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Ka band narrowband parametric amplification via non-linear dynamics in superconducting waveguide cavities

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Narrowband parametric amplifiers with superconducting (SC) thin films on planar transmission lines have been realised by numerous groups. These paramps rely on resonators with non-linear elements within them to allow for harmonic generation that gives rise to signal gain when certain conditions are satisfied. Such params, however, have not yet been realised in SC circular and rectangular waveguide resonators. Considering very small frequency scales of the order of 10-100s of kHz where the dispersion in waveguides is effectively small – the phase matching condition which is key to parametric gain may also be satisfied. Hence, narrowband gain within the profile of a resonance of a cavity resonator is possible.

Reported here are the results from the investigations of SC resonators realised with circular and rectangular waveguides in series and parallel arrangements to the waveguide feedline. These waveguide cavities –milled from bulk Nb or copper with a thin layer of Nb deposited via chemical vapour deposition (CVD) –were designed such that their resonance frequencies lay within Ka band (26.5 –40 GHz). This frequency range was chosen to accommodate for an in-house-built test cryostat with Ka band thermal breaks that ensured thermal isolation of the waveguide cavities and allowed temperatures below 1 K to be reached. Characterisation of the transmission properties of the cavities showed temperature and power dependant behaviour and the appearance of inherently non-linear duffing oscillator features –analogous to weak link non-linearities in SC planar transmission lines –manifesting themselves as 'kinks'of the order of a few kHz in the S-parameter spectra of the resonances. Harmonic generation, as a result of non-linear phenomena, was observed when two separate tones were injected into the cavities. Under certain frequency (and phase) conditions this harmonic generation led to parametric amplification of a weak signal in the presence of a strong pump.

Less than 5 years of experience since completion of Ph.D

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