Superconducting Qubit Advantage for Dark Matter (SQuAD)

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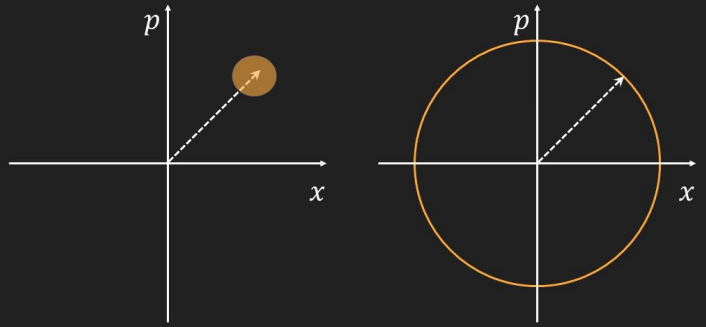
Motivation

Dark matter searches in the GHz region encounter two main challenges

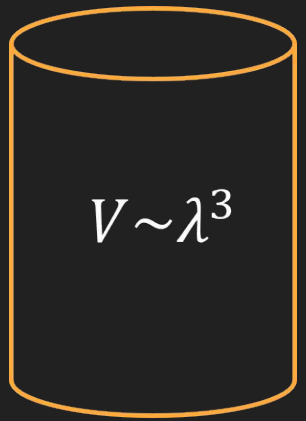
Quantum noise associated with state of the art linear amplifiers

Signal scales with volume and quality factor of the cavity

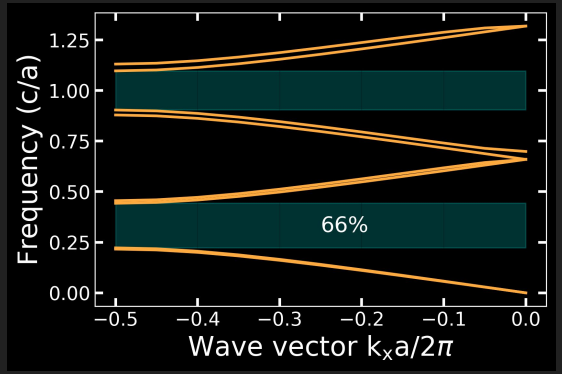


Parametric amplifiers

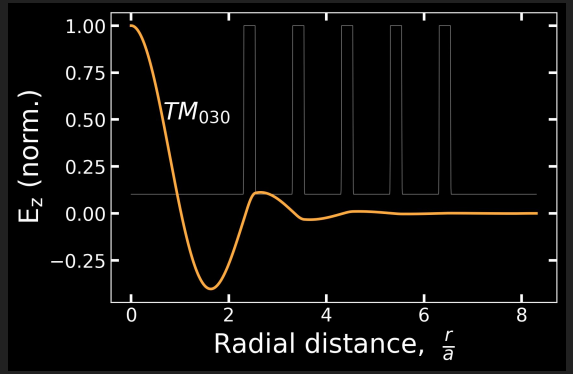
Photon counting



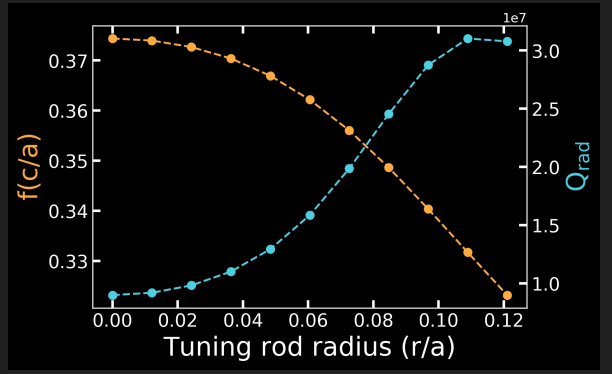
High-Q Photonic Bandgap Cavities



Periodic arrangement of dielectric shells



Higher order mode has larger effective volume (*C*V*)



