On the concept of a cold-electron bolometer mixer

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A novel type of phase-sensitive Terahertz heterodyne detector with Cold Electron Bolometer (CEB) sensor has been proposed. In CEB mixer a normal metal absorber of sub-micrometer size is connected with planar antenna via superconductor-insulator-normal metal (SIN) tunnel junctions. The power mixer is different from conventional switching mixer, it can be viewed as a combination of power detector and interferometer in which signal and local oscillator fields interfere to form the interference pattern with rapidly varying interfered component. Signal and LO interfere as $Cos(\omega t)+Cos(\omega+\delta)t=2Cos[(2\omega+\delta)t/2]\cdot Cos(\delta t)/2$ These interference signal of combined fields heats our slow bolometer and produce power that brings after averaging in the signal frequency time scale the IF power. CEB mixer combines advantages of Hot Electron Bolometer (HEB) mixer such as high signal frequency and low LO power, and advantages of SIS mixer such as low noise, high IF and immunity to small temperature variations. At the same time it avoids drawbacks of HEB and SIS such as sensitivity to magnetic field interference, additional noise due to Josephson effect and superconducting transition.

When operate at millikelvin temperatures CEB without strong cooling demonstrate rather slow response in a MHz range due to reduced electron-phonon interaction and slow cooling of the overheated electrons. With increase of temperature, the electron-phonon interaction increases and time constant decrease as $\tau \sim T^{-3}$. The estimated values are 10 μs at 100 mK and 150 ps at 4.2 K. With strong electron cooling the time constant can be reduced by a factor of 10 to 1000.

The conversion efficiency can be estimated from the basic principles of electron cooling: if we have incoming signal power P_{sig} it will be completely compensated by electron cooling to have the same electron temperature. One electron of current roughly removing the energy of kT, and it means, that $P_{cool}=P_{sig}=kT\cdot\Delta I/e$, or $\Delta I=eP_{sig}/kT$. Power absorbed in the IF load can be estimated from Joule heating by IF current at bias voltage close to the gap voltage. Finally for CEBM we can have moderate power gain.

Power matching to the input signal is much easier to achieve in CEBM compared to SIS mixer. In CEBM we do not need to compensate the intrinsic capacitance of tunnel junction, its impedance is rather low and we have mainly real resistance of metal absorber (normal metal film) that is terminated to the planar antenna. In this case it is very easy to achieve perfect impedance matching, even in the wide frequency range.