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Metamaterials in applications: tunable filters and resonant detectors

A. Benz[1,3*], S. Campione[2], M. Krall[3], S. Schwarz[3], D. Dietze[3], H. Detz[4], A. M. Andrews[4], W. Schrenk[4], G. Strasser[4], J. Klem[5], M. B. Sinclair[5], E. A. Shaner[5], F. Capolino[2], K. Unterrainer[3] and I. Brener[1,5]

[1] *Center for Integrated Nanotechnologies (CINT), Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185, USA*
[2] *Department of Electrical Engineering and Computer Science University of California, Irvine, 4131 Engineering Hall, Irvine CA 92697*
[3] *Photonics Institute and Center for Micro- and Nanostructures, Vienna University of Technology, Gusshausstrasse 29/387, 1040 Vienna, Austria*
[4] *Institute of Solid-State Electronics, Vienna University of Technology, Floragasse 7/362, 1040 Vienna, Austria*
[5] *Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185, USA*

Abstract - We present two possible applications for optical metamaterials combined with intersubband devices: optical filters in the strong-coupling regime and resonant detectors. A two dimensional meta-surface is used for the designed, sub-wavelength resonator.

Optical metamaterials (MM) in the mid-infrared (MIR) and terahertz (THz) spectral range have recently caused tremendous research interest. Their designed frequency response makes them very attractive for variety of applications. It is defined purely by the geometry of the structure.
Here, we present the design and realization of metamaterials for the MIR and THz spectral region and their benefit to two potential applications: filters and detectors. We always use a conventional two-dimensional metallic meta-surface processed on top of a semiconductor. Our optical filters operate in the strong light-matter interaction regime and are designed for 10 μm. Fig. 1 shows the simulated and experimental transmission spectra for an intersubband device. The characteristic anti-crossing for a strongly coupled system is clearly visible. It shows a separation between the upper and lower polariton of 3.6 THz, corresponding to 15% of the center frequency. Instead of manipulating the shape of the MM or the refractive index of the substrate, we propose to control the coupling strength of the system. This is the first crucial step towards an all electrically tunable MIR filter.
Our detectors are based on a conventional THz quantum-cascade laser designed for 3 THz. The metamaterial layer on top of the device allows us to couple the normal incidence radiation resonantly to the intersubband transitions. At zero bias the heterostructure shows transitions below and above the reststrahlenband of gallium-arsenide. These transitions set the possible operating wavelengths for the detector; the metamaterial defines the active ones.

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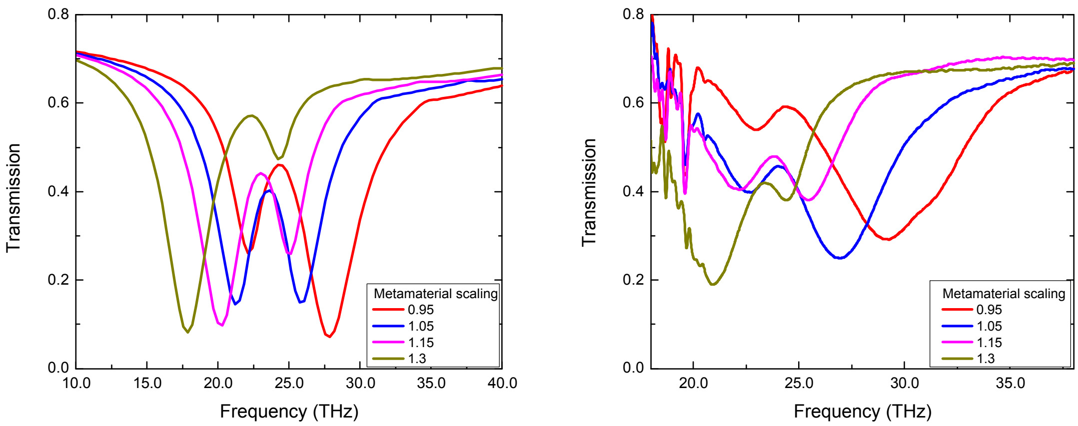

Fig. 1: Simulations (left panel) and experimental results (right panel) of a strongly coupled metamaterial to an IST. Both systems are set to be resonant at 24 THz. The scaling factor corresponds to different metamaterial resonances

Email: anbenz@sandia.gov
Phone: +1 (505) 844-9642