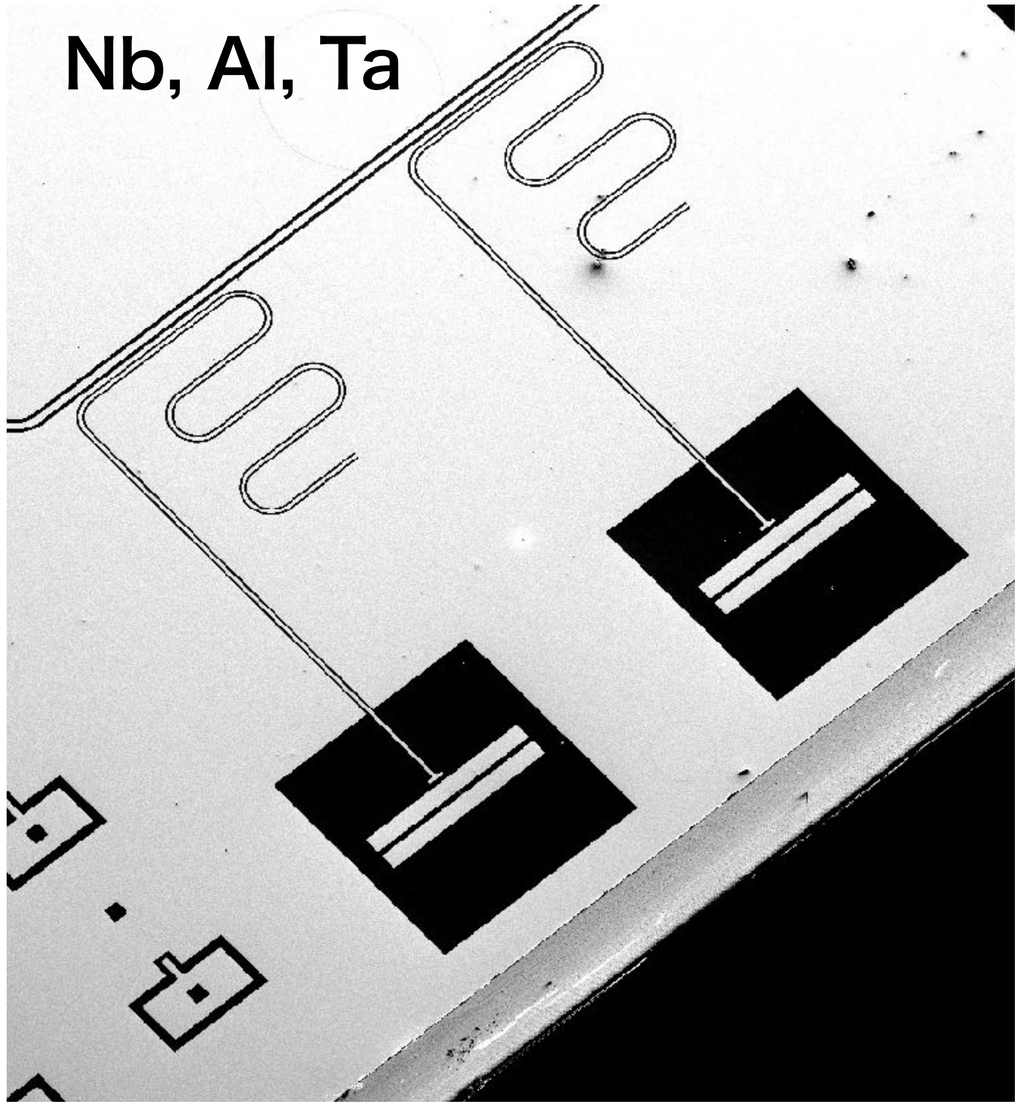
Cons: More difficult

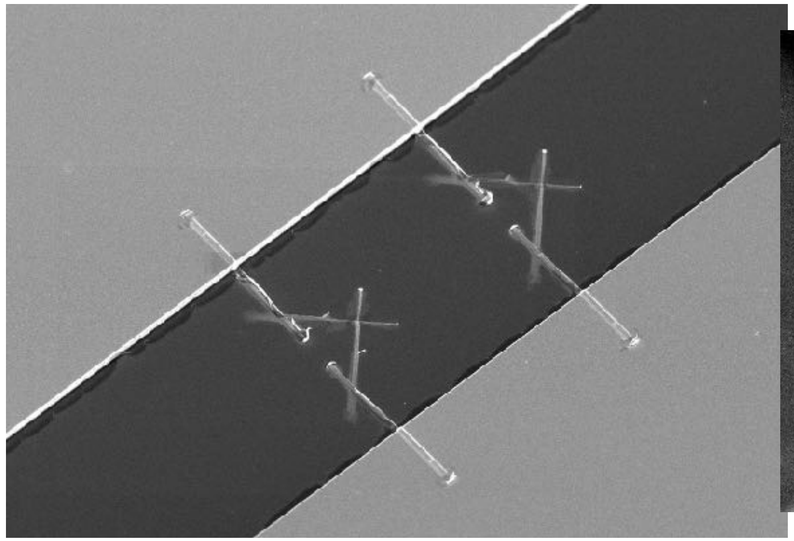


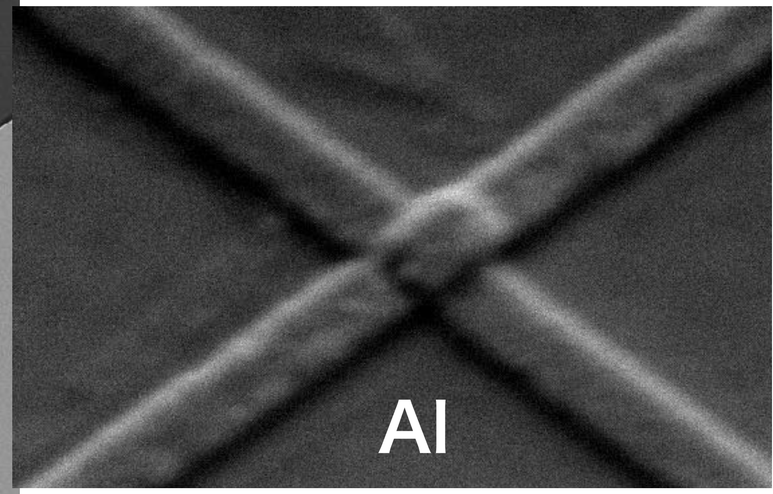
Qubits worked at least 1T

