Supplementary information

Tailoring dispersion of room temperature exciton-polaritons with perovskite-based subwavelength metasurfaces

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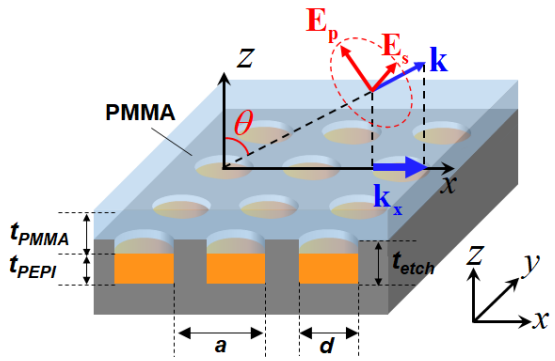
I. DESIGN OF HYBRID PEROVSKITE METASURFACE: THE ROLE OF DIFFERENT PARAMETERS

As a reminder, the general design of PEPI 2D lattice metasurfaces shown in Fig.1 (e) of the main text is presented again in figure S.1. In such scheme, PEPI is infiltrated completely inside the nano-hole-lattice of SiO_2 and encapsulated by a film of PMMA. From the photonic point of view, the PMMA/ PEPI nano-pillars/ SiO2 stack is equivalent to PEPI nano-pillars standing in a homogeneous optical medium, since the refractive index of PMMA (1.49) is closely matched with the SiO_2 one (1.47) in the whole spectral range of interest (400-600nm). Thus, photonic modes of the structures are solely given by PEPI lattice parameters: period *a*, aspect ratio *d/a* and thickness of PEPI t_{PEPI}.



