THE UNIVERSITY OF WESTERN AUSTRALIA

Hidden Sector Photon Cavity Experiments at UWA

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Overview

- Light Shining Through a Wall (LSW) V2
- Frequency Coupling

Parker et al, In Preparation (2013)
Parker, Rybka & Tobar, Phys. Rev. D. **87** 115008 (2013) [arXiv:1304.6866]

Previous Work

- LSW V1 (room temperature)
- Power Threshold Crossing

Povey et al, Phys. Rev. D., **82** 052003 (2010) [arXiv:1003.0964]
Povey et al, Phys. Rev. D., **84** 055023 (2011) [arXiv:1105.6169]

Hidden Sector Photons

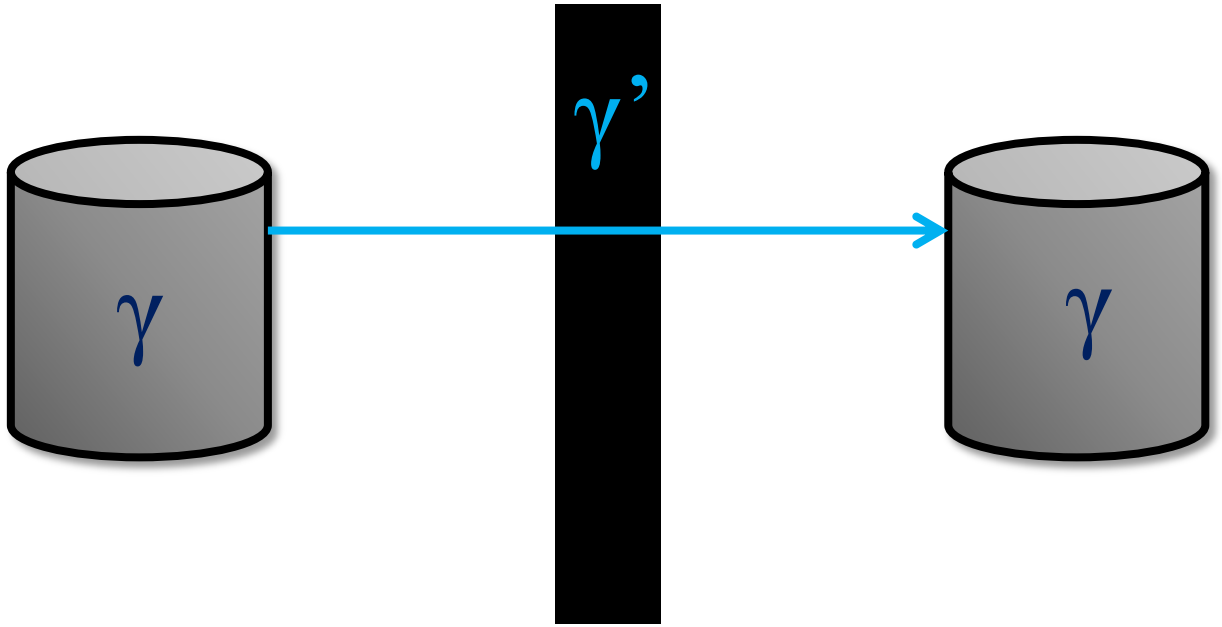
Axion-like particle, weakly coupled to the photon.

Big experimental difference: don't need a magnetic field.

$$\mathcal{L} = -\frac{1}{4} F^{\mu\nu} F_{\mu\nu} - \frac{1}{4} B^{\mu\nu} B_{\mu\nu} - \frac{1}{2} \chi F^{\mu\nu} B_{\mu\nu} + \frac{1}{2} \left(\frac{c}{\hbar} m_{\gamma\prime} \right)^2 B^{\mu} B_{\mu}$$

photon paraphoton mixing mass

Light Shining Through a Wall (LSW)

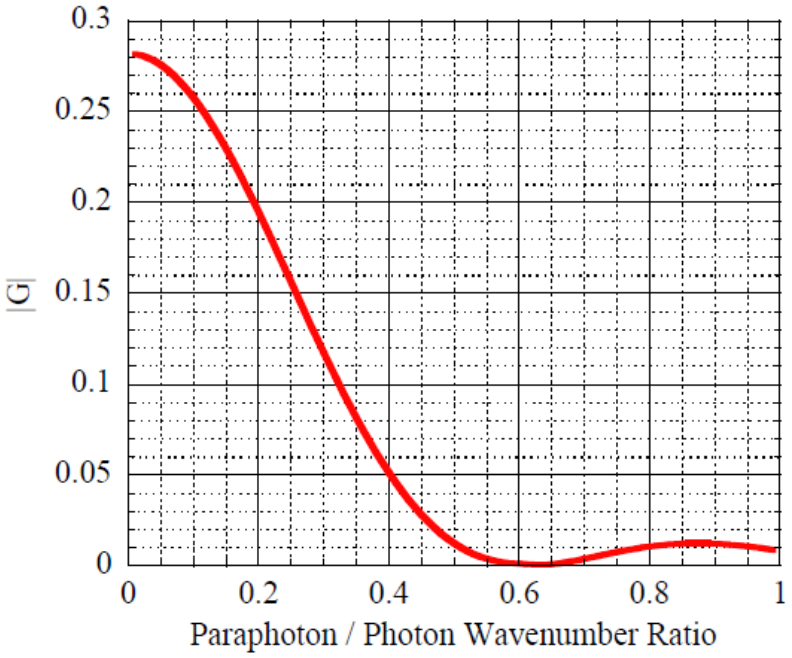


LSW Sensitivity

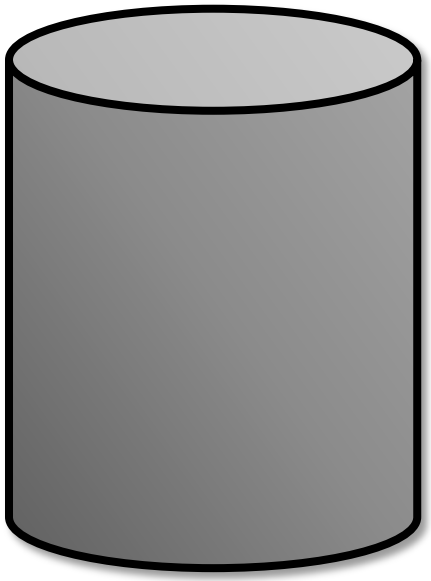
$$\mathbb{P}_{\text{trans}} = \frac{P_{\text{det}}}{P_{\text{emit}}} = \chi^4 \, Q_{\text{emit}} \, Q_{\text{det}} \left(1 - \frac{k_{\gamma\prime}^2}{k_\gamma^2}\right)^4 |\mathcal{G}|^2$$