J. Krause et.al., Phys. Rev. Applied 17, 034032 (2022)

Difficulty



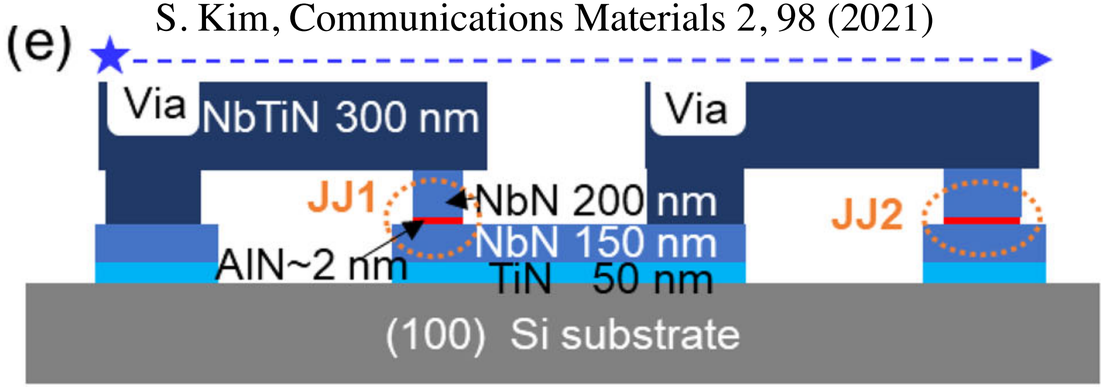


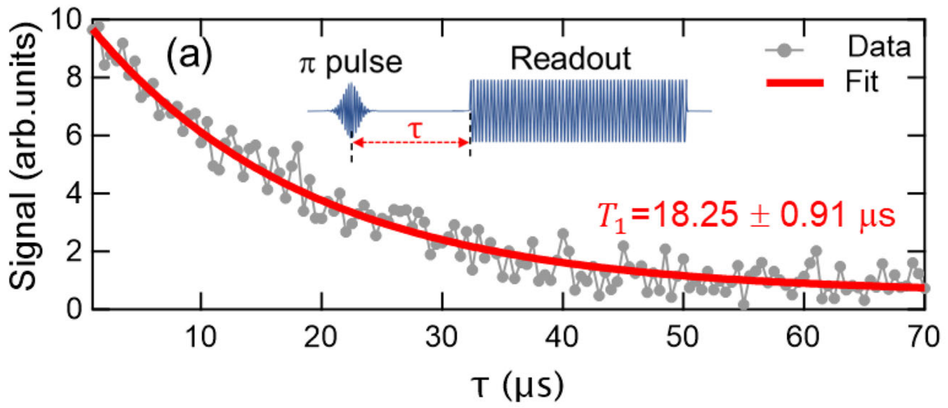