S1. Structure design

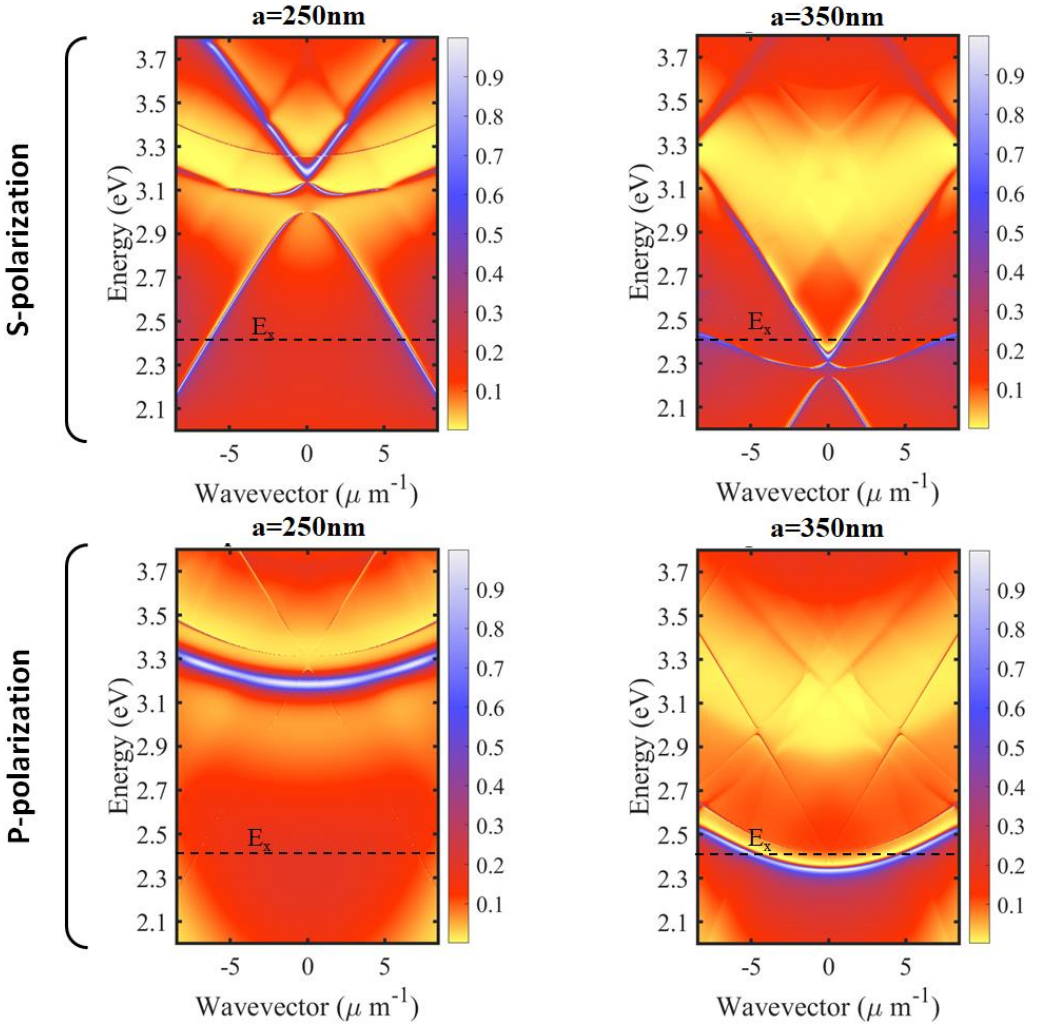
In the range of varying parameters *a* = [250:350] (nm); *d/a* = [0.6:0.95] and t_{PEPI} = [30:100] (nm), we note that there is no significant change in the dispersion shape for a given polarization. Indeed, the most important factor for dispersion engineering is the lattice period. With the change of period, different photonic modes can be shifted to lower or higher energy level. Hence, in the vicinity of exciton energy, by adjusting the period, we can choose to couple different photonic modes with the exciton of PEPI for dispersion engineering. Meanwhile, other lattice parameters as *d/a* and t_{PEPI} can be used to finely tune dispersion but don't change the shape of the mode. The following numerical simulation results report in detail the effect of each parameters.