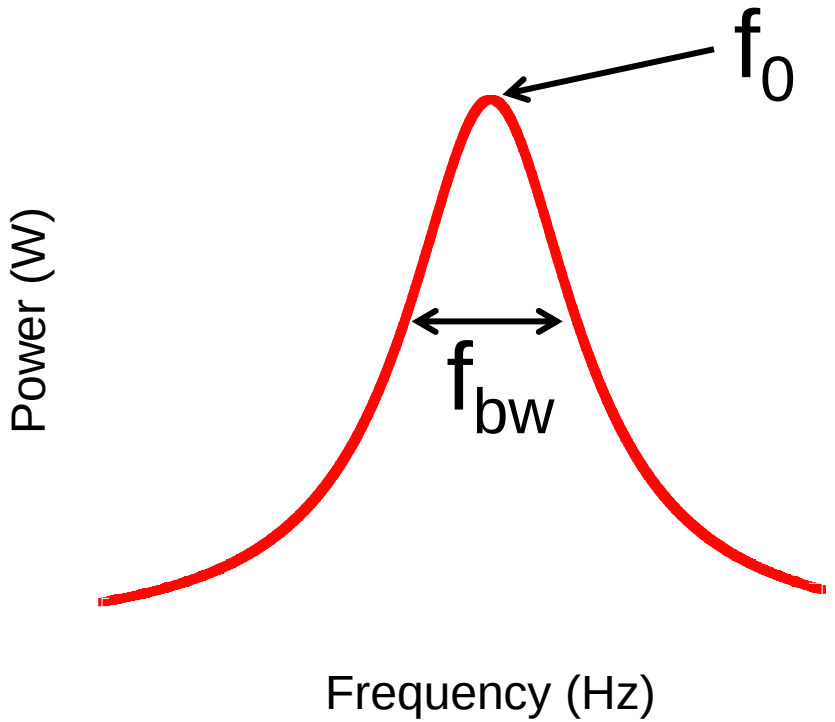
$$\mathcal{G}\left(\frac{k_{\gamma\prime}}{k_\gamma}\right) = k_\gamma^2 \oint_{V_{\text{emit}}} \oint_{V_{\text{det}}} \frac{\exp(i\, k_{\gamma\prime}\, |\mathbf{x} - \mathbf{y}|)}{4\pi |\mathbf{x} - \mathbf{y}|} \, \boldsymbol{A}_{\text{emit}}(\boldsymbol{y}) \cdot \boldsymbol{A}_{\text{det}}(\mathbf{x}) \, \mathrm{d}^3\mathbf{x} \, \mathrm{d}^3\boldsymbol{y}$$