- Critical field
- Suppression of Josephson effect

Solution: All-nitride qubits

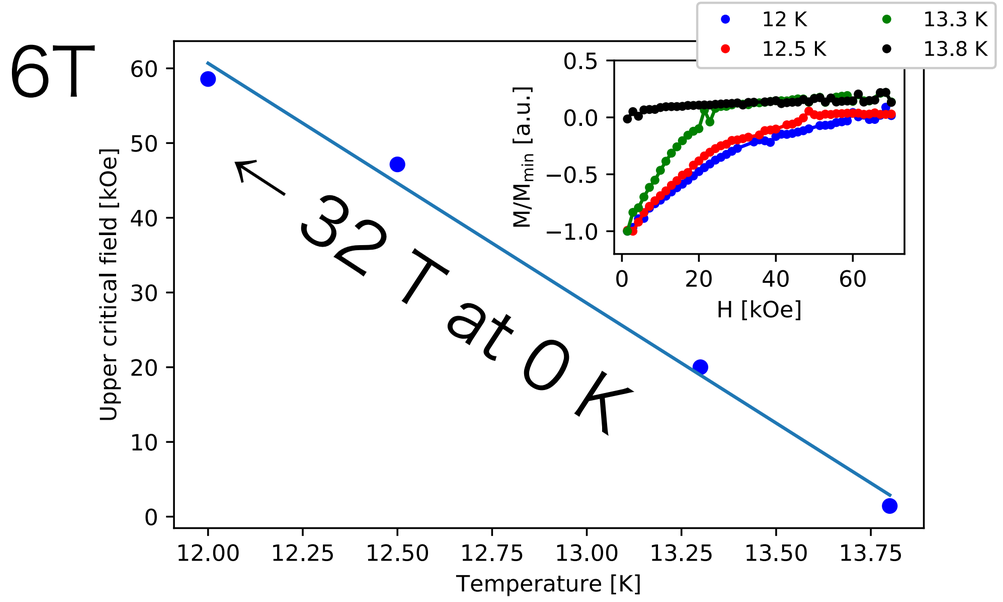
S. Kim, Communications Materials 2, 98 (2021)





