MODELING OF A KINETIC INDUCTANCE THZ MIXER FOR LOW-BACKGROUND APPLICATIONS

Boris S. Karasik and William R. McGrath
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109

Andrew V. Sergeev and Vladimir V. Mitin
Wayne State University, Detroit, MI 48202

Further development of the low-noise hot-electron bolometer (HEB) mixers in teraherz frequency range dictates necessity for studying new superconducting materials with lower critical temperature. There are two reasons for that. First, as long as the practical mixers are not quantum-noise limited yet the noise temperature should decrease with the critical temperature of the superconductor. Second, the luck of powerful solid state sources in THz range can be offset to some extent by low local oscillator power requirements on the mixer side. An interesting alternative for achieving this goal may be a kinetic inductance (KI) mixer. Such a device does not have to operate within the superconducting transition region and, therefore, may allow for a better tunability of its temperature dependent parameters in a relatively high critical temperature material (e.g., Nb). Another advantage is the absence of the Johnson noise in KI devices and the large intermediate frequency (IF) bandwidth.

Kinetic-inductance response of superconducting films to electromagnetic radiation has been studied for a number of years. The radiation creates non-equilibrium quaisiparticles, which suppress superconductivity and increase the kinetic inductance. At low modulation frequencies, the output voltage signal is proportional to the frequency. At frequencies larger than the inverse electron cooling time (~1-100ns), the signal reveals a plateau. The response decreases at high frequencies corresponding to the inverse quasiparticle cascading time (1-10ps) so the IF bandwidth of the mixer can be ≥ 10 GHz.

KI mixer is based on a nanobridge biased with a constant current at temperatures well below the superconducting transition. The local oscillator power increases the effective quasiparticle temperature up to 0.5-0.95 T_c. The intrinsic noise temperature is determined by fluctuations of either the quasiparticle temperature, or the number of quasiparticles and can be very low. Since the Johnson noise is absent in such a mixer, the noise contribution of the IF amplifier is the only limiting factor.

We will present a modeling of the performance of the KI mixer based on non-equilibrium response in Nb, NbC, MoRe and Ta. The noise temperature due to the intrinsic noise and to the IF amplifier is calculated as function of temperature and local oscillator power. The requirements for the mixer element optimal size are formulated.