IF01: Quantum Sensors

Key Points

Quantum Sensors and Snowmass Science

- Ultralight wavelike dark matter (generalized axions, hidden photons, scalars)
- Scattering / absorption of dark matter particles
- Electric dipole moment measurements (electron, nuclear, neutron)
- Gravitational waves
- Dark energy
- Violations of fundamental symmetries
- New forces and particles

Quantum Sensors in Context

Quantum sensors instrumentation has close connection with:

- IF2: Instrumentation Frontier, photon detectors
- IF7: Electronics/ASICs subgroup
- CF1: Cosmic Frontier, Dark Matter particle-like
- CF2: Cosmic Frontier, Dark Matter wave-like
- AF5: Accelerator for PBC and Rare Processes

Important to make sure that interfaces are well defined, and nothing is “dropped in the cracks.”

This is an emerging technology area and there are many connections to other frontiers.

Community White Papers

- Received 74 LOIs tagged with IF01
- Grouped LOIs into 4 groups - planned coordinated white paper for each
  - Superconducting Sensors
  - Quantum Calorimeters
  - AMO: Spins, NMR, and Defects
  - Interferometers, Clocks, and Traps
- Coordinated white papers:
  - https://arxiv.org/abs/2203.09488: Quantum Sensors for High Precision Measurements of Spin Dependent Interactions
  - https://arxiv.org/abs/2203.07250: Snowmass 2021: Quantum Sensors for HEP Science - Interferometers, Mechanics, Clocks, and Traps
  - Development of Single Quanta Detectors with Low Dark Count Rates
- 11 additional white papers cross-listed under IF01

Key Points

- Quantum sensors have a broad range of science applications
- Many “small” experiments are shovel ready and can have a big impact
- Support interactions outside of ‘traditional’ HEP
- Theoretical support is needed address issue of materials and measurement methods
- Workforce development is needed to maintain momentum and for long-term success

Quantum sensors have a broad range of science applications

- Taken as a single entity, quantum sensors can have a very broad scientific impact
- Key areas
  - Dark matter - wave and particle
  - Gravitational waves
  - EDM
  - BSM
- More broadly, quantum systems are also being considered as ways to improve existing detector technologies (e.g. wavelength shifters)

Many “small” experiments are shovel ready and can have a big impact

- Broad range of technologies, each of which carves out slightly different parameters space
- Many of the current experiments are small - ‘tabletop’
  - Carried out by a few investigators
  - Fit within a lab
  - Commensurate budget
- Approaching science target from new direction exposes low hanging fruit -> can quickly examine previously unreachable parameter space
- Experiment scale allows for rapid evolution and development of new techniques

Support interactions outside of ‘traditional’ HEP

- Historically, much of the work on quantum sensors has come from outside of HEP (e.g. QIS, AMO)
- For HEP science to benefit, we must work together with other fields
- Need pathways to support scientists outside of HEP, and support those in HEP to learn new areas

Theoretical support is needed address issue of materials and measurement methods

- Generic measurement methods (e.g. squeezing and back action evasion)
- Noise sources in low threshold detectors
- Materials properties
  - High-Q resonators
  - atoms/ions with larger sensitivity factors
- Quantum Network protocol

Workforce development is needed to maintain momentum and for long-term success

- Educational skill sets fall outside HEP
- Strong competition for skilled workers from commercial quantum computing