T. Polakovic, APL Materials 6 (2018) 076107

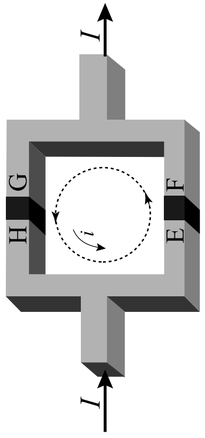
NbN 240 nm film



Nitride has high Tc2 → **We don't have to care about critical field**

Suppression of Josephson Effect

SQUID



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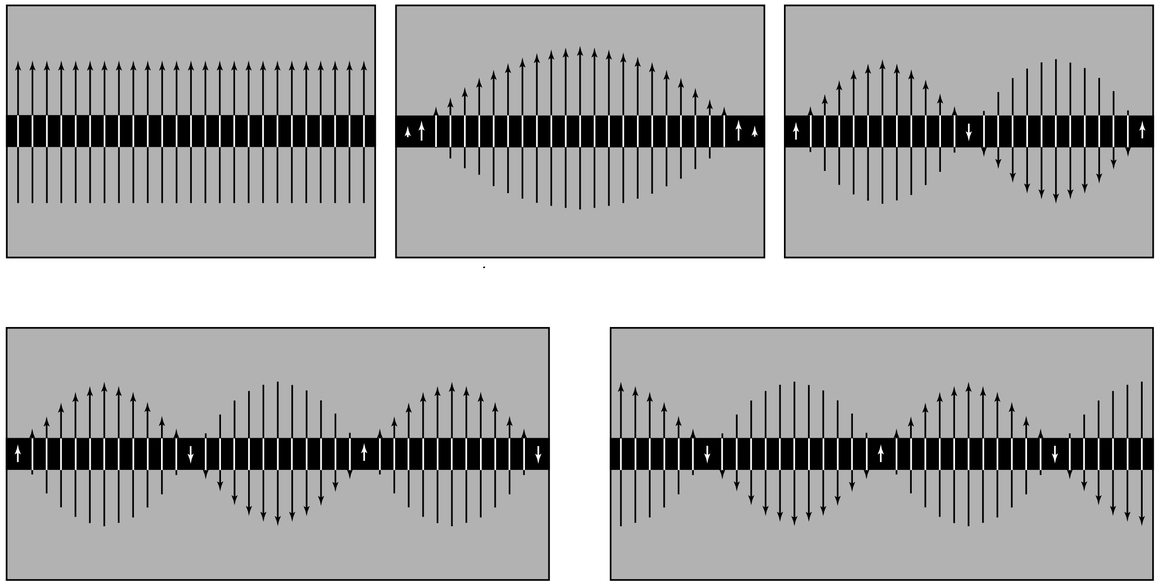
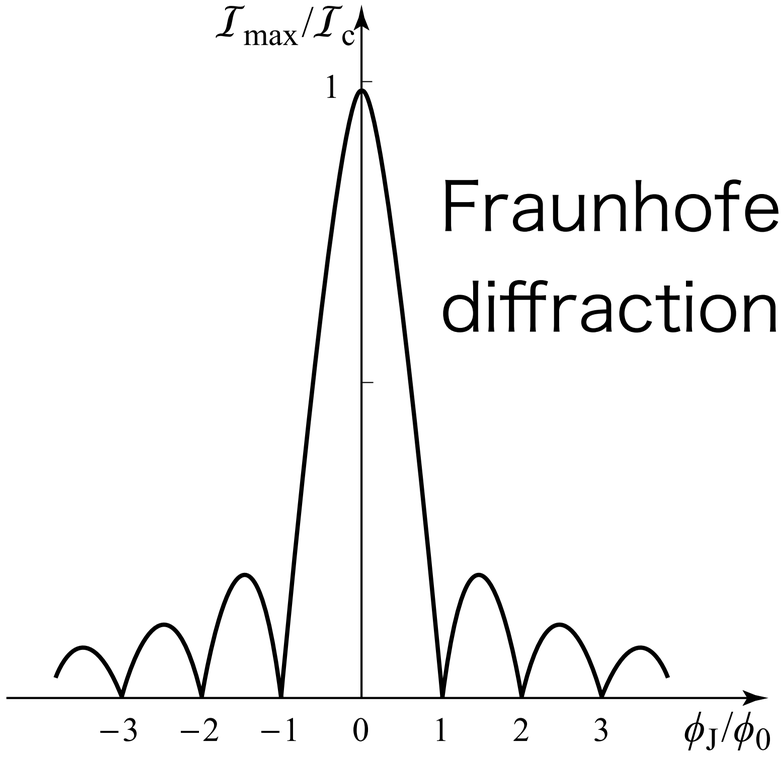
single JJ under high B-field



