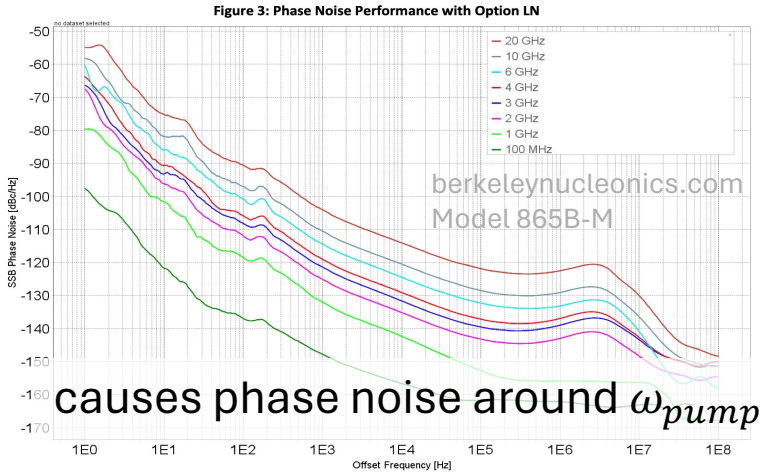
MAGO/LLRF Meeting

Tom Krokotsch, 21.02.2024

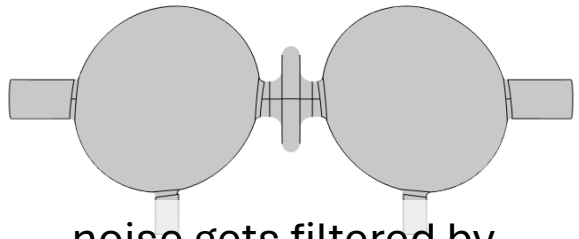
MAGO Oscillator Noise Requirements

Oscillator Noise Power in the Signal Mode

Master Oscillator



causes phase noise around ω_{pump}



noise gets filtered by the cavity resonator

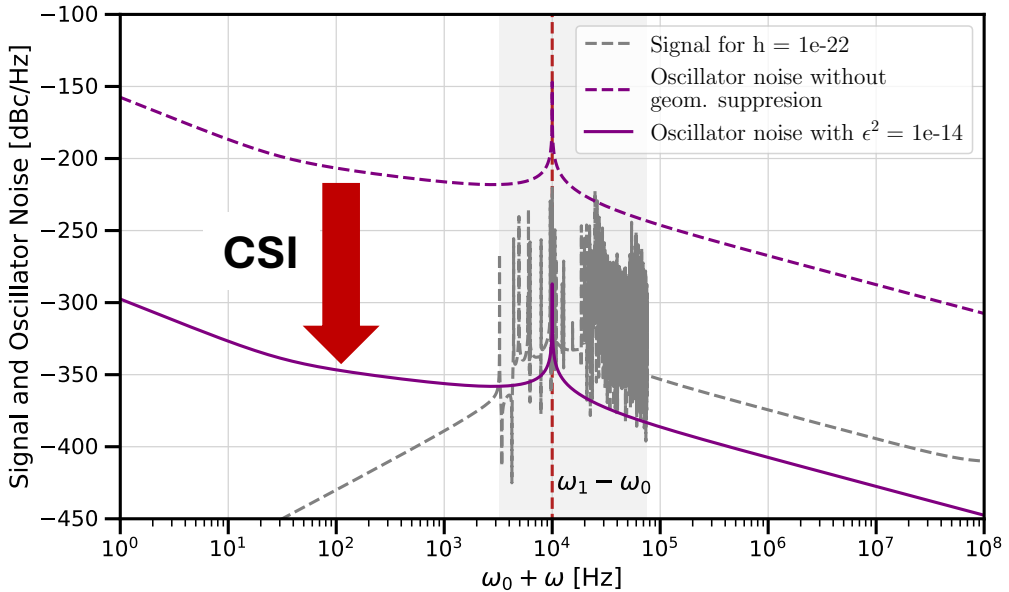
$$S_{noise}(\omega) \propto P_{in} \cdot S_{MO}(\omega - \omega_{pump}) \cdot \frac{\left(\frac{\omega\omega_{sig}}{Q_1}\right)^2}{\left(\omega^2 - \omega_{sig}^2\right)^2 + \left(\frac{\omega\omega_{sig}}{Q}\right)^2}$$

However:

Noise level still too high for GW detection

→ Need to suppress Carrier by a further ~ **140 dB**

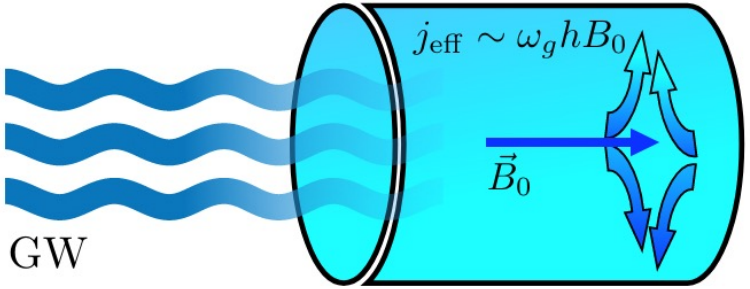
'geometric carrier rejection' $\epsilon_{01}^2 \sim 10^{-14}$



