Broadband Waveguide-to-Substrate Transition Using a Unilateral Etched Finline Structure

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***Abstract*—We present a novel broadband waveguide-to-substrate transition that aims to be used for broadband mixer design. The transition consists of a unilateral finline structure with etched substrate between the fins. This particular feature reduces the overall insertion loss and facilitates matching with the waveguide. The transition is designed of a thin silicon substrate covered by a superconducting niobium thin layer. An auxiliary gold layer situated on top of the Nb-layer provides grounding for the fins and facilitates a simple mounting process in the split-block waveguide mount. In order to compare simulations with measurements, a back-to-back arrangement was designed and simulated using HFSS in the 211-373 GHz frequency band. The back-to-back simulation results show an insertion loss of less than 0.3 dB in the whole band. Furthermore, a fractional bandwidth of 55% with a return loss better than 15 dB is achieved.**

***Index Terms*—Unilateral Finline, Broadband Waveguide to Substrate Transition.**

I. INTRODUCTION

SINCE THz active components are produced using thin film technology, the transition from a waveguide to substrate plays an essential role in the performance of any THz system. Both a good impedance match and ease of fabrication are both fundamental features required in the design of such transitions. Mounting accuracy is also of high importance.

For decades, one of the most popular structures in the THz receivers field has been waveguide E-probes. Although this solution achieves large fractional bandwidths [1,2], its performance is rather sensitive to its position inside the waveguide. As alternative solution, unilateral finline structures [3] are more tolerant in terms of accuracy of their positioning in the waveguide, yet, this approach results in problems related to impedance matching between the waveguide and the substrate, which affects its performance over large operational bandwidths. Other approaches that make use of transmission lines different from microstrip and slotline have been proposed over the years, such as the presented in [4]. Nevertheless, none of these structures is able to address simultaneously all the outlined requirements.

We report on a novel broadband waveguide-to-substrate transition, which employs a unilateral finline structure for prospective use in a broadband mixer design.

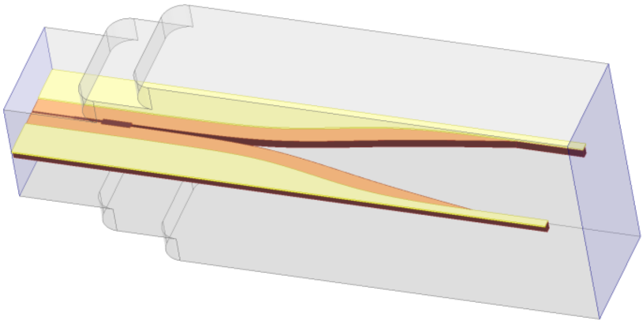

Fig. 1. CAD model of the proposed waveguide-to-substrate transition. The whole structure is centered in the split-plane of a rectangular waveguide (split-block configuration). The layer legend: gold (yellow), niobium (orange) and silicon (black).

II. DESIGN AND SIMULATION

The matching between the high impedance of the full-height waveguide and a slotline is accomplished in two stages. The first stage employs a unilateral etched finline structure, while a 2-section slotline Chebyshev transformer is implemented to finally reach the desired slotline impedance of 60 Ohm. A CAD model of the proposed structure is shown in Fig. 1.

Although several different methods of unilateral finline design have been reported [5,6], none have been formulated for etched finlines. Therefore, we suggest an alternative approach to define the finline profile. Using Ansys HFSS, the impedance and guided wavelength for finline sections of different widths was investigated and mapped. This data was employed to create a 4-step Chebyshev transformer. Finally, a spline curve was drawn through the centre of each step. The same procedure was applied for the slotline Chebyshev transformer.

The transition is designed on a 30 μm silicon substrate covered by a layer of 400 nm thick superconducting niobium. The fins gradually shrink into a slotline defined by the niobium layer. The substrate between the fins has been removed in order to enable a smoother impedance transition between the waveguide and the substrate and avoid dielectric material loss in the weveguide. A 5 μm thick gold layer deposited over the niobium film extends 200 μm beyond the substrate in each direction and serves as beam-leads. This way, upon closing the waveguide, the gold layer is clamped between the two waveguide halves, providing grounding for the fins and facilitating the mounting process. Additionally, the waveguide

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width is gradually reduced in 2 steps to obtain subcritical dimensions. These steps are introduced late in the transition, i.e. when the field has already concentrated inside the fins. Because of this, the waveguide shrinking have almost no influence over the impedance of the transition but provide good isolation against unwanted waveguide modes.

In order to compare simulations with measurements, a back-to-back arrangement was design and simulated using HFSS in the 211-373 GHz frequency band. The simulation results are depicted in Fig. 2. An insertion loss less than 0.3 dB and a return loss better than 15 dB is achieved over the whole band. This result implies a fractional bandwidth of 55%. It is important to note that with the intention of facilitating mounting and improving the mechanical strength of the assembly, silicon tips have been introduced in the back to back transition as it is depicted in Fig. 3. These tips extend from the main substrate and fit inside cavities located in the lower end of the split block.

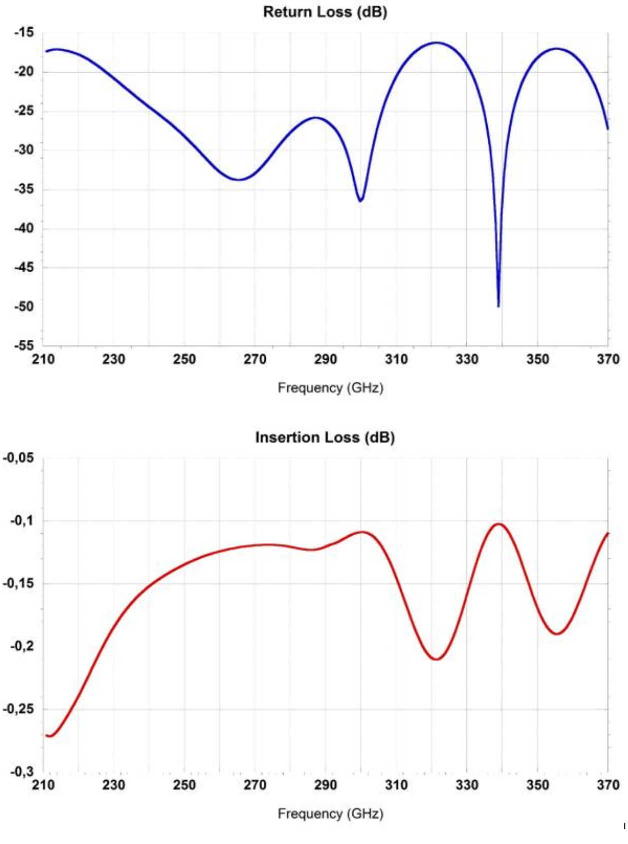

Fig. 2. Simulated scattering parameters for the back to back arrangement. The return loss is below 15 dB and the insertion loss is better that 0.3dB in the whole band.

III. FABRICATION

The fabrication of the back-to-back transition was made in-house. The devices were processed using SOI wafer with a 30 um thick device layer. First, an Nb thin film with a thickness of 400 nm was deposited by DC magnetron sputtering. The first lithography step served to pattern the finline structure and the central slotline transformer. A thin 100 nm sputtered aluminum film was employed as hard mask to protect the underling Nb layer from the subsequent dry etch process. In a second lithography step a resist patch was created to preserve the silicon layer that outlines the slotline. Next, 5 μm of the unprotected silicon were anisotropically etched with help of Bosch process. This guarantees an accurate definition of the etched finline structure in the first microns, which are the most critical for the device performance. The 5 μm gold beamleads were created by photolithography and electroplating process. A Ti/Au bilayer was used for the electroplating seed.

For backside processing, the chip was mounted upside down on a transparent 4-inch sapphire wafer using a release layer and adhesive layer. The next step consists on etching the thick silicon handle layer using the buried SiO$_2$ layer as etch stop. The SiO$_2$ was later striped away in order to allow the final lithography step on top of the remaining 30 μm thick silicon layer. Backside lithography over a thick photo resist provided an etch mask for the subsequent anisotropic etching that completed the device definition. Finally, the adhesive layer and the release layer were removed in solvent, freeing the samples. SEM pictures of the devices are shown in figure 3.

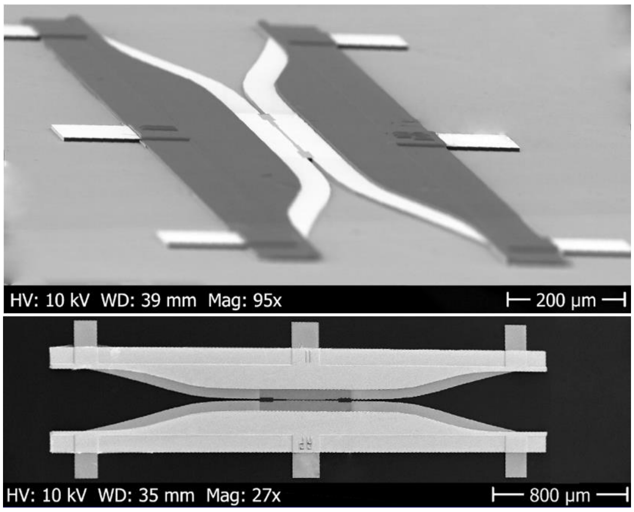

Fig. 3. Scanning Electron Microscope photograph of the fabricated back to back device. Silicon tips facilitates the mounting process and aids handling of the devices.

IV. CONCLUSION

A novel waveguide to substrate transition have been designed and fabricated for the 211-375GHz frequency band. Simulation predicts a promising 55% fractional bandwidth with less than -15 dB return lost. Moreover, the insertion loss is less than 0.3 dB. A back to back transition have been fabricated and experimental verification is in progress.

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