- High Q
- Need to detect low levels of power
- Keep cavities frequency tuned



Microwave Cavities – quick summary





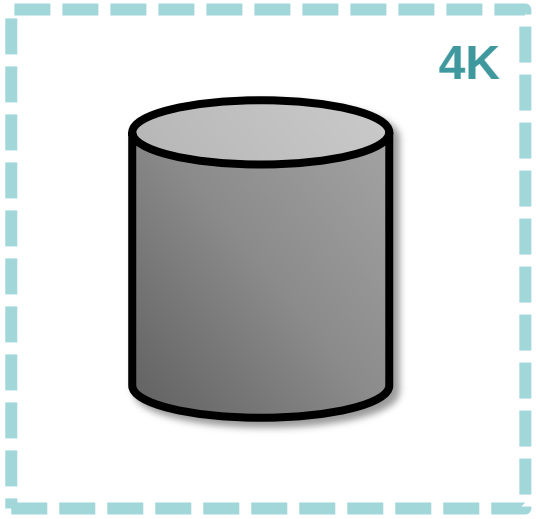
$$Q = f_0 / f_{bw}$$

$$Q = 10^5 \quad f_0 = 10\ \text{GHz} \quad f_{bw} = 100\ \text{kHz}$$

TM_{020} Resonant Mode

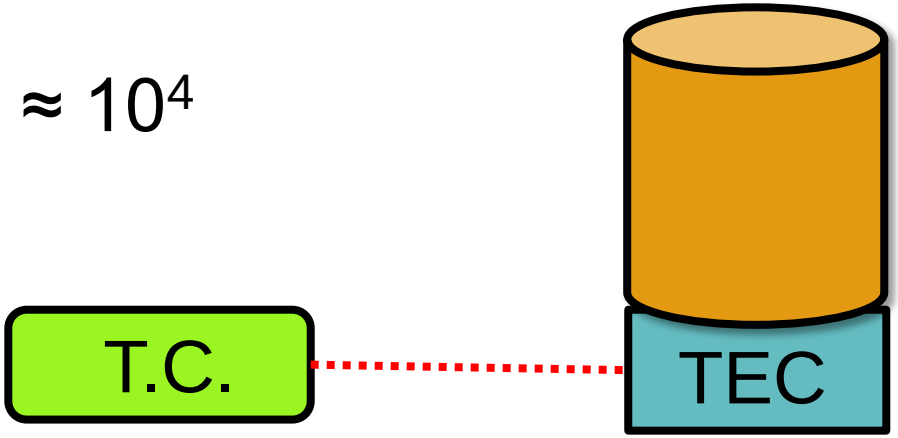
$f_0 \approx 12.8$ GHz

$Q \approx 10^5$

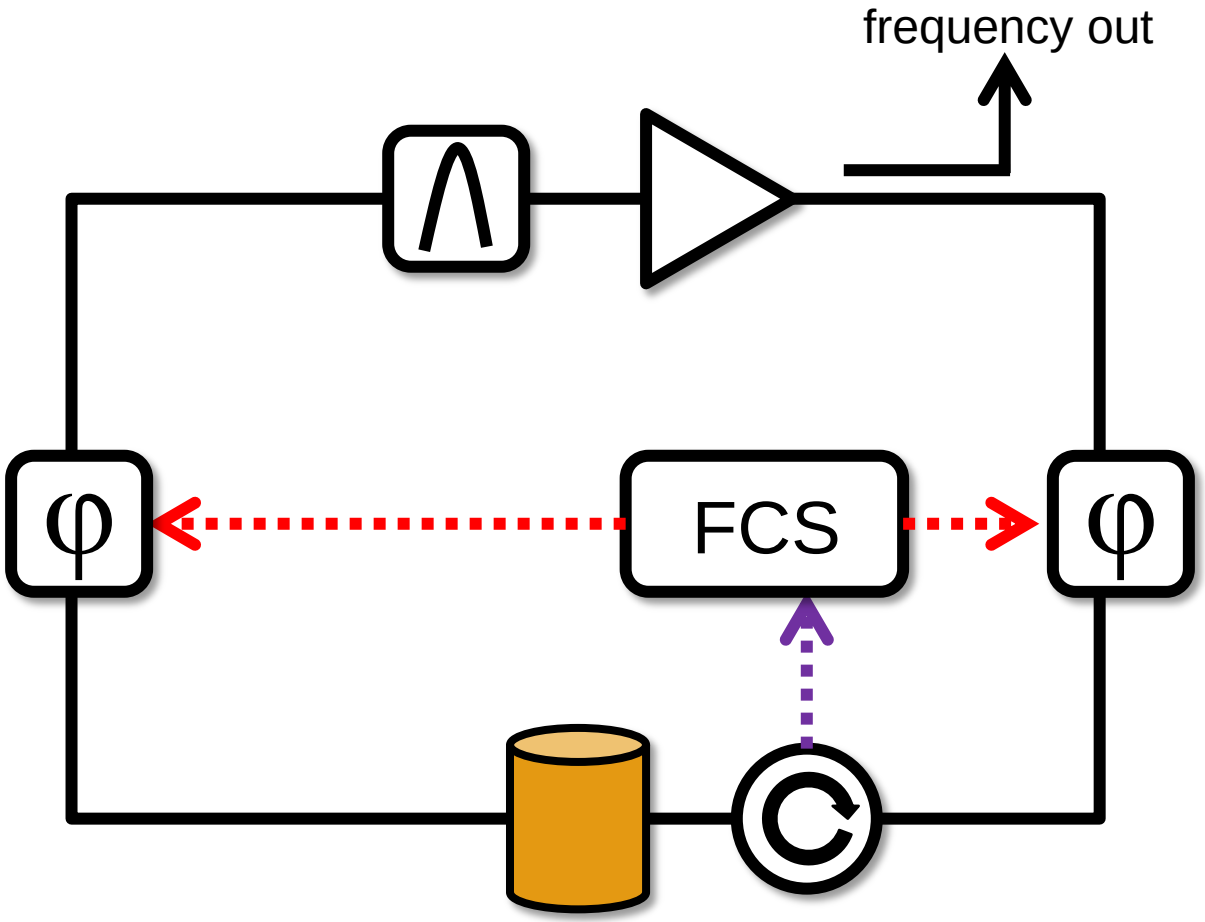


