### **Supporting Information for:**

## Mid-Infrared Black Phosphorus Surface-Emitting Laser with an

# **Open Microcavity**

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#### S1. The crystal structure of the lamellar BP utilized in this work:

The crystalline structure of the lamellar BP was revealed by the method of transmission electron microscopy (TEM). Figure S1a displays a typical TEM image of a lamellar BP flake, showing its obvious layered structure. Figure S1b shows a high resolution TEM (HRTEM) image, illustrating an orthorhombic crystal structure with two sets of interplanar spacing of 3.3 Å and 4.2 Å, respectively. The selected area electron diffraction (SAED) pattern in Figure S1c is well indexed to an orthorhombic structure and reveal the single-crystal nature of the material.



Figure S1. The TEM images of the lamellar BP utilized in the work. (a) The typical TEM image of a lamellar BP flake. (b) The HRTEM image of this lamellar BP flake. (c) The SAED pattern of an orthorhombic structure.

# S2. The simulated and measured reflectivity of distributed Bragg reflectors mirrors:

The simulated and measured reflectivity spectra of the DBR mirrors are shown in Figure S2. The typical DBR mirror consists of alternating layers of  $1/4 \lambda$ -thick dielectrics with different refractive indexes, and Figure S2a presents the simulated reflectivity spectra at normal incidence of the DBR mirrors with 4, 6, 8 pairs (labeled N<sub>C</sub>) of Si<sub>3</sub>N<sub>4</sub> and SiO<sub>2</sub>, exhibiting the peak reflectivity at 3700 nm, the stop band of 1250 nm at full width at half-maximum (FWHM), and peak reflectivity of 82.1%, 96.0%, 98.8%, respectively. Figure S2b shows the measured reflectivity spectrum of a DBR mirror with 8 pairs of Si<sub>3</sub>N<sub>4</sub> and SiO<sub>2</sub>, indicating a high reflectivity plateau from 3450 to 3850 nm which covers the whole PL spectrum of the lamellar BP.



Figure S2. The simulated and measured reflectivity spectrum of DBR. (a) The simulated reflectivity spectrum at normal incidence of light of DBR with 4, 6, 8 pairs of  $1/4 \lambda$  thick of Si<sub>3</sub>N<sub>4</sub> and SiO<sub>2</sub> in the wavelength range of 1750-5750 nm. (b) The measured reflectivity spectrum of DBR with 8 pairs of  $1/4 \lambda$  thick of Si<sub>3</sub>N<sub>4</sub> and SiO<sub>2</sub> in the wavelength range of 2500-6500 nm. The inset is the room temperature photoluminescence measurement for lamellar BP device.