Testing of the 2.6 GHz SRF Cavity Tuner For The Dark Photon Experiment at 2 K

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Introduction

- At FNAL two 2.6 GHz SRF cavities are being used to search for dark photons, the experiment can be conducted at 2 K or in a dilution refrigerator.
- Precise frequency tuning is required for these two cavities so they can be matched in frequency.
- A cooling capacity constraint on the dilution refrigerator only allows piezo actuators to be part of the 2.6 GHz cavity tuner design.
- Modifications were implemented on the first tuner design due to the small preload from the cavity
- Three brass rods with Belleville washers were added to the design to increase the overall force on the piezos.
- Testing was conducted at FNAL in the vertical test stand (VTS)

Cavity Frequency Tuner

- Three long piezo capsules are used for resonance control
- The capsules each contain two $10 \times 10 \times 36$ mm stacks glued together; from 0 to 120 V the nominal displacement is 38 μm per stack and 76 μm per capsule at room temperature
- Prior to testing the piezos are preloaded by using the screws (see Fig. 1a) on the Ti bracket thus stretching the cavity and providing a load to the piezos
- The required preload per piezo was found to be 1 kN per piezo
- The force on the piezo is determined from the 35 kN/mm cavity stiffness and the 10 kHz/μm frequency longitudinal deformation sensitivity
- With proper preload the piezos can increase and decrease the cavity frequency (see Fig. 2a)

Initial Measurement and Original Design

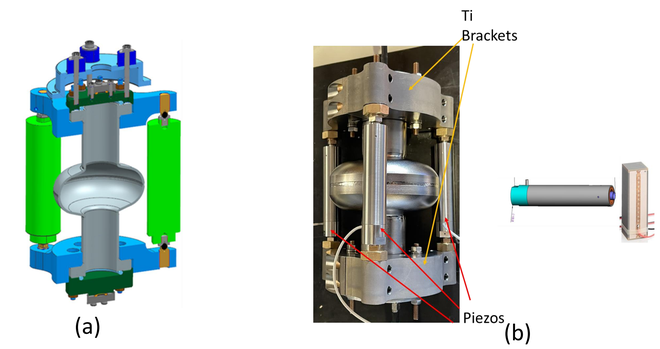

Figure 1: (a) Cross-section view of the cavity. (b) Picture of cavity with piezos installed. The picture of the actuator with a single stack is also shown.

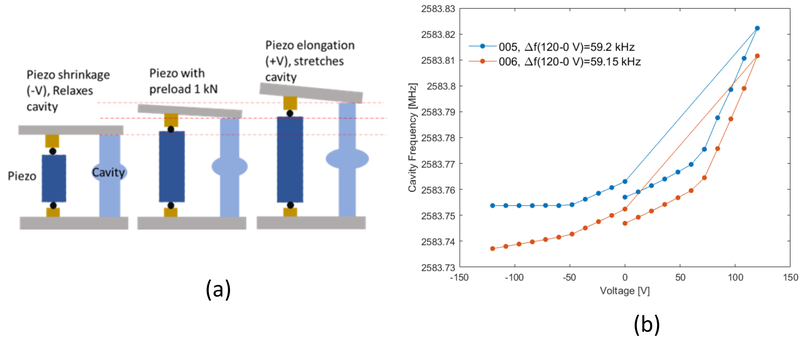

Figure 2: (a) Schematic of piezo with 1 kN preload. The piezo elongation under a positive voltage will cause the cavity to stretch. A negative voltage will relax the cavity. (b) Results of both cavities when the preload was 2.45 kN. Note that three different trend lines are observed .

- First test at 2 K resulted in a range of 10 kHz, the piezo preload was 1.05 kN (350 N per piezo), **frequency match was not possible**
  - This was attributed to different shrink rates such as the brass screws and pressure outside cavity volume changed from 293 K to 2 K
- A piezo preload of 2.45 kN (816 N) using the cavity yielded results (see Fig. 2b), not all the piezo stroke went to stretch the cavity, **frequency match possible**
  - Culprits: Same as previous test.
- A preload of 2.45 kN caused the cavity to overstretch into the inelastic limit
- The preload that the piezo can obtain from the cavity is limited by the inelastic limit, which is equivalent to 1.4 kN

Second Design

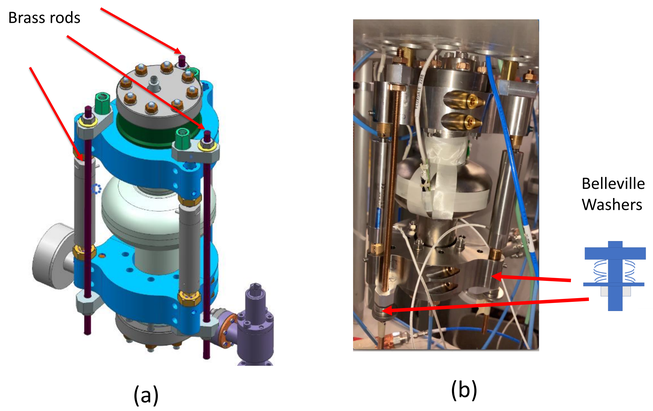

Figure 3 : (a) 2nd design of cavity tuner with brass rods. (b) Picture of cavity installed on the VTS insert, schematic of how the Belleville washers go on the brass rod.

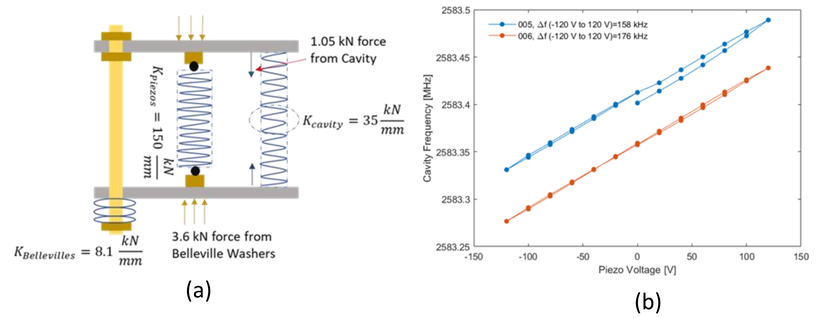

Figure 4 : (a) Schematic of the Belleville washers, piezos, and cavity equivalent stiffness. (b) Results of frequency change with piezo with the second design. The different curves are due to long wait times to get the data for the 005 cavity.

- The second design of the tuner used long brass rods and Belleville washer to compress piezo
- The Belleville washers act as a spring and were arranged to provide a stiffness of 2.7 kN/mm per rod
- The preload was set to 3.6 kN total (1.2 kN per piezo). The results of this design are shown in Fig. 4a, **frequency match possible**.
- With this preload the range is larger
- The difference are summarized in the table below

Table 1: (a) 2nd design of cavity tuner with brass rods. (b) Picture of cavity installed on the VTS insert, schematic of how the Belleville washers go on the brass rod.

	Total Forces on Piezos [kN]	Piezo Sens. [Hz/V]	Full Range [kHz]
1st Design	2.45	970	60
2nd Design	4.65	673	176 and 158

Conclusion

- Both cavities were tested with the Belleville washers design, frequency match between both cavities was possible
- This modification results in a frequency range of ~ 176 kHz compared to 60 kHz of the original design
- The Belleville washers provide most of the total force therefore the cavity doesn't need to be stretched to the inelastic limit

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