- **Effect of lattice period on dispersion**

In order to interpret clearly the role of lattice period on dispersion engineering, numerical simulation of ARR in passive structure has been conducted with two different values of period (250 nm and 350 nm) and fixed d/a = 0.8, t_{PEPI} = 50 nm (see Fig.S.2). The results show the same dispersion curves for a given polarization (S or P), only shifted in term of energy:

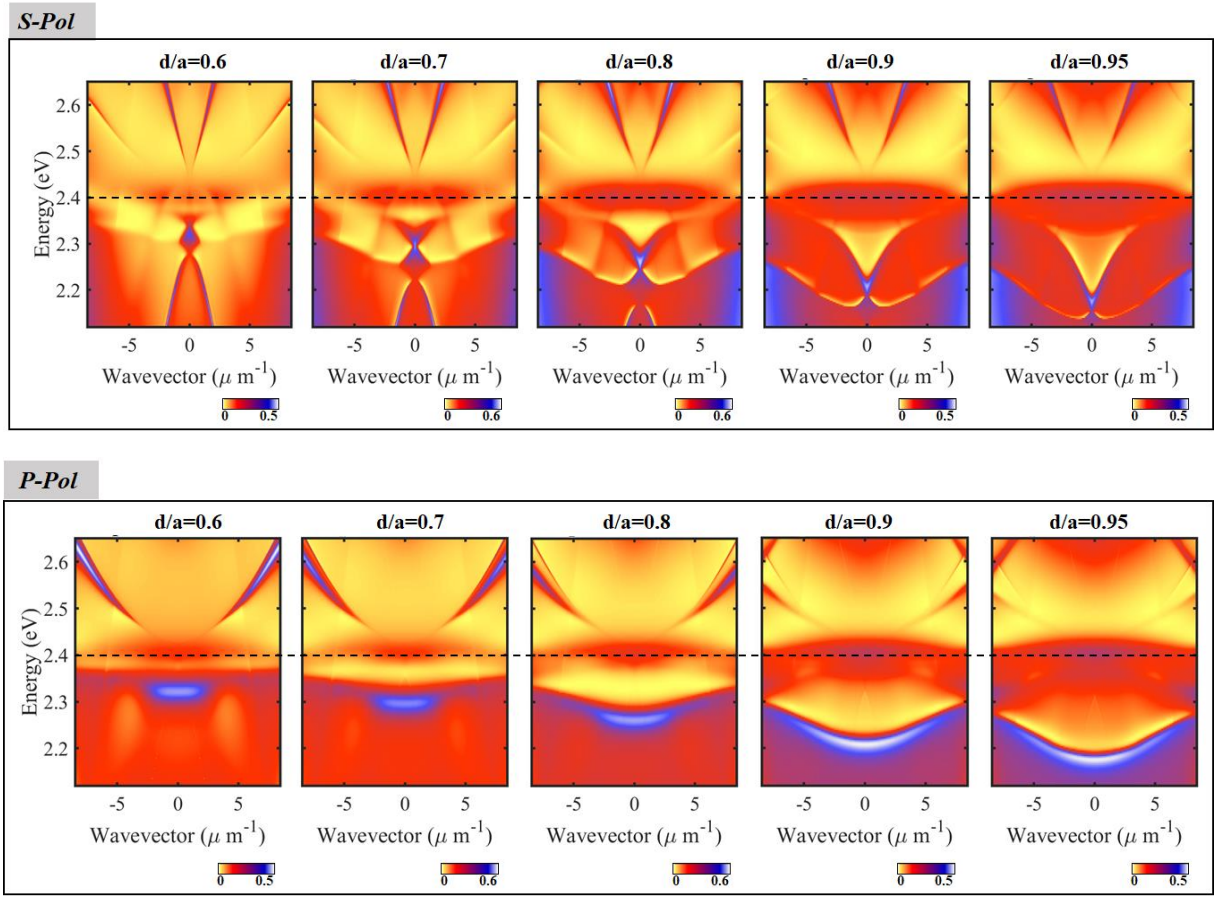
- The structure with a period of 250 nm (as structure A in the paper), in S-polarization, has linear dispersion in the vicinity of exciton energy. Hence, the strong coupling with PEPI exciton in this case provides linear dispersion polaritons. Meanwhile, in the P-polarization, there is no modes close to the exciton energy which results in no exciton-polariton obtained.
- In case of structure with a period of 350 nm (similar to structure B in the paper), we obtained a multi-valley photonic mode in S-polarization and a slow-light mode in P-polarization within the proximity of the exciton. They can be in strong coupling with exciton to form multi-valley polariton dispersion and slow-light polariton dispersion (as discussed in the main text).

For the effects of aspect ratio and PEPI thickness, we perform directly the simulations with active structures (see Fig.S.3 and Fig.S.4).



