

Supplementary information for
**Inverse orbital Hall effect and orbitronic terahertz emission
observed in the materials with weak spin-orbit coupling**

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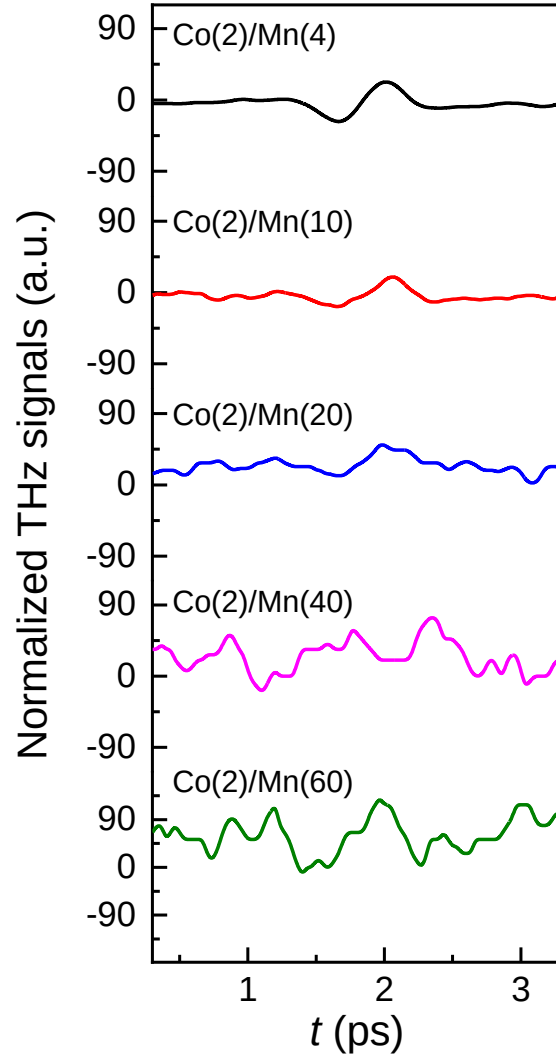
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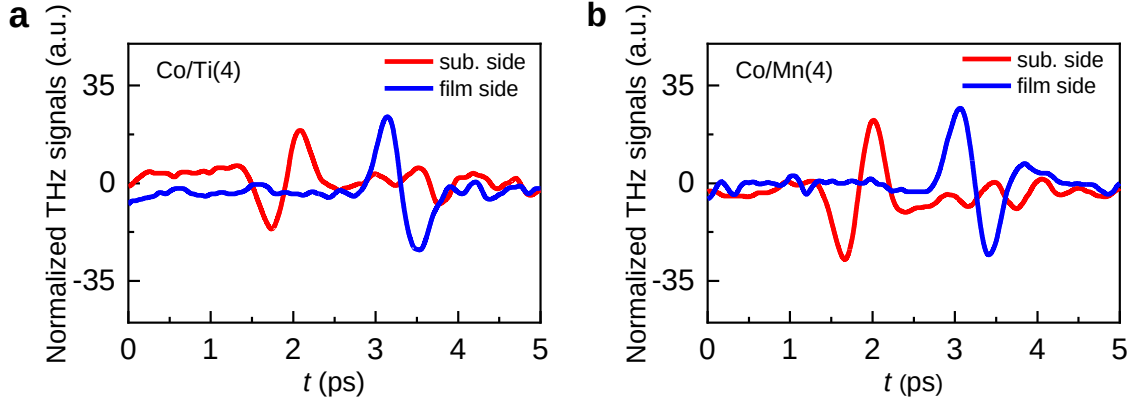
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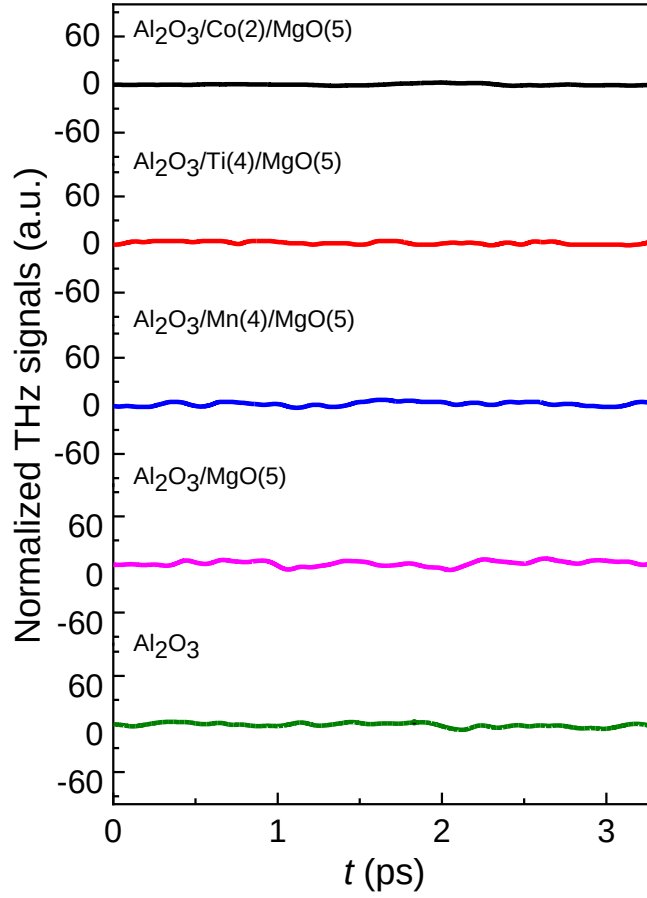


Supplementary Figure 1 Orbitronic THz emission from IOHE. The normalized THz signals of the Co (2 nm)/Mn (4-60 nm) structures. The obvious THz signals can be observed in the Co (2 nm)/Mn (4-20 nm) structures, but the THz signals disappear at $d_{\text{Mn}} \geq 40$ nm.



