RF Performance of a 600 - 720 GHz Sideband-Separating Mixer with All-Copper Micromachined Waveguide Mixer Block

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***Abstract*— Here we report on the RF performance of a 2SB mixer (600-720 GHz) fabricated in a new method that combines traditional micromachining with waveguide components fabricated by photolithography and electroplating. The latter allows reaching, in a reproducible way, the stringent accuracies necessary for the critical RF components at these high frequencies.**

I. INTRODUCTION

A sideband-separating (2SB) mixer has several advantages over its double sideband (DSB) counterpart. Despite those advantages, its implementation at high frequencies is rather challenging as a more complex design is needed. In fact, the required waveguide circuitry becomes extremely difficult to fabricate employing traditional machining. Previously, we have demonstrated state-of-art performance of a 2SB mixer for 600–720 GHz band constructed exclusively by traditional micromachining [1]. In order to build such mixer one needs to produce a waveguide hybrid with a minimum branch width of 71 μm made with an accuracy better than 5 μm. However, traditional mechanical milling fails to deliver the required accuracy of the dimensions in a reproducible way.

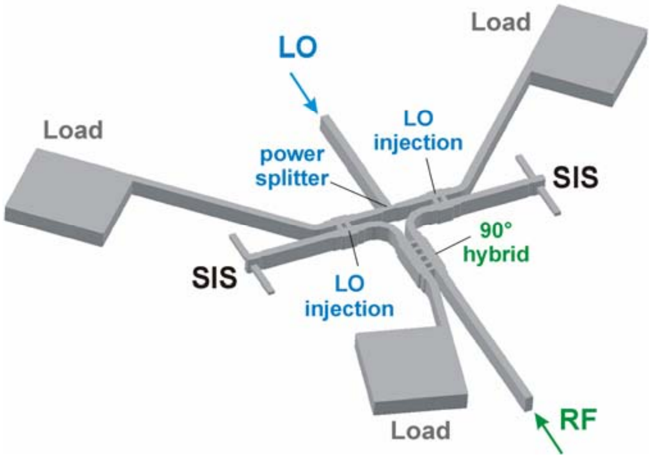

Fig. 1 Proposed realization of the critical RF components. They are designed in waveguide and, therefore, represent the channels to be patterned. The transversal dimensions of the waveguide are 310×145 μm.

Here we report the first results on the RF performance of a 2SB mixer suitable for, e.g., ALMA Band 9 and fabricated using our cutting-edge microfabrication technique [2]. This technique meets the requirements for the dimension accuracy along with surface quality. It, moreover, allows the fabrication of the waveguide components with high yield and repeatability. This approach combines lithographical copper micromachining [3] for making the very fine waveguide structures while allowing regular milling of the remaining not critical mixer parts.

II. DESIGN AND FABRICATION

A. Design

The mixer we describe here is based in a design we have presented in detail previously [1] and is intended to cover the 600-720 GHz range. The design, summarized in Fig. , uses waveguide components and it is planned for construction using the split-block technique. The critical RF waveguide component are a 90° hybrid, a LO splitter, two LO injectors, and two waveguide-to-microstrip transitions.

B. Fabrication

To fabricate the split-block we have followed a new approach which combines two different techniques. We first produce the critical waveguide RF components using a combination of lithography and electroplating. The result of this process is a single copper plate containing all the (small) RF components as shown in Fig.. Gold is finally sputtered on the plate to improve conductivity. Accuracies of less than

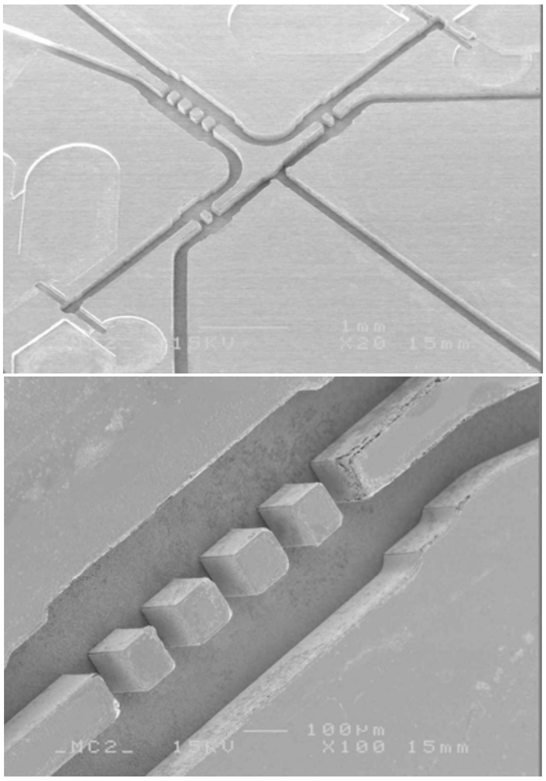

Fig. 2 SEM micrograph of one the copper plates produced lithographically. *Top:* General view of all the RF components. *Bottom:* Details of the 90° RF hybrid.

1 µm and a roughness of ~300 nm RMS can be achieved. This process has been described in detail elsewhere [2, 3, 4] and we refer to those references for details.

The next step in the fabrication process of the mixer's block is summarized in Fig. . First a rectangular cavity is machined in a copper block such that the plate can be fit and soldered using a low-melting-point alloy. Care is taken to have the upper plane of the plate coplanar with the upper plane of the block. Then, all the other non-critical cavities are milled out by conventional means. Finally, all the extra components are placed inside the respective cavities. As mixing elements we have used Nb/AlN/Nb junctions [5].

