Supplementary Figure 1: Quantum transmission probabilities of different metal–semiconductor interfaces. The barrier heights of Ti–Si, Ag–Si, and Au–Si interfaces are 0.5, 0.7, and 0.75 eV, respectively. The quantum transmission probability of the Ti–Si interface was much higher than those of the Ag–Si and Au–Si interfaces in the IR spectral regime.
Supplementary Figure 2: The measured current–voltage characteristic of the DTDM–based devices. The rectification of I–V curve indicated obviously the DTDM–based active antenna device was a Schottky diode because of the smaller turn–on voltage compared with that of conventional PN junction. Additionally, the dark current of this device at reverse bias was low. In the operation region, the dark current density was around $8.7 \times 10^{-9}$ A cm$^{-2}$ at zero–bias.
Supplementary Figure 3: The explanation about discrepancy between simulation and experiment. (a) The simulated absorbance spectrum of the real H07P14 DTTM device. (b) The quantum efficiency ($\eta$) of Au/Si diode calculated by modified Fowler equation. (c) The responsivity curve calculated from equation (2) (as displayed in Supplementary Note 2) for the H07P14 DTTM device. (d) The measured responsivity curve of the H07P14 DTTM device.
Supplementary Figure 4: Experiment for comparison of different DTTM structures. The measured responsivities of the H04P08 DTTM device revealed much lower than that of the H07P14 DTTM device in the spectral regime between 1250 and 1650 nm, although the H04P08 DTTM device also possessed large Au/Si junction area in the cavity structures. This result can be attributed to the SPR peak of the H04P08 DTTM structure (at ca. 780 nm) far away from the detection spectral regime (from 1250 to 1650 nm). Accordingly, we suggested that the SPR and 3D cavity effects both are very important for the DTTM structures to enhance the electric field around Au/Si interface and absorbance of Au layer in the telecommunication wavelengths.
Supplementary Note 1: Quantum transmission probabilities of different metal–semiconductor interfaces.

The spectral response of an active antenna–based device can be considered as that of a Schottky diode in the absence of a specific plasmon resonance. The responsivity depends only on the quantum efficiency ($\eta_i$) of the photoemission process, which can be approximated by the modified Fowler equation\(^1\),

$$\eta_i \approx C_F \frac{(h\nu - q\Phi_b)^2}{h\nu}$$  \hspace{1cm} (1)

where $C_F$ is the Fowler emission coefficient, $h\nu$ is the photon energy, and $q\Phi_b$ is the Schottky barrier height. This equation describes the number of carriers with sufficient energy to overcome the barrier height and, thereby, contribute to the photocurrent. To investigate the quantum transmission probabilities, according to equation (1), we calculated the quantum transmission probability–wavelength diagrams for various metal–semiconductor interfaces at distinct wavelengths. In previous studies of photodetection by Si substrates in the IR regime, all of the active antennas were composed of two kinds of metal to form a bilayer structure. The bilayer active antennas were prepared by first depositing a thin Ti layer onto Si to form a Ti/Si interface and then depositing and patterning a Au layer on the Ti film to obtain the LSPR–based optical antenna\(^1\). Moreover, Ag possesses superior optical properties that make it suitable for constructing nanostructures having strong SPR characteristics.
Supplementary Fig. 1 displays the calculated quantum transmission probability–wavelength diagrams for Ti–Si, Ag–Si, and Au–Si interfaces at distinct wavelengths. According to previous reports, the barrier heights\(^2\) of Ti–Si, Ag–Si, and Au–Si interfaces are 0.5, 0.7, and 0.75 eV, respectively. Because the barrier height of a Ti–Si interface is much lower than those of Ag–Si and Au–Si interfaces, the quantum transmission probability of a Ti–Si interface in the IR regime is significantly higher than those of Ag–Si and Au–Si interfaces. Although the Ti–Si interface possesses a low barrier height, the nature of its optical properties limits a single–layer Ti–based antenna from generating plasmonic phenomena. Accordingly, all previous studies\(^1,3\) have been performed using bilayer active antenna structures: a bottom Ti layer has been used to form a low–barrier–height Ti–Si interface and a top Au nanostructure has been used to generate surface plasmon waves and harvest the incident light. In this study, with regard to the simplicity of the fabrication processes and the stability of the metal, we applied a single–layer Au film to prepare the active antenna. Moreover, because the plasmonic–induced hot electrons were generated directly in the Au layer, we could focus on the optical behaviors of DTTM antenna structures that may straight affect the photoresponse of devices. In addition, the stability of the metal should also be taken into consideration. Even though a Ti–Si or Ag–Si interface might provide a higher quantum transmission probability than that of
a Au–Si interface, Ti and Ag are much more prone to oxidation in air than is Au. In this study, with regard to the simplicity of the fabrication processes and the stability of the metal, we prepared a DTTM–based active antenna structure that featured only a single–layer Au antenna. Furthermore, we employed the deep–trench structure, possessing excellent light trapping and hot electron generation capabilities, to overcome the much lower quantum transmission probability at the Au–Si interface, relative to that at the Ti–Si interface.

**Supplementary Note 2: The explanation about discrepancy between simulation and experiment**

When the Schottky barrier is formed by an active antenna rather than a continuous film, the active antenna–based devices responsivity will show a Fowler equation modified by the plasmon absorption spectrum,

\[
R(\lambda) = \eta_i S(\lambda)
\]

where the \( R(\lambda) \) is the spectral responsivity, and the \( S(\lambda) \) is the plasmon absorption spectrum. Generally, \( S(\lambda) \) will depend on many factors, including geometry, species of metal, and the dimension of active antennas. With the extended Fowler relation, we can fit the experimental responsivities with equation (2), using a known plasmon absorption spectrum for \( S(\lambda) \).
Here, we further compared the calculated spectral response with the measured responsivity of the DTTM (H07P14) device. Firstly, according to the SEM image shown in the Fig. 1c (in the manuscript), we used the 3D–FDTD to simulate the absorbance spectrum $S(\lambda)$ of the real DTTM active antenna device. The Supplementary Fig. 3a displays the simulated absorbance spectra $S(\lambda)$ of the real DTTM active antenna device. We found that the absorbance peak of the real DTTM device only slightly blue–shift toward shorter wavelength than that of perfect structure displayed in Fig. 2c (in the manuscript). Through the simulation result of the real DTTM structure, the spectral features of the active antenna device still possess high absorbance over broadband wavelength. Then, we calculated the quantum efficiencies ($\eta$) of Au/Si with the barrier height (0.75 eV). The spectrum of quantum efficiencies ($\eta$) revealed much higher value in the shorter wavelengths and decreased gradually as increasing the wavelengths (as shown in the Supplementary Fig. 3b). Finally, we calculated the spectral responsivities by multiplying the absorbance spectrum $S(\lambda)$ of the real DTTM device (Supplementary Fig. 3a, there is a clear peak) and the quantum efficiency ($\eta$) of Au/Si diode (Supplementary Fig. 3b). The calculated responsivities [in the Supplementary Fig. 3c, (there is no obvious peak)] also reveal higher values in the shorter wavelengths and decreased gradually as increasing the wavelengths. Next, we compared the measured spectral responsivities
of H07P14 DTTM device (Supplementary Fig. 3d) with that of the calculated one (Supplementary Fig. 3c). We found that the line of the experimental spectral responsivities was very similar to the calculated one. By the modified Fowler equation, we could explain the discrepancy between simulations and experiments.

**Supplementary References**