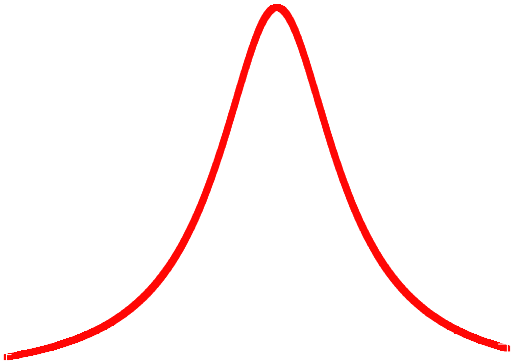
Detector

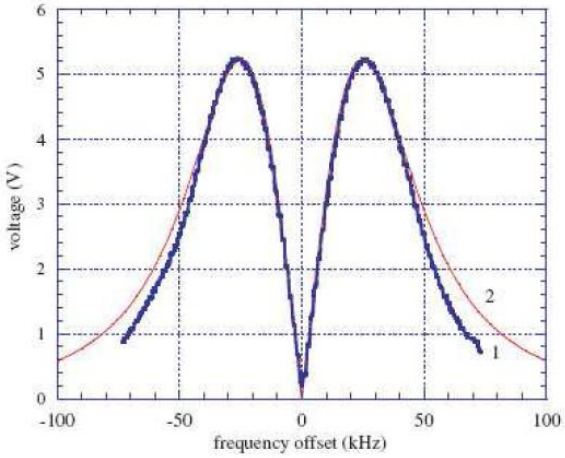
$Q \approx 10^4$



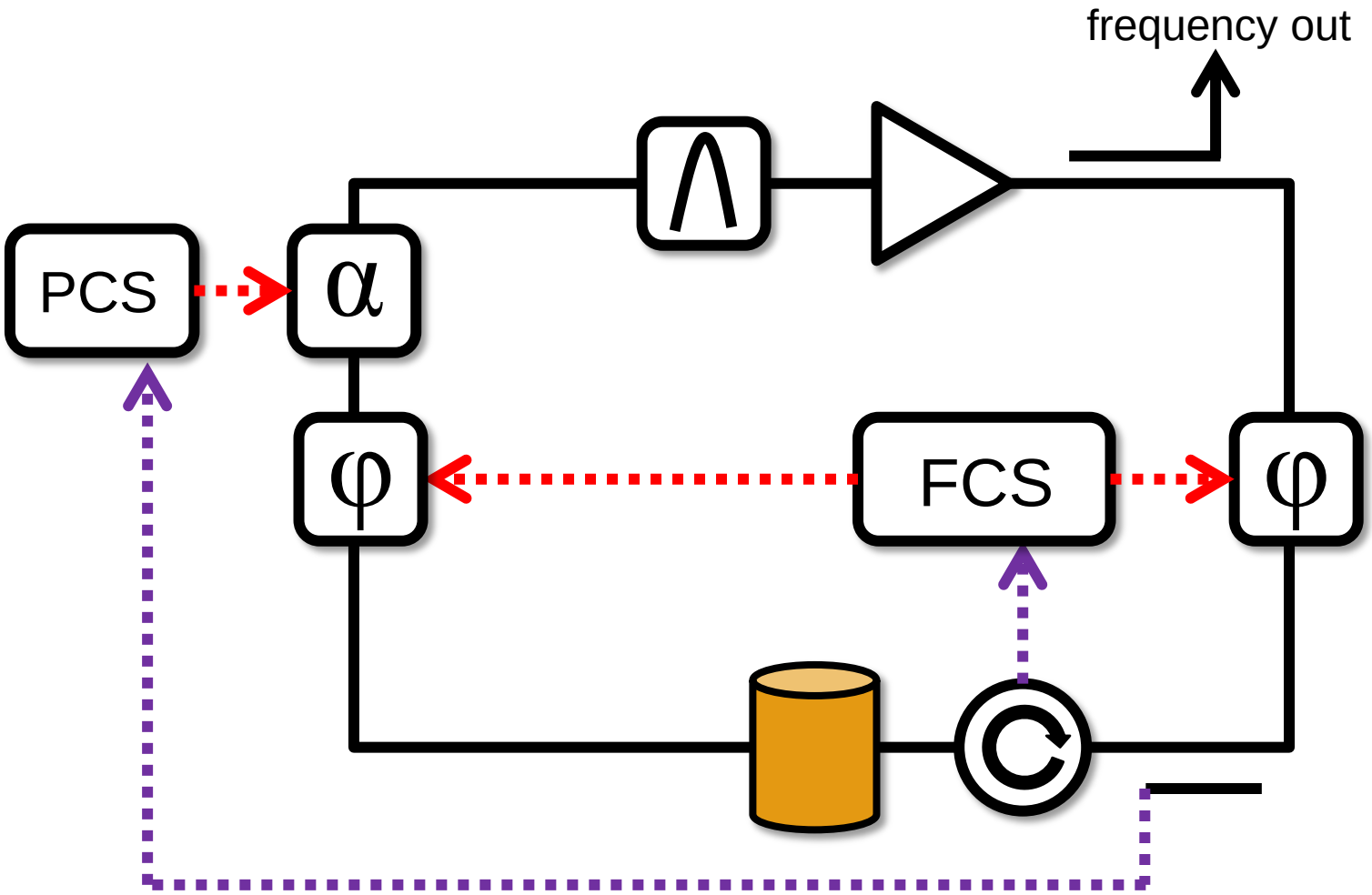
Emitter



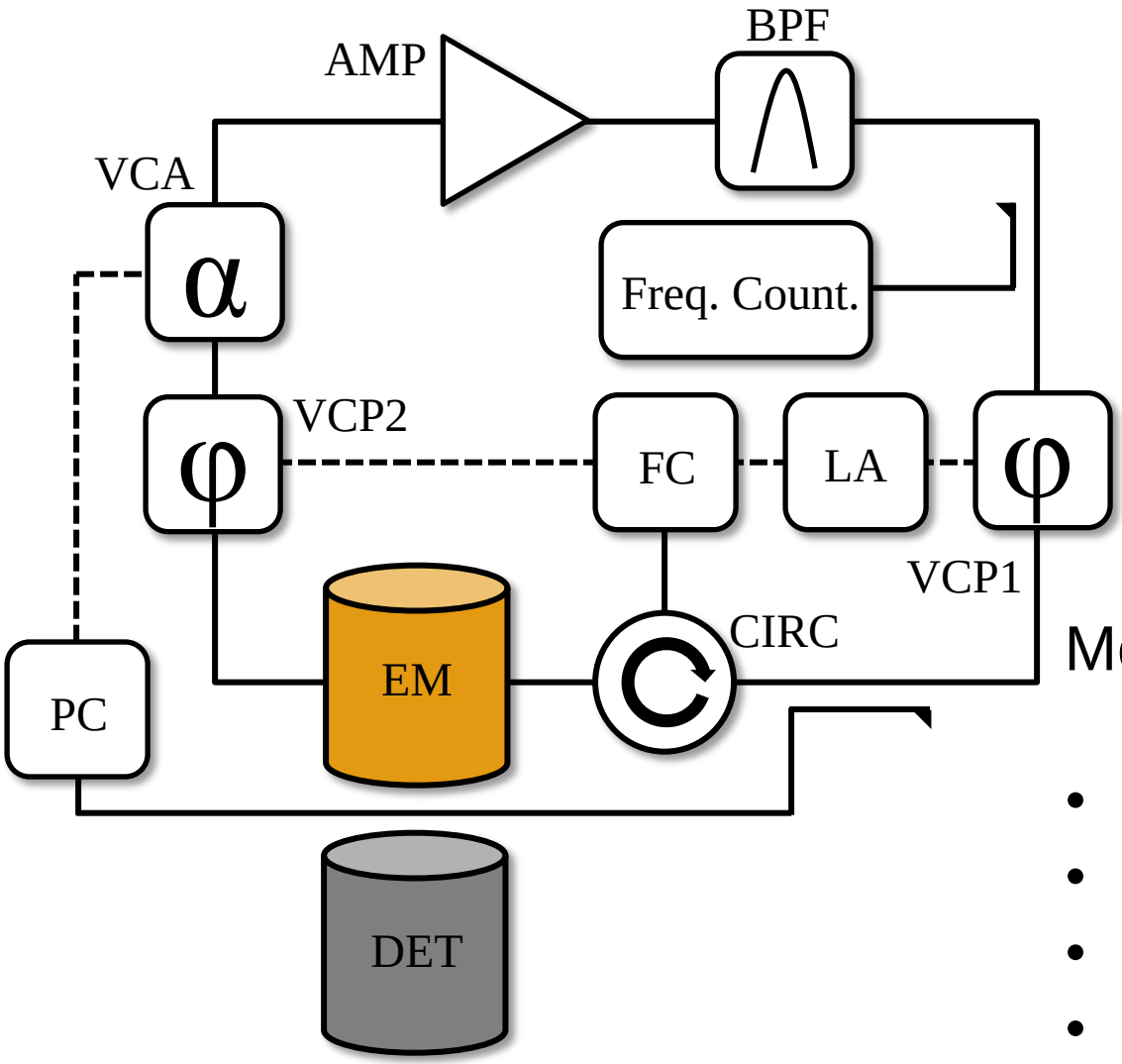




Frequency Control System



Power Control System



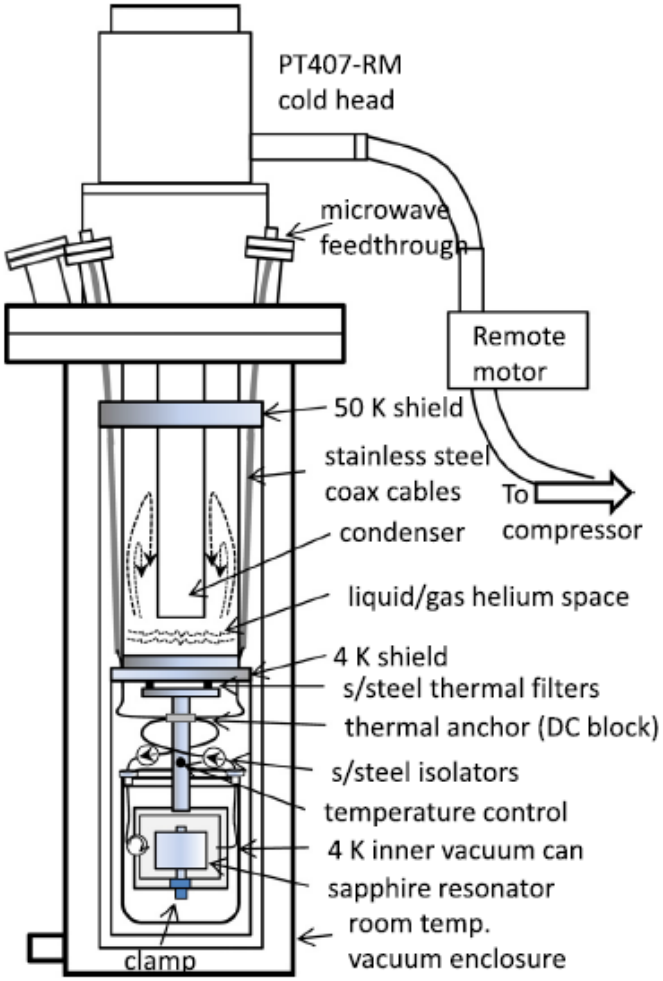
Cavity power ≈ 3 mW

TEC + sensor allows frequency tuning via temperature control

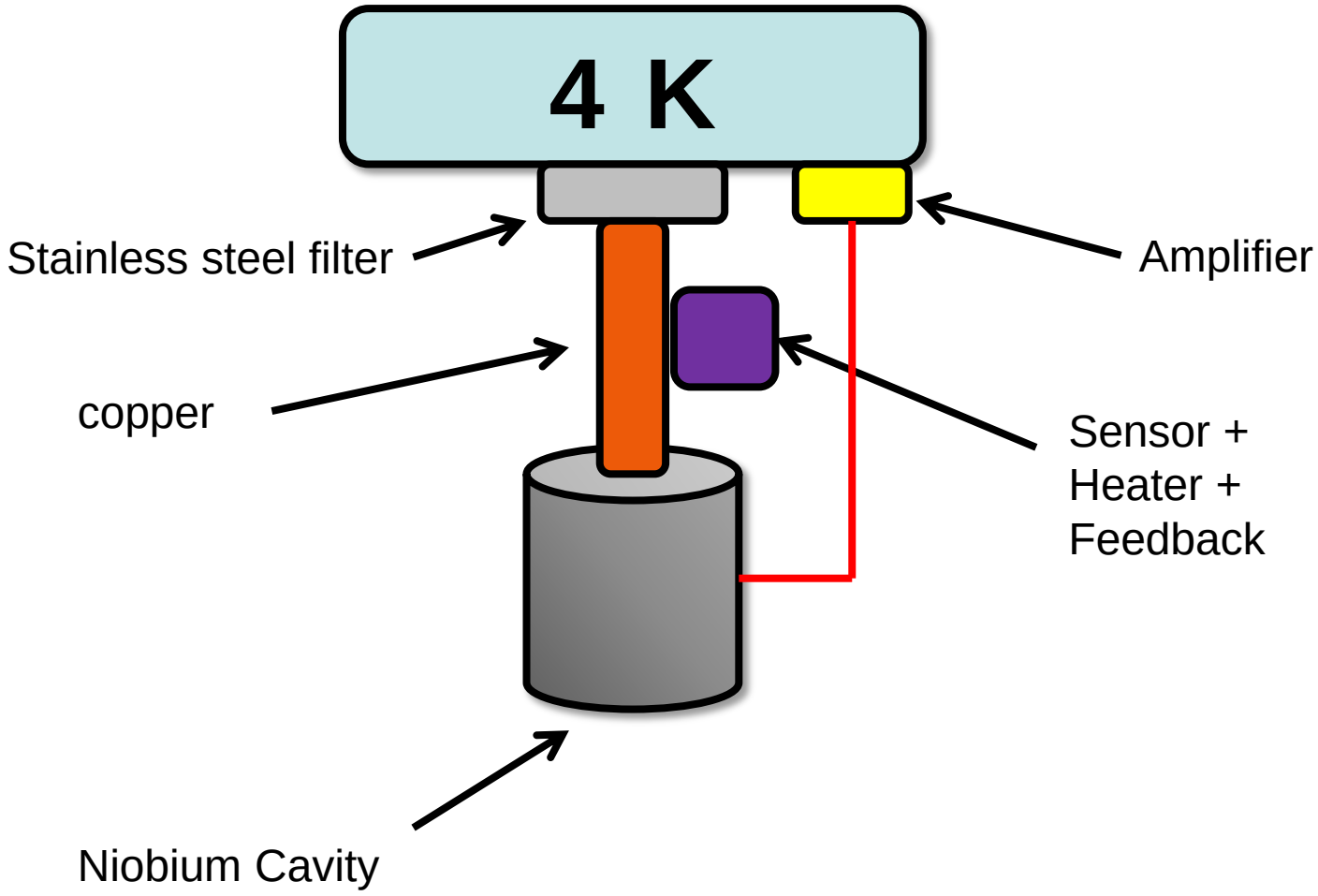
Monitor:

