*Supplementary Materials*

# Enhancement of spin wave transmission through antiferromagnet in Pt/NiO/CoFeB heterostructure

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## I. Sample preparation, X-ray reflection (XRR), and Ni L edge X-ray absorbtion spectra (XAS) of thin films

All thin films were deposited sequentially by magnetron sputtering on a two-side optically polished 5×5 mm² (111)-oriented MgO in a high vacuum chamber with base pressure below $1 \times 10^{-6}$ mTorr. The deposition temperatures for Pt, NiO and CoFeB layers were 585 °C, 450 °C and room temperature, respectively. The pressure of Ar gas during deposition was 5 mTorr. The speed of deposition was measured by X-ray reflection (XRR) shown in Figure S1a. The thicknesses are consistent with the high-resolution transmission electron microscopy (TEM) results. Figure S1b shows the Ni L edge XAS spectra of Ni foil (for reference), NiO powder (for reference), and our NiO film. The result of our film is quite the same as pure NiO powder.

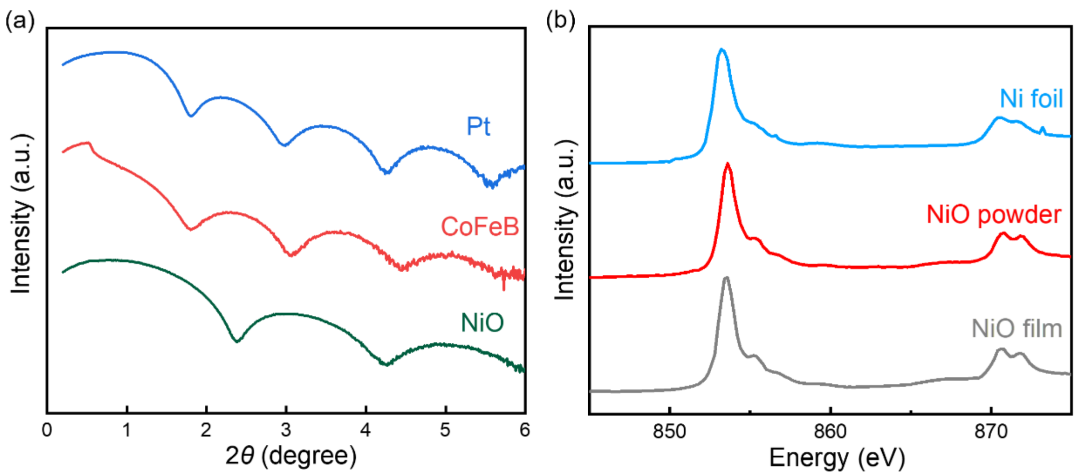


**Figure S1.** (a) XRR for Pt, CoFeB and NiO single layers. (b) The Ni L edge XAS spectra of Ni foil, NiO powder, and our NiO film.

## Ⅱ. Emitted THz signals of different magnetic field directions and both sides.

In terahertz emission experiments, the laser can be incident from the substrate side or the sample side. Figure S2a shows THz signals emitted from different sides for a Pt(6)/CoFeB(3) sample. The signal from the sample side is smaller due to the THz absorption of the MgO substrate. In our main experiments, the laser was incident from the substrate side to avoid undesired THz absorption by the substrate.

