Lens based Focal Plane Arrays Coupled to Distributed Absorbers
Imaging System Trade-offs

Dabironezare, S.O.; Luomahaara, J.; Llombart, N.

DOI
10.1109/IRMMW-THz50926.2021.9567345

Publication date
2021

Document Version
Final published version

Published in
2021 46th International Conference on Infrared, Millimeter, and Terahertz Waves, IRMMW-THz 2021

2021 46th International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW-THz) | 978-1-7281-9424-0/21/$31.00 ©2021 IEEE | DOI: 10.1109/IRMMW-THz50926.2021.9567345

Lens based Focal Plane Arrays Coupled to Distributed Absorbers: Imaging System Trade-offs

S.O. Dabironezare[1], J. Luomahaara[2], N. Llombart[1]

[1]Microelectronic Department, Delft University of Technology, the Netherlands, dabironezare.shahab@ieee.org

[2]VTT Technical Research Center of Finland, Ltd., Espoo, Finland

***Abstract*— To characterize the spectral coupling between a lens based Focal Plane Array and its Quasi-Optical system, Coherent Fourier Optics methodology is employed. A lens absorber design is proposed and compared to an existing bare absorber-based imaging system. It is shown that the performance of the two imagers is comparable in terms of aperture efficiency, Point Spread Function, and normalized throughput. Moreover, the proposed lens absorber achieves 5 folds better NETD in comparison to the bare absorber due to its smaller physical area. A prototype of the proposed geometry is under fabrication as a proof of concept.**

I. INTRODUCTION

Large Field of Views (FoVs) with low integration times are required for current generation of sub-millimeter security imagers to improve image acquisition speed of full human body. Employing large format focal plane arrays (FPAs) below a focusing Quasi-Optical (QO) system leads to designs with none or very limited mechanical scanning. As a result, the detector's sensitivity requirements can be relaxed by increasing the integration time. A promising solution for development of commercial imaging systems with large format FPAs at sub-millimeter wavelength is based on kinetic inductance bolometers (KIBs) [1] which are incoherent superconductor detectors. A single low-frequency read-out line can be coupled to about 100 KIBs, significantly decreasing the complexity of large FPA architectures. Assuming a fixed thermal bandwidth and heat capacitance that scales with detector area, the phonon-noise limited Noise Equivalent Power (NEP) of bolometers, such as KIBs, is proportional to the width of the detector w [2]. In this work, the coupling of distributed absorbers to dielectric lenses is investigated to reduce the absorbing area with a potential improvement in the imager's sensitivity.

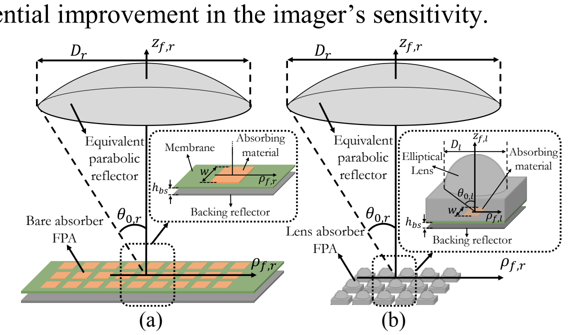

Fig. 1. Illustration of the considered imaging systems geometries: (a) bare absorber and (b) lens absorber FPAs below an equivalent parabolic reflector.

The trade-offs for FPAs based on absorbers were derived recently [3]. In this work, this methodology is expanded using Coherent Fourier Optics model [4] to characterize the coupling of distributed absorbers to multiple cascading QO components such as dielectric lens FPAs below a reflector system. By using this methodology, the performance of a proposed lens absorber based imager is compared with an existing bare absorber in terms of the aperture efficiency, Point Spread Function (PSF), normalized throughput as well as Noise Equivalent Temperature Difference (NETD). The results shown here are validated using full wave simulations with excellent agreement. Moreover, a prototype of silicon lenses coupled to strip absorbers is under fabrication as a proof of concept.

II. PERFORMANCE OF BARE VERSUS LENS ABSORBER

In this section, we compare the performance of the two absorber-based imaging systems: An FPA based on distributed bare absorbers (Fig. 1(a)) and one based on an FPA of dielectric lenses coupled to distributed absorbers (Fig. 1(b)). Here, we considered an example scenario based on an existing imaging system with an FPA of bare absorbers [5]. The detection frequency window of the system is from 200GHz to 1000GHz. The QO system above the FPA is modeled by an equivalent parabolic reflector with diameter $D_r = 120$ mm and f-number (F/D ratio) of $f_\#^r = 2.2$. In [5] a bare absorber array with a pitch of 1.5mm and detector side length of $w = 1$mm is proposed. For comparison, we study an array of silicon elliptical lens (permittivity $\varepsilon_r = 11.9$) with diameter $D_l = 1.5$ mm. The lens surface is covered with a standard quarter wavelength matching layer. In both FPAs, a quarter wavelength backing reflector is also employed.

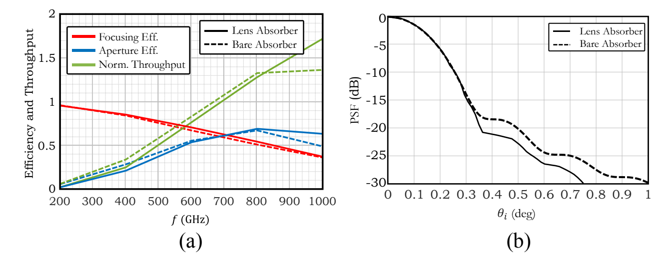

Fig. 2. (a) Efficiency and normalized through put, and (b) Point spread function for the two absorber-based geometries.

The performance of a distributed absorber below a QO component depends on its relative side length [3], i.e. for lens absorber $w_n = w/(\lambda_d f_\#^l)$, where λ_d is the wavelength in the lens material, $f_\#^l$ is the lens f-number, and w is the physical side length of absorber. The aperture efficiency and NEP increase with larger relative and physical side lengths, respectively. As a result, the lens f-number is chosen as small as possible to increase the relative side length while keeping the physical size small. Here, the lens f-number is $f_\#^l = 0.65$ and the physical side length of the absorber is $w = 200$ μm. As a result, the performance of the lens absorber is comparable to the one of the bare absorber in terms of efficiencies, normalized throughput and PSF as shown in Fig. 2(a) and (b). Moreover, the NETD of the proposed lens absorber is 5 folds smaller than the one of bare absorber due to reduction of its physical size and comparable normalized throughput.

REFERENCES

[1]. A. Timofeev, et al., "Optical and electrical characterization of a large kinetic inductance bolometer focal plane array," *IEEE TTST*, 2017.

[2]. A. V. Timofeev, et al., "Submillimeter-wave kinetic inductance bolometers on free-standing nanomembranes," *Superconductor Sci. and Technol.*, 2013.

[3]. N. Llombart, et al., "Reception Power Pattern of Distributed Absorbers in Focal Plane Arrays: A Fourier Optics Analysis," *IEEE TAP*, 2018.

[4]. S. O. Dabironezare, et al., "Coherent Fourier Optics Model for the Synthesis of Large Format Lens Based Focal Plane Arrays," *IEEE TAP*, 2021.

[5]. J. Luomahaara, et al., "A passive, fully-staring THz video camera based on kinetic inductance bolometer arrays," *IEEE TTST*, 2021.