From “Superconductivity An introduction” Mangin - Kahn

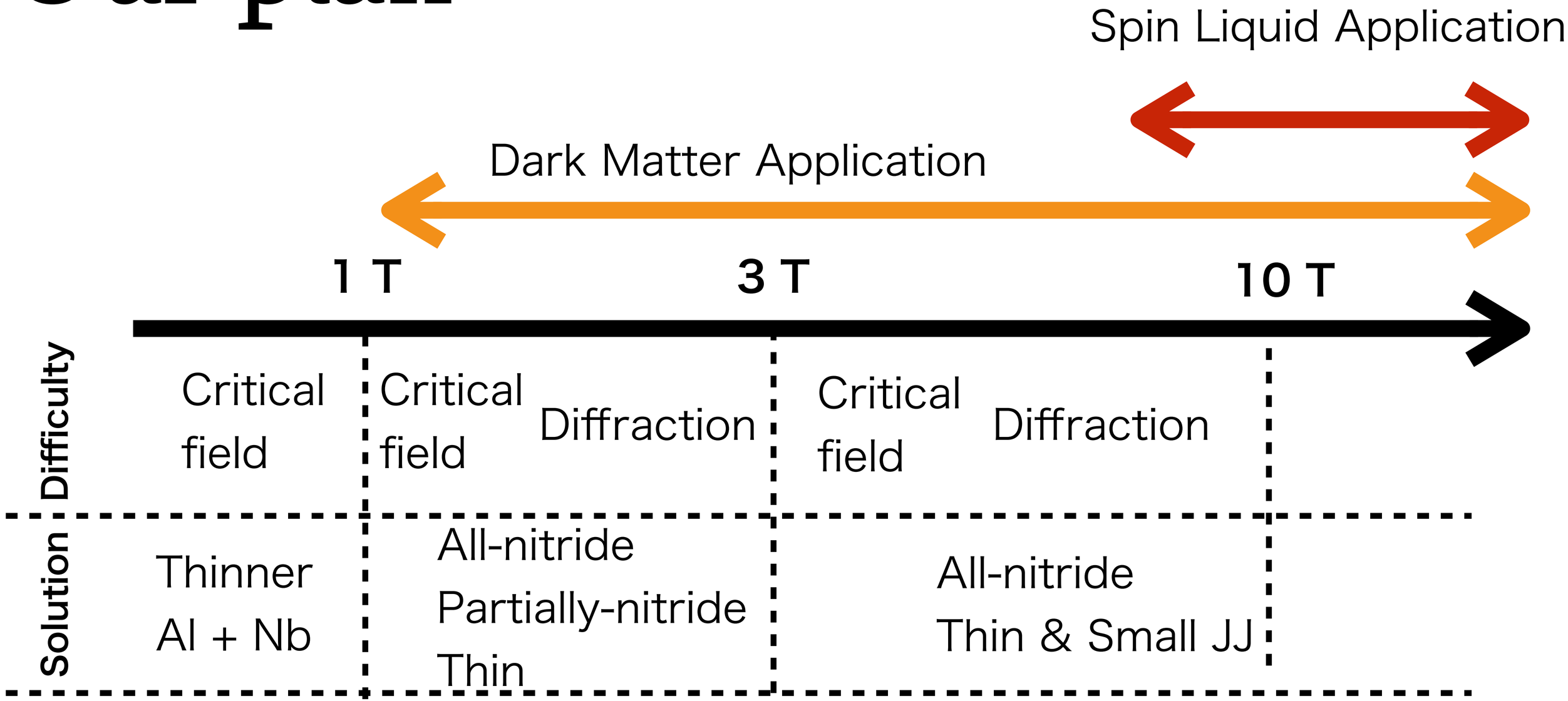


Fraunhofer diffraction

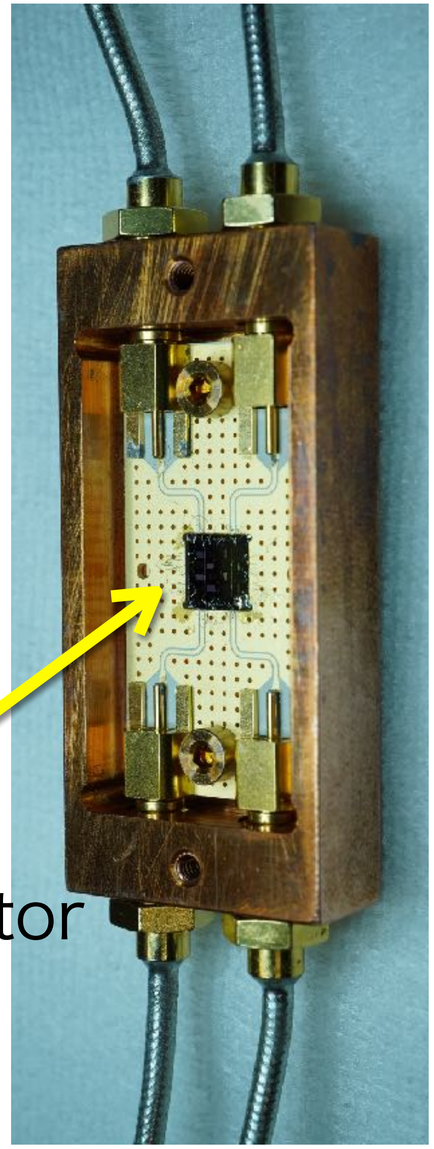
10 T = 1 flux quantum / (14 nm)^2

→ **Have to keep the cross-section to the magnetic field small**

