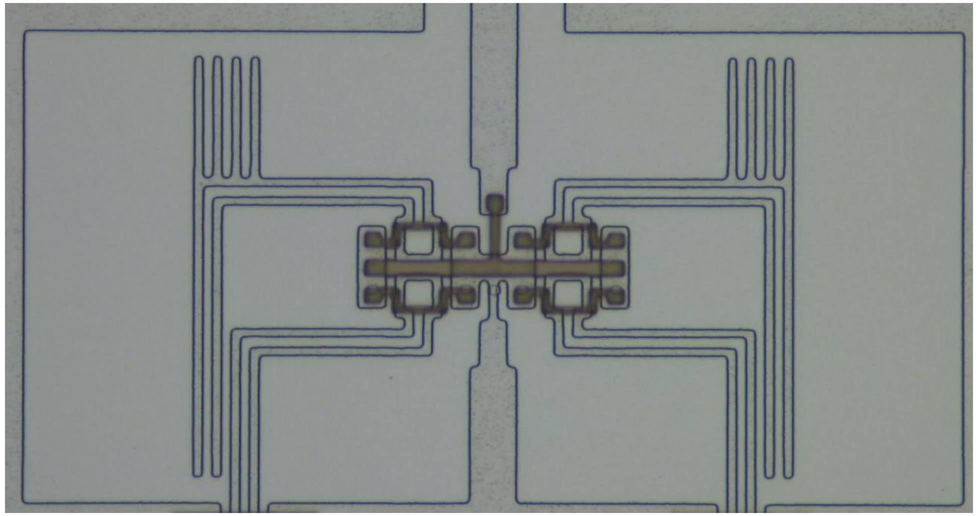
RF Quantum Upconverters

Quantum Sensing for Sub-μeV Dark Matter

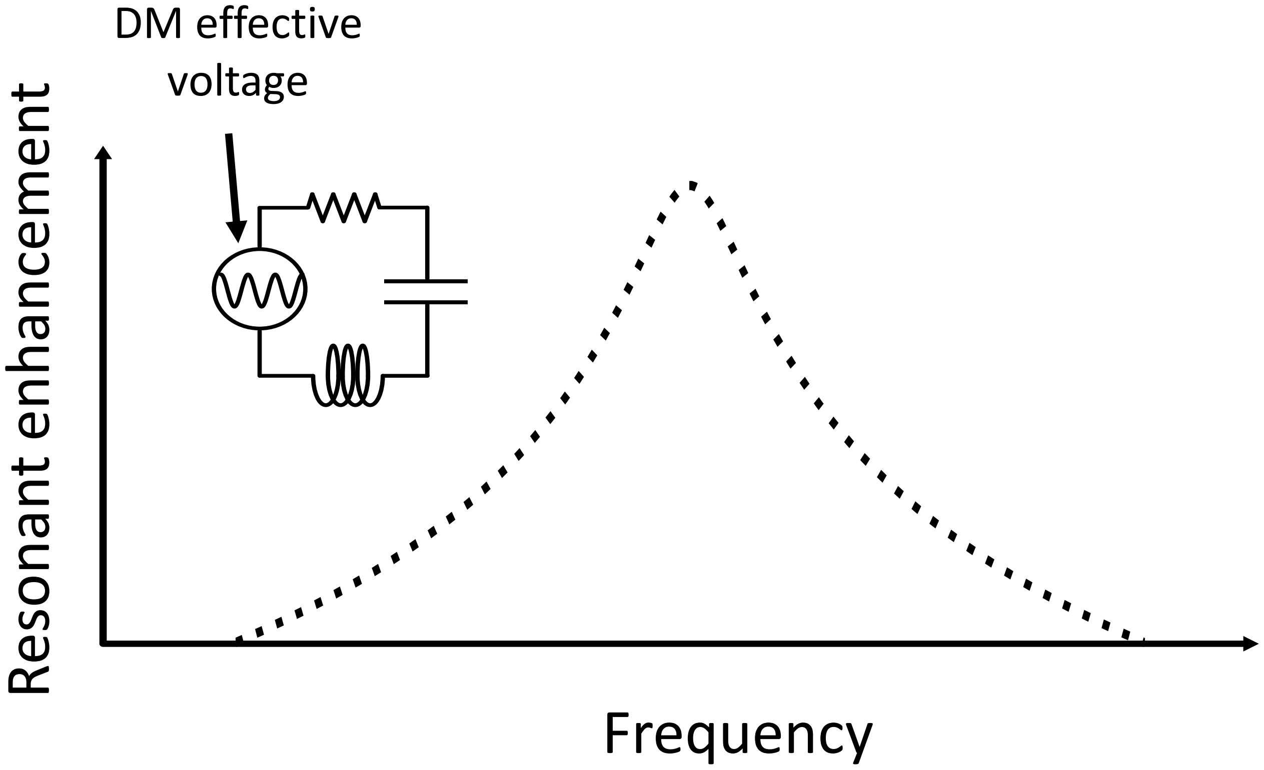
Snowmass Quantum Sensors Information Session