- Resonance Frequency
- Power Incident
- Power Reflected
- Power Transmitted

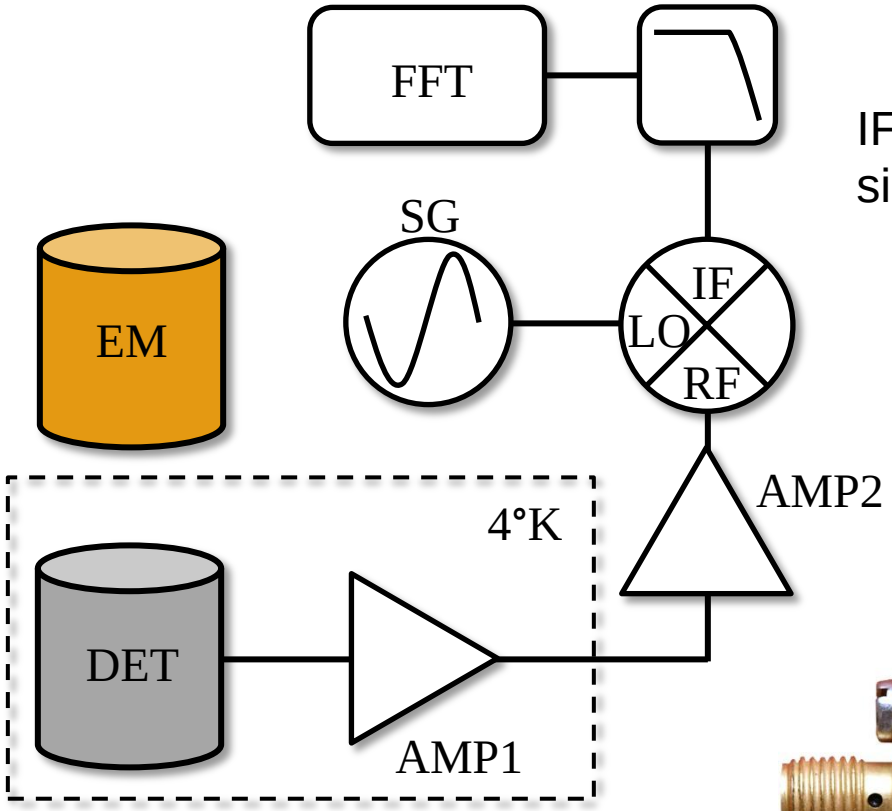
Cryogenic System



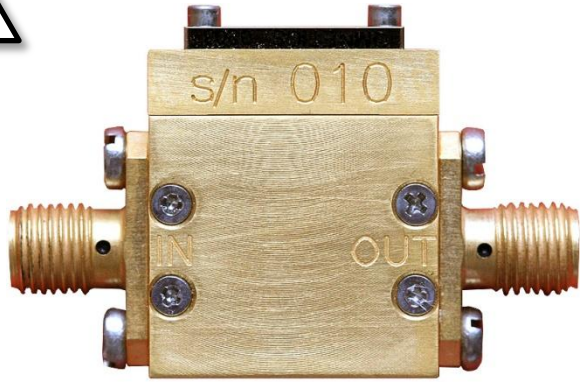
Cryogenic System

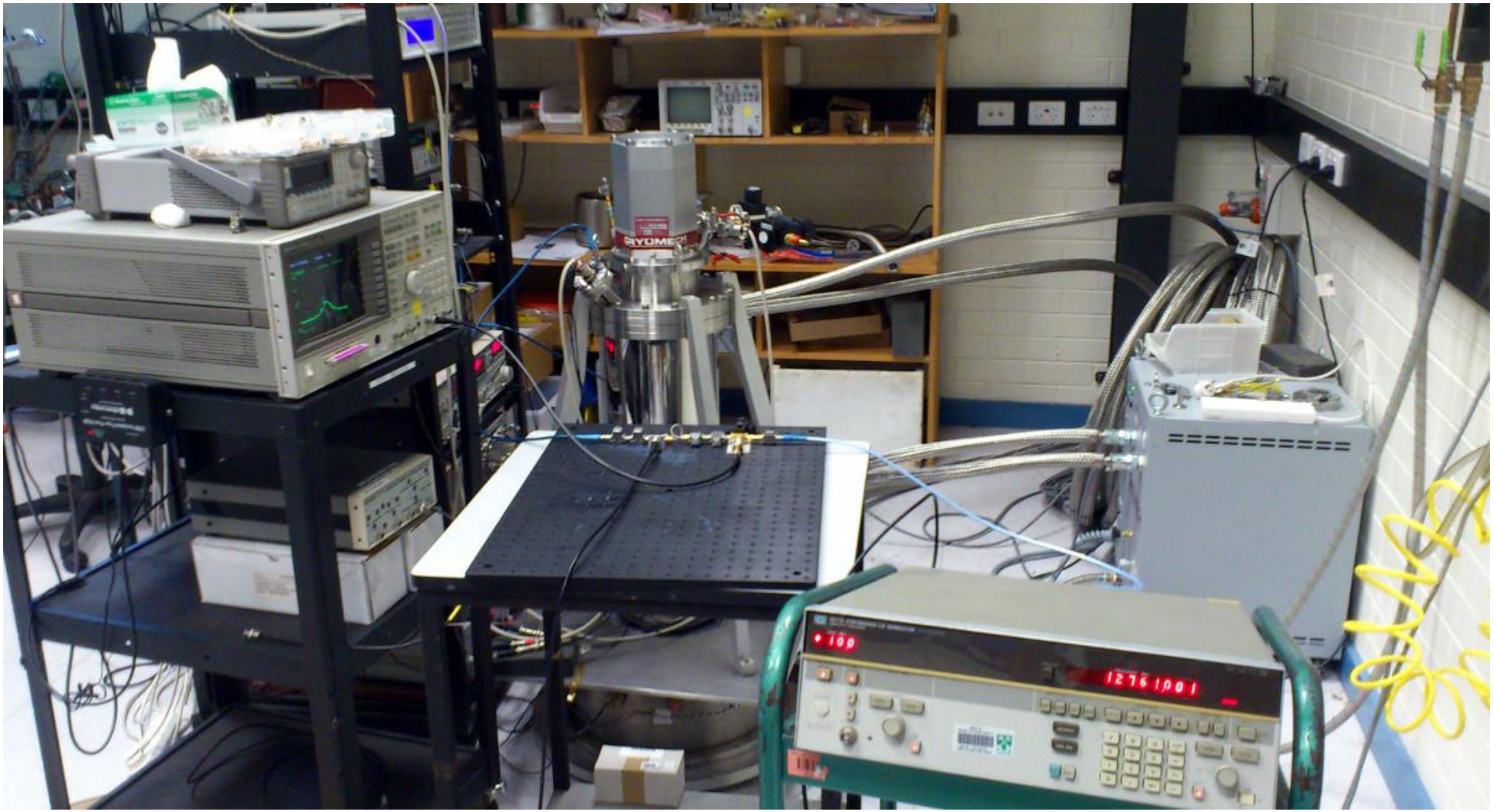


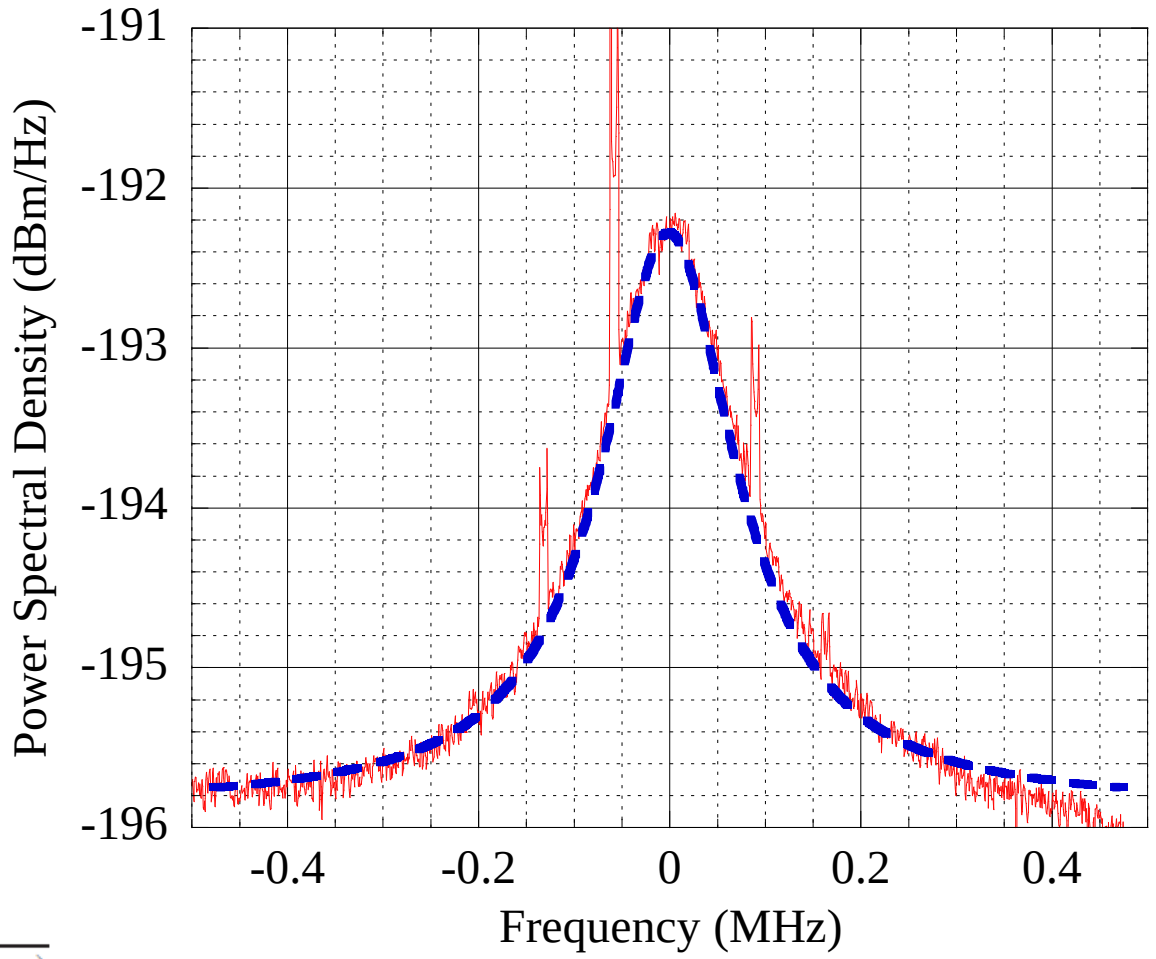
