GQuEST Status

June 2023

1 Theory

At CIT, Vincent Lee and Dongjun Li are both partially supported from GQuEST funds. They are authors on the recent paper **Interferometer Response to Geontropic Fluctuationhttps** `https://arxiv.org/pdf/2209.07543.pdf`

Graduate student Jerry Zhang is moving to GQuEST support, and is co-author on **Stochastic Description of Near-Horizon Fluctuations in Rindler-AdS** `https://arxiv.org/pdf/2304.12349`

The onging connection with the Qurios collaboration resulted in **From Shockwaves to the Gravitational Memory Effect** `https://arxiv.org/pdf/2305.14411.pdf`

2 Experiment

Lee McCuller authored **Single-Photon Signal Sideband Detection for High-Power Michelson Interferometers** `https://arxiv.org/pdf/2211.04016.pdf` This work extends and completes the description of techniques GQuEST uses to surpass the standard quantum limit.

2.1 Cryogenics

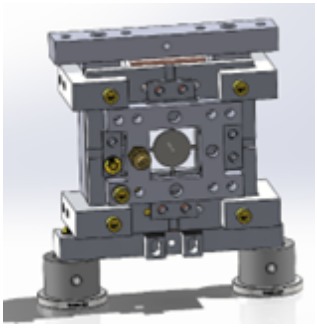

Figure 1: Mirror Mount

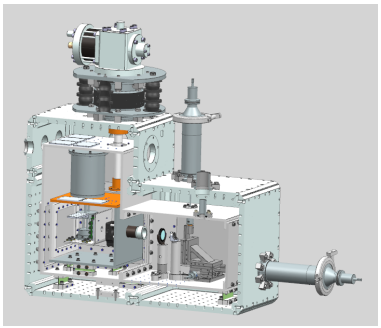

Figure 2: Cryogenic Readout Coupling.

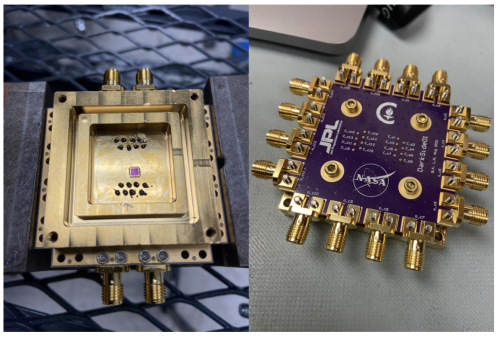

Fig. S7. Photographs of the detector packaging. The left photo shows the detector chip mounted. Care was taken to ensure no dielectric materials interfaced directly to the inner chamber. The right photo shows the PCB interface.

Figure 3: Detector Packaging

- At CIT, the mechanical design of cryogenic-compatible mirror mounts with coating-stress compensation trimming, with wavefront correction tuning, is near completion
- Cryogenic Readout Coupling designed at Fermilab in collaboration with CIT/JPL. Once mechanical layout is finalized, we will complete a simple thermal distribution calculation to ensure the thermal straps are properly sized, and then move to making fabrication drawings and procuring OTS items.
- The dark box for housing the SNSPD has been designed, fabricated, and tested at JPL.

  Coldhead and compressor have been received at CIT. We are leveraging INQNET/CIT collaboration. JPL collected quotes for additional components and sent them to Fermilab for procurement: cryoamps, custom filters, coaxes, and thermometry.

