ORGAN: State of Play & Future Plans

Ben McAllister, Aaron Quiskamp, Graeme Flower, Catriona Thomson, Will Campbell, Cindy Zhao, Maxim Goryachev, Eugene Ivanov, Michael Tobar
Overview

- ORGAN introduction
- Design considerations
- Photon counting
- Status and run plan
ORGAN: Axion Detection

• High mass axion haloscope
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- Axion-photon conversion in resonant cavity
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• Mass range of interest – 60-200 micro-eV
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- Oscillating Resonant Group AxioN Experiment
- Mass range of interest – 60-200 micro-eV
- Motivations:
  - SMASH model
  - Josephson Junction results
  - High mass range relatively unexplored
ORGAN: Axion Detection

• Critical research areas:
  • Tunable resonators
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  • Data acquisition and analysis
ORGAN Sensitivity Considerations

- Haloscope scan rate:

\[
\frac{df}{dt} \propto \frac{1}{\text{SNR}_{\text{goal}}^2} \frac{g_{a \gamma \gamma}^4 B^4 C^2 V^2 \rho_a^2 Q_L Q_a}{m_a^2 (k_B T_n)^2}
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- We can’t really do anything about the rest of it…
ORGAN Dilution Refrigerator

- New dedicated dilution refrigerator arrived! (Nov 2019)
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- Equipped with 12.5 T magnet
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- Proposed here:

Tunable Supermode Dielectric Resonators for Axion Dark-Matter Haloscopes

Ben T. McAllister, Graeme Flower, Lucas E. Tobar, and Michael E. Tobar
Phys. Rev. Applied 9, 014028 – Published 26 January 2018
The DBAS Method in WGM Modes

• Take a higher order azimuthal TM mode and make it axion sensitive by placing dielectric in out of phase regions.

• Result $\rightarrow$ decreased $E_z$ field in those regions $\rightarrow$ increase in $C$
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![Graphs showing TM410 mode](image-url)
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![Graphs and diagrams illustrating the change in electric field and mode shapes before and after DBAS method application.](image-url)
4 Sapphire wedges FEM

Built-in tuning → 2-wedges remain stationary, while the other 2 are allowed to move relative to the stationary ones.
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Dielectric-Boosted Sensitivity to Cylindrical Azimuthally Varying Transverse-Magnetic Resonant Modes in an Axion Haloscope

Aaron P. Quiskamp, Ben T. McAllister, Gray Rybka, and Michael E. Tobar
Phys. Rev. Applied 14, 044051 – Published 27 October 2020
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  - 100 mK
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- If we lower the temperature this ratio can become order of thousands
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- Initial design of 25 GHz+ detector
Single Photon Counters

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- In the dilution fridge right now
- Watch this space
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Standard TM010 Tuning
Rod Resonators

Phase 2:
Novel Dielectric Resonators
Better Amplifiers
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Efficient GHz SPC
ORGAN: Run Plans

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Phase 1a underway

Less optimistic: HEMT or SQL Linear Amplifiers

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ORGAN: Phase 1a

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- HEMT Amplifier
- ~15 – 16 GHz
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Aaron Quiskamp, PhD Student
ORGAN: Phase 1b

• Expected to commence late 2021
• Currently prototyping dielectric wedge resonator
ORGAN: Phase 1b

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ORGAN: Phase 2

• Commencing 2022+
• Broken into 5 GHz chunks
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- Ideally employ SPCs
- Multiple cavity arrays
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Conclusion

• ORGAN:
  • High mass axion haloscope
  • 2021 commencement
  • Two phases:
    • Short, targeted scans with existing equipment
    • Longer, broader scans with new technology

• Quantum Sensing
  • Testing a few SPC concepts for integration