

*Supporting Information for:*

**Facet-dependent growth of InAsP quantum wells in InP nanowire and nanomembrane array**

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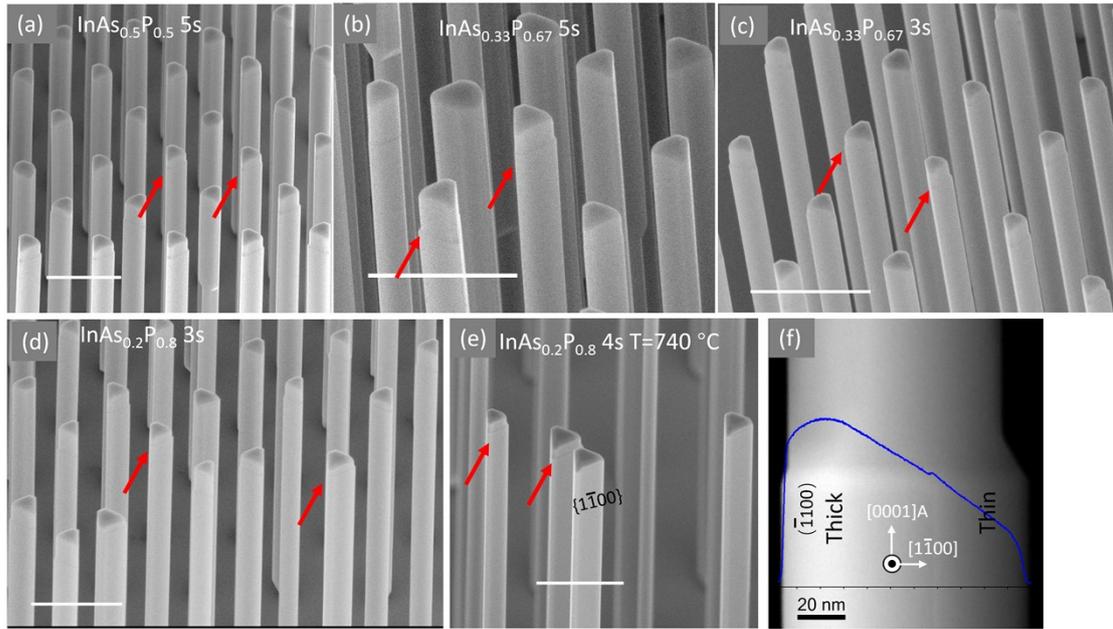


Figure S1. More SEM images of InP/InAsP QD nanowire arrays grown at different conditions, demonstrating the asymmetric growth nature in this QD nanowire system. Nanowire growth temperature ( $T$ ) is  $730^{\circ}\text{C}$  for (a-d) and  $740^{\circ}\text{C}$  for (e); TMIn flow is  $4.048 \times 10^{-6}$  mol/min for (a-b) and  $3.373 \times 10^{-6}$  mol/min for (c-e); the  $\text{PH}_3$  flow is  $5.804 \times 10^{-4}$  mol/min for (a-d) and  $6.25 \times 10^{-4}$  mol/min for (e). The nominal As/(As+P) ratio and growth time for the QD is: (a) 50%, 5s; (b) 33.3%, 5s; (c) 33%, 3s; (d) 20%, 3s; (e) 20%, 4s. (f) HAADF image along the  $[11\bar{2}0]$  zone axis of the reference sample, showing a thickness contrast. The inset blue line indicates intensity scan. Based on the intensity contrast, the thickness of left-handed side is thicker than the right-handed side. Therefore, the thicker side represents the main facets observed from the SEM images. Thus, the main side-facets of the nanowires are determined to  $\{1\bar{1}00\}$ . The scale bars are 500 nm.

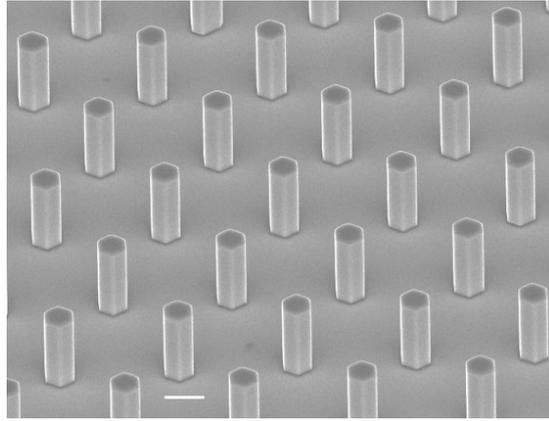


Figure S2. Symmetric growth InP nanowire array at similar growth conditions, showing the hexagonal shape of the nanowire with  $\{1\bar{1}00\}$  side facets. Scale bar is 1  $\mu\text{m}$ . During the growth, temperature is 730  $^{\circ}\text{C}$ , mole flow of TMIIn is  $4.05 \times 10^{-6}$  mol/min and the V/III ratio is 143.

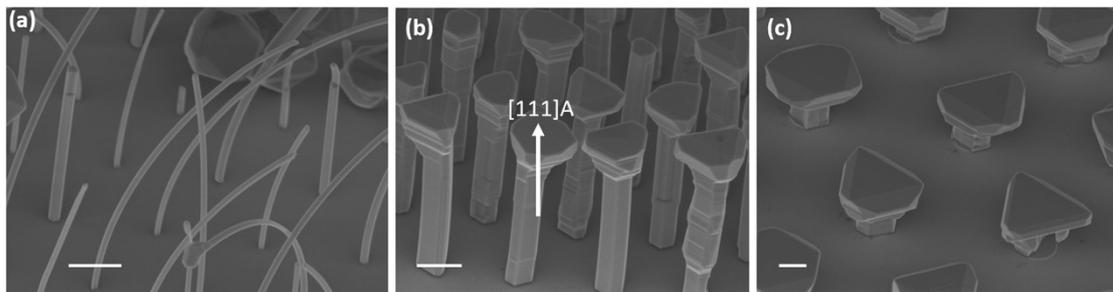


Figure S3. SEM images of the InP/InAs<sub>0.5