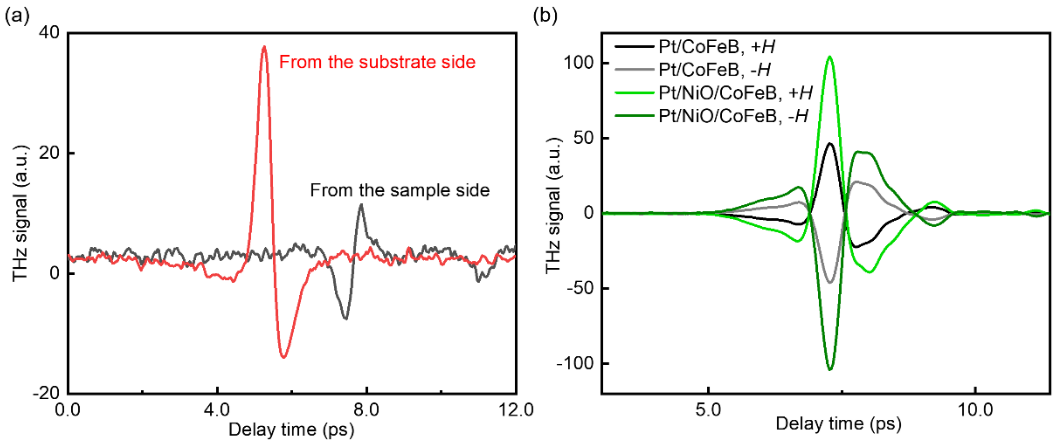


**Figure S2.** (a) THz signals emitted from different sides for a Pt(6)/CoFeB(3) sample. (b) The THz signals emitted from Pt(6)/CoFeB(3) and Pt(6)/NiO(2)/CoFeB(3) under different magnetic field directions.

The THz signals emitted from Pt(6)/CoFeB(3) and Pt(6)/NiO(2)/CoFeB(3) under different magnetic field directions are shown in Figure S2b. The phase of the THz signal undergoes a 180° shift when the direction of the magnetic field is reversed.

## Ⅲ. Comparison between the THz signals emitted from a Pt(6)/NiO(2)/CoFeB(3) multilayer film and commercial ZnTe crystal

The peak amplitude of the THz signal emitted from the Pt(6)/NiO($t_{NiO}$)/CoFeB(3) multilayer film reaching a maximum when $t_{NiO}$ = 2 nm at room temperature. We compared the THz signal emitted from a Pt(6)/NiO(2)/CoFeB(3) multilayer film with a commercial 500-μm-thick 10 × 10 mm$^2$ ZnTe crystal (see Figure S3a), finding that the THz signal from

Pt(6)/NiO(2)/CoFeB(3) multilayer film reached ~110% of the ZnTe crystal at the same pump fluence (720 μJ·cm$^{-2}$). Figure S3b shows the Fourier spectra of the THz signal, where the bandwidth is limited b y the detection crystal.

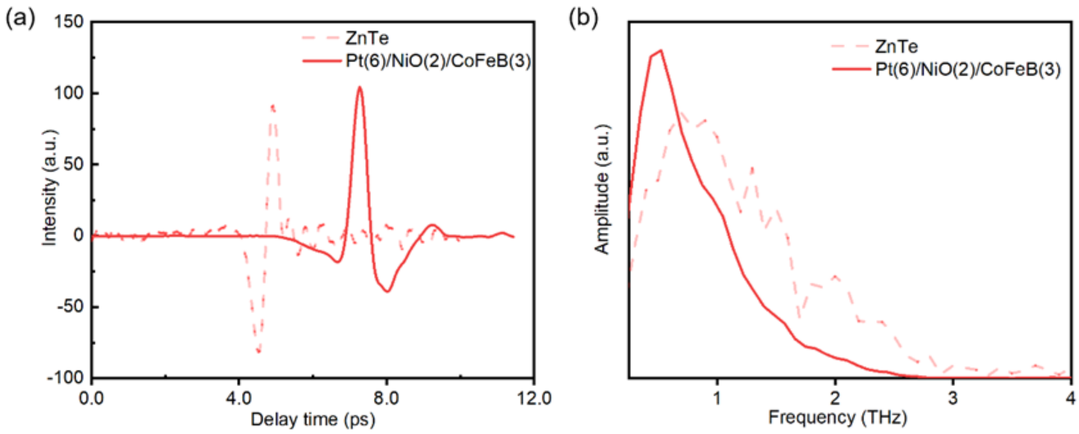


**Figure S3.** (a) Comparison between the time-domain THz signal from the Pt(6)/NiO(2)/CoFeB(3) (solid red line) and that from the ZnTe crystal (light red dash line), at the same pump power. (b) Fourier spectra obtained from the Pt(6)/NiO(2)/CoFeB(3) (solid red line) and ZnTe crystal (light red dash line).

