Ultra-low Noise, High Gain, Microstrip Kinetic Traveling Wave Parametric Amplifier
MSc thesis project

202Q-lab, Quantum Technology Laboratory

The 202Q-lab is looking for a MSc student who is interested in superconducting quantum circuits.

Background – A wide range of quantum technologies relies on the detection of low-level microwave signals at millikelvin temperatures. For most applications, the sensitivity is limited by the first amplifier of the detection chain. The Traveling Wave Parametric Amplifier (TWPA), one of the emergent technologies, appears to be the ultimate microwave amplifiers since they offer large gain, wide bandwidth, high saturation power and low noise level approaching the quantum limit (Esposito *et al.*, 2021; Malnou *et al.*, 2021). TWPA relies on a careful engineering of a non-resonant, non-linear transmission line in which the microwave amplification arises step by step.

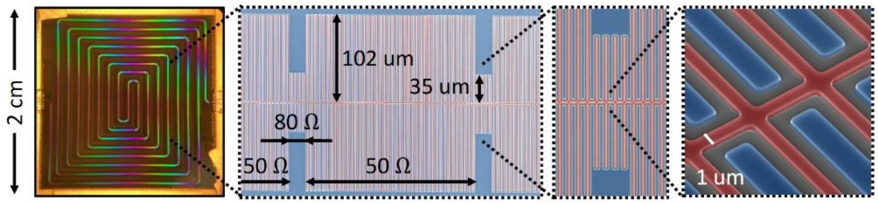

Figure 1 NbTiN TWPA developed by Malnou et al.

The challenge –The main challenge remains in the design of the transmission line for the development of TWPA: this transmission line needs to be impedance matched to 50Ω to avoid unwanted reflection. Also, the velocity and phase of the pump, idler and signal need to be addressed carefully to have an efficient parametric amplification. The latter condition is known as phase matching. Generally, TWPAs relies on high kinetic inductance superconductor such as NbTiN to provide the high non-linearity required for the amplification(Ho Eom *et al.*, 2012). The impedance matching is obtained using tapers of coplanar waveguides (CPW) while the phase matching is enforced using periodic loading structures.

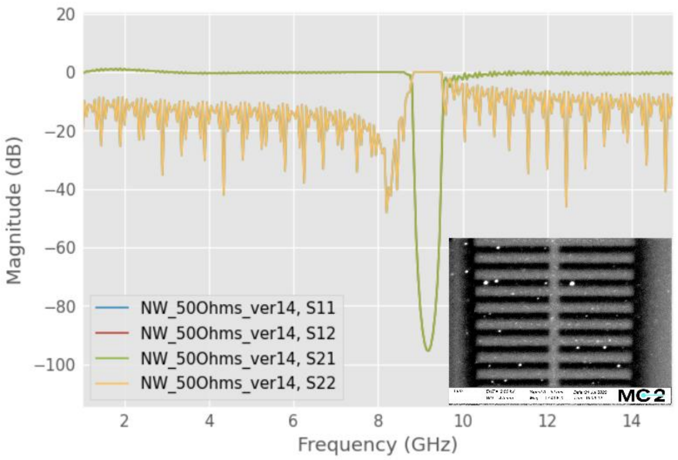

Figure 2 Simulation of the scattering parameters of a microstrip TWPA centered around the band gap. Insert: SEM image of a portion of non-linear microstrip line made at Chalmers.

The project: The project will start from these preliminary works and go a step further into reducing the physical footprint of these devices while conserving or increasing the available gain amplification. Notably, we will explore the integration of TWPA with NbTiN microstrip transmission lines using low tangent losses dielectric materials. The candidate will design the microstrip TWPA which will be then fabricated with the support from other members of the group. Finally, the candidate will perform measurements of the devices at millikelvin temperatures inside a cryostat. They will characterize the non-linear transmission line in the microwave regime, evaluate the available gain and characterize the noise temperature of the device.

About us – We are part of the Quantum Technology Laboratory, a division of the Department of Microtechnology and Nanoscience (MC2) at Chalmers University of Technology. We are also part of the Wallenberg Centre for Quantum Technology (WACQT).

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References:

Esposito, M. *et al.* (2021) 'Perspective on traveling wave microwave parametric amplifiers', *Applied Physics Letters*, 119(12), p. 120501. Available at: https://doi.org/10.1063/5.0064892.
Ho Eom, B. *et al.* (2012) 'A wideband, low-noise superconducting amplifier with high dynamic range', *Nat. Phys.*, 8(8), pp. 623–627.
Malnou, M. *et al.* (2021) 'Three-Wave Mixing Kinetic Inductance Traveling-Wave Amplifier with Near-Quantum-Limited Noise Performance', *PRX Quantum*, 2(1), p. 010302. Available at: https://doi.org/10.1103/PRXQuantum.2.010302.