Status report of Microwave Cavity Hidden Sector Photon searches at The University of Western Australia

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We report on the latest work on microwave frequency hidden sector photon searches performed at The University of Western Australia (UWA). This includes recent efforts to design an experiment to try and constrain the strength of photon / hidden sector photon mixing via measurements of resonance frequency shifts in a pair of microwave resonant cavity structures.

1 Light shining through a wall

One of the most sensitive laboratory-based search techniques for hidden sector photons (and similar particles) is the Light Shining through a Wall (LSW) experiment, whereby photons are generated on one side of an impenetrable barrier and then photon detection is attempted on the other side, presumably having crossed the barrier by mixing with hidden sector photons. In the microwave domain, mode-matched resonant microwave cavities can be used for the generation and detection of photons (Fig. 1). Experimental sensitivity is ultimately dictated by cavity design and losses, amount of power in the emitting cavity and noise in the detecting cavity and readout electronics.

In our most recent work the emitting cavity was a room temperature copper cavity housed in a vacuum chamber. A loop oscillator circuit and temperature control was used to prevent frequency drifting. The detector cavity was a superconducting niobium cavity operated at 4 K, the first stage amplifier had a noise temperature of 4 K. The TM_{020} resonant mode was used with a frequency of 12.8 GHz. Bounds obtained for photon-hidden sector photon mixing are shown in Fig. 2 [1].

2 Hidden Sector Photon coupling of resonant cavities

LSW experiments focus on the one way flow of hidden sector photons from a driven emitter cavity to an undriven detection cavity. However, it is also possible to treat the two-way exchange of hidden sector photons as a weak coupling between the cavities, creating a system analogous to two spring-mass oscillators connected via a third weak spring. When both cavities are actively driven the hidden sector photon mediated coupling will cause a phase-dependent

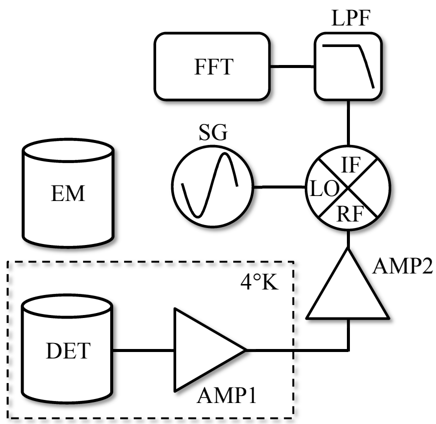

Figure 1: Schematic of detector cavity and readout circuit for a LSW search. FFT = Fast Fourier transform vector signal analyzer, LPF = low pass filter, SG = signal generator and AMP = amplier. The dashed rectangle represents the cryogenic environment..

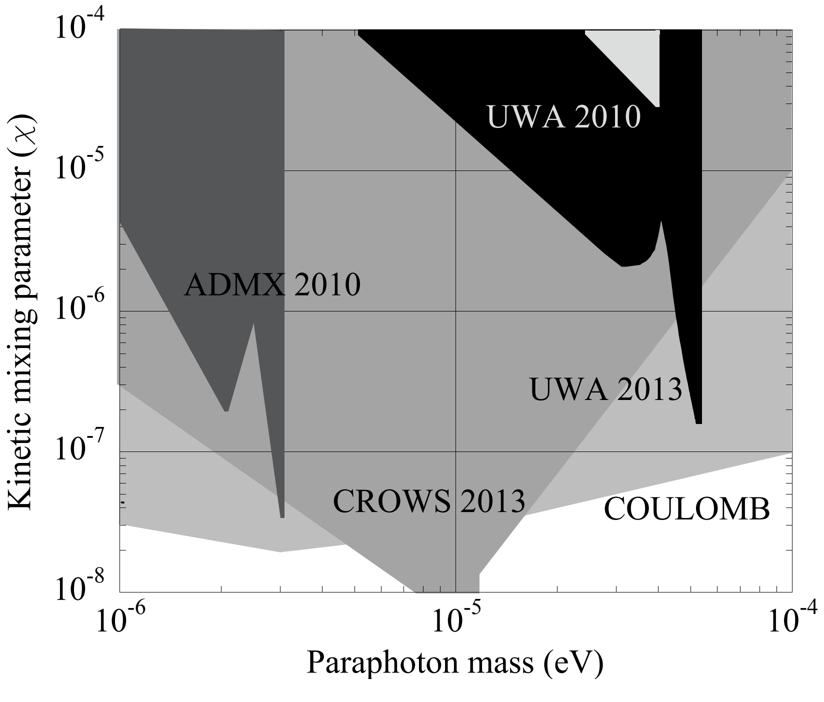

Figure 2: Limits on the kinetic mixing parameter, χ, as a function of hidden sector photon mass. The mass range corresponds to frequencies from 240 MHz to 24 GHz. Different shaded regions correspond to bounds obtained by other experiments, with the bounds from this work presented in black.

