Sensitive Near-IR Detector Using Plasmonic Bowtie Nanoantenna Integrated with InGaAsSb Nano-load

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Traditional infrared (IR) detectors make use of anti-reflection coating to match the impedance between the surrounding medium and the high index semiconductor material (D.W. Peters, C. M. Reinke, P. S. Davids, J. F. Klem, D. Leonhardt, J.R. Wendt, J.K. Kim, and S. Samora, Proc. of SPIE, 8353, 83533B). This merely reduces the reflection without providing other advantages as pertain to improved signal-to-noise ratio that is critical for enhancing the detector sensitivity. Also, a thick conventional infrared detector's performance is limited by the absorption coefficient of the active semiconductor material (M. N. Abedin, T. F. Refaat, R. P. Joshi, O.V. Sulima, M. Mauk, and U.N. Singh, Proc. of SPIE, 5074, 332-342). To increase the signal-to-noise ratio or sensitivity, the antenna-coupled detectors where the antenna is mounted at the boundary between the surrounding media and the active material have been studied (L. Novotny, Physical Rev. Let., 98, 26, 2007). The antenna collects the incoming signal into a small volume of the active material, and the collected signal is enhanced due to the surface plasmonic effect of the antenna at the optical band. The enhanced field is confined near the antenna terminals and the thickness of the active area can be reduced. This reduction of the active region will reduce the dark current which in turn increases the signal-to-noise ratio of the detector. Basically the antenna captures the energy using its effective area and concentrates it at its terminal very much similar to optical lenses. However, the advantage here is that the focused area is much smaller than a wavelength, something that lenses cannot do due to diffraction limit.

In this study, the sensitivity of an antenna-coupled infrared detector (1 μm to 2.2 μm wavelengths) is investigated by considering the field enhancement at the antenna terminals, material properties, and the relevant antenna parameters. Specifically, the bowtie antenna structure, loaded with Indium Gallium Arsenide Antimonide (InGaAsSb) low bandgap semiconductor with E_g = 0.52 eV, is considered. The antenna structure has been optimized to maximize the field enhancement at its terminals for a desired frequency (180 THz) at which the maximum quantum efficiency of InGaAsSb is observed. The antenna dimensions have been optimized for achieving a high impedance value for the maximum power transfer and the load reactance is compensated with an integrated parallel line open stub. Also a planar metallic reflector behind the antenna at a quarter wavelength is envisioned for capturing most of the incident power. The improved sensitivity of the plasmonic bowtie antenna-coupled InGaAsSb detector relative to the traditional InGaAsSb bulk detector is measured by the detectivity parameter which is derived from the conventional signal-to-noise formulations. When Johnson noise for the infrared detector is dominant, the detectivity is expected to be increased linearly by the amount of the field enhancement factor, approximately 20.