Optical Antennas: a Boost for Infrared Detection

Huifeng Li, and Xing Cheng
Solid-State Electronics, Photonics and Nano-Engineering Laboratory
Department of Electrical and Computer Engineering
Texas A&M University, College Station, TX 77843-3128

Recently, optical antennas have been intensively investigated due to its potential applications in optoelectronics, microscopy and optical lithography [1-3]. Optical antennas can bridge the gap between the radiated optical energy to the confined and intensity-enhanced optical energy in a local volume of a subwavelength scale. Till now, most research has focused on the applications in the visible light range. One of the potential applications of optical antennas is to enhance the sensitivity of infrared photodetectors. High performance semiconductor-based photodetectors such as HgCdTe photoconductor and quantum-well infrared photodetector all require cryogenic cooling to operate. Those infrared detectors are expensive and not trivial to be scaled down for portable infrared systems. Integrating optical antennas with infrared photodetector may present a practical way to greatly enhance the signal-to-noise ratio and enable low-cost and non-cooled infrared photodetectors.

In this paper, optical antennas that operate at wavelengths from near infrared to far infrared are explored. A finite-difference-time-domain algorithm is used to simulate and optimize the performance of the antennas with different geometries. Figure 1(a) shows a snapshot of mid-infrared field distribution in a dipole antenna and Figure 1(b) shows the intensity enhancement in the gap region of the optical antenna as a function of incident wavelengths. Strong field enhancement in the gap region suggests that the optical antennas can have the potential to significantly enhance the sensitivity of infrared photodetectors. The intensity enhancement factor is found to increase monotonously with narrower gap and it can be over 20,000 for mid-infrared wavelengths at resonance. Base on the simulation, optical dipole antennas and bow-tie aperture antennas are fabricated using the electron-beam lithography, as shown in Figure 2. The infrared absorption measurement of these antennas will be performed to verify our simulation results and demonstrate the advantageous usage of optical antennas in infrared technologies. The optical antennas for infrared wavelengths have a scale of hundreds of nanometers to several micrometers. It is much easier to fabricate such devices compared to the optical antennas operating in visible wavelengths, which often require structures in tens of nanometers. Simple lithography techniques, such as nanoimprint lithography, can be employed for time and cost effective fabrication of optical antennas for infrared applications such as antenna arrays used in infrared imaging systems.

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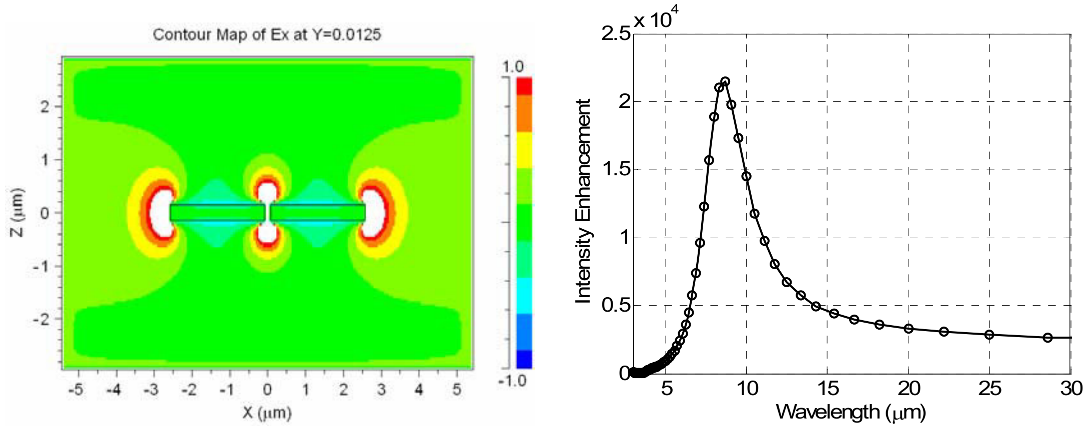
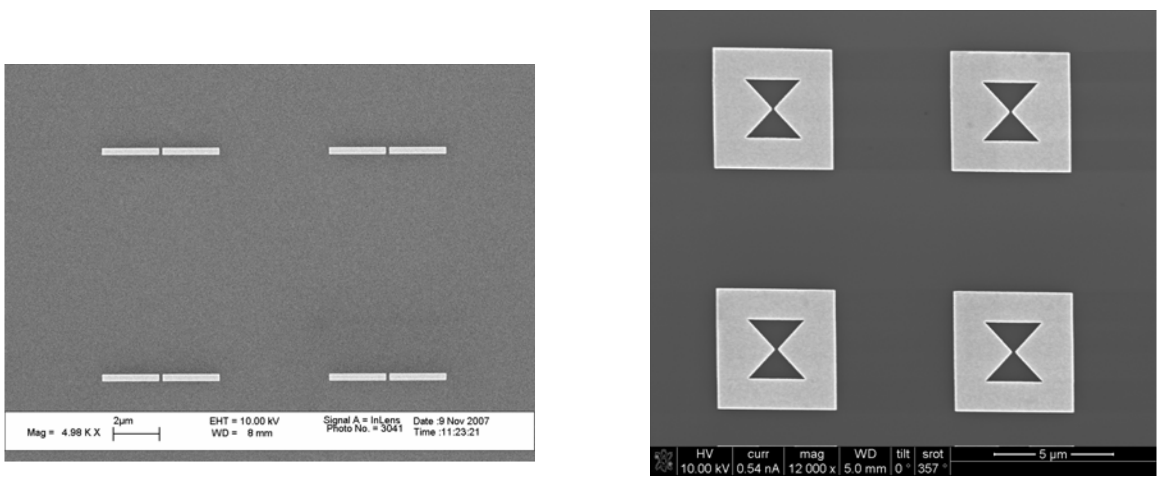


(a) (b)

Figure 1. (a) Optical field distribution in a dipole antenna; (b) Optical intensity enhancement in the gap region as a function of excitation wavelengths.



(a) (b)

Figure 2. SEM micrographs of optical antennas fabricated on a silicon wafer. (a) dipole antennas; (b) bow-tie aperture antennas.