Graphene-Enhanced Infrared Near-Field Microscopy

Peining Li, Tao Wang, Hannes Böckmann, Thomas Taubner[*]

[*] taubner@physik.rwth-aachen.de

1st Institute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany

Supporting Information:

Transfer matrix of the graphene layer. In the transmission calculations, the characteristic matrix of the graphene layer is deduced by using a mathematical trick. We treat the graphene layer as a thin metallic layer with the thickness Δ and an equivalent permittivity $\varepsilon_{eq} = \varepsilon_0 + i\sigma_g/(\omega\Delta)$. We employ this equivalent permittivity with the thickness Δ into the commonly used characteristic matrix for layered systems and let $\Delta \rightarrow 0$. The thickness Δ will be cancelled in the formulas. Finally, we obtain the matrix of the graphene as shown in the Method of the main text.

Transmittance for different graphene positions. In Fig. S1, we calculate the transmittance of both PMMA-graphene and graphene-PMMA configurations as a function of k_x at the same wavelength of 11.3 μm. It can be seen that the results of two cases are the same, which means they provide the same enhancement of evanescent fields.

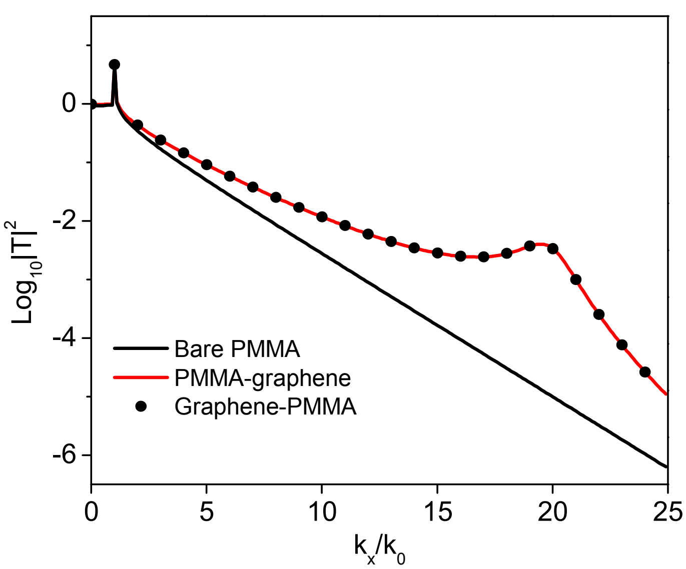

Fig. S1. Transmittance as a function of k_x for both PMMA-graphene and graphene-PMMA configurations at the same wavelength of 11.3 μm. The case with a bare PMMA layer is shown for comparison.

Wavelength-dependent near-field imaging for the graphene-PMMA configuration. The wavelength-dependence near-field imaging for the PMMA-graphene configuration is already shown in Fig. 2a. The additional imaging results for the graphene-PMMA case are shown in Fig. S2. For both PMMA-graphene and graphene-PMMA configurations, the infrared contrast of the buried hole becomes weaker with the decrease of the illumination wavelength.

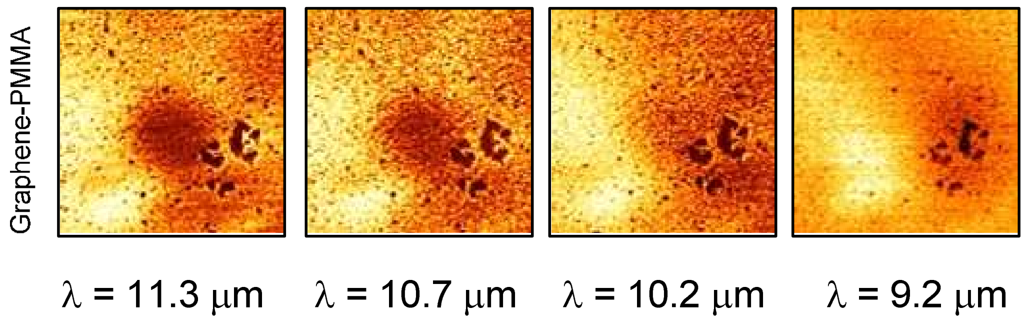

Fig. S2. Near-field amplitude images of resolving the buried hole for the graphene-PMMA configuration taken at four different wavelengths.

