600 GHz GaAs Schottky Diode Mixer in Split-block Technology

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***Abstract*— In this paper we present measurement results of a micro-machined split-block waveguide mixer for 600 GHz. The mixer implements a planar GaAs Schottky diode on a quartz substrate. Two different diode designs used for this mixer design are compared. The overall performance of the waveguide mixer is demonstrated by measurements of the mixer in a quasi-optical setup at 600 GHz. In this setup we are able to measure single sideband conversion losses of 9-14 dB at 600 GHz and voltage responsivities of 421-1690 mV/mW.**

***Index Terms*— heterodyne mixer, split-block, micromachining, 600 GHz, THz-technology, GaAs Schottky diode**

I. Introduction

One of the major problems for measurement systems at submillimeter wavelengths is the lack of devices which are capable to acquire data at these high frequencies. Especially the interest in the THz frequency range for radio astronomy and material science is pushing forward the development of frequency down-converters. Sub-harmonic or fundamentally driven mixers are therefore utilized to down-convert THz signals to intermediate frequencies where measurement equipment for detailed signal analysis is available.
Our heterodyne mixer design is based on a single planar GaAs Schottky diode. The diode is mounted on a quartz substrate and integrated in a split-block waveguide. The waveguide dimensions for the used frequency of 600 GHz are 420 μm x 210 μm. To fabricate these miniaturized waveguides for the mixer block we are using micro-mechanical milling with milling cutter diameters of down to 150 μm. Additionally we use combinations of dry and wet etching processes on standard silicon wafers for advanced geometrical structures like horn antennas [1]. For the measurement verification of the mixer design, a quasi-optical setup is used. The local oscillator (LO) and RF signals are quasi-optically diplexed and then fed into the mixer block by an octagonal horn antenna. The main advantage of this split-block design is the mechanical robustness compared to whisker contacted diode setups and open corner cube structures.

II. The Mixer Design and Components

The three main components of the manufactured 600 GHz mixer are the octagonal horn antenna, a quartz substrate with a waveguide to microstrip transition and filter structures and the Schottky diode. The passive components are simulated and optimized using the 3D field solver Microwave Studio (MWS) from CST. The miniaturized waveguide structures are realized by micromechanical milling in brass[2]. Silicon etching technology is used for the octagonal horn antenna[1]. Fig. 1 shows the lower part of the mixer split-block with the quartz substrate mounted in a trench parallel to E-field in the RF waveguide. The required filter structures and a flip-chip mounted Schottky diode on the substrate are also visible together with the semi-rigid cable used as an IF output port.

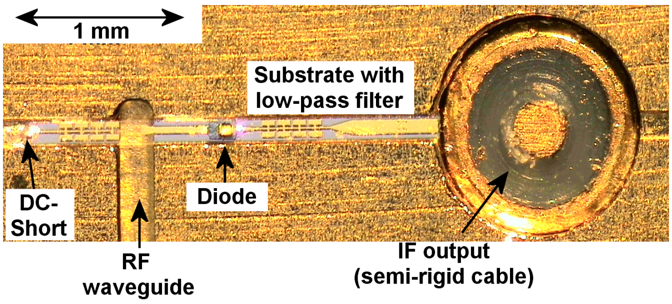

Fig. 1. 600 GHz mixer in split-block technology (before wire bonding)

The coupling element between the waveguide TE_{10} field mode and the micro-strip line on the quartz substrate is a broadband radial stub antenna[2]. The IF output is realized by wire bonding the micro-strip line behind the IF low pass filter to the semi-rigid cable shown on the right of Fig.1. The DC bias for the diode is fed through the IF output by a Bias-T. A small micro-strip line at the stub antenna is required to short the DC bias at the other end of the quartz substrate. The Schottky diodes we are using in this mixer design are provided by the *Advanced Technologies Group (ATech)* at the Technical University of Darmstadt [3]. The first engineering samples were flip-chip Schottky diodes with typical series resistances of $R_s = 14 \ldots 19\Omega$, parasitic capacitances of $C_p = 10 \ldots 12$ fF and ideality factors of $\eta = 1.20 \ldots 1.21$. The typical junction capacitance is approximately $C_{j0} \approx 1.2$ fF.
The parasitic parallel capacitance C_p and the series resistance R_s are the most critical diode parameters for the design of a mixer at THz frequencies as both reduce the available LO and RF signal power at the Schottky contact in the diode. For this reason we optimized the diode's geometrical layout in MWS. The optimum diode structure turned out to be a monolithically integrated diode on the quartz substrate. This diode design significantly reduces the diode parasitics but leads to technological problems in the fabrication process.