shift in the resonance frequencies and quality factors of the system. This opens up the possibility of conducting experiments that constrain the strength of photon-hidden sector photon mixing by observing this coupling induced resonant frequency shift. With careful experimental design these searches could be more sensitive than standard LSW measurements [2].
The effect on the cavity resonance frequencies due to coupling is demonstrated in Fig. 3. Strength of the coupling can be manipulated through alterations or modulations of the two cavity fields, geometries and relative positions. Figure 4 sketches out how an experiment could be made to constrain the kinetic mixing parameter, χ, with a measurement of frequency.

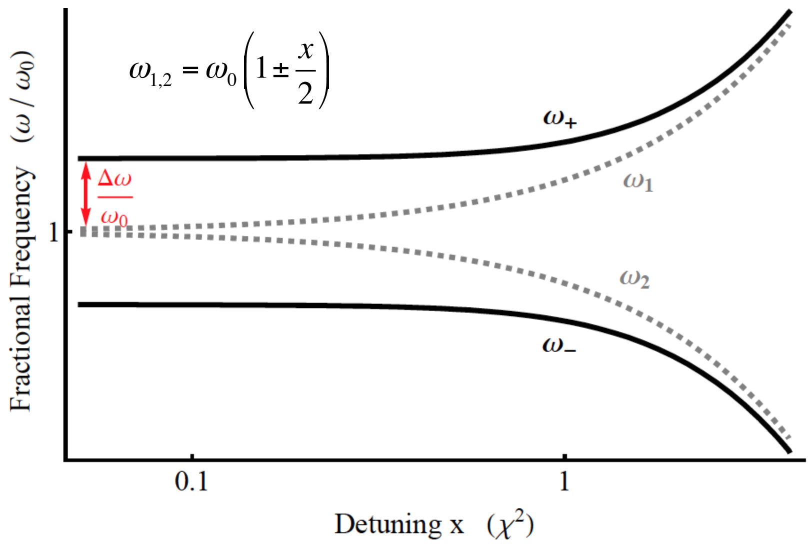

Figure 3: Log-Log plot of resonant frequencies relative to a common central frequency, ω_0, as a function of detuning for a pair of cavities that are coupled (black, full) and uncoupled (gray, dashed). The detuning, x, is given as a factor of the square of the hidden sector photon kinetic mixing parameter, χ.

3 Other work

Ongoing areas of research include new measurement techniques for microwave cavity-based axion and WISP searches and further development of hidden sector photon resonant cavity coupling and LSW experiments.

4 Acknowledgments

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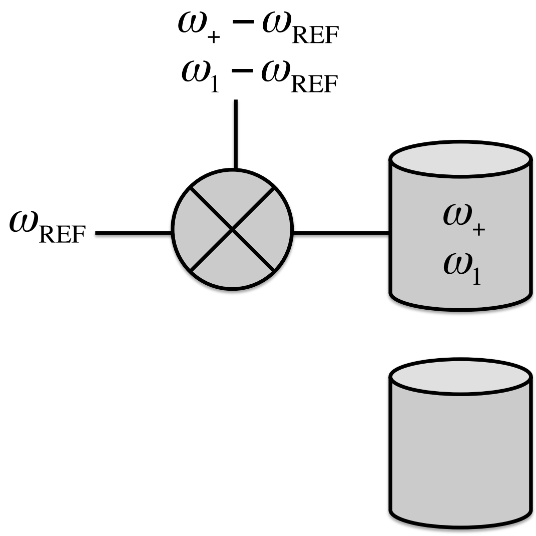

Figure 4: Sketch of experimental concept. The top cavity is compared against a stable frequency reference while the bottom cavity is used to manipulate / modulate the strength of the coupling. The resonance frequency of the top cavity will change between ω_+ and ω_1.

References

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