

# Detection of Single Photons under Strong Parallel Magnetic Fields Using NbTiN-based Superconducting Nanowire

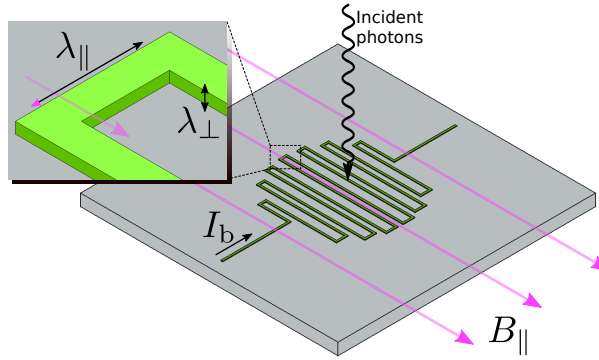


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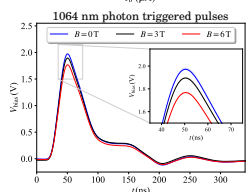
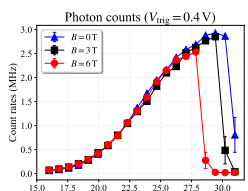
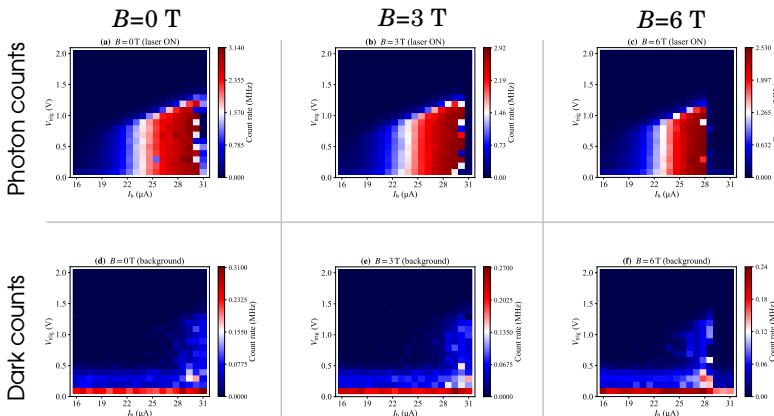
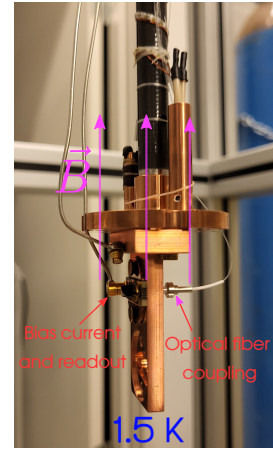
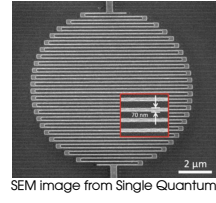
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**ABSTRACT:** We present our investigations of the performance and limitations of a NbTiN-based superconducting nanowire single-photon detector (SNSPD) for detecting 1064 nm photons under parallel magnetic fields up to 6 T, while also providing insights into the underlying physics governing the photon response of the nanowire. In particular, the effect of parallel-field-induced Pauli (paramagnetic) pair breaking of spin-singlet superconductivity is discussed together with existing photon response models in the literature. Our results show that quasi-particle diffusion and multiplication play an important role in the physical processes resulting in voltage pulse after photon absorption.



- SNSPD provided by Single Quantum
- Material: NbTiN
- Thickness: 11 nm
- Width: 70 nm
- Operated at 1.5 K temperature
- Operated under parallel magnetic fields up to 6 T
- Direct applications in axion-searches:
  - ALPS II [1]
  - BREAD [2]



- Photon counts = Quantum Efficiency (QE)
- QE decreases as a function of B
- Pulse amplitudes also decrease with field
- This does not explain the observed decrease in photon counts for low V<sub>trig</sub>

- Decrease of QE as a function of B can be explained by paramagnetic (Pauli) breaking of Cooper pairs  
 → Decrease of energy gap ( $\Delta$ ):

Pauli critical field:  $B_{c,p}^{\parallel} = \frac{\Delta}{\sqrt{2}\mu_B}$

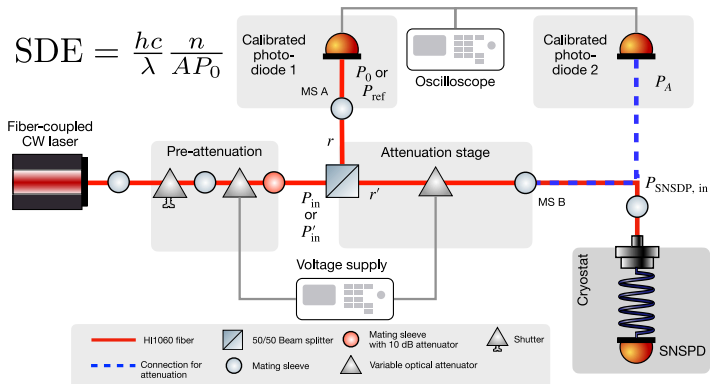
Ginzburg-Landau field-dependent gap:  $\frac{|\Delta(B)|}{|\Delta_0|} = \sqrt{1 - \left(\frac{B}{B_{c,p}^{\parallel}}\right)^2}$

- Our results align with QE being proportional to quasiparticle multiplication efficiency derived by Semenov et al. [3]:

Quasiparticle multiplication efficiency [3]:

$$\zeta = \frac{N_0 \Delta^2 w d \sqrt{\pi D \tau_{th}}}{h \nu} \cdot \left(1 - \frac{I_b}{I_c}\right)$$

- Measuring the system detection efficiency:
  - Based on calibrated photodiodes
  - Measured for unpolarized photons (lower SDE)
  - SDE=16% @B=0 T



**REFERENCES**

[1] Ortiz, M. Diaz, et al. "Design of the ALPS II optical system", Physics of the Dark Universe 35 (2022): 100968.  
 [2] Liu, Jesse, et al. "Broadband solenoidal haloscope for terahertz axion detection", Physical Review Letters 128.13 (2022): 131801  
 [3] Semenov et al., "Spectral cut-off in the efficiency of the resistive state formation caused by absorption of a single-photon in current-carrying superconducting nano-strips", Eur. Phys. J. B 47, 495-501 (2005)