Detection System



IF = Low frequency signal at 1.7 MHz



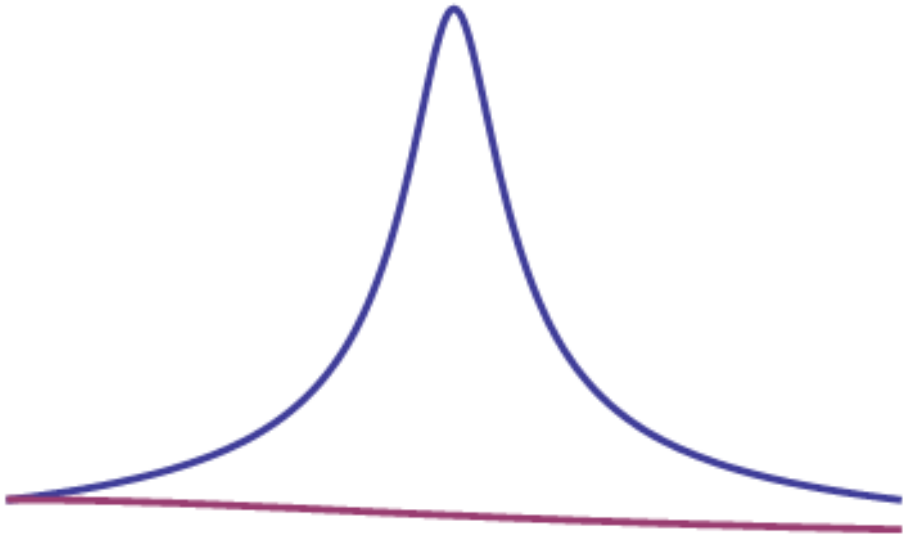

CRYOMECH



$$N = \frac{k_B T}{2} |\mathcal{T}(i\omega)|^2$$

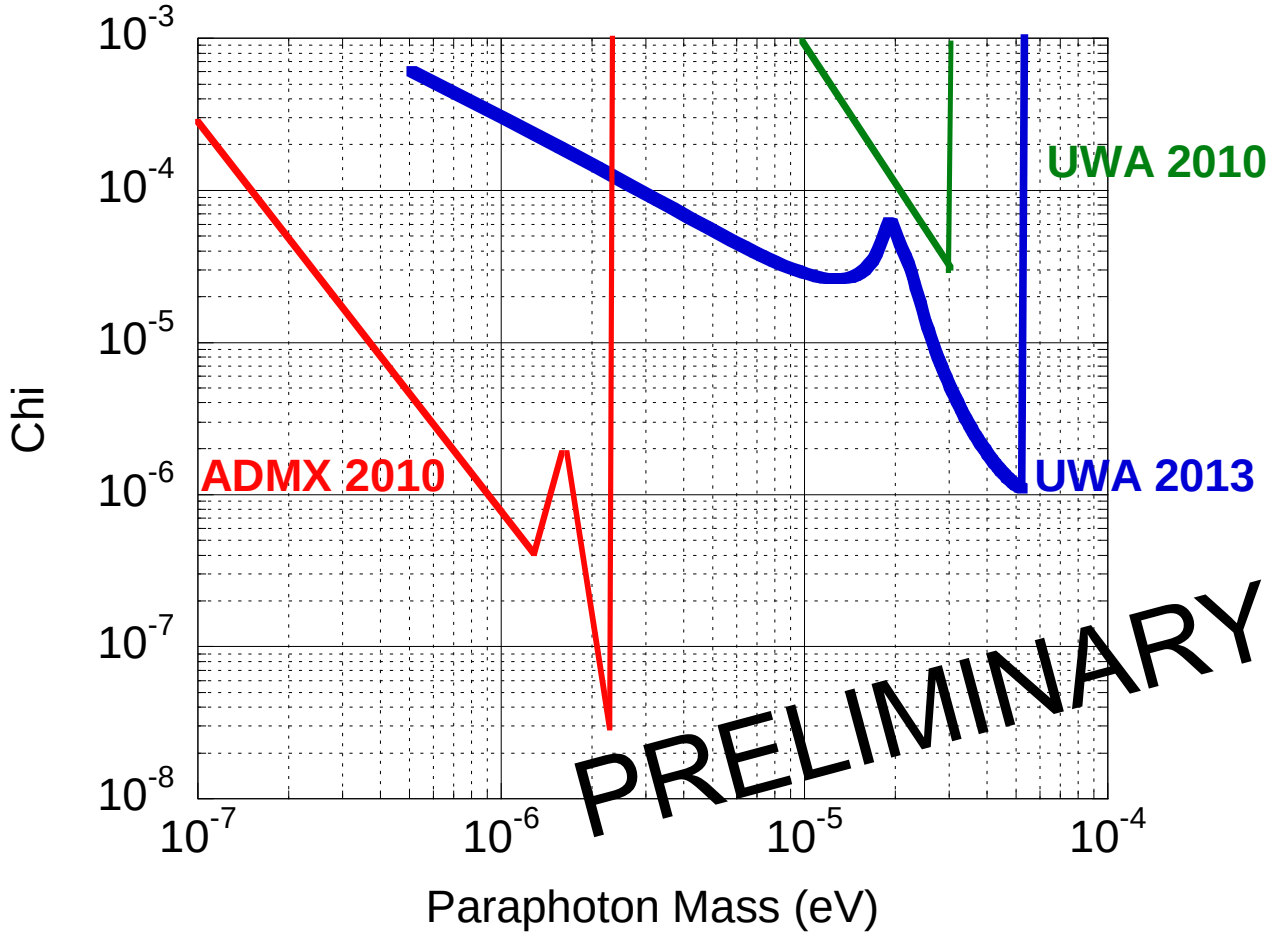
$$\mathcal{T}(i\omega) = \frac{2\sqrt{\beta}}{(1+\beta)(1+2iQ(\omega-\omega_0)/\omega_0)}$$

