Status of the CASCADE Microwave Cavity Experiment

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The CASCADE experiment is a "light shining through a wall" (LSW) experiment consisting of microwave cavities. It is dedicated to search for photon oscillations into hidden sector photons (HSP). The main measurement setup consists of two normal conducting TM_{010} pillbox cavities at 1.3 GHz. In this paper we present the planned measurement campaign that is divided in four main phases.

1 Introduction

The CASCADE (CAvity Search for Coupling of A Dark sEctor) experiment utilizes microwave cavity technology to search for the new particle interactions. The method that is used is a "light shining through a wall" (LSW), where the detector cavity will be isolated from the emitting cavity and from external RF sources. Since the cavities are identical and tuned to same resonance frequency, the possible signal in the detector cavity could be identified to be originating from photon-HSP-photon oscillations.

2 Measurement Setup

The main parts of the measurement setup are the two pillbox cavities that are used to study the photon HSP oscillations. The cavities are normal conducting copper cavities that are powered in the first transverse magnetic mode (TM_{010}) at 1.3 GHz. With the cavities, the complexity of the measurement setup can be increased in stages with the main goal to replace the measurement setup with two superconducting cavities [1].

Schematic of a CASCADE cavity can be seen in Fig. 1. The cavities were designed by using CST Microwave Studio. With the program it was estimated that the cavities can have Q-values of up to 22 000 at the room temperature. The cavities are tunable in the range of 100 MHz and have a bandwidth of 330 kHz.

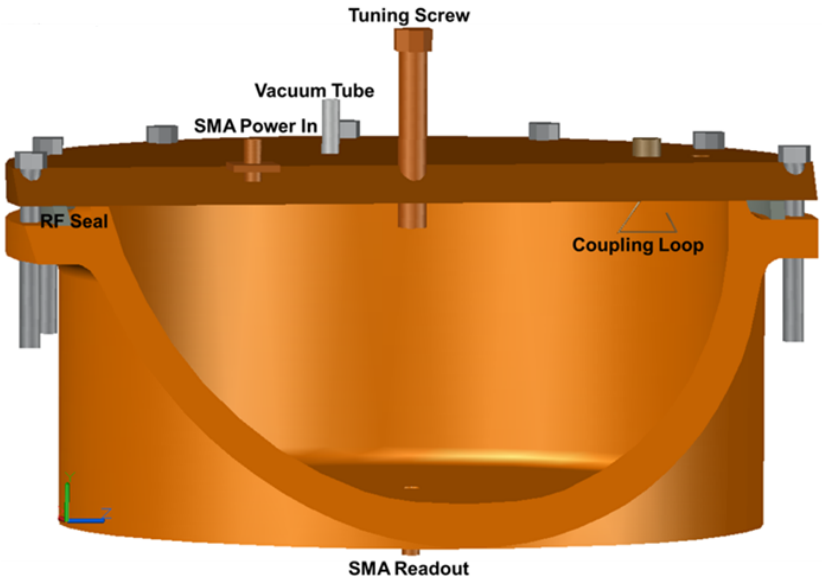

Figure 1: CAD model of the CASCADE pillbox cavity.

The measurement setup is adapted from [2]. Schematic of the setup can be seen in Fig. 2. It consists of a signal generator and a signal analyzer which are frequency locked by 10 MHz reference. The signal generator can produce input power of up to 10 mW which is fed into the source cavity. Both the detector and the source cavities are placed inside a RF shielding box. The required attenuating shielding between the cavities is at least 220 dB. With this shielding, measurements of signal powers of the order of 10^{-25} W can be done.

The signal analyzer will perform the fast Fourier transformation and the data taking. In the early measurements it was discovered that the signal analyzer produces an internal 1.3 GHz signal which has signal power of the order of -140 dBm. Because of this, the exact 1.3 GHz frequency cannot be used in the measurements, so the cavities were tuned slightly off from this frequency. Test measurements showed that the signal analyzer was already able to make a clear isolation between the peaks, when the off-tuning was only 1 Hz. Since the internal signal has been measured to be stable and almost constant in signal power, it is used as a reference in the measurements.

3 Measurements

The measurements will be divided in four main stages, each introducing more sensitivity and more complexity to the overall setup. The division in stages is done to better understand the requirements and effects of new elements in the setup.

