# Photon Counting for GQuEST

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**GQuEST** Gravity from Quantum Entanglement of Space-Time





### GQuEST



Simplified Layout

#### GQuEST



FIG. 5: Detailed view of experimental optical layout and readout electronics setup

Advanced Layout



#### **Bow-tie Filter Cavities**







### **Current Research Goals**

- Develop skills testing and characterizing SNSPDs
- Characterize SNSPD's for GQuEST
- Verify a dark count rate of less than 10e-4 for GQuEST
- Implement the SNSPDs into QQuEST
- Develop a low-cost and low-noise Avalanche Photodiode (APD) circuit for preliminary photon detection in GQuEST

1 K stage with -SNSPD



Filter stack @ 4 K



#### **SNSPD** Efficiency Calculations

- PCR = CR SDCR
  - Photon Count Rate (PCR) is the difference between the response pulse count rate (CR) and the dark count rate (SDCR)
- Efficiency = PCR / (Input\_Number\_of\_Photons)
  - For our calculations the input number of photons was 100476

#### **SNSPD** Measurement Experimental Setup



F. Marsili, Et al., 2013, Detecting Single Infrared Photons with 93 % System Efficiency: Supplementary Information

#### Laboratory Setup





#### **Experimental Procedure**



#### **DIFF2 and DIFF3 RAW Measurements**



#### Calculated Efficiencies DIFF2/DIFF3



# Next Steps: Finding the Uncertainty of the Efficiency Measurements

$$\left(\frac{\sigma_{\text{SDE}}}{SDE}\right) = \sqrt{\left(\frac{\sigma_{\text{PCR}}}{PCR}\right)^2 + \left(\frac{\sigma_{\text{PC}}}{P_{\text{C}}}\right)^2 + 2 \cdot \left(\frac{\sigma_{\alpha_{2,3}}}{\alpha_{2,3}}\right)^2 + \left(\frac{\sigma_{\text{RSW}}}{R_{\text{SW}}}\right)^2}$$

The uncertainty of the System detection efficiency is calculated with the following:

 $\sigma_{PCR}$  = uncertainty of the photoresponse count rate

 $\sigma_{PC}$  = uncertainty of the power incident on the control power meter

 $\sigma_{\alpha_{2,3}}$  = uncertainty of the attenuation of attenuator 2, 3

 $\sigma_{RSW}$  = uncertainty of the splitting ratio of the optical switch

F. Marsili, Et al., 2013, Detecting Single Infrared Photons with 93 % System Efficiency: Supplementary Information

#### SNSPD for GQuEST



# Thank you!



#### Free-space coupled SNSPD to room temperature





Mueller, Korzh *et al*, **Optica 8**, 1586 (2021)

#### Efficiency and dark count rate



Mueller, Korzh *et al*, **Optica 8**, 1586 (2021)

#### Avalanche Photodiode (APD)



#### APD Circuit Development



Homodyne Detector circuit design: Tomoki Isogai, LIGO\_DCC: LIGO-D1300671

#### Simulating APD's in Spice



Dong Huang Et al., 2013, SPICE modeling for single photon avalanche diode