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FUNDAMENTAL MIXING AT 9.05 GHz USING INDIUM MICROBRIDGES

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Abstract.- We report measurements in which electromagnetic radiation at 9.05 GHz was coupled into indium microbridges using an impedance matching structure similar to that of Taur and Richards. Input coupling efficiency was estimated as -5 dB and overall conversion efficiency of -5 dB was achieved in one instance. Measurements were made on single-bridge samples and on series arrays of microbridges.

INTRODUCTION.- Josephson point contacts have been shown to provide excellent performance as heterodyne detectors of microwave radiation [1]. Microbridges have the advantage that they provide better stability under temperature cycling, but the disadvantage that they exhibit relatively low resistance, making the problem of input and output coupling more difficult. Microbridge arrays, readily fabricated using electron beam lithography, have higher resistance and thus should exhibit better coupling. We have investigated the performance of microbridges and microbridge arrays as heterodyne detectors.

EXPERIMENTAL PROCEDURE.- Experiments were performed using samples mounted in a standard X-band waveguide (dimensions 0.4 x 0.9 inches). Each of our samples was fabricated on a sapphire rod 2 mm in diameter x 50 mm long using an electron beam lithography technique. The rod was coated with indium except for a gap 0.6 mm wide which was spanned by a microbridge array. The rod was then mounted in the waveguide parallel to the short dimension, so that the microbridge array was at the center of the waveguide.

Matching of microwave radiation was accomplished by using a sliding short at the end of the waveguide and a tuning screw located at 3/4 \( \lambda_g \) on the opposite side of the sample rod from the short. Current was introduced into the sample via an RF choke electrically isolated from the waveguide. Two X-band sweep oscillators provided local oscillator (LO) power at 9.05 GHz and signal power at 9.05 GHz + \( v_{IF} \) where \( v_{IF} \approx 2 \) MHz. Typical local oscillator power, \( P_{LO} \), was \( 10^{-6} \) Watts. An intermediate frequency (IF) signal generated by the interaction of the two RF signals with the junction was conveyed to amplifiers having 40 dB of gain and a 5 dB noise figure and then displayed on a spectrum analyzer. Before measurements were performed, the sliding short and tuning stub were adjusted to settings which provided maximum interaction with LO power as indicated by the observed depression of the junction critical current. The temperature was controlled by regulating the pressure above the He-bath containing the sample.

RESULTS.- Mixing was performed at a series of fixed temperatures, varying \( P_{LO} \) and the current bias, while monitoring the IF output on the spectrum analyzer. IF signals were observed when the current bias corresponded to points on the I-V curve where the differential resistance was high.

For a one-bridge sample the optimum bias current was slightly greater than \( I_c \). Efficiency of conversion, \( \eta \), from microwave to IF power increased as the temperature was lowered but the noise background also increased. Variation of the noise power spectral density with differential resistance was similar to that of the signal. For a single microbridge the highest measured conversion efficiency was \( \eta = -9 \) dB and the lowest noise temperature was \( T_M = 6000 \) K.

Series arrays with one exception showed poorer performance since the individual bridges could not be simultaneously biased at their best operating
points. The exceptional case was a two element array in which synchronization automatically occurred at $V = -\frac{\nu_0}{2e}$. This array gave the highest IF output at a current bias corresponding to the steep leading edge of the first order current step.

Figure 1 contains experimental plots of IF power output from the junction versus signal power introduced into the waveguide. IF amplifier noise referred to the input was $-127$ dBm at 30 kHz bandwidth. When the junction noise was added the power spectral density increased by one dB near the IF frequency. Linearity of IF response was observed over a range of 30 dB above noise. The highest measured conversion efficiency was $-5$ dB and the mixer noise temperature was estimated to be $T_N = 390$ K.

The power output was proportional to the product of the coupling efficiency for microwave current entering the sample, and that for IF power leaving it. The former was estimated from reflection measurements to be $0.33$, while the latter, calculated from the differential resistance of the $I-V$ curve was $0.2$. An overall increase of 12 dB should be realizable if near unity coupling efficiency can be attained. Improved RF coupling efficiency could reduce $T_N$ by a factor of 3.

Reference