Supplementary Materials for

Plasmon-Exciton Coupling Effect on Plasmon Damping

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Figure S1. Experiment characterizations of GNR on WSe2/hBN heterostructure. a) Experiment setup. b) The optical microscopy image of a representative heterostructure is shown in b (1). The scale bar is 10 μm. The white dashed line indicates the boundary of the thin hBN. The yellow dashed line indicates the boundary of the monolayer WSe2. The b (2) is the corresponding AFM-scanned height along the white line shown in the AFM image. The b (3), (4), (5), and (6) are several representative AFM images during the track of GNR.

Figure S2. (a) shows a bright-field image of a WSe2 flake exfoliated onto PDMS. The most translucent area in the right straight flange of the flake corresponds to the monolayer region. The thickness dependence of the PL intensity reflects the changes of the WSe2 band structure with increasing numbers of layers. While monolayer WSe2 is a direct bandgap semiconductor, the bandgap becomes indirect for bilayers, leading to a strong quenching of the PL. Figure S2b compares PL spectra recorded in different regions of the flake. The monolayer region shows bright PL with an emission peak centered at 752 nm (green line). The direct-to-indirect bandgap transition in bilayer WSe2 leads to a shift of the emission maximum to lower energies and one order of magnitude reduction of the emission intensity (red line). And the PL spectrum broadens.
Figure S2. Experiment characterizations of GNR on the different layers of WSe₂. a) Optical image of the WSe₂ 1L-2L lateral homojunction. The scale bar is 5 um. b) During nanomanipulation, the AFM topographic images demonstrate a single GNR was moved from the glass onto the monolayer and bilayer WSe₂. c) PL spectra of monolayer WSe₂ and bilayer WSe₂. d) Scattering spectra of the same GNR on the glass (black), on the monolayer WSe₂ (red), on the bilayer WSe₂ (blue).

We tested the transmission spectra of the glass sheet and different thicknesses of hBN. As shown in Figure S3b, they have a little different change. So we can rule out the enhancement of scattering spectra caused by the enhanced light reflection of hBN.

Figure S3. a) Optical image of the hBN. The thickness of hBN in (1) is thinner than in (2). b) The transmission spectra of glass (black), thin hBN (red), thick hBN (blue) corresponding to a).

Considering the enhancement of the scattering spectra, we have calculated the downward collection rate on the glass without and with the 2D material using the FDTD method. The downward
collection rate was calculated by the cross-section, $r = \frac{\Sigma I_{\text{to-glass}}}{\Sigma I_{\text{total}}}$, respectively. For these four different interfaces, the downward collection ratio (around 0.8) changes slightly.

**Figure S4.** Calculated the downward collection ratio of scattering intensity of a GNR on the glass without and with the 2D material using the FDTD method. a) Schematic illustrations of downward collection ratios on the glass without (top) and with the 2D materials (bottom, respectively. b) The downward collection ratios on the WSe$_2$ (blue), on the hBN (red), on the graphene (black), and glass (green), respectively.

The finite-difference time-domain (FDTD) method, a powerful technique for metallic nanostructures with arbitrary geometries, is employed to calculate the optical responses. The individual GNR is modeled as a cylinder capped with hemispheres at each end that was placed on a TMDCs layer on top of a 500-nm-thick SiO$_2$ layer. In addition, the GNR with different length–diameter ratios are employed in the simulations. The Drude–Lorentz dispersion model is used for the optical dielectrics of gold, and the refractive indexes of the dielectric media are set to 1.49 for silica, 1.0 for air. The dielectric functions of WSe$_2$ contain real and imaginary parts. And the thickness of the WSe$_2$ and the graphene is set to 1 nm. The thickness of the hBN is set to 10 nm. The mesh grid is set 0.2 nm for the 2D materials region and 1 nm for other regions.
Figure S5. Calculated scattering spectra using the FDTD method. a) Scattering spectra of the GNR with large blue detuning on the glass (black), on the WSe$_2$. b) Scattering spectra of the GNR with slight detuning on the glass (black), on the WSe$_2$ (red). c) Scattering spectra of the GNR with large red detuning on the glass (black), on the WSe$_2$ (red). d) Scattering spectra of the same GNR on the glass (black), on the graphene (red). e) Scattering spectra of the same GNR on the glass (black), on the hBN (red). f) Scattering spectra of the same GNR on the glass (black) and different layers WSe$_2$.

And then, we record the scattering step by step of the same GNR on the different thicknesses of hBN. From the optical image of Figure S6a (1), the thickness of the hBN changed slightly. The further away from the edge of the hBN flake, the thicker hBN. But it is a pity that the accuracy of our AFM measurement is limited and cannot give accurate thickness changes. And then, we moved the single GNR around the edge and recorded the scattering spectra step by step. We obtained that with the increase of the thickness, the scattering intensity increased. At the same time, as the number of hBN increases, the amount of high refractive index increases. So the scattering energy experiences a similar redshift.
**Figure S6.** a) Optical microscopy image of the different thickness hBN (top). The scale bar is 5 um. The AFM topographic images of the different layers hBN. b) The scattering spectra of the same GNR on the glass (black) and different thickness hBN. The value represents the distance of the GNR from the edge of the hBN. The further away from the edge of the hBN flake, the thicker the hBN sheet.

Here, we show some of the other experimental results in Figure S7. The intensity, resonant peak, and FWHM of scattering spectral of different nanorods are variable due to different shapes or sizes. As we can see from Figure S7, the scattering intensity increased when the GNR was moved from the glass surface to the hBN sheet. On the other hand, a dip appeared when the GNR was moved from the glass to the WSe$_2$ surface. Although the intensity variation ratio for different particles changes to some extent, we can still come to the same conclusion.
Figure S7. a), b) Scattering spectra of the same GNR on the glass (black), on the WSe$_2$ (red), on the WSe$_2$/hBN (orange), and the few layers hBN (blue). c), d) Scattering spectra of the same GNR on the glass (black), on the monolayer WSe$_2$ (red), and bilayer WSe$_2$ (blue). The scattering spectra have been normalized against the scattering peak maximum of each Au nanorod on the glass.

As we can see in Figure S8, the GNR’s spectra on the same surface are stable, and the error is less than 10%, even though we moved the particle over several micrometers.
**Figure S8.** a) Scattering spectra of GNR on the glass surface when it is moved from area I to area II. b) During the nanomanipulation, the AFM topographic images demonstrate a single GNR was moved from area I to area II on the glass. c) Scattering spectra of GNR on the WSe$_2$ moving from area I to area II. d) The AFM topographic images demonstrate a single GNR was moved from area I to area II on the glass. The measured point is marked with a white dotted circle.

Furthermore, the changes in scattering intensity were significant (increasing over 50%, even up to 100%) when the GNR was moved across the boundary between the glass and 2D materials. As shown in Figure S9, after moving the GNR from the hBN to the glass, the scattering intensity decreased by about 40%. It is larger than the measurement error. And then, when we pushed the nanorod from the glass back to the hBN, the scattering intensity enhanced ~1.6 fold. Thus, there is little change in the scattering spectrum of the nanorods when the GNR was moved back to the hBN sheet.
Figure S9. a) AFM topographic images of the movement trajectory of nanorods. b) Scattering spectra of GNR moving from hBN to glass and then back to the hBN sheet. Position “I, II, III” corresponds to the AFM images I, II, and III.