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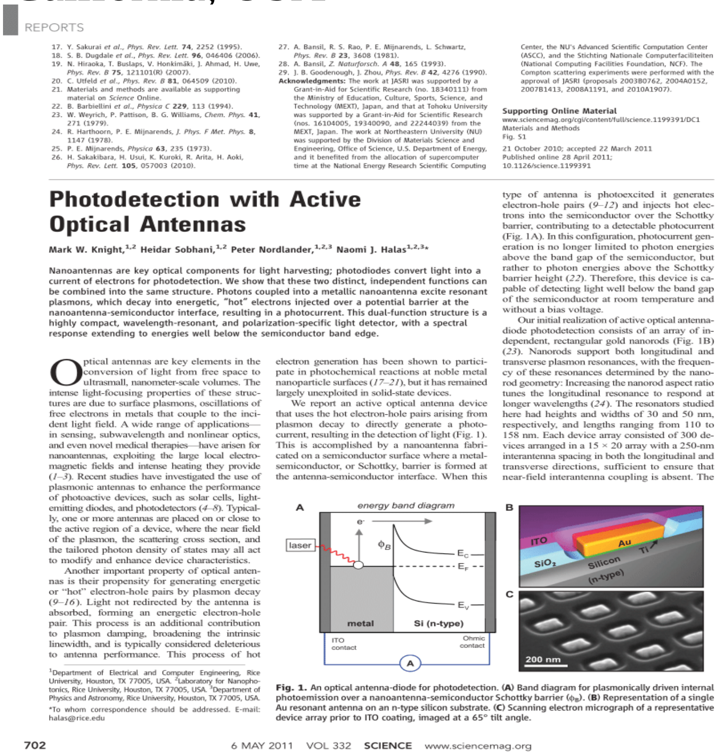

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Fig. S1

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Photodetection with Active Optical Antennas

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Nanoantennas are key optical components for light harvesting; photodiodes convert light into a current of electrons for photodetection. We show that these two distinct, independent functions can be combined into the same structure. Photons coupled into a metallic nanoantenna excite resonant plasmons, which decay into energetic, "hot" electrons injected over a potential barrier at the nanoantenna-semiconductor interface, resulting in a photocurrent. This dual-function structure is a highly compact, wavelength-resonant, and polarization-specific light detector, with a spectral response extending to energies well below the semiconductor band edge.

Optical antennas are key elements in the conversion of light from free space to ultrasmall, nanometer-scale volumes. The intense light-focusing properties of these structures are due to surface plasmons, oscillations of free electrons in metals that couple to the incident light field. A wide range of applications—in sensing, subwavelength and nonlinear optics, and even novel medical therapies—have arisen for nanoantennas, exploiting the large local electromagnetic fields and intense heating they provide (*1–3*). Recent studies have investigated the use of plasmonic antennas to enhance the performance of photoactive devices, such as solar cells, light-emitting diodes, and photodetectors (*4–8*). Typically, one or more antennas are placed on or close to the active region of a device, where the near field of the plasmon, the scattering cross section, and the tailored photon density of states may all act to modify and enhance device characteristics.

Another important property of optical antennas is their propensity for generating energetic or "hot" electron-hole pairs by plasmon decay (*9–16*). Light not redirected by the antenna is absorbed, forming an energetic electron-hole pair. This process is an additional contribution to plasmon damping, broadening the intrinsic linewidth, and is typically considered deleterious to antenna performance. This process of hot electron generation has been shown to participate in photochemical reactions at noble metal nanoparticle surfaces (*17–21*), but it has remained largely unexploited in solid-state devices.

We report an active optical antenna device that uses the hot electron-hole pairs arising from plasmon decay to directly generate a photocurrent, resulting in the detection of light (Fig. 1). This is accomplished by a nanoantenna fabricated on a semiconductor surface where a metal-semiconductor, or Schottky, barrier is formed at the antenna-semiconductor interface. When this type of antenna is photoexcited it generates electron-hole pairs (*9–12*) and injects hot electrons into the semiconductor over the Schottky barrier, contributing to a detectable photocurrent (Fig. 1A). In this configuration, photocurrent generation is no longer limited to photon energies above the band gap of the semiconductor, but rather to photon energies above the Schottky barrier height (*22*). Therefore, this device is capable of detecting light well below the band gap of the semiconductor at room temperature and without a bias voltage.

Our initial realization of active optical antenna-diode photodetection consists of an array of independent, rectangular gold nanorods (Fig. 1B) (*23*). Nanorods support both longitudinal and transverse plasmon resonances, with the frequency of these resonances determined by the nanorod geometry: Increasing the nanorod aspect ratio tunes the longitudinal resonance to respond at longer wavelengths (*24*). The resonators studied here had heights and widths of 30 and 50 nm, respectively, and lengths ranging from 110 to 158 nm. Each device array consisted of 300 devices arranged in a 15 × 20 array with a 250-nm interantenna spacing in both the longitudinal and transverse directions, sufficient to ensure that near-field interantenna coupling is absent. The

Fig. 1. An optical antenna-diode for photodetection. (**A**) Band diagram for plasmonically driven internal photoemission over a nanoantenna-semiconductor Schottky barrier (ϕ_B). (**B**) Representation of a single Au resonant antenna on an n-type silicon substrate. (**C**) Scanning electron micrograph of a representative device array prior to ITO coating, imaged at a 65° tilt angle.

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