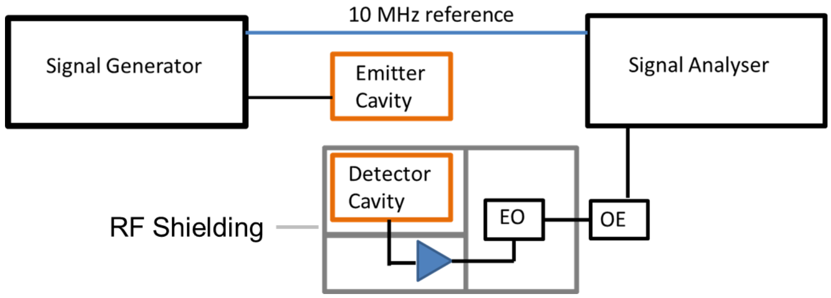

Figure 2: Schema of the measurement setup. The amount of shielding around the detector cavity will be increased according to the requirements of the measurements. Also the optical conversions will not be used in the first measurements but will be developed and implemented when required.

3.1 Stage 1

The first stage of measurements will be done at room temperature. In this stage, the cavities are first isolated with a minimal shielding which is then increased gradually. The main focus in this stage is to study the shielding requirements between the cavities since the amount of shielding cannot be increased in the later stages. To monitor the shielding quality, a set of patch antennas will be placed inside the shielding structures to monitor the attenuating power and to locate the possible RF leaks. Since the emitter and the detector cavity will be in room temperature, this stage also allows the studies of effects of varying the distance and positioning of the cavities.

3.2 Stage 2

To increase the overall Q-value of the system, the detector cavity will be placed inside a liquid nitrogen cryostat. This will increase the detecting sensitivity of the of the cavity since the thermal noise is reduced. Also, since the cavity will be inside a vacuum box that is placed in the cryostat, the RF shielding between the cavities is increased significantly. The flask where the cavity is placed can hold the 77 K temperature for several weeks and allows long duration measurements to be performed.

3.3 Stage 3

The third stage can be seen as an intermediate stage between using plain normal conducting cavities and using superconductive cavities as part of the setup. In this stage, both pillbox cavities will be placed inside the liquid nitrogen cryostat. Since the shielding between the cavities was already optimized in the first stage and since the input power is not increased, the setup will improve the combined Q value of the system. Although there will be some improvements in the overall sensitivity, the detection probability will not improve significantly since there is no changes in the detector cavity. The main goal in this stage is to study the stability and performance of the two cavity system before it is used as combined detector in the next stage.

3.4 Stage 4

In the fourth stage the two pillbox cavity setup will be used as a single detector for superconducting emitter. At the Daresbury Laboratories, a single cell 1.3 GHz superconducting niobium cavities were developed as part of the STFC Industrial Programme Support Scheme [3]. These cavities are operated in $TM_0 10$ mode and can reach Q values of 10^{10}. They also allow input powers over 100 W. By combining the two pillbox cavities as detector for the superconducting emitter, unprecedented regions can be charted in the exclusion plot. Figure 3 shows the expected reach of each planned measurement stage of the CASCADE measurement campaign.

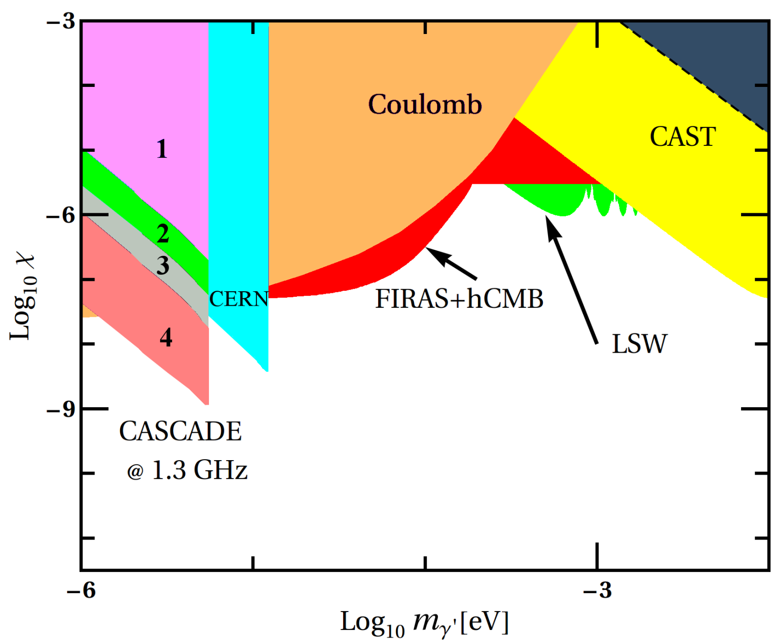

Figure 3: Expected reach of the four measurement stages.

Acknowledgments

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