Signal Readout of Static B-Field GW Searches With RF Cavities

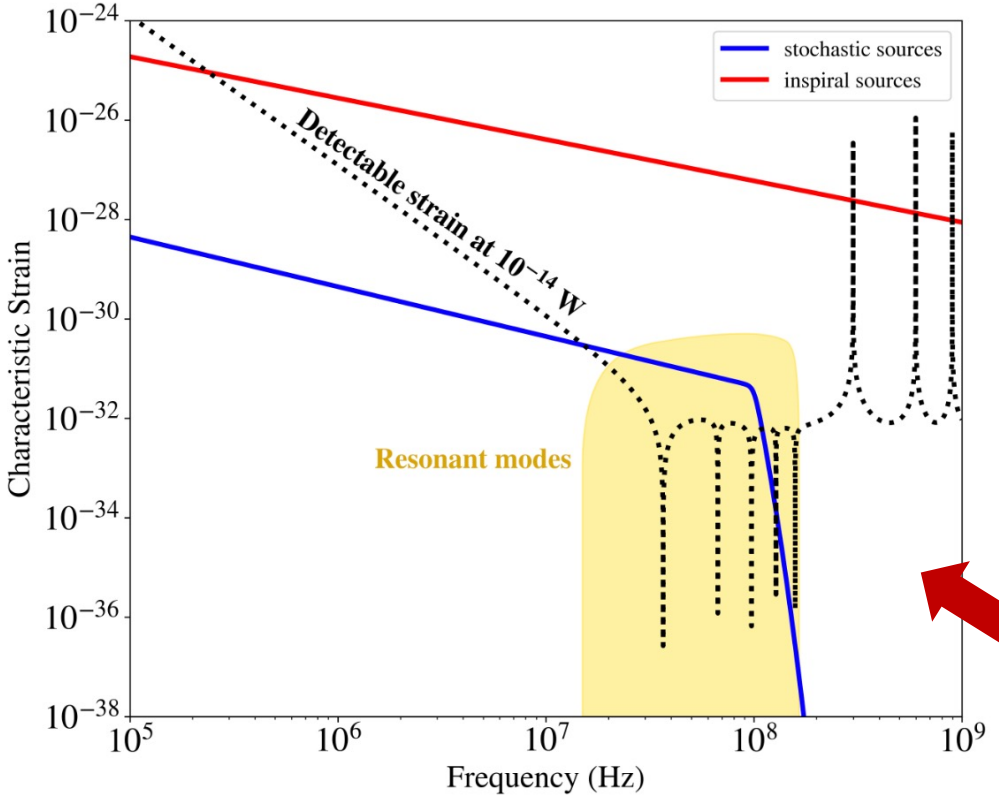
Sensitivity of static B-field GW searches

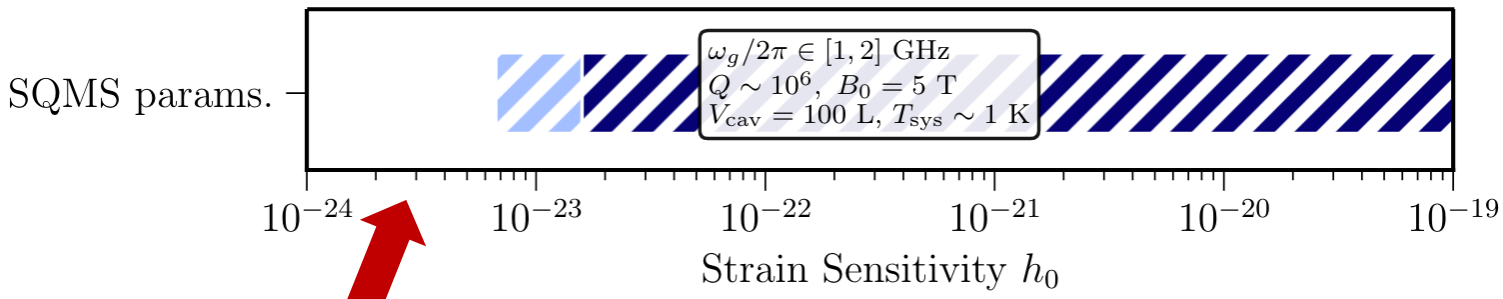
Detection Principle:



Interaction of GW with RF cavity in **static** B-Field (Berlin et al. 2112.11465)

-> Requires no driving of any mode





Berlin et al. 2112.11465

Fünzfa et al. 2203.15668

Difference in Signal Prediction:

Energy Density in Cavity:

$$W_{total} \sim (\boldsymbol{B_0} + \boldsymbol{B}_{GW}(t))^2 = W_0 + 2\,\boldsymbol{B_0} \cdot \boldsymbol{B}_{GW}(t) + \boldsymbol{B}_{GW}^2(t)$$

Fünzfa et al. 2203.15668:

- $E_{signal} = \Delta W \sim 2\,\boldsymbol{B_0} \cdot \boldsymbol{B}_{GW}(t) + \mathcal{O}(h_{GW}^2)$
  first oder in GW strain h_{GW}
- $P_{first\ order\ noise} = 10^{-14}$ W

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Berlin et al. 2112.11465:

- $E_{signal} = \langle \Delta W \rangle_t \sim \langle \boldsymbol{B}_{GW}^2(t) \rangle_t$
  second oder in GW strain h_{GW}
- $P_{PSD\ noise} \approx 10^{-22}$ W

Question: **Can the instantaneous *first order* energy be read out?**
→ Requires sampling rate $\mathcal{O}(\mathrm{GHz})$

Equivalent Calculation for Heterodyne Search

Energy Density in Cavity (for monochromatic GW):

$$W_{total} \sim (\boldsymbol{B_0}(\boldsymbol{x},t) + \boldsymbol{B_1}(\boldsymbol{x},t))^2 = W_0 + W_1 + 2\underbrace{\boldsymbol{B_0}(\boldsymbol{x}) \cdot \boldsymbol{B_1}(\boldsymbol{x})}\cos(\omega_g t)$$

$\int_{V_{\text{cavity}}} \boldsymbol{B_0} \cdot \boldsymbol{B_1} = 0$ but $\neq 0$ for other integration volumes