Stephen Kuenstner - Stanford University - 8/19/2020

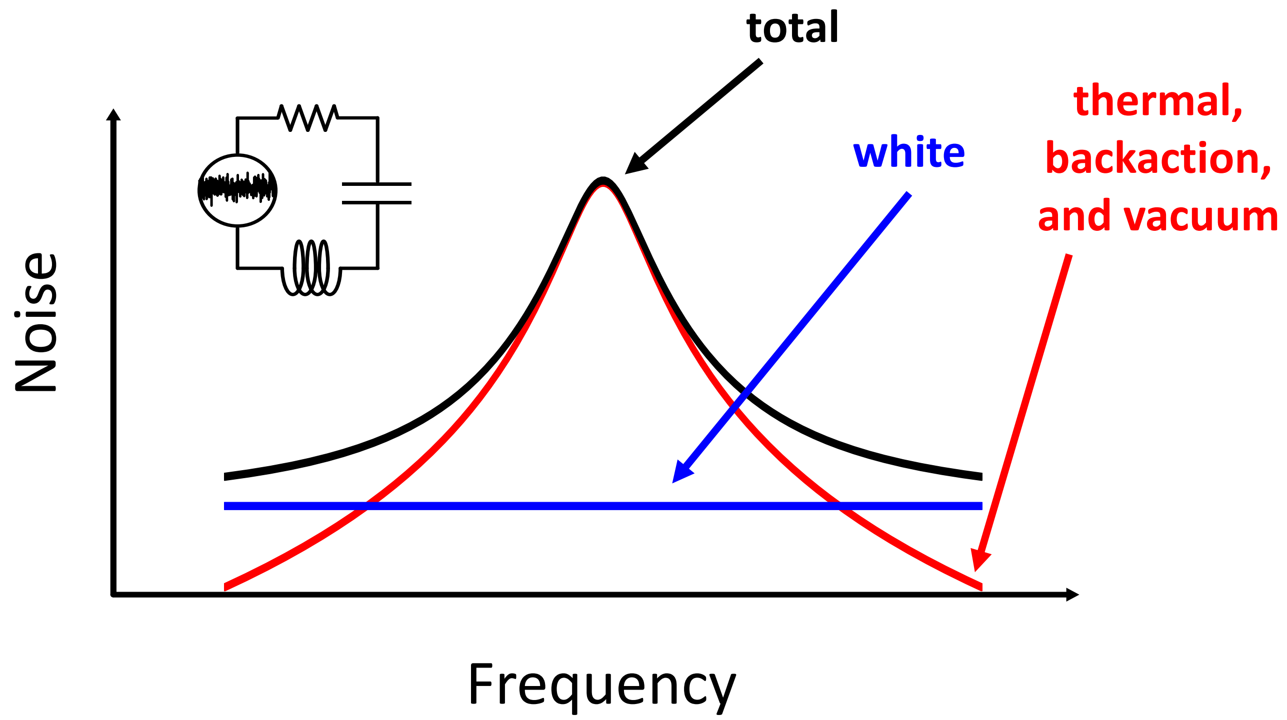
Receivers for Wave-Like Dark Matter

- Very light dark matter behaves like a **coherent, oscillating background field**.
- A dark matter receiver aims to detect this field via its weak coupling to the Standard Model (e.g. electromagnetism, nuclear spin….).
- A **resonant LC circuit** tuned near the dark matter rest mass is one example of a sensitive dark matter receiver.



