Quasioptical High-T_c Superconductor Josephson Mixer at Terahertz Frequencies

Marian Darula
Institute of Thin Film and Iontechnology (ISI), Research Center Juelich, 52425 Juelich, Germany

Alex D. Semenov
Physical Department, State Pedagogical University of Moscow, 119891 Moscow, Russia

Heinz-Wilhelm Hübers, Josef Schubert
DLR Institute of Space Sensor Technology and Planetary Exploration, D-12489 Berlin, Germany

Mixers based on Josephson junctions from conventional superconductor materials have demonstrated excellent performance at subgap frequencies. The advantages of Josephson mixers are low optimal power of the local oscillator and large intermediate frequency bandwidth but their noise temperature increases dramatically at frequencies corresponding to the energy gap of the superconductor, which is typically below 1 THz for widely used materials. The large energy gap of oxide superconductors makes them promising candidates for development of terahertz Josephson mixers. Here we report on experimental study of the quasioptical mixer utilizing bicrystal Josephson junction from high-transition-temperature $YBa_2Cu_3O_{7-\delta}$ film. Junctions with a width of 2 μm were fabricated from 100 nm thick laser ablated films on bicrystal MgO substrates and had the and the J_CR_n product of about 2 mV at 4.2 K. The planar complementary logarithmic spiral antenna incorporated into co-planar waveguide was patterned from 200 nm thick gold film thermally evaporated in situ on top of the $YBa_2Cu_3O_{7-\delta}$ film. The mixer chip was clamped to the extended hemispherical silicon lens. Performance of the mixer was investigated at 4.5 K bath temperature. We used FIR laser as a local oscillator at frequencies 0.698 and 2.52 THz. System noise temperature (DSB) was determined from Y-factor measured with 300 K and 77 K loads. At 0.698 THz the lowest noise temperature 1750 K was observed when the mixer was biased with the fixed current to the region in the vicinity of either the first Shapiro step or the critical current. Between these two bias points the noise temperature increased to ≈ 20000 K. As function of the local oscillator power the noise temperature reached the minimum when the critical current was suppressed to the half of its equilibrium value. Power of the local oscillator absorbed by the mixer at optimal operation was of the order 100 nW. The present design of our antenna limits the upper operation frequency to the value of 1.8 THz. Nevertheless, we clearly observed Shapiro steps at the frequency 2.52 THz. Bearing in mind an improved design of the antenna, we estimate the 3000 K DSB noise temperature at this frequency.