## Ⅳ. The exchange bias field $H_{bia}$ in NiO($t_{NiO}$)/Co(3) films

To estimate the blocking temperature $T_B$ at which exchange bias of a ferromagnetic layer exchange coupled to the NiO vanishes, we measured the temperature dependences of exchange bias field $H_{bia}$ in NiO($t_{NiO}$)/Co(3) films. For example, the magnetic hysteresis loop of a NiO(1)/Co(3) bilayer film shifts to a positive field at T = 80 K after cooling from 300 K under a 1 T field (see Figure S4). The $H_{bia}$ is 30.1 Oe for $t_{NiO}$ = 2 nm at 80 K.

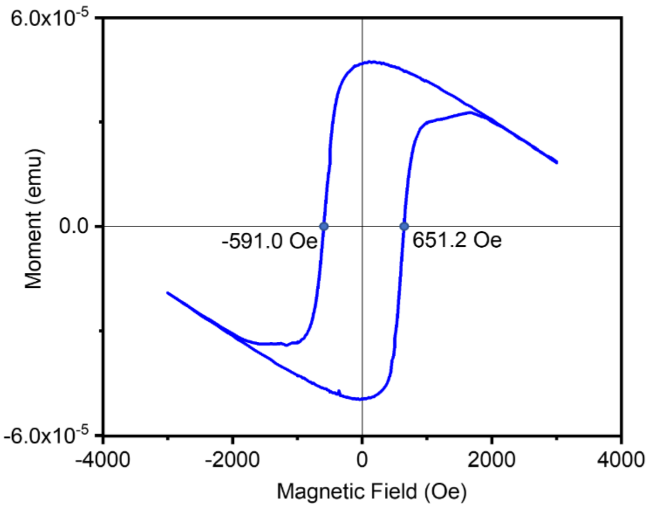


**Figure S4.** The magnetic hysteresis loop of the NiO(1)/Co(3) bilayer film at T = 80 K after the field cooling.

## Ⅴ. The phase spectra of Pt(6)/MgO(2)/CoFeB(3) and Pt(6)/Cu(2)/CoFeB(3)

The phase shift caused by AFM layer is a significant difference between evanescent wave model with other theoretical models. The THz emission of Pt(6)/MgO(2)/CoFeB(3) and Pt(6)/Cu(2)/CoFeB(3) are measured to verify the influence of other possible effects. (see Figure S5a) The phase shifts caused by Cu and MgO layers are quite small and irregular. (see Figure S5b)

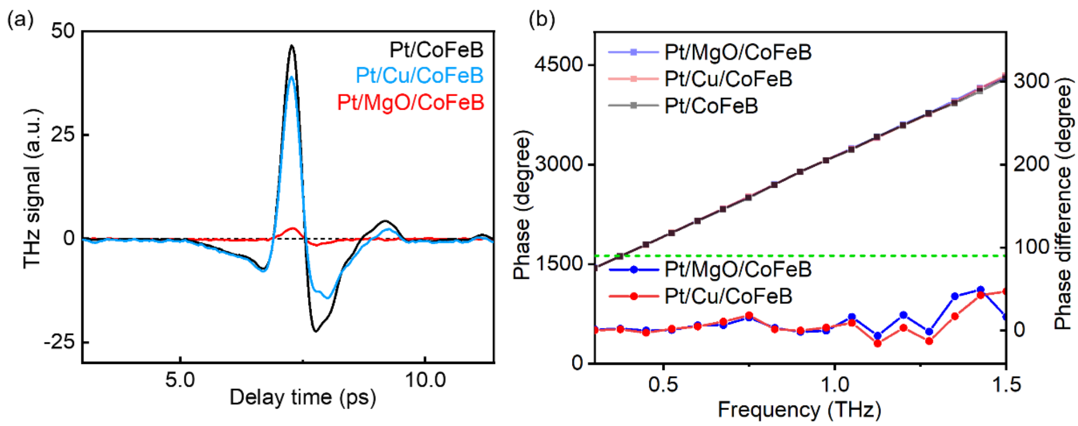


**Figure S5.** (a) The THz emission from Pt/CoFeB, Pt/MgO(2)/CoFeB and Pt/Cu(2)/CoFeB. (b) The phase spectra of Pt(6)/CoFeB(3) (black squares), Pt(6)/MgO(2)/CoFeB(3) (blue squares), and Pt(6)/Cu(2)/CoFeB(3) (red squares) at 80 K. The blue circles and red circles are the phase difference. The green dashed line is the position of 90° (π/2).