Superconducting Kinetic Inductance-Based On-Chip Frequency Conversion

Grant Giesbrecht[(1)(2)], Nathan Flowers-Jacobs[(1)], Adam Sirois[(1)], Michael Vissers[(1)], Manuel Castellanos-Beltran[(1)], Taylor Barton [(2)], and Paul Dresselhaus[(1)]

(1) National Institute of Standards and Technology, Boulder, Colorado 80305, USA
(2) The University of Colorado Boulder, Boulder, Colorado 80303, USA

In addition to the standard geometric inductance, superconductors have a kinetic inductance that can have a strong quadratic dependence on current. We use this nonlinearity to generate large harmonics of GHz signals by etching a 0.5 m long meandered coplanar waveguide from a 60 nm thick NbTiN sputtered film. After cooling the fabricated chip to 3 K, we measure a maximum on-chip conversion efficiency from 10 GHz to 20 GHz of 14% when applying a 2.5 dBm 10 GHz signal and a 20 mA dc current bias. The measured powers up to the third harmonic and changes in phase agree with harmonic balance simulations of the nonlinear system. We anticipate that further optimization of the design including frequency dispersion engineering will significantly increase the conversion efficiency. This approach and material, which has a critical temperature above 15K, is also extendable up to THz frequencies; we chose to operate at 10s of GHz based on the available instruments and cabling.

The observed efficiency is comparable or better than commercially available frequency converters, especially at lower input RF powers. However, the required cryogenic environment implies that this technology is better aimed at applications that already require cryogenic temperatures. Some example applications are in Josephson voltage standards where the output voltage scales linearly with the frequency of the RF bias, superconducting qubits where the required temperature increases linearly with RF frequency of the qubit, and as the local oscillator for astronomical detectors. In these cases, locating the frequency conversion near the cryogenic application will simplify the RF design and reduce system loss.