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A Broadband Silicon-Integrated Chopper for Passive Terahertz Cameras

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***Abstract*— In this contribution, we describe a reconfigurable surface, designed in 130um SiGe technology, to realize a fully-electronic, planar chopper aiming at passive terahertz imaging applications. This surface consists of subwavelength metallic patches that are interconnected using FET-based varactors. By switching the bias voltage of the varactors between 0V and 1.2V, the reconfigurable surface can switch between a transmissive and opaque state, respectively. The expected transmissivity is simulated to be between 0.2 and 0.9 over a wide frequency band, from 250 GHz to 550 GHz. This chopping solution would enable a high degree of system integration for future passive terahertz cameras.**

Keywords—passive imaging, terahertz, modulator, chopping, SiGe, reconfigurable surface.

I. INTRODUCTION

Direct-detection terahertz imagers are slowly approaching passive and near real-time performance [1]. Integrating a high density of these detectors in a focal plane array imaging system, would allow for a THz camera with both a high spatial and thermal resolution. In these imaging systems, or in radiometers in general, the (thermal) signal of interest is ON-OFF modulated, or `chopped', to discriminate it against the background and to prevent noise-equivalent power degradation due to flicker noise, drift and offset errors.

This chopping operation is usually implemented in passive imaging using either a mechanical chopping wheel between the source and the antenna, or via a Dicke-switch between the antenna and the detector/known load. However, a chopping wheel is bulky, cannot be integrated and limits the chopping frequency. A Dicke-switch is usually used in conjunction with a (narrowband) LNA driving the detector. Since the LNA would require a large silicon area [2], it highly limits the detector density in focal plane array imager concepts and thus the spatial resolution of the camera. In case of a broadband power detector using active illumination, the modulation is implemented in the source itself [1], [3]. Evidently, none of these options allow for a THz camera that is passive, fully-integrated and has high spatial resolution.

In this contribution, we propose a reconfigurable layer, operating as a quasi-optical chopper, that can be integrated between a silicon lens and a focal plane detector array. Since it is located directly on top of the detector chip, the effective area of the chip is comparable (albeit slightly larger) than the detector array chip, making this a very compact solution. Moreover, the design concept is also ultrawideband, operating between 250 and 550 GHz.

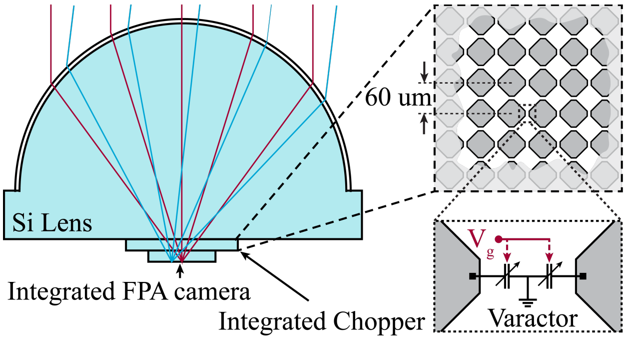

Fig. 1 Terahertz camera consisting of a silicon lens, chopper integrated in 130um SiGe technology and focal plane detector array [3] in the same technology. The inset shows the chopper layer, which consists of subwavelength metal patches loaded with varactors

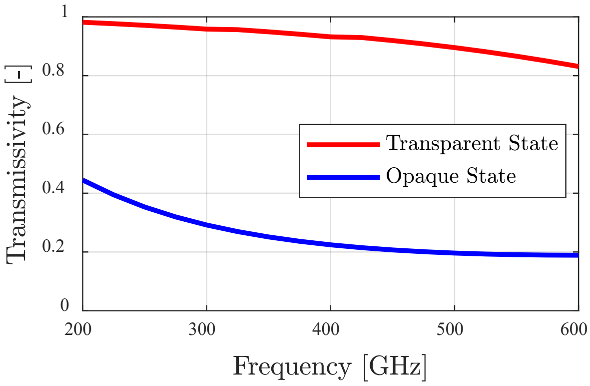

Fig. 2 Simulated power transmission for transparent and opaque states of the chopper, where varactors are biased with V_g=0V.and 1.2V, respectively

II. DESIGN OF SILICON-INTEGRATED CHOPPER

The imaging system architecture, including the proposed integrated chopper is shown in Fig. 1. The chopper is designed in a 130um SiGe technology, and consists of an array of sub-wavelength ($0.28\lambda_{Si}$ at 400GHz) metal patches arranged in a chessboard [3] configuration. A varactor, connected to the gaps between adjacent elements, is used to control the transmissivity of the chopping layer. These varactors are realized using a differential pair of NMOS devices of which the bulk, drain and source terminals are shorted to the ground while gates are connected to the metallic patches.

The bias voltage across the gates, V_g, via the FET channel capacitance, controls the transmissivity of the array layer, and thus can be used to switch between a transparent and opaque state of the array. A large capacitance corresponds to the opaque state, since the geometry comes to resemble a dense wire-grid (i.e., a high-pass filter) with a cut-off frequency beyond the operational band. When the varactor capacitance is very small, the array is in its transparent state. The power transmission through the chopping layer, when embedded in silicon, as extracted from full-wave simulations is shown in Fig. 2, for both the transparent ($V_g = 0V$) and opaque ($V_g = 1.2V$) states. The difference of these two transmission parameters give the total modulation depth of the chopper. It can be seen that, although the chopper achieves moderate modulation depth, it is operational over a large bandwidth. In the lower half of the band, the losses are dominated by the opaque state, and vice versa for the upper half of the operational band.

This chip has been designed and it is currently being fabricated. The measurements are expected to be presented in the conference.

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