PI Loop Resonance Control For The Dark Photon Experiment at 2 K Using A 2.6 GHz SRF Cavity

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**Introduction**

- Two 2.6 GHz cavities are being used for dark photon search at VTS in FNAL.
- During testing at 2 K the cavities experience frequency detuning caused by microphonics and slow frequency drifts.
- These two cavities are equipped with frequency tuners consisting of three piezo actuators.
- A PI feedback loop was used to control the frequency of the emitter cavity.
- The integration time was also calculated with a simulation.

**Setup**

![Setup Image](image1)

**Table 1: Figures of merit of both cavities, the bandwidth is calculated using the loaded Qs.**

<table>
<thead>
<tr>
<th>Cavity</th>
<th>R/Q [Ω]</th>
<th>Bandwidth [Hz]</th>
<th>Qs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emitter</td>
<td>104.7</td>
<td>5.84</td>
<td>4.42 × 10⁹</td>
</tr>
<tr>
<td>Receiver</td>
<td>104.7</td>
<td>0.56</td>
<td>6.46 × 10⁹</td>
</tr>
</tbody>
</table>

**Figure 1:** (a) Left picture shows the setup of the experiment. The right picture shows a schematic of the process of dark photon production and detection. (b) Actual cavity setup.

**Figure 2:** Setup of the PI loop for the emitter cavity.

**Figure 3:** (a) Frequency stability of the receiver cavity using a network analyzer. The cavity frequency drift can be linear or can plateau. (b) Frequency stability of the emitter cavity with a gradient of 15 MV/m and piezo DC voltage of 108 V.

- **Figure 4:** (a) Frequency drift of the emitter cavity is shown in blue and for the receiver it is shown in red. A frequency counter is used to record the frequency on the emitter and NA for the receiver. (b) Voltage of the piezos on the emitter cavity with PI algorithm.

**Integration Time Simulation**

- The purpose of this simulation is to estimate the field inside the receiver cavity considering the slow frequency drift.

**Conclusion**

- Result with PI resonance control on the emitter reduce the slow drift from 657 Hz/hr to 0.1 Hz/hr.
- This improvement in frequency stabilization improved the frequency matching capability which will greatly help increase the dark photon detection sensitivity.
- Simulation results show that even with a PI loop after 1 hour the field of the receiver drops to 15 % of its initial value.
- A constrain of integration time is calculated to be about ~200 s.