Figure 4: Readout test equipment

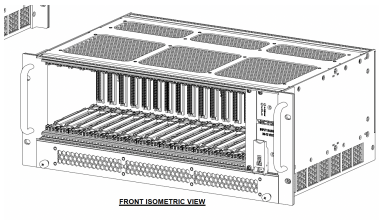

Figure 5: Crate for SNSPD circuits

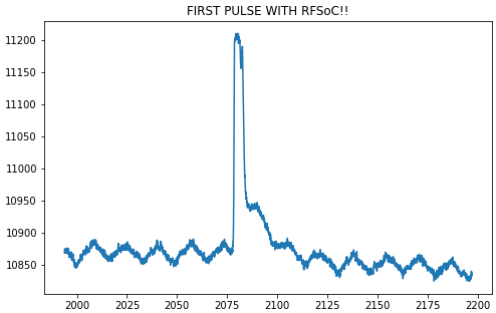

Figure 6: RFSoC Readout of SNSPD

2.2 Readout

- At CIT, detection efficiency setup has been started (laser, attenuators, switch, power meter), will be qualified prior to assembly of cryostat. We are leveraging existing control software developed at JPL.
- JPL and CIT started design of low noise biasing circuitry for SNSPDs which will be housed in commercial VME racks. We are leveraging NASA programs for rack procurement.
- Firmware and software written by Fermilab is used at JPL to read out single photon pulses from SNSPDs.

2.3 Optics

2.3.1 Simulation

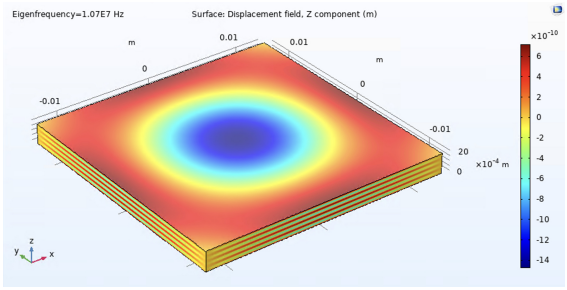

Figure 7: mirror simulation

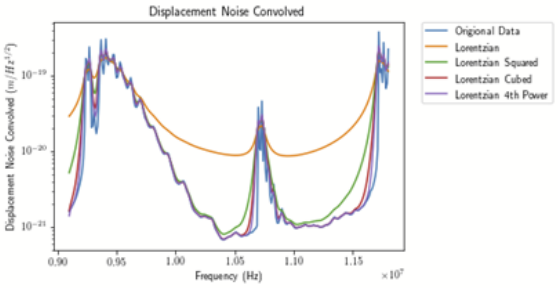

Figure 8: Noise Density

- LM's group has studied the thermal noise properties of GQuEST mirror geometries using COMSOL, finding additional bulk thermal modes to avoid, which are unexpected from the boundary conditions of simplified acoustic wave PDEs assumed in the proposals. The figure shows bulk acoustic mode shape at unexpected mid-frequency. This is promising as it shows clean regions of low noise.
- Spectral density showing excess in the center of otherwise-clean spectra region at 10.6MHz. Different plot colors show the effect of a series of filter cavities on the power spectral density.

2.3.2 Fabrication and Testing

The bowtie cavities (Figure 9) used for readout have been designed and fabricated at CIT. Optics and piezo controls have been ordered and are expected in 8-10 weeks.

LM's lab commissioned a test stand to evaluate laser frequency noise using a fiber Mach-Zehnder interferometer (fiber in lower left of Figure 10). Repurposing high-finesse cavities from Rana Adhikari (inside green vacuum chamber, image below), we are locking the cavities to study high-frequency noise suppression. We will migrate this setup to the GQuEST Bowtie cavities 9 once we have optics in 8-10 weeks (order placed).

