Non-linear pulse response of a MKID

In most applications, the sensitivity of a Kinetic Inductance Detector (KID) is limited by the noise from the cryogenic amplifier. By increasing the readout power, this limit could be overcome at the cost of leading the resonator to the non-linear regime of response. In a view of using the KID as a single particle detector, the pulse response of this devices deserves an in-depth study. We, therefore, worked to build a pulse response model for a KID operated in the non-linear regime, taking into account not only the electrical effects due to the non-linear kinetic inductance but also the temperature variations caused by power absorption.

Evidence of temperature variation...

Moving from the low- to the high-power regime: reduction in the pulses decay time.

Indirect temperature evaluation

• High input power.
• Pulses acquired at different frequencies (y) along the resonance.
• \( \tau_W \), measured fitting the pulses.
• Temperature evaluated from the \( \tau_W(T) \) function.

Results and validation of the model

Pulse response expression including thermal effects due to power absorption:

\[
\delta \phi(y, a) = \frac{S(f_c, T)}{S(f_c, T_0)} \left( 1 + \frac{4a}{1 + 4a^2} \right) \frac{S(f_c, T_0) + 4a^2}{1 + 4a^2}
\]

The model demonstrates to correctly reproduce the data within a maximum deviation of 10%.

...and its effects

1. \( f_r \) shift produced by thermally generated quasiparticle.
2. \( \delta \phi \) and \( \delta a \) depends on the temperature through \( S_2(f, T) \) and \( S_0(f, T) \).

Resonance parameters including \( S_2/T_0 \):

\[ a \], \( f_r \), \( Q \), \( Q_c \), \( Q_i \)

To understand the magnetic response of the detector, a detailed analysis of its components is needed. This includes the study of the response to magnetic fields and the evaluation of the magnetic field induced by the KID itself. The magnetic response of the detector is influenced by various factors, such as the geometry of the detector, the material properties, and the operating conditions. A comprehensive understanding of these factors is essential for the design and optimization of MKID systems.

The sensitivity of the detector to magnetic fields is a critical aspect of its performance. This sensitivity is characterized by the magnetic field penetration depth and the magnetic field response at the KID edges. The magnetic field penetration depth is determined by the thickness of the material and the applied magnetic field strength. As the magnetic field increases, the magnetic field penetration depth decreases, leading to a decrease in the magnetic field response at the KID edges. This decrease can be detrimental to the detector's performance, as it reduces the effective area of the detector and therefore the signal-to-noise ratio.