III. CHARACTERIZATION

A. *Band Coverage*

The direct response, as function of frequency, of both superconductor-insulator-superconductor (SIS) junctions contained in our mixer was determined using a home-made Fourier-transform spectrometer. Notice that the incoming light was coupled into the mixer via the RF port and that no changes were made between both measurements. The results are presented in top panel of Fig. . Both junctions show practically the same response albeit shifted towards low frequencies. The fact that the response is practically identical in the two junctions corroborates the good quality of the fabricated waveguide pattern.

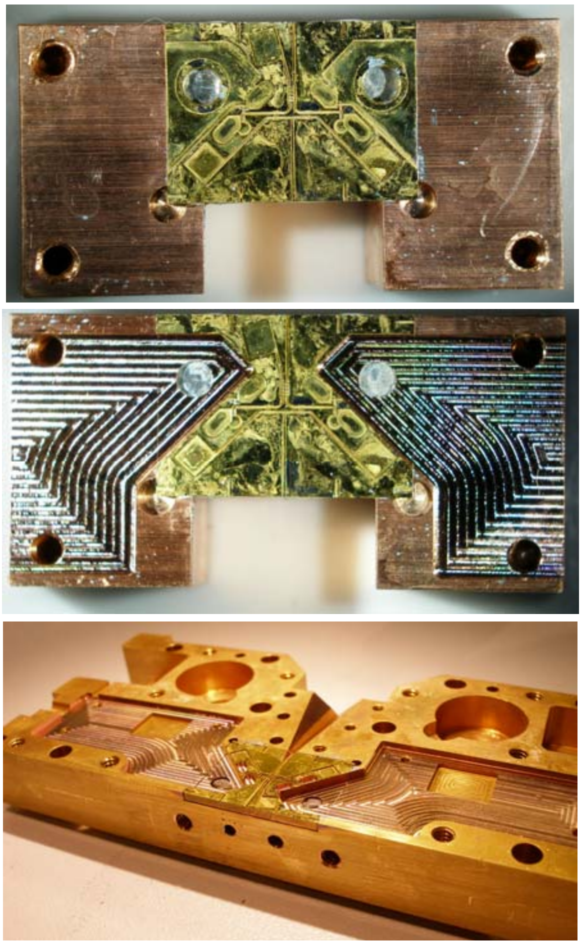

Fig. 3 *Top:* Plate inserted in a test copper block. *Middle:* Test copper block after conventional machining. *Bottom:* Lower part of the fabricated split-block. Notice the inserted plate at the hearth of the block.

B. *Pumping*

Further indication of the good quality of the fabricated pattern is given in the bottom panel of Fig. . In that Figure we indicate the pumping current of both junctions at $V_{BIAS} = 2.5$ mV after subtracting their respective leakage currents. Once more, both junctions show identical response.

IV. CONCLUSIONS AND FUTURE WORK

Here we have presented the RF performance of a heterodyne receiver covering the 600–720-Ghz band. This mixer was fabricated combining two different fabrication techniques. For the small and critical RF components we have used a technique that combines lithography and electroplating. This technique allows to achieve the small dimensions required for these high frequencies with high accuracy and repeatability. On the other hand, the non-critical details were obtained by conventional micromachining. The first results are encouraging as we have demonstrated that we can pump the SIS junctions inserted in the block. Unfortunately, problems with the de-fluxing magnets did not permit the determination of the noise

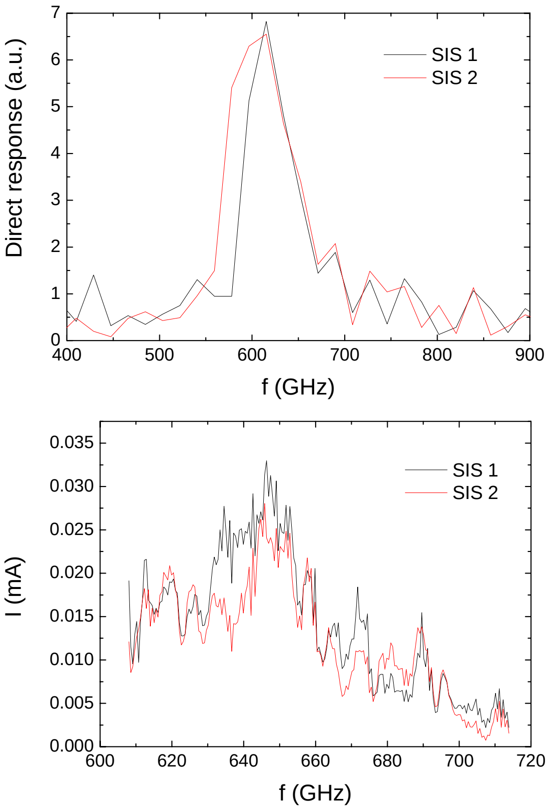

Fig. 4 RF response of the SIS junctions inside the mixer. *Top*: Direct response. *Bottom*: Pumping current on both junctions. The structure of this curve reflects the frequency dependence of the used LO source.

temperature. Once these problems are solved we will be able to characterize completely this innovatively fabricated mixer. Given the good reproducibility in the fabrication of the small RF components, we believe that this technique is promising for the construction of future heterodyne arrays.

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