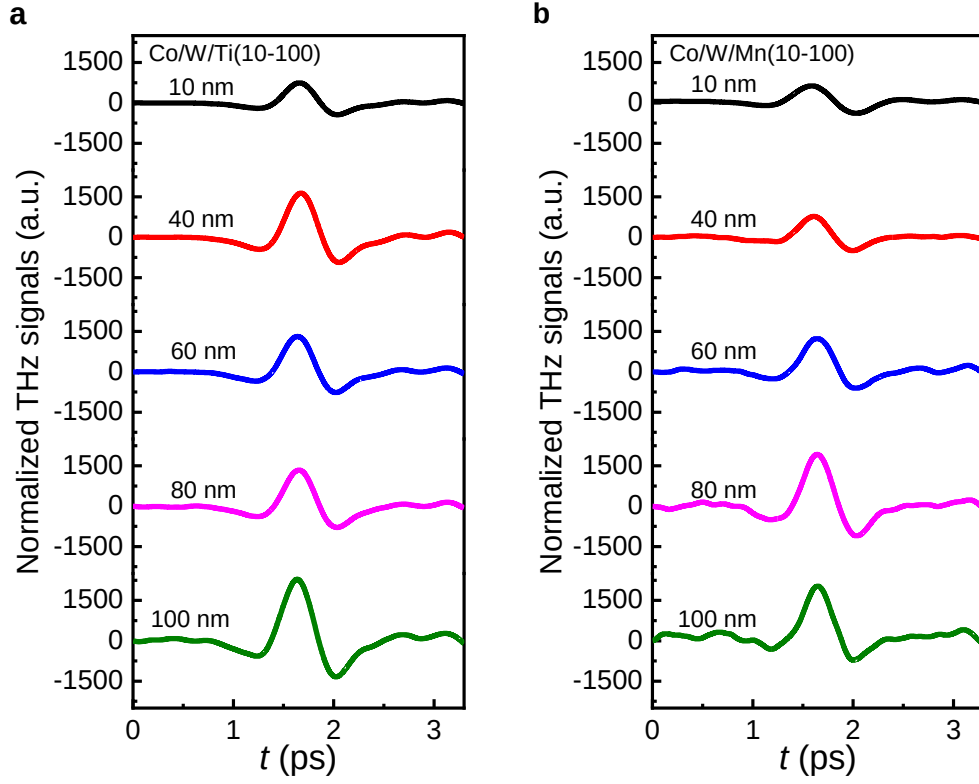
Supplementary Figure 2 The THz polarity with the different incident directions of the *fs* laser. The opposite polarity of the normalized THz signals with flipping of the samples of **a** the Co (2 nm)/Ti (4 nm) structure and **b** the Co (2 nm)/Mn (4 nm) structure.

The incident directions of the *fs* laser can influence the THz polarity. The Co (2 nm)/Ti (4 nm) and Co (2 nm)/Mn (4 nm) structures show the THz signals with opposite polarity when the samples are flipped, which attributed to the opposite directions of $\mathbf{J}_L$ from the Co layer to the Ti and Mn layers. Supplementary Figures 2a and 2b also confirm that the Co (2 nm)/Ti (4 nm) and Co (2 nm)/Mn (4 nm) structures have the same THz polarity.



Supplementary Figure 3 The THz signals of the reference samples. The normalized THz signals of Al_2O_3 sub./Co (2 nm)/MgO (5 nm), Al_2O_3 sub./Ti (4 nm)/MgO (5 nm), Al_2O_3 sub./Mn (4 nm)/MgO (5 nm), Al_2O_3 sub./MgO (5 nm) structures, and Al_2O_3 substrate.

In order to confirm the origination of the THz signal, the reference samples were prepared and measured. The THz signals of the Al_2O_3 sub./Co (2 nm)/MgO (5 nm), Al_2O_3 sub./Ti (4 nm)/MgO (5 nm), Al_2O_3 sub./Mn (4 nm)/MgO (5 nm), Al_2O_3 sub./MgO (5 nm) samples, and Al_2O_3 substrate are almost negligible, as shown in Supplementary Figure 3. Therefore, the contribution of the substrate, Co, Mn, Ti or MgO layers to the THz signals can be excluded.



Supplementary Figure 4 Enhanced orbitronic THz emission assisted by efficient spin-orbital current conversion. The normalized THz signals of **a** the Co (2 nm)/W (2 nm)/Ti (10-100 nm) structures and **b** the Co (2 nm)/W (2 nm)/Mn (10-100 nm) structures. The enhancement of the amplitude of the THz signals is exhibited but weakened with the increasing of d_{Ti} and d_{Mn} with inserting 2-nm W layer with strong SOC between the Co and X ($X = \text{Ti}, \text{Mn}$) layers.