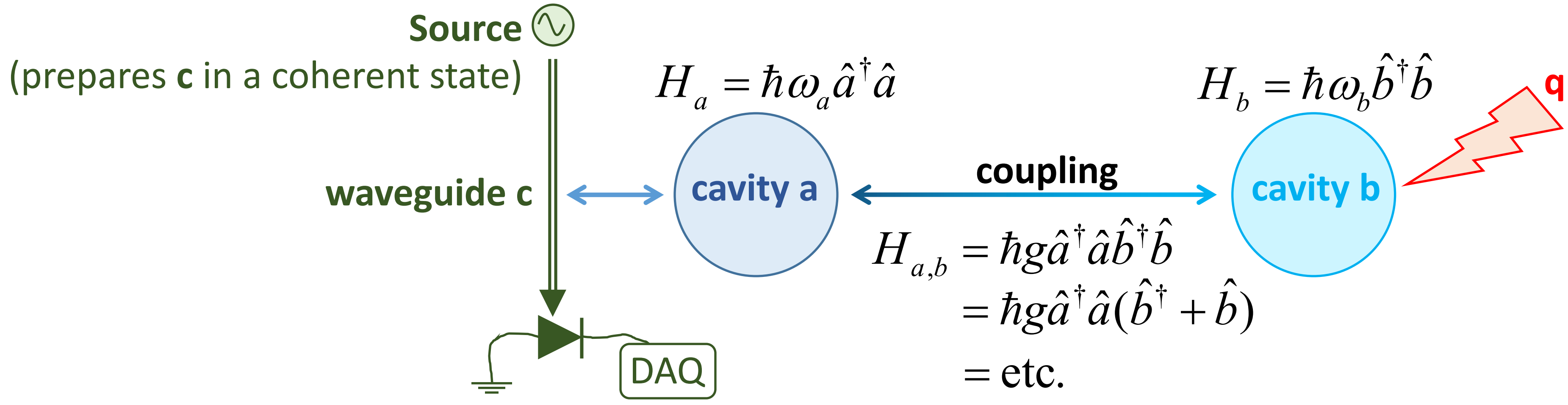
(Many types of) quantum sensors in a nutshell:



$$H_a = \hbar\omega_a \hat{a}^\dagger \hat{a}$$

$$H_b = \hbar\omega_b \hat{b}^\dagger \hat{b}$$

$$H_{a,b} = \hbar g \hat{a}^\dagger \hat{a} \hat{b}^\dagger \hat{b} = \hbar g \hat{a}^\dagger \hat{a}(\hat{b}^\dagger + \hat{b}) = \text{etc.}$$

detects quanta of "c": single quanta resolution (PMT) or time-averaged flux of quanta (photodiode)

- Quantity of interest is encoded in the state of system "**b**": $|\psi_b\rangle = \sum c_n |n\rangle_b$ "*n* photons in mode *b*"
- In general, we cannot make a measurement that reveals $|\psi_b\rangle$ (i.e., all the c_n)
- Most measurements return a single number
  (project $|\psi_b\rangle$ onto the measurement basis, chose an eigenvalue from a random distribution specified by the c_n).
- This process changes $|\psi_b\rangle$ (measurement back-action)
- Usually this process is accomplished via an auxiliary system "**a**" that scatters photons from a waveguide "**c**"
- **Given all of this, what is the SNR for determining the quantity of interest? What arrangements optimize this?**

Optomechanical quantum sensors

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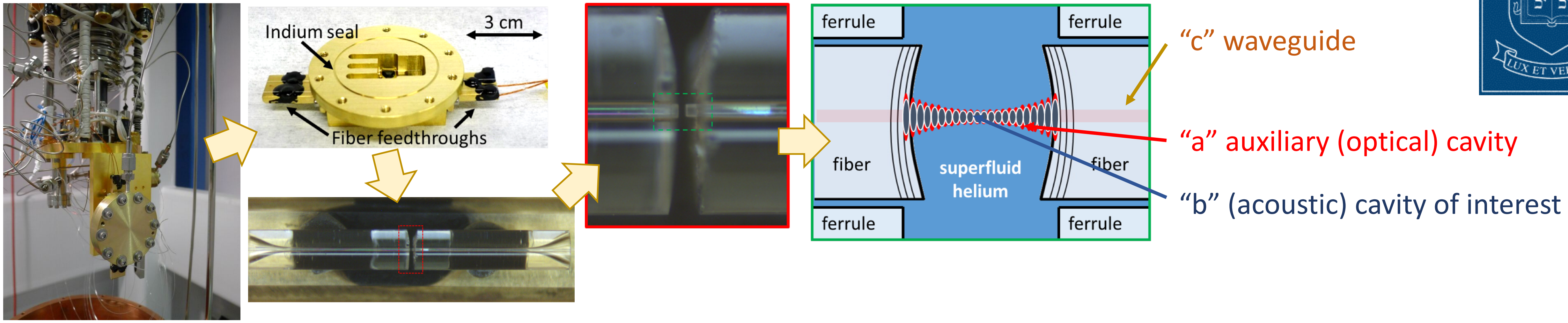
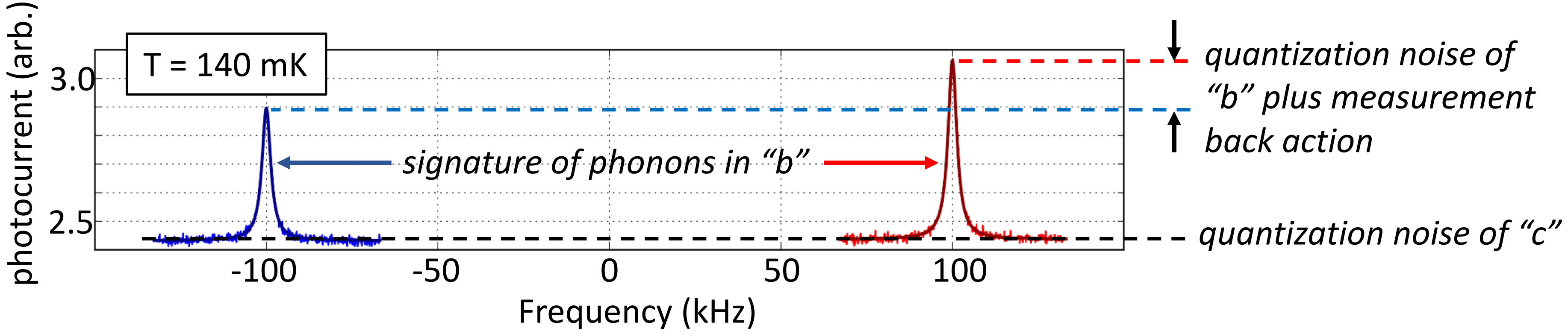


Detection of "c" photons w/ photodiode (quantity of interest: is there a phonon in the LHe?):



Next steps:
Replace photodiode with PMT
Improved performance via levitated superfluid sample

Key Instrumentation Requirements (100% selfish perspective):

- New physical insights regarding measurement and control processes (QND, quantum control, decoherence-free spaces, etc.)
- Advanced nanofab for electronic, mechanical, and optical components
- Optical photon number-resolving detectors (not PMTs!!!)
- Feedback & classical control
- Affordable and reliable cryogenics