Frequency Detuning and Effective Q



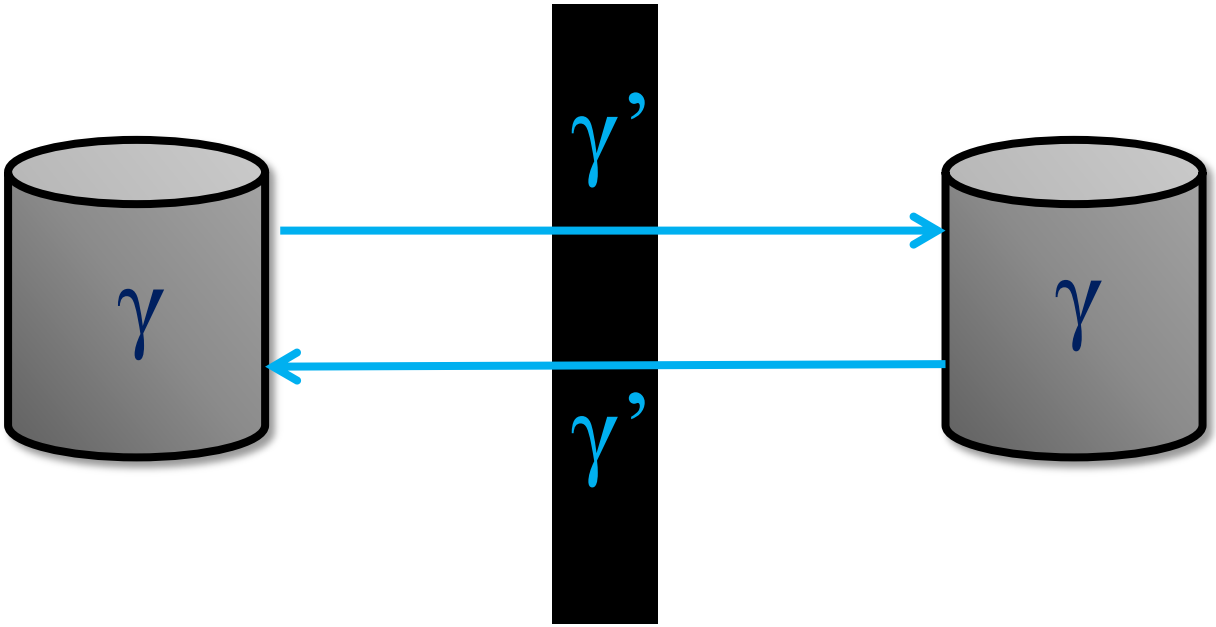
$$Q_{eff} = \left| \frac{iQ\left(1 \pm \frac{x}{2}\right)}{i + Q - Q\left(1 \pm \frac{x}{2}\right)^2} \right|$$

Bounds

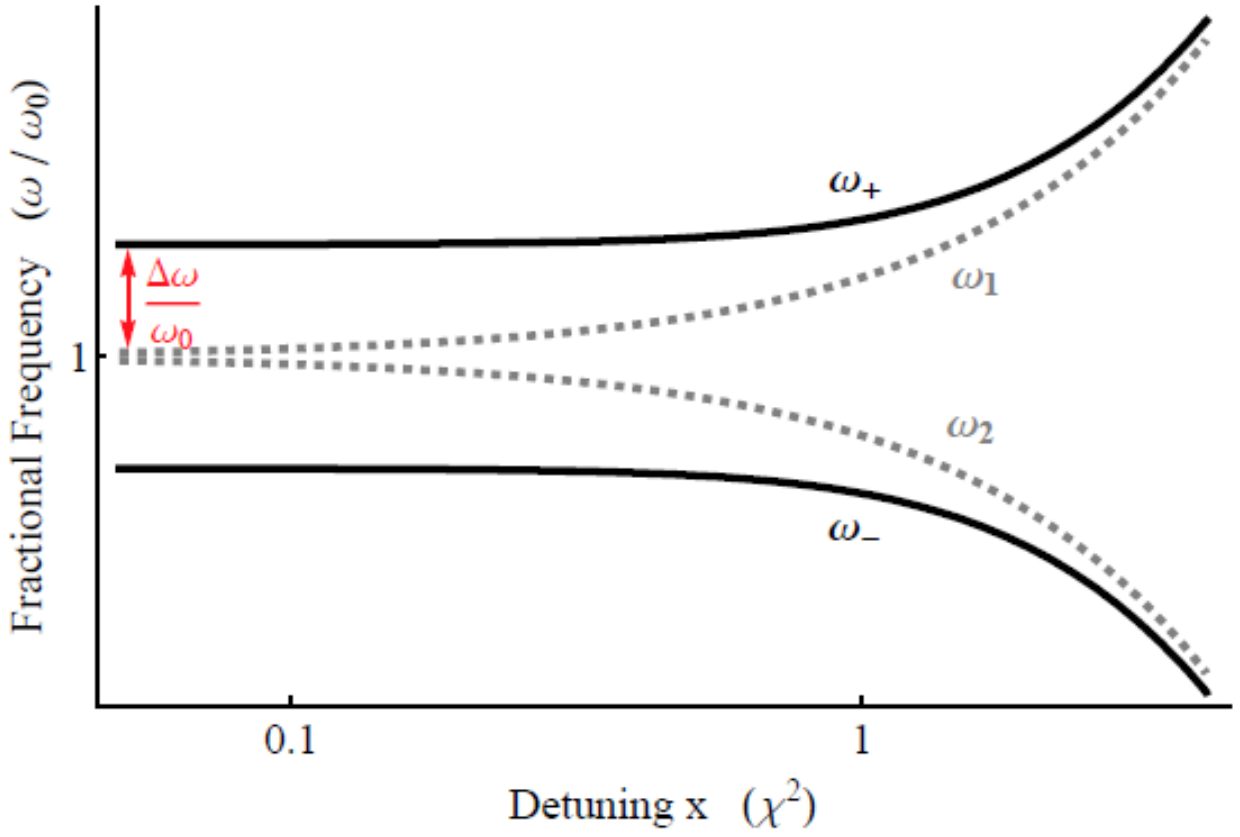


Wagner et al, Phys. Rev. Lett, **105** 171801 (2010) [arXiv:1007.3766]
Povey et al, Phys. Rev. D., **82** 052003 (2010) [arXiv:1003.0964]
Parker et al, In Preparation (2013)

