Analysis and Optimization of Terahertz Bolometer Antennas

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Abstract—Bolometer antennas are required to have not only a large gain–bandwidth product but also a fast heating rate for video rate operation. However, while the gain–bandwidth product of an antenna increases with the fraction of the antenna bulk volume occupied by its enclosing sphere, its heating rate decreases. In this paper, we show that for a typical heating rate requirement, wire antennas such as dipole and bow-tie antennas are preferable over planar antennas such as triangular and pentagonal antennas. More complex bent-wire antenna geometries achieved by a genetic algorithm are shown to yield better performance.

Index Terms—Antennas, bolometer, genetic algorithm (GA), terahertz (THz).

I. INTRODUCTION

THz WAVES (300 GHz–10 THz) can be used for security screening, medical imaging, spectroscopy, high-rate communication, astronomy research, etc. On the one hand, devices based on electron transport have difficulty operating above a few hundreds of GHz [1]. On the other hand, efficient operation of photonic devices is challenging in the THz range [2]. Emerging THz detection devices that try to bridge the gap created are summarized in [3]. Most of these devices (e.g., nanotubes or tunnel junctions) are not based on standard chip technologies and hence, are less preferable. However, thermal bolometers can be fabricated using the complementary metal–oxide–semiconductor (CMOS) process [4], and therefore offer a way for attractive THz imaging detectors. In order to increase the absorbed power, an antenna can be added to the bolometer. Most of the present studies of THz antenna-coupled bolometers separate between with the electromagnetic (EM) analysis of the antenna [5] and the thermal analysis of the rest of the system [6]. A more accurate analysis should take into account both the thermal and EM aspects when designing the antenna. Here, we suggest a gain–bandwidth product subject to heating rate and antenna size constraints that catches the physics of the EM absorption together with the thermal considerations. This allows to choose, among commonly used antennas, one that is the most suitable for bolometers. We also use a GA that offers new optimized antenna geometries with enhanced performance for bolometer imagers.

The problem under consideration is described in Section II.

The remainder of this paper is organized as follows. The problem under consideration is described in Section II.

II. PROBLEM DESCRIPTION

In this work, we concentrate on room-temperature passive antenna-coupled bolometers fabricated using CMOS technology. These bolometers offer the benefits of small form factor, low cost, low power consumption, and a potential for mass production. They can be used for real-time imaging in applications ranging from security to medical. In passive imaging, the black-body radiation emitted by the object is focused through an imaging lens (whose area is assumed to be smaller than the coherence area of the radiation [7]) and captured by a focal plane array of detectors.

An EM heating model is given in Section III. In Section IV we explain about the gain–bandwidth and heating-rate requirements from a bolometer antenna. Performance of commonly used bolometer antennas is compared in Section V. The optimization procedure is described in Section VI, followed by conclusions in Section VII. In the Appendix, we present the relative bandwidth calculation method used in the comparison presented in Section V.

Fig. 1. Description of the bolometer pixel developed at IBM Research [8].