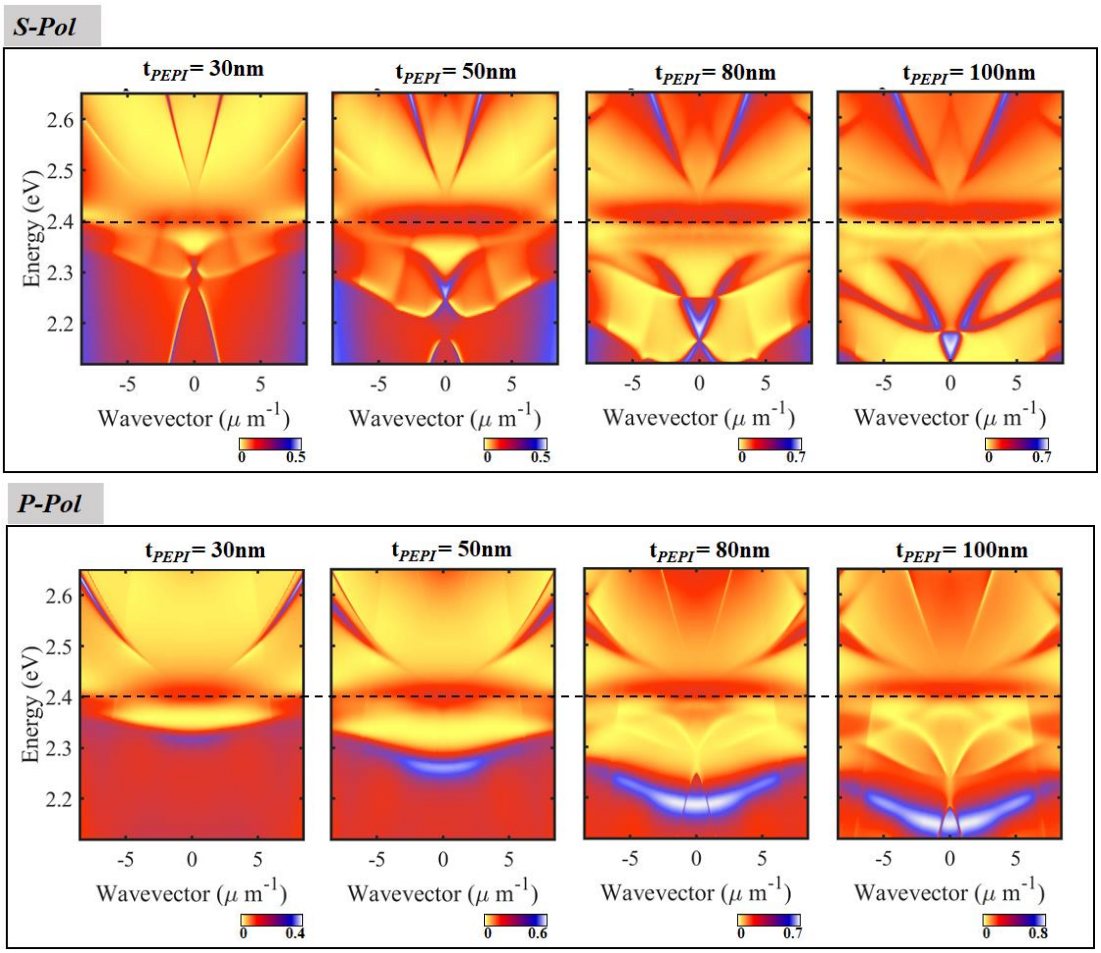
S2. Numerical simulation of the passive structure of HOP 2D lattice metasurfaces for different lattice periods with fixed d/a=0.8, t_{PEPI}=50nm. Black dash lines represent position of exciton energy.

- **Effect of aspect ratio d/a on dispersion**



S3. Numerical simulation in S-polarization of the active structure of HOP 2D lattice metasurfaces for different d/a values with fixed period a=350nm and PEPI thickness t_{PEPI}*=50nm*

- **Effect of PEPI thickness on dispersion**



S4. Numerical simulation in P-polarization of the active structure of HOP 2D lattice metasurfaces for different values of PEPI thickness with fixed period a=350nm and d/a=0.8

II. EXPLANATION OF THE MISMATCH BETWEEN ABSORPTION SIMULATIONS AND PHOTOLUMINESCENCE MEASUREMENTS

We would like to point out the difference in term of intensity distribution between experimental data and numerical simulation shown in Fig.2. (g,h,i) of the main text. Such mismatch is due to the fact that the experimental measurement is related to photoluminescence signal while the simulation reports an absorption calculation. Indeed:

- In photoluminescence experiment, the measured intensity is related to population of polaritions, thus involving many mechanisms: i) Absorption of the continuum at the excitation energy (non-resonant excitation), ii) Relaxation to the excitonic reservoir, iii) Relaxation from the excitonic reservoir to the lower polartion branches, iv) Radiative and non-radiative losses. Depending on the efficiency of these mechanisms, the polariton branchs can be highly/poorly populated at k=0 (efficient/inefficient relaxations with respect to losses). For example, Fig.2.h illustrates the famous bottle-neck effect of polariton physics: the losses are more efficient than relaxation mechanism, leading to a poorly populated of polaritons at k=0.
- In absorption simulation, the calculated intensity is only dictated by the capacity of the system to absorb light at the given energy. Thus it only involves the radiative and non-radiative losses.

As a consequence, the absorption calculation is only used to illustrate the dispersion curves of lower polariton branches that are observed in photoluminescence experiment, not the intensity of photoluminescence measurement itself.