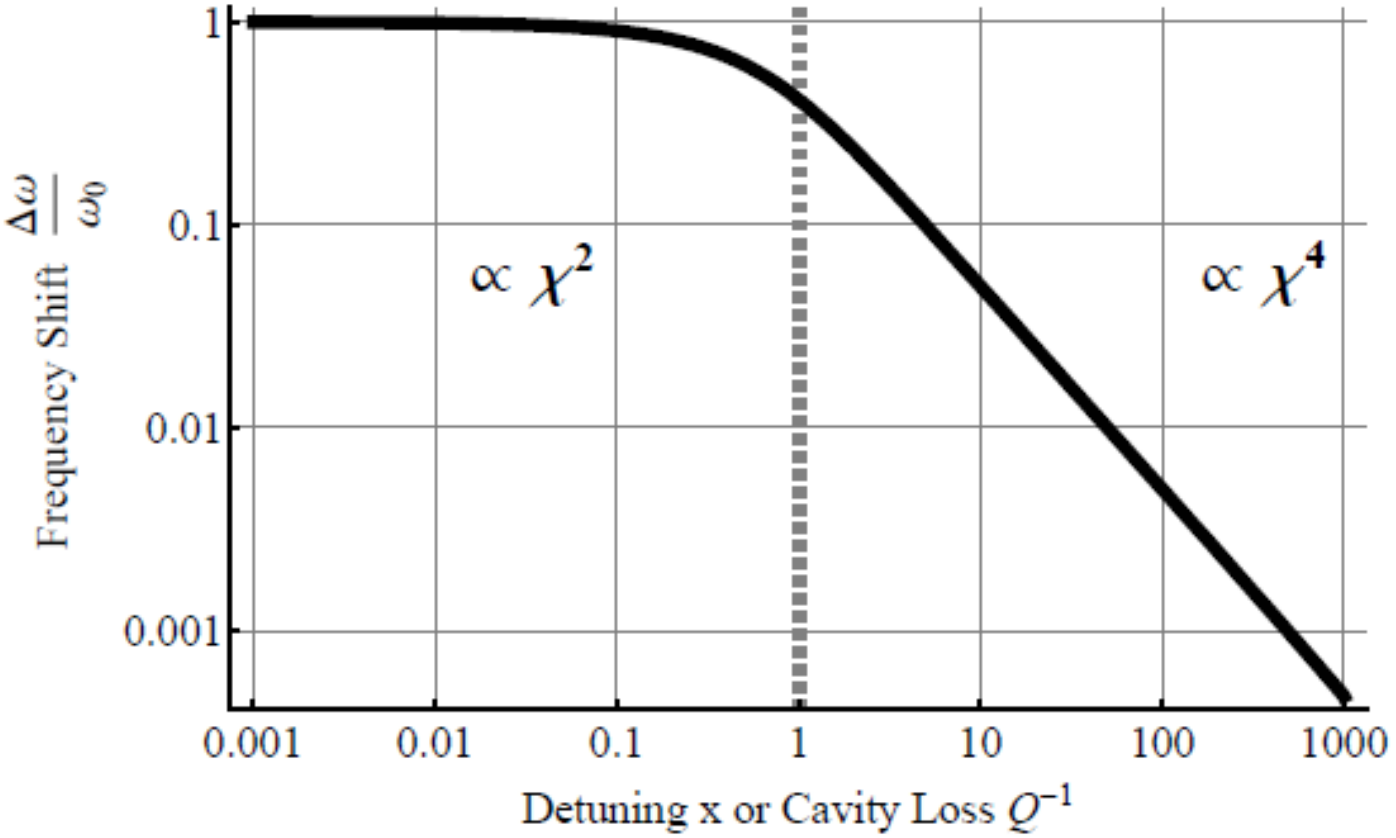
Frequency Coupling



Parker, Rybka & Tobar, Phys. Rev. D. **87** 115008 (2013) [arXiv:1304.6866]

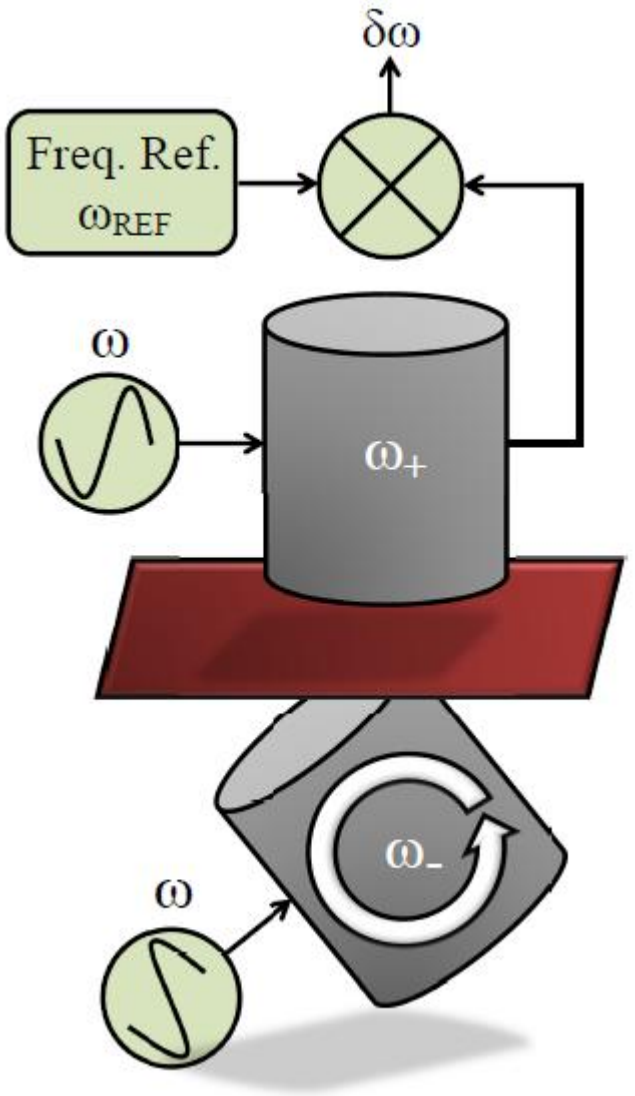


$\omega = \omega_0 (1 +/- 0.5x)$


Frequency Shift $\frac{\Delta\omega}{\omega_0}$
1
0.1
0.01
0.001
$\propto \chi^2$
$\propto \chi^4$
0.001
0.01
0.1
1
10
100
1000
Detuning x or Cavity Loss Q^{-1}

Modulate the strength of |G| to induce modulation of resonance frequency

$$\mathcal{G}\left(\frac{k_{\gamma\prime}}{k_\gamma}\right) = k_\gamma^2 \oint_{V_{\text{emit}}} \oint_{V_{\text{det}}} \frac{\exp(i\, k_{\gamma\prime}\, |\mathbf{x}-\mathbf{y}|)}{4\pi|\mathbf{x}-\mathbf{y}|}\, \boldsymbol{A}_{\text{emit}}(\boldsymbol{y}) \cdot \boldsymbol{A}_{\text{det}}(\mathbf{x})\, \mathrm{d}^3\mathbf{x}\, \mathrm{d}^3\boldsymbol{y}$$

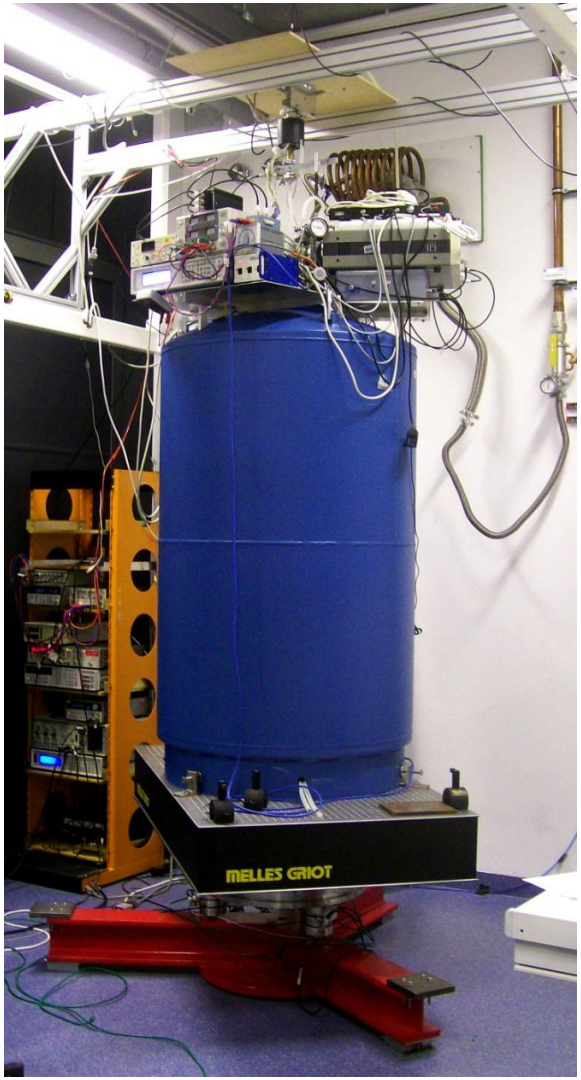


"Easy" – chi ≈ 10^{-6}

Achievable – chi ≈ 10^{-7} -10^{-8}

Very optimistic – chi ≈ 10^{-9} -10^{-10}

Rotating cavity experiments have been performed in different contexts (i.e. searches for violations of local Lorentz invariance)



Summary

- Second LSW experiment generated modest improvements
- Further improvements are relatively easy to obtain
- Frequency coupling effects could provide useful alternative measurement technique

Acknowledgements

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