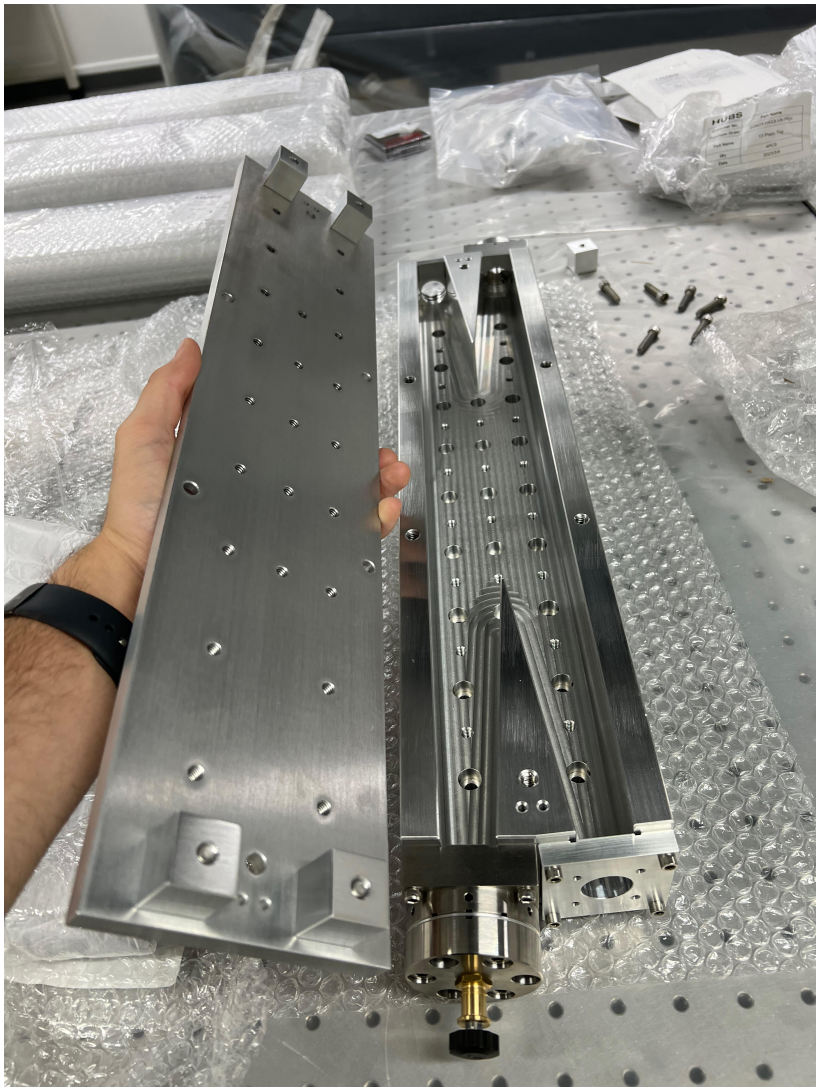

Figure 9: Bowtie Readout Cavity

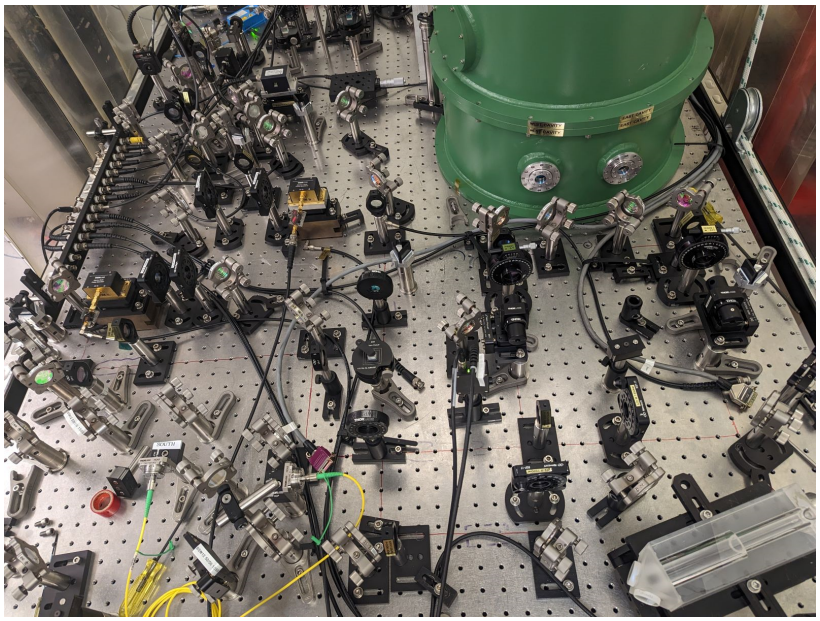

Figure 10: Test Stand