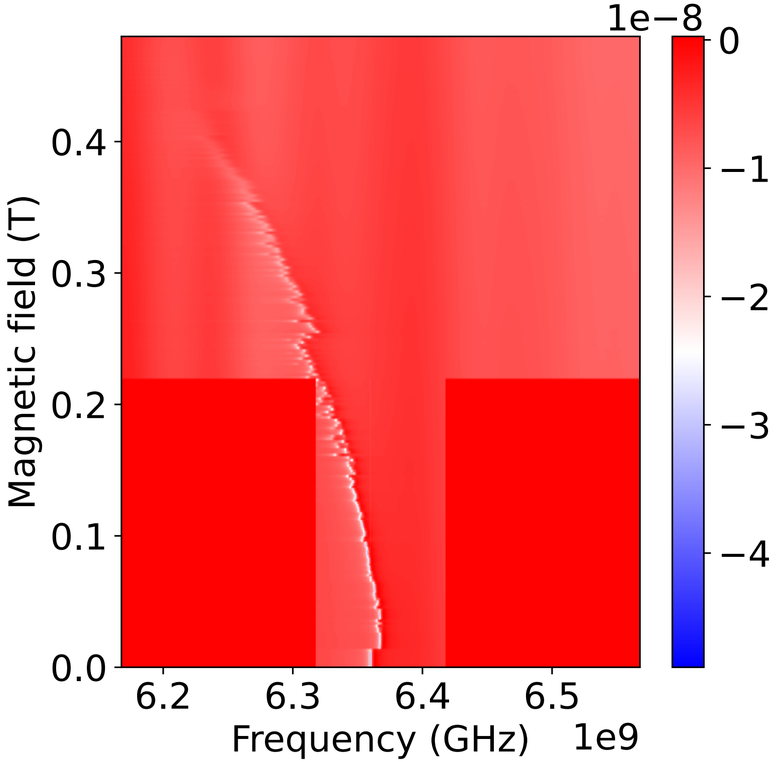
Our plan

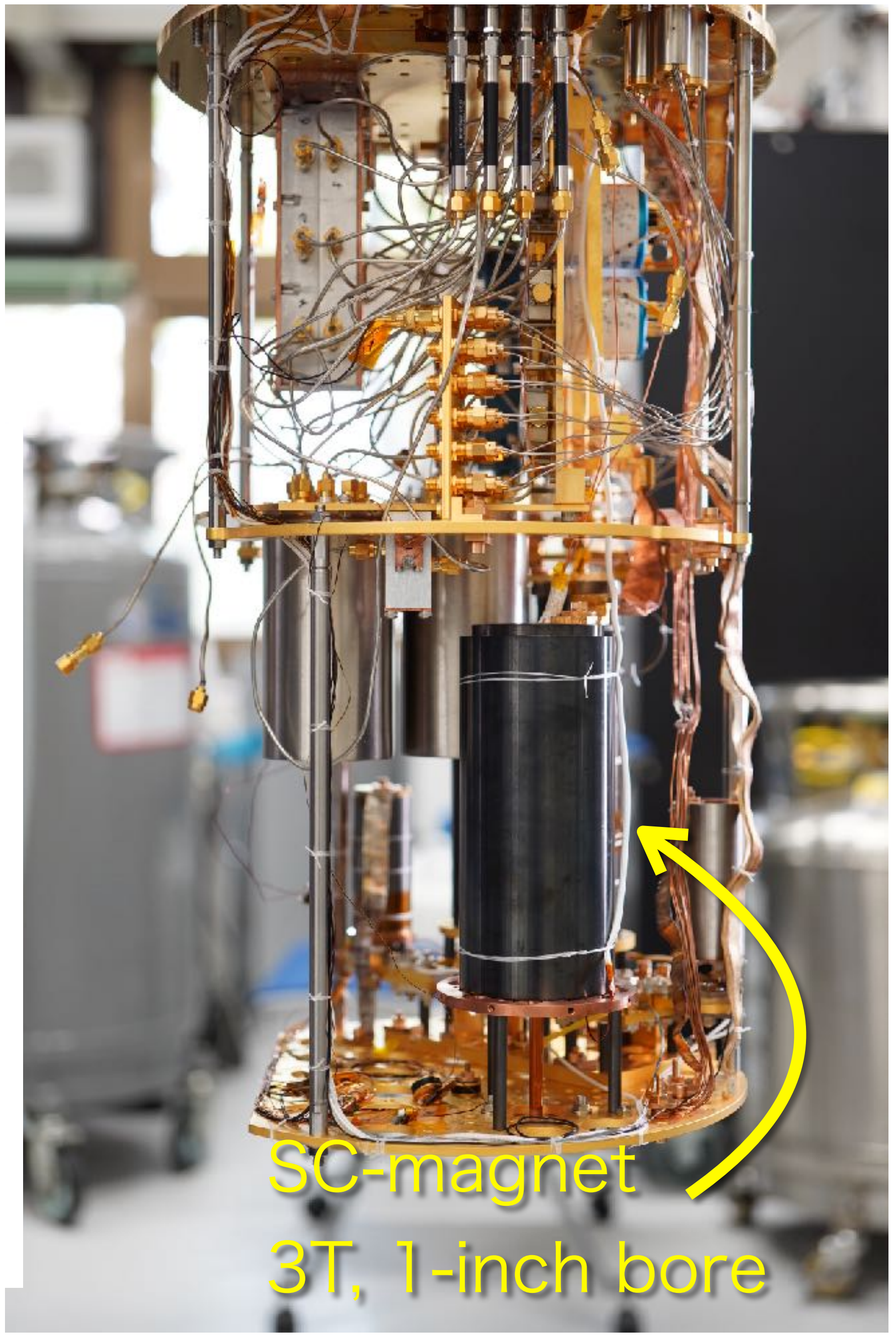

Spin Liquid Application
Dark Matter Application
1 T
3 T
10 T
Difficulty
Critical field
Critical field
Diffraction
Critical field
Diffraction
Solution
Thinner Al + Nb
All-nitride Partially-nitride Thin
All-nitride Thin & Small JJ

Current Status



TiN 2D resonator





Summary

- Qubits working under 10 T → Dark matter or QSL study
- Nitride has high Hc
- Collaborating with NICT scientists (All nitride qubits)

  and FNAL scientists (Better shapes of JJ, magnets, etc)