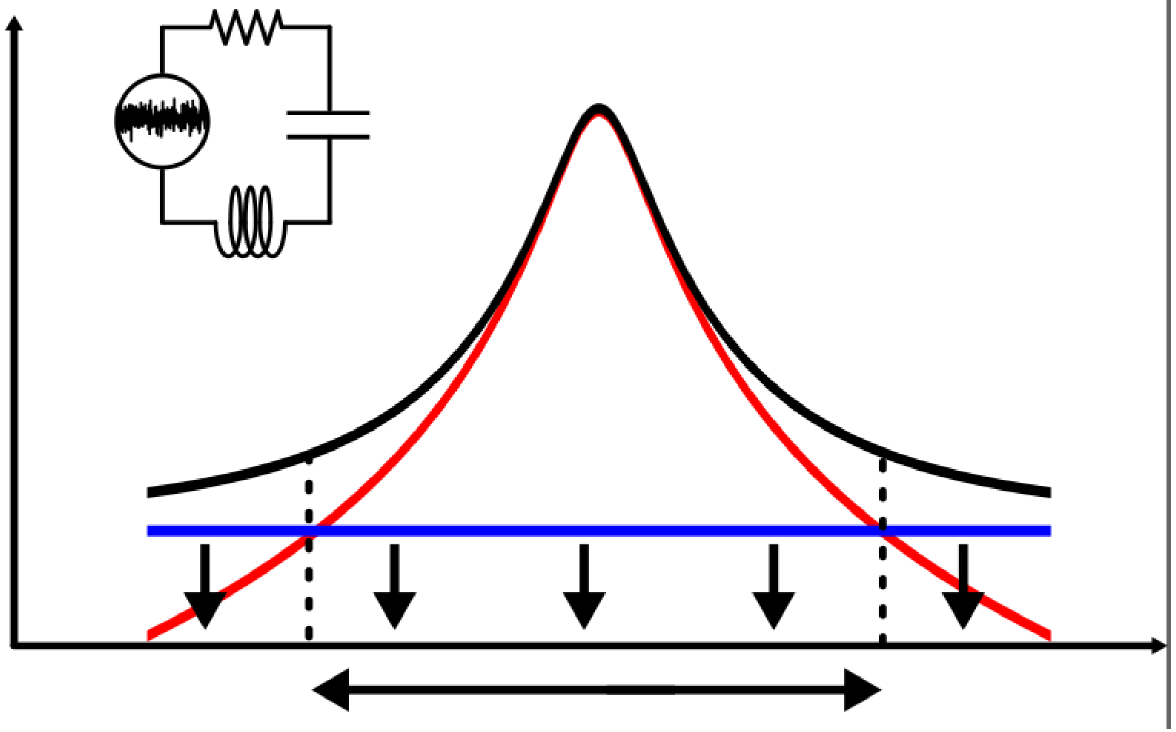
Noise in Dark Matter Receivers

- For masses below ~1μeV (frequencies below ~300MHz) **thermal noise is an important noise source.**
- The **total noise** is made up of **white noise** and **other noise sources**.
- **White noise** is added by amplifier imprecision noise.
- **Other noise** comes from thermal, vacuum, and quantum backaction fluctuations.



