Supplemental Document

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Probing Mid-Infrared Surface Interface States Based on Thermal Emission: supplemental document

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1. Methods

The fabrication process of the superlattice (and the structure with only one interface) designed in this scheme mainly included electron-beam evaporation (EBE) and photolithography. A 200-nm gold layer and a germanium (Ge) layer with a thickness of h_a were continuously deposited on a silicon wafer (2×1.6 cm^2) with EBE, and then the gold grating was fabricated with photolithography. After that, a second Ge layer was deposited on the top gold grating with a tunable thickness of h_b with EBE.

ARTES was the measurement setup used in this work to record the signals from the meta-crystal with simplicity and stability [1]. Our sample was embedded in a heater (FTIR600 from Linkam) to maintain a temperature of 100 °C (200 °C in thermal imaging), with a perturbation of less than 0.1 °C, and the heater was placed on a rotational stage starting from -40° to 40°, with the minimum step of rotation angle being 1°. The thermal emission from our sample was transmitted through the window of the heater and a polarizer, which ensured that only the TE waves (Ez) were recorded. Then the emission travelled about 1 m into the Fourier transform infrared (FTIR) spectroscope (Vertex 70 from Bruker) at various angles by rotating the stage around the *z*-axis, as shown in Fig. 1(b). This platform provided excellent angular resolution due to the large distance between the sample and the detector, and there was an acceptable resolution in the frequency (0.03 THz or 1 cm^{-1}). In this case, we chose the working frequency to be around 30 THz in the atmospheric window. In the case of thermal imaging, the best spatial resolution is 10 μm, which is limited by the wavelength.

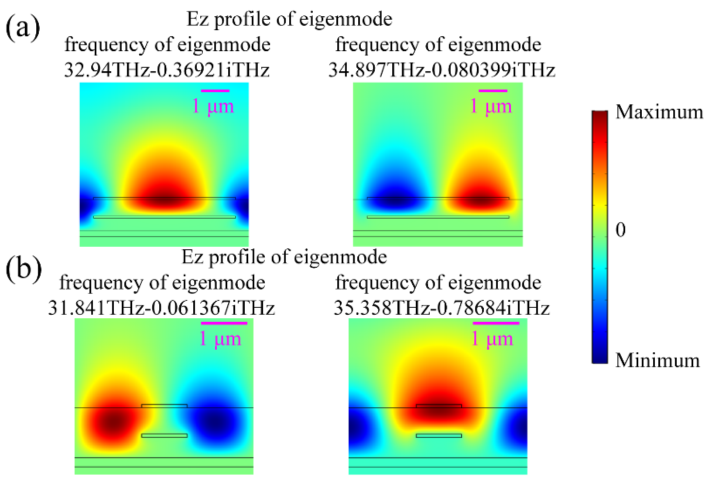

Fig. S1. The Ez cross-section profiles of the eigenmodes in *x-y* plane calculated by COMSOL in the unit cells when h_a=0.45 μm, h_d=70 nm, h_b=0.65 μm, and *k*=0. The symmetries of Ez profiles of the eigenmodes in the periodic unit cells were used to construct the waveguide interface state shown in Fig. 1. (a) shows the case for unit cell No. 1 (meta-crystals-1) with the design of Λ_1=6 μm and the metal width of d_{b1}=5 μm, as used in Fig. 2(a). (b) shows the case for unit cell No. 2 (meta-crystals-2) with the design of Λ_2=4 μm and the metal width d_{b2}=1 μm, as used in Fig. 2(b).

