# Many body simulation with high kinetic Inductance superconductors

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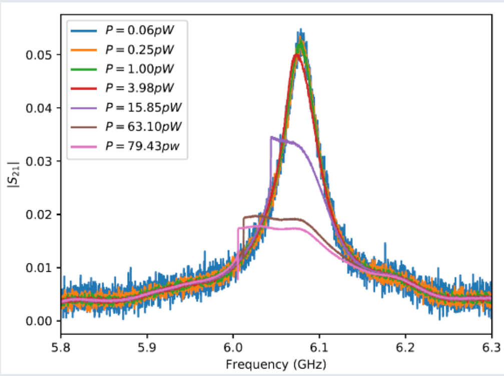
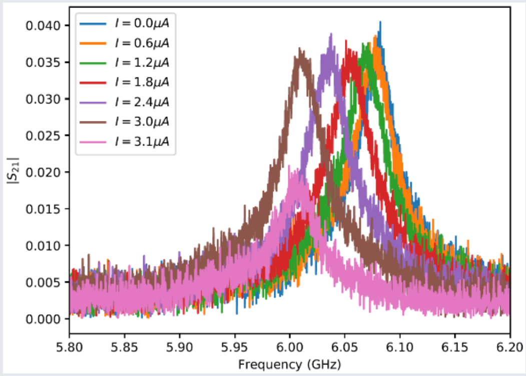
High kinetic superconductors have been of great interest both for fundamental research, for example in the disorder-driven superconducting to insulator transition, and for technical applications, mainly as detector in astrophysics (transition-edge sensor, bolometer, etc.). In our group we are exploring the possibility of using these materials to study classical and quantum many body systems of photons on a lattice of superconducting microwave resonators. Exploiting the intrinsic nonlinearity, given by the kinetic inductance, would allow us to realize photon-photon interactions as described by the Bose-Hubbard model.

During the first year of the project we started focusing on NbSi, whose properties have been studied for many years in the Cryogenic Detector Group at the CSNSM. We decided to start by studying the properties of the material for different niobium concentration, thickness of the film and annealing temperature. In particular, since our final goal was to have a cavity with a decay rate preferably smaller than 1MHz and since our experimental setup works at a base temperature of 10 mK we decided to choose combinations of the parameters which gave us a critical temperature of Tc = 1K in order to better optimize the ratio between the quality factor and the characteristic current that sets the nonlinearity. The sample chosen were $Nb_xSi_{1-x}$ with a concentration x = 18%, thickness t = 500Å and annealing temperature θ = 140° C and a second one with x = 25%, t = 50 Å, θ = 140° C. The two samples were prepared at the CSNSM facility in ultra-high vacuum chamber ($10^{-8}$ mbar) by electron beam codepostion of Nb and Si. The thickness and composition were checked after by Rutherford backscattering spectroscopy (RBS) which confirmed the values expected.




*Nonlinear behavior of the resonator as function of the cf power*




*Shift of the resonance frequency as function of the injected dc current*

We started by characterizing the samples as a function of the width of the film. The critical temperature is the desired one for all the widths ($T_c$ = 1K) and the resistance per square matches the one previously obtained by the Cryogenic Detector Group ($R_n$ = 170 **Ω** for the 1st sample and $R_n$ = 1.3 k**Ω** for the second one). For what concerned the critical current instead, while in the t = 500 Å sample it varies linearly with the wire width with an average current density of Jc = 620 μA/μm$^2$, in the t = 50 Å there isn't any clear and uniform behavior. This is maybe due to inhomogeneity of the thin film or to the possible presence of defects that behaves as thermal 'hotspots' that, under the presence of DC current, dissipate power and heat up the wire causing a measurement of critical current lower than the real one.

To better understand and characterize the $Nb_{25}Si_{75}$ composition we decided to realize a superconducting resonator whose resonant frequency was in the range between 4 GHz and 8 GHz. We designed a Fabry Perot cavity of 400 μm length and 2 μm width, that was coupled to the external injection line by direct contact with a Nb coplanar waveguide. The difference in characteristic impedance between the two materials allowed us to have a coupling rate of 30 MHz at a resonant frequency of 6 GHz. T his geometry allowed us to directly measure the characteristic current of the nonlinearity. In fact, by exploiting the direct coupling with the external line we could inject both RF and DC signal and measure shift in resonance frequency as a function of the DC current. From this variation we extracted the characteristic current of the wire which resulted to be almost 10 bigger than the measured critical one. With the ongoing analysis we will try to determine if the measurement of the critical current is reliable or if the behavior of the NbSi departs from the BCS theory.

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