## Hybrid NbTiN-Al MKIDs

**R.M.J. Janssen**, A. Endo, P.J. de Visser, T.M. Klapwijk, J.J.A. Baselmans

1. Kavli Institute of Nanoscience, Faculty of Applied Sciences, Delft University of Technology
2. Faculty of Electrical Engineering, Mathematics and Computer Science, Delft University of Technology
3. SRON Netherlands Institute for Space Research

**E-mail:** r.m.j.janssen@tudelft.nl

### Introduction

Lens-antenna coupled hybrid NbTiN-Al Microwave Kinetic Inductance Detectors (MKIDs) [1] are a detector candidate for large format sub-mm camera's and spectrometers developed in the next decade. For large array development electrical and thermal tests are preferred as initial tests over a full optical evaluation, which requires a time-consuming measurement and a dedicated setup with a controlled illumination source. Based on a simplified model analysis Gao et al. [4] have argued that the change in complex conductivity due to thermally and optically excited quasiparticles is equivalent. We test the performance of NbTiN-Al MKIDs as well as test the equivalence between their optical and thermal response.

### NbTiN-Al MKID Design

The antenna coupled NbTiN – Al MKID design [1] aims to simultaneously maximize the MKID response and minimize the detector noise.

### Photon Noise Limited Performance

The antenna coupled NbTiN – Al MKIDs show photon noise show photon noise limited performance down to 100 fW [1]. Photon noise limited operation can be used to accurately (uncertainty ~ 5%) determine the optical power absorbed by the MKID and thus verifying its optical reception properties.

### MKID Response: Optical versus Thermal

The evolution of the resonance curve as a function of increasing temperature (grey) and limiting optical loading a bath temperature can be found, which produces an identical resonance curve.

### Experimental Method

In our experiment we use a bath temperature \( T_0 = 100 \) mK and blackbody temperature \( T_{bb} = 4.2 \) K as initial conditions for both our optical and thermal measurement. Starting from \( (T_{bb}, T_0) \) we change either \( T_{bb} \) or \( T_0 \) in the optical or thermal measurement, respectively.

We determine the optical responsivity from a linear fit between the measured change in phase (\( \theta \)) and amplitude (\( A \)) as a function of the absorbed optical power \( (P_{opt}) \).

We determine the electrical (dark) responsivity from the measured temperature responsivity, quasi-particle recombination time, pair breaking efficiency and the superconducting transition temperature [2].

\[
\delta F_{21,r+h} = \frac{\partial A}{\partial (T_0)} \frac{\partial \theta}{\partial (T_0)} \delta T_0 + \delta \epsilon_p \frac{\partial T_0}{\partial (T_0)} \delta T_0 + \delta \epsilon_p \frac{\partial T_0}{\partial (T_0)} \delta T_0
\]

We derive \( \Delta \) from the well-known BCS relation and determine \( N_{qp} \) using an integral over the fermi-dirac energy distribution and the BCS density of states.

### Conclusions

We have shown that [1,2]:

- Hybrid NbTiN-Al MKIDs are photon noise limited down to 100 fW.
- Thermal and optical excitations have an equivalent effect on the resonance feature of hybrid MKIDs.
- The electrical (dark) responsivity is within a factor of two of the optical responsivity.

We attribute this to the unique geometry of the hybrid NbTiN-Al MKIDs, which integrate a 1 mm long Al absorber in a NbTiN resonator. In different MKID embodiments the equivalence between optical and electrical response is not a priori justified.

In addition, we show that the Optical efficiency can be more accurately be determined from the photon noise (uncertainty ~ 5%) than by comparing the optical and electrical NEP (uncertainty ~15%).

### References