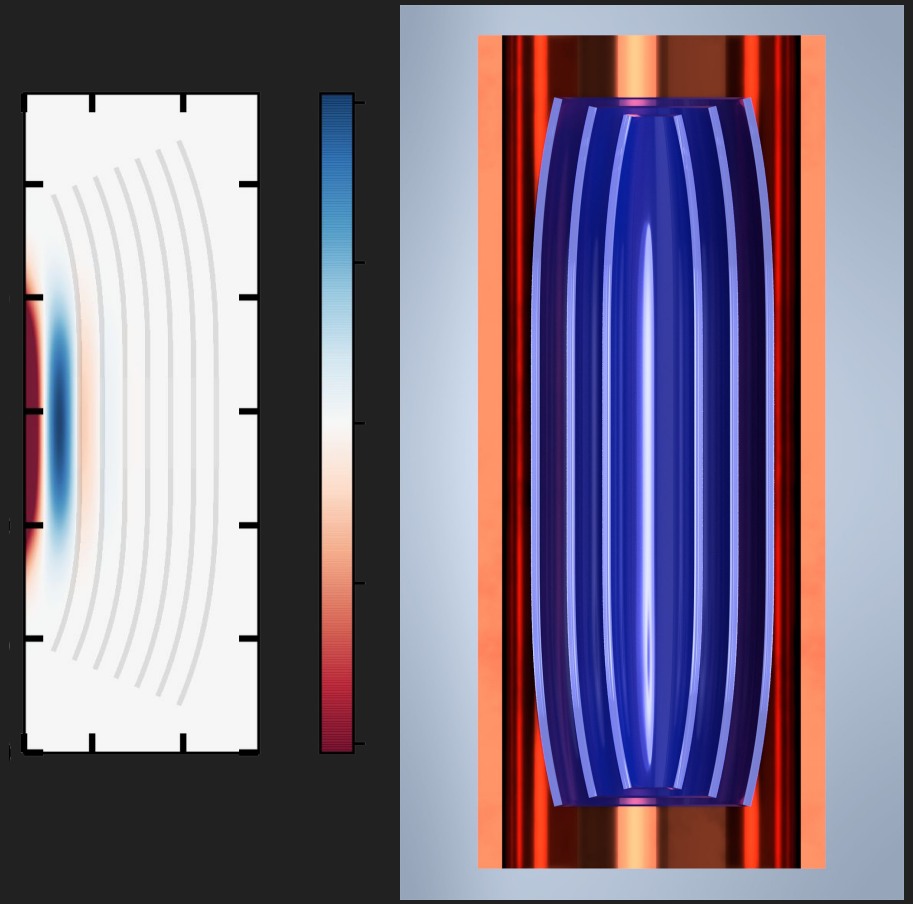
> 10% tuning range

- Compatible with high magnetic fields
- Dielectric cavities can achieve Q's of **10^8**
- Signal rate increases by a factor of **10^8 /10^4**

Nested cylindrical cavity

Tapered ends help with radiation loss along the axial direction

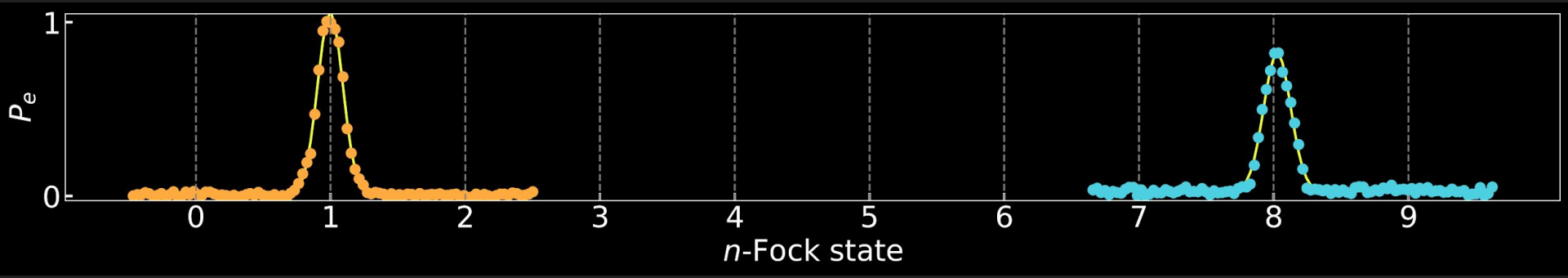
Copper helps with radiation loss and cooling the dielectric



Stimulated Emission

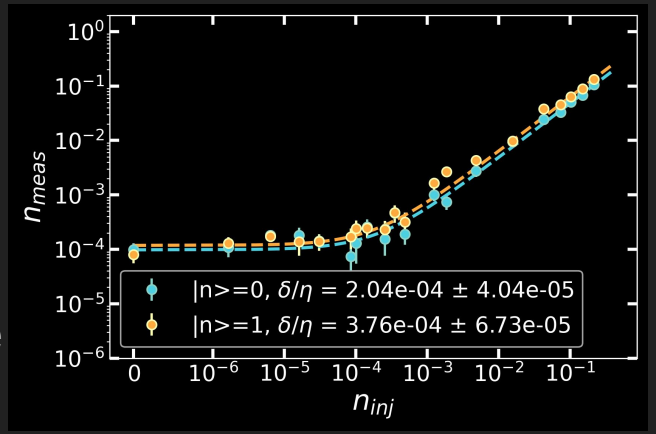
$$\left|\langle n+1|\hat{D}(\alpha)|n\rangle\right|^2 \propto (n+1)$$

- Initializing the cavity in a Fock state enhances the signal by ***(n+1)*** factor
- Quantum optimal control pulses used to generate Fock states in the cavity



Conclusion

- Signal improvement with high-Q PBG cavity (fabrication in progress)
- Further signal enhancement with stimulated emission, only limited by the dephasing time of the cavity



Snowmass2021 - Letter of Interest

Superconducting Qubit Advantange for Dark Matter (SQuAD)

Thematic Areas:

- (CF2) Dark Matter: Wavelike
- (IF1) Quantum Sensors
- (IF2) Photon Detectors

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