On embedding of an HEB mixer into a THz photonic integrated circuit

Alexander Shurakov[*1,2], Ivan Belikov[1,2], Anatoliy Prikhodko[1,2], and Gregory Goltsman[1,2]

***Abstract*—Photonic integrated circuits are worth using at frequencies beyond 1 THz, where they greatly outperform conventional hollow metallic waveguides. In this paper, we propose design of a THz HEB mixer that comprises Si photonic crystal waveguide integrated with two silicon dielectric rod antenna arrays via multimode interference power dividers. These arrays are to couple an HEB element with local oscillator and signal at 2.5 THz. The design is justified by EM modeling and performance tests of the mixer key elements.**

Keywords—terahertz, hot electron bolometer, photonic crystal waveguide, dielectric rod antenna

I. Introduction

Photonic integrated circuits (PICs) are worth using for terahertz applications. Above 300 GHz, they mostly rely on Si platform and make use of either an effective media or photonic crystal waveguides (PCWG) [1]. Si PICs enable creation of RF circuits with numerous passive and active components interacting through low-loss dielectric waveguides. They are especially in demand at frequencies beyond 1 THz, where performance of conventional CNC-machined hollow metallic waveguides is compromised.

In this paper, we propose design of a terahertz (THz) hot electron bolometer (HEB) mixer that comprises Si PCWG integrated with 2 Si dielectric rod antenna (DRA) arrays through multimode interference power dividers. These arrays are to couple an HEB element with local oscillator (LO) and signal at 2.5 THz. Details on the design considerations are provided further in the text.

II. Results

The proposed design relies on a linear 4-element [2] Si DRA array with a taper angle $\alpha = 12°$ and input cross-section of $0.25\lambda_0 \times 0.275\lambda_0$ (height × width) of each element, where λ_0 is the free-space wavelength. It provides a half power beamwidth $HPBW = 24.6°$ and 65.9° in H- and E-planes, respectively. The values are justified by both EM modeling at 2.5 THz and beam profile measurements of the array 1:50 scale model at 50 GHz. EM modeling also suggests that acceptable beam properties can be achieved even in case of a single DRA. The best performance is observed for $\alpha \leq 2°$, when $HPBW \approx 50°$ for both H- and E-planes, gain equals 13.7 dB or more and a side lobe level is well below -30 dB. Since fabrication of the narrow-angle DRA is challenging, we first focus on fabricating the structure with $\alpha = 10°$.

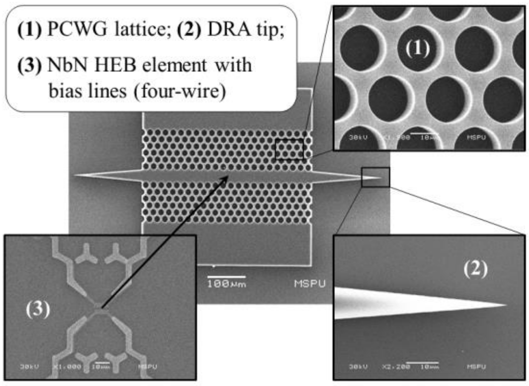

Fig. 1. Key elements of an HEB mixer intended for integration with a THz photonic circuit.

Fig. 1 provides SEM image of a PCWG integrated with 2 DRAs fabricated from SOI via Bosch process. No violation of the PCWG lattice (1) or the DRA tip (2) geometries is observed. The fabricated structure is intended for integration with an NbN HEB element (3) operated at 2.5 THz. The PCWG footprint implemented on SOI with a 30 µm thick topmost layer provides insertion loss due to the energy leakage into a free space $L \leq 0.1$ dB/mm. This is justified by EM modeling and insertion loss measurement of the PCWG 1:16.7 scale model at 150 GHz. Coupling efficiency between the HEB element and the PCWG is to be enhanced by a resonator [3]. Additionally, to increase the NbN/Si interface area and not to drastically enlarge the required LO power, NbN bridge has a size of 1.5×10 µm^2 (length × width) and 2 symmetric 0.25×4.25 µm^2 slots in its central part. We preliminary observe reasonable sensitivity for conventional waveguide HEB mixer with a similar NbN bridge (4 nm thick film) at the LO frequencies below 1 THz. Details on the performance tests of the proposed HEB mixer design at 2.5 THz are to be presented at the conference site.

References

[1] Withawat Withayachumnankul, et al., “Integrated Silicon Photonic Crystals Toward Terahertz Communications”, *Advanced Optical Materials*, 2018

[2] Henning Tesmer, et al., “Fully Dielectric Rod Antenna Arrays with Integrated Power Divider”, *Frequenz*, 2019

[3] Andreas Vetter, et al., “Cavity-enhanced and ultrafast superconducting single-photon detectors”, *Nano letters*, 2016

[1]Moscow Pedagogical State University, Moscow, 119991, Russia; [2]National Research University Higher School of Economics, Moscow, 101000, Russia; [*]alexander@rplab.ru

NOTES: