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Plasmonics and Nanoantennas for Infrared Detectors

David W. Peters, Paul S. Davids, Jin K. Kim, Darin Leonhardt, Joel R. Wendt, Charles M. Reinke

Sandia National Laboratories
PO Box 5800 M/S 1082, Albuquerque, NM USA
dwpeter@sandia.gov

Abstract: Detectors that take full advantage of the energy confinement offered by surface waves could have significant performance advantages. We use a subwavelength patterned metal nanoantenna structure to convert incoming plane waves to these surface waves.

We are integrating nanoantennas to midwave infrared (MWIR) detectors. A nanoantenna in close proximity to the active material of a photodetector allows us to take advantage of the concentrated plasmonic fields of the nanoantenna. The role of the nanoantenna is to convert free-space plane waves into surface plasmons bound to a patterned metal surface without reflection. These plasmonic fields are concentrated in a small volume near the metal surface. The nanoantenna allows us to

- Integrate different optical functionality on a pixel-by-pixel basis (polarizers, wavelength filters).
- Lower the dark current since there is less active material.
- Operate at higher temperatures with the same performance.
- Eliminate antireflection coatings as the nanoantenna is reflectionless.
- Strain the material with more freedom: we can push the cutoff wavelength higher by tenths of microns.
- Improve all IR platforms as nanoantennas could be used with III-V, HgCdTe, Ge, or bolometer-based detectors.
- Spectral filtering with a passband that is virtually independent of angle.

The surface wave is bound to the underside of the patterned metal layer.[1] In the MWIR this field extends only a short distance: depending on the material and structure design from tens to a couple hundred nanometers. The active layer of the detector need only fill this volume. The basic structure is shown in Figure 1. The active material is sandwiched between the patterned metal nanoantenna and a solid metal backplane. Reduction in active material volume leads to a reduction in dark current.

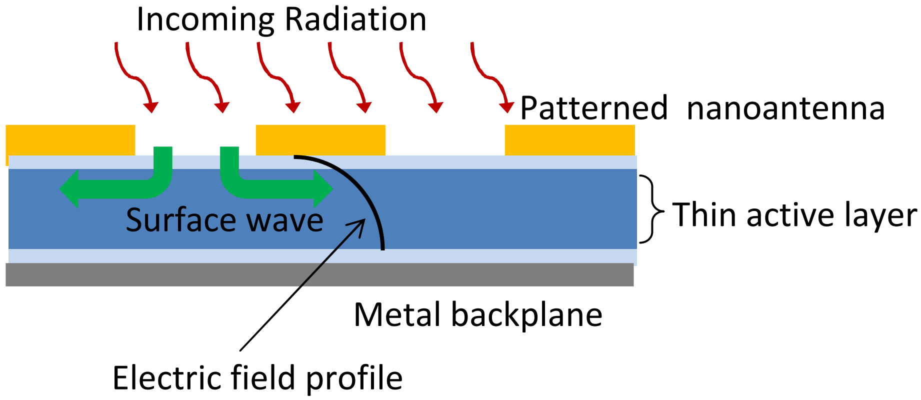

Figure 1. A cross-section of a potential infrared detector. The bound surface wave leads to an electric field concentrated near the patterned metal layer, allowing us to use only a thin layer of active material.

In a focal plane array (FPA), the nanoantenna also has the advantage of being able to be used as a spectral filter, or as a polarizing element. The functionality may be changed from pixel to pixel as the nanoantenna pattern is defined lithographically. Four adjacent FPA pixels with different functionalities are shown in Figure 2. Different patterns have different bandwidths and different center frequencies, allowing multispectral capabilities. The lower-right pixel demonstrates the ability to have a polarizing element as opposed to polarization independent.

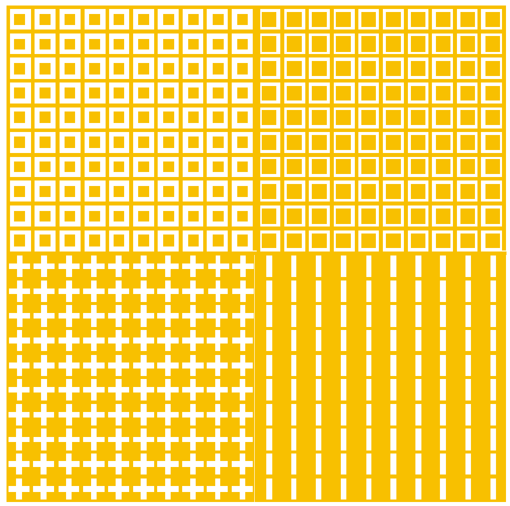

Figure 2. Four adjacent pixels with different nanoantenna patterns displaying ability to have different passbands, bandwidths, or in the case of lower-right, polarization capabilities.

In this talk we will discuss the progress we have made in integrating a nanoantenna with a aluminum arsenide antimonide MWIR detector with an active volume that is over an order of magnitude less than that of a traditional MWIR FPA.

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REFERENCE

[1] Peters, D.W., Davids, P., Wendt, J.R., Cruz-Cabrera, A.A., Kemme, S.A. and Samora, S., "Metamaterial-inspired high-absorption surfaces for thermal infrared applications," Proc. SPIE 7609, 76091C (2010).