2024 SURF Interim Report I

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Introduction

As part of the QGuEST experiment, I have been working on designing a new detection apparatus based on a new photon counting technique that will provide the necessary sensitivity to detect the predicted geontropic fluctuations in the metric of spacetime.[1] This apparatus, which will be able to distinguish between the desired signal and other sources of noise, is composed of an atomic cavity. Using an atomic cavity, as opposed to an optical cavity, will reduce signal loss and improve the filtering effect of the incoming light. This cavity uses a laser-cooled cloud of Rubidium atoms in a 4-mirror setup that creates a self-intersecting quadrilateral, with two consecutive mirrors being curved and the other two being flat. Two of the mirrors were curved in order to focus the incoming laser beam to a minimum waist, which is where the beam reaches its lowest beam size. This is done in order to increase the probability of an interaction between the incoming photon and an Rb atom, which is what will be used to readout the signal. This will work by determining if the 5s valence electron of the Rb atom is an excited state, which would indicate that it absorbed the signal photon as desired.

Approach

In order to help design the 4-mirror cavity, I have been using Finesse-3 on Python to model the beam profile of the setup with varying lengths and angles. The goal of this simulation is to determine the best configuration to minimize the beam size at the waist, as can be seen by the dip in Figure 1. Issues have come up in making sure that the cavity is stable, but this has been resolved with the help of members of the lab group.

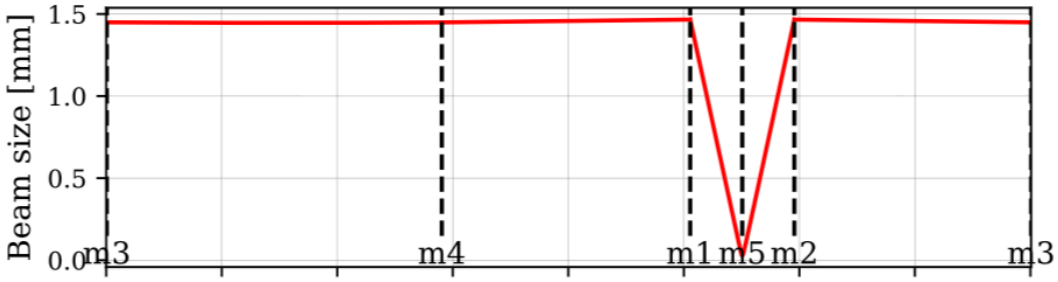

Figure 1: Plot of Beam size based on lengths between the fours mirrors, their angles, and the radii of curvature of the two curved mirrors (m1 and m2). M5 is simply used as a reference point to readout the beam size.

[1] Vermeulen, Photon Counting Interferometry to Detect Geontropic Space-Time Fluctuations with GQuEST

Conclusion

The ultimate goal is to design an atom cavity with a focused beam, which is important because it will allow for the sensitivity necessary to make the desired detection.

Acknowledgments

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Works Cited

- Vermeulen, S. M., Cullen, T., Grass, D., MacMillan, I. A., Ramirez, A. J., Wack, J., ... & McCuller, L. (2024). Photon Counting Interferometry to Detect Geontropic Space-Time Fluctuations with GQuEST. *arXiv preprint arXiv:2404.07524*.