On-chip near-field THz imaging probe integrated with a detector

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Abstract—**We present an all-integrated near-field terahertz imaging probe on a semiconductor. This robust and easy-to-use scheme enables us to detect only the evanescent field very efficiently. We obtain a spatial resolution corresponding to λ/24.**

I. Introduction And Background

THE advantageous properties of terahertz (THz) waves - permeability through objects opaque for visible light, etc. - potentially enable various applications of imaging in this band. A promising approach for achieving high spatial resolution is to utilize near-field imaging (NI) technique. This method has been well established in visible and microwave regions. However, the development of the NI in the THz region has been hindered by the lack of high transmission wave line and the low sensitivity of the commonly used detector. Though we have previously constructed a THz imaging setup based on a solid immersion lens[1], its resolution is restricted by the diffraction limit.

In earlier THz-NI systems[2-3], the propagation field arising from the scattering of the evanescent wave is measured with a distant detector, which requires detecting very weak waves, and the influence of far-field waves is unavoidable. In contrast, we have developed a new device for THz-NI in which all components: an aperture, a probe, and a detector are integrated on one semiconductor chip. This scheme allows highly sensitive detection of the evanescent field alone.

II. Results

In Fig. 1, we show a sketch of our device. An 8-µm diameter aperture and a planar probe, each of which is insulated by a 50-nm thick SiO_2 layer, are deposited on a surface of a GaAs/AlGaAs heterostructure chip. A two-dimensional electron gas (2DEG), located 60nm below the chip surface, works as a THz detector[4]. As depicted in Fig. 1, the presence of the planar probe changes the distribution profile of the evanescent field, enhancing the coupling of the evanescent field to the probe and, thus, to the 2DEG detector. This leads us to expect that the presence of the probe will result in strongly enhanced THz transmission through the small aperture, *i.e.*, an increase in the detection sensitivity. In addition, the 2DEG detector is not affected by the far-field wave due to its 2D plane.

We measured the THz transmission profile by scanning the device across a sample. For comparison, we used two kinds of THz-NI devices; the aperture plus the probe and the aperture alone. Figure 2 plots the data obtained for the two devices. In the former case, we can see a clear profile, whereas in the latter case, no signal is observed. These results provide clear evidence of significant enhancement in the detection sensitivity of the THz evanescent field due to the existence of the planar probe. From a signal decay curve, we obtain a spatial resolution of 9µm. The resolution: (i) does not depend on the wavelength of the incident THz wave, (ii) almost matches the aperture diameter of 8µm, and (iii) corresponds to λ/24 for the wavelength λ=214.6µm. These facts clearly demonstrate that the present device properly functions as a THz-NI probe.

We are now trying to utilize a carbon nanotube THz detector, which we have recently developed[5,6]. Compared to the 2DEG detector, the carbon-nanotube detector exhibits much higher sensitivity and has a much smaller sensing area (~200nm). This detector, integrated with an aperture and a probe, would show ultra-high sensitivity and a sub-µm resolution simultaneously.

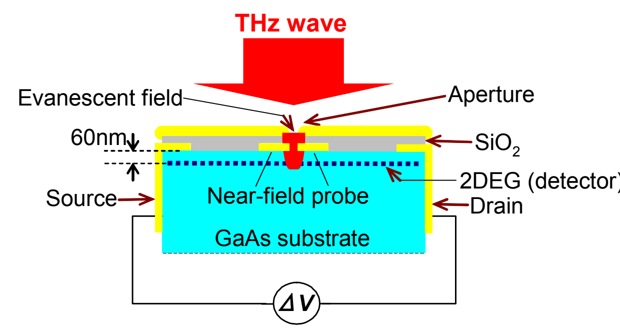

Fig. 1. ***Schematic representation of the THz-NI device.***

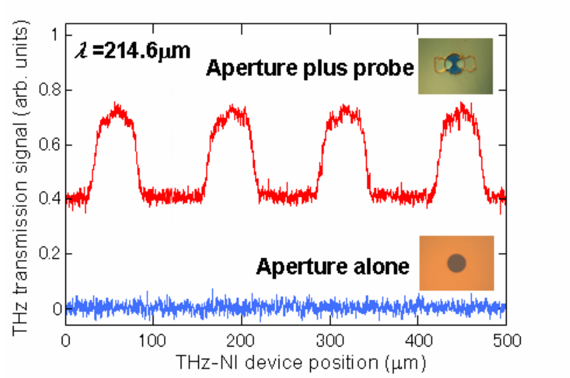

Fig. 2. ***THz transmission signal as a function of the THz-NI device position. The sample has the alternate geometry of the THz opaque (80-µm width) and transparent (50-µm width) regions. The insets show optical images of the two kinds of THz-NI devices used.***

References

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