Sample information. Figure S3 shows the typical Raman spectra of monolayer graphene with the PMMA layer. The 2D-peak with a FWHM of 28 cm^{-1} (Lorenz fit) is found at the position of 2680 cm^{-1} (the 2D/G ratio is about 1.1), indicating an intrinsic *n*-doping ($\sim 2\times10^{13}$ cm^{-2})[1].

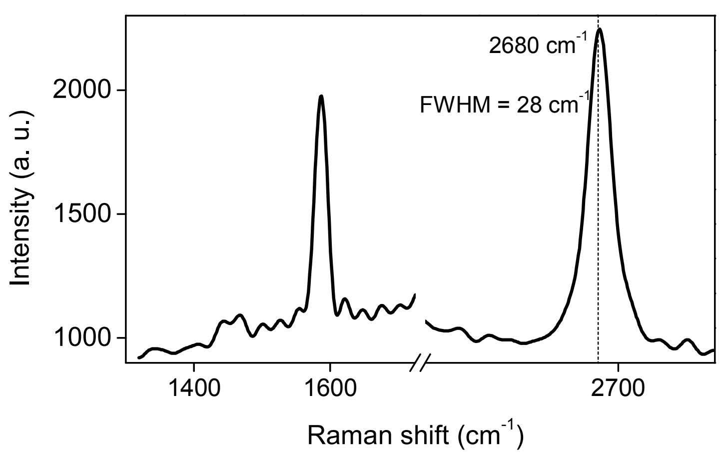

Fig. S3. Raman spectra of our monolayer graphene attached with a PMMA layer.

Enhancement estimation. We estimate the graphene enhancement by defining a peak visibility as $V = (F_p - F_b) / (F_p + F_b)$, where F_p and F_b are corresponding values of the grating harmonic peaks and the background. The background value F_b is defined as the average value of two neighboring positions: $F_b = (F_A + F_B)/2$, as sketched in Fig. S4. Then we obtain about 1.8-fold enhancement (V_w/V_{wo}, V_w and V_{wo} for the cases with and without graphene) for the first-order grating harmonic ($k_x = 3.8k_0$), 3-fold for the second order ($k_x = 7.5\ k_0$) and 7-fold for the third order ($k_x = 11.3\ k_0$), respectively.

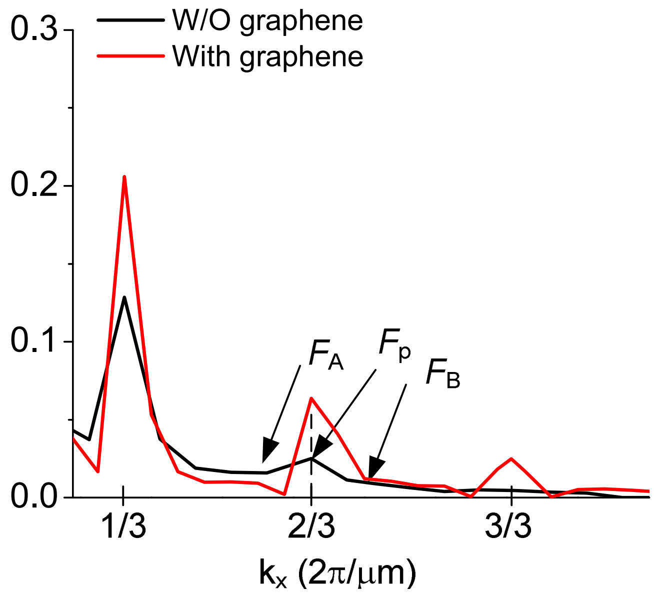

Fig. S4. Visibility estimation of the grating harmonic peaks.

References:

1. Das, A.; Pisana, S.; Chakraborty, B.; Piscanec, S.; Saha, S. K.; Waghmare, U. V.; Novoselov, K. S.; Krishnamurthy, H. R.; Geim, A. K.; Ferrari, A. C.; Sood, A. K. *Nat. Nanotechnol.* **2008,** 3, 210−5.