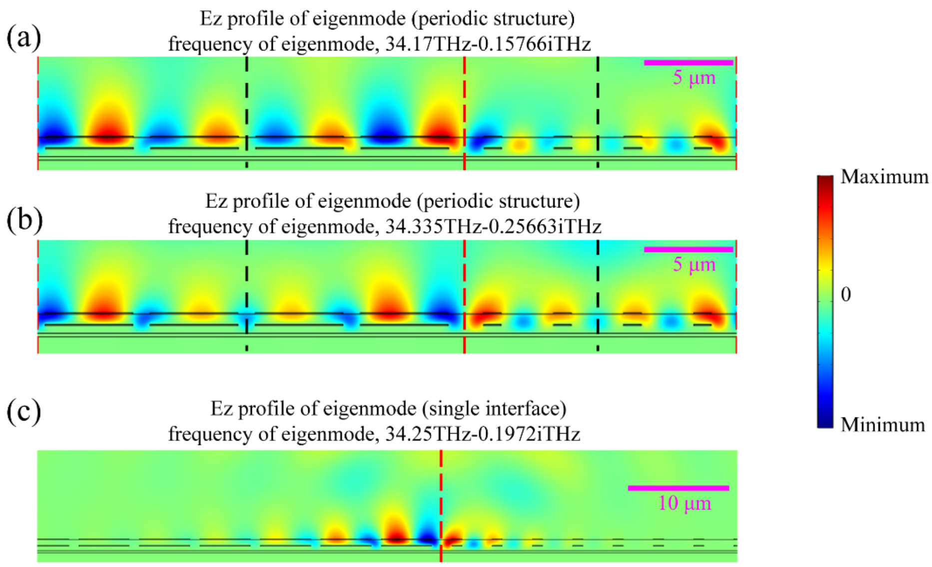

Fig. S2. The Ez profiles of the eigenmodes in *x-y* plane with the interface states. (a, b) The Ez cross-section profiles of the interface states calculated by COMSOL, whose periodic structure displayed in Fig. 2(c), show the periodic coupling induced splitting of the dispersion with two eigenmodes that is (a) antisymmetric and (b) symmetric, when h_a=0.45 μm, h_d=70 nm, h_b=0.65 μm, and *k*=0. The black dashed lines denote the mirror symmetry of the structure, and the red dashed lines denote the positions of the interfaces. (c) The Ez cross-section profile (partly presented around the interface) of the interface state calculated by COMSOL shows that the intensity of Ez decays rapidly around the interface and the energy is localized in *x*-direction. Here, the corresponding structure displayed in Fig. 3 had only one interface and only one interface state around 34THz. The red dashed line denotes the position of the interface.

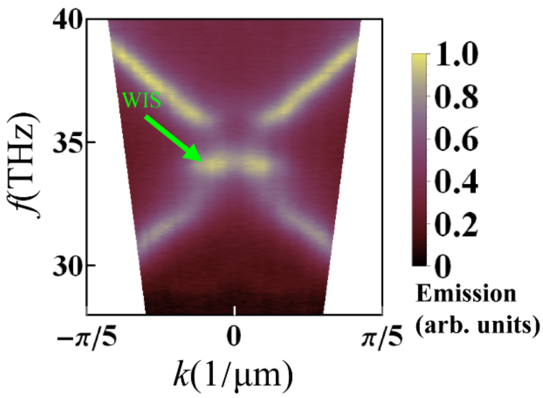

Fig. S3. The experimental result of the thermal emission of the WIS with different structural parameters. The structure can also be described by Fig. 1(a), while it had different periodic parameters and widths of gold grating compared with the structure in Fig. 2(f), and the rest of the parameters remained the same. In this structure, the period had four unit cells with Λ_1=5 μm, d_{b1}=3 μm, and another four unit cells with Λ_2=4 μm, d_{b2}=1 μm. k is in x-direction.

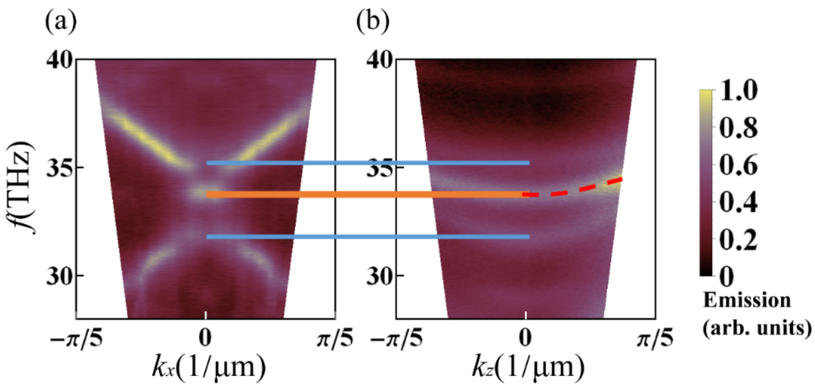

Fig. S4. The experimental results of the thermal emission of the WISs shown with varying k_x and k_z. Experimental results of the emission signals of the structure shown in Fig. 1(c) are presented here. (a) Emission signals of the WISs with varying k_x. (b) Emission signals of the WISs with varying k_z. The orange line links the interface states in the two pictures, the blue lines denote the band edges, and the red dashed line shows the waveguide interface state shifting in frequency along k_z.

References

1. F. Zhong, K. Ding, Y. Zhang, S. Zhu, C. T. Chan, and H. Liu, "Angle-Resolved Thermal Emission Spectroscopy Characterization of Non-Hermitian Metacrystals," Physical Review Applied **13**, 014071 (2020).