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Measuring Transmission Line Losses at sub-mm wavelengths with an on-chip Fabry-Perot resonator

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Transmission line losses at sub-mm wavelengths present a significant challenge for highly integrated superconducting circuits, such as on-chip spectrometers, multi-color/dual polarization detectors for measurements of the CMB or phased array antennas. In the case of on-chip spectrometers like DESHIMA or SuperSpec, an internal loss better than $\tan^{-1}\delta = Qi \sim 10^4$ is required to eliminate power loss at both the individual filters and on the path between the antenna feed and the filterbank. While ohmic losses are negligible at frequencies significantly below the gap frequency of the superconductor ($2\Delta \approx 1.1$ THz for NbTiN), other loss mechanisms become significant, such as radiation loss in the case of co-planar waveguides (CPW) and dielectric loss in microstrips (MS). At very high frequencies, above 500 GHz for NbTiN, also the superconducting losses can increase.

We present the design and measurement results for a novel lab on-chip experiment capable of characterizing the internal losses of arbitrary transmission line geometries at frequencies up to 1 THz allowing accurate loss tangent estimates down to $\tan\delta = 10^{-4}$. We use a Fabry-Perot resonator operated at mode numbers $n > 50$ that is coupled to a frequency-tunable THz source via a lens-antenna. The power transmitted through the Fabry-Perot is read out using an Al-NbTiN hybrid CPW microwave kinetic inductance detector(mKID). Multiple chips with both CPW and MS transmission lines have been designed, fabricated and measured using NbTiN as a lossless superconductor and a-Si as dielectric in case of the microstrips. Measurements were carried out in a ^{3}He/^{4}He sorption cooler at 250 mK at frequencies from 320 to 370 GHz.
We find $Q_i > 1.5 \times 10^4$ for CPW resonators and $Q_i = 1 \times 10^4$ for PECVD deposited a-SI, reaching the performance required for the implementation of microstrip filters in on-chip spectrometers.

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