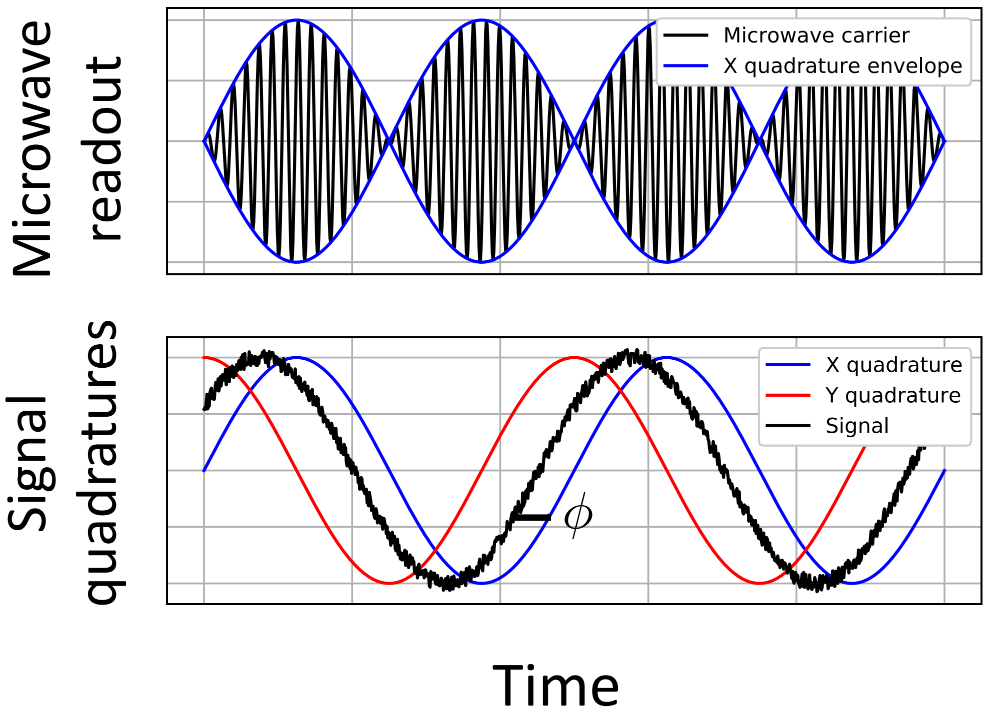
Advantage of Quantum Sensors

- **In this frequency range, photon counting techniques are not helpful.**
- Instead of photon counting, use phase-sensitive techniques to achieve **Backaction-Evading (BAE) measurements.**
- This reduces imprecision (**white**) noise component, without penalty in backaction (**rung-up**) noise, for a single quadrature.
- However, it allows for **constant SNR to be maintained over a much broader bandwidth,** enhancing overall search rate.

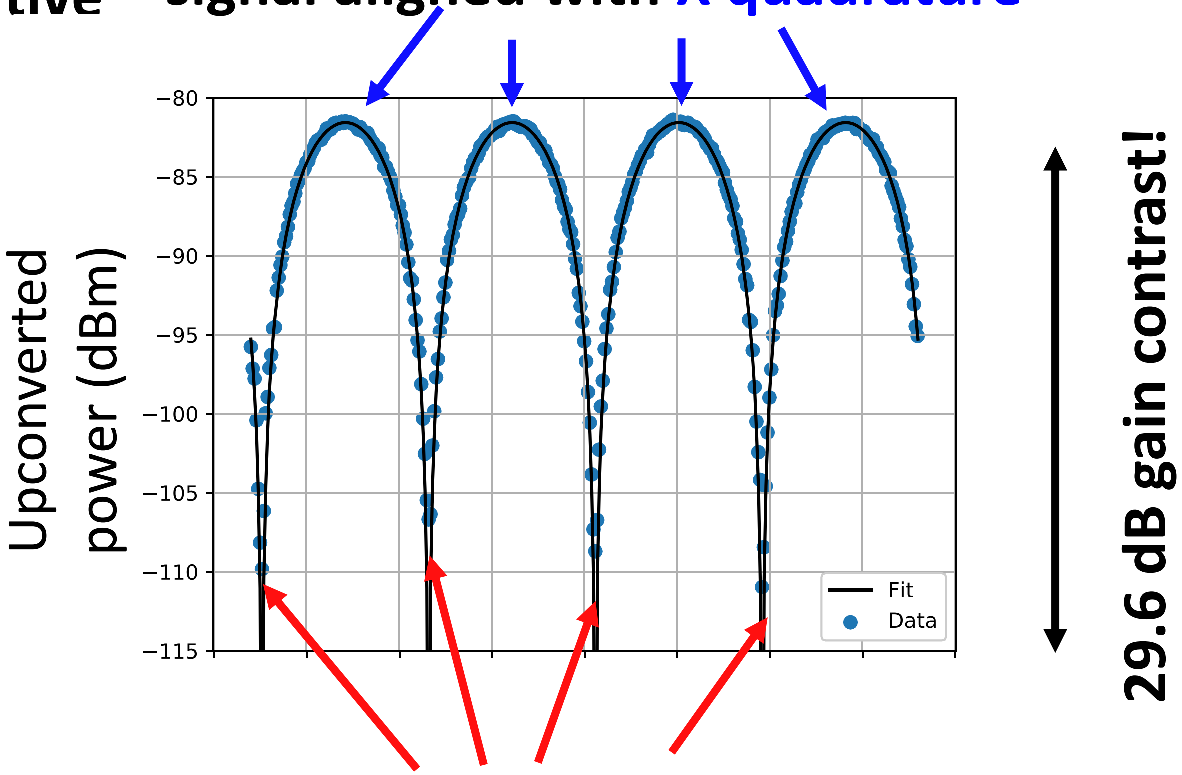


BAE with RF Quantum Upconverters

Upconversion gain data is phase-sensitive



signal aligned with X quadrature



29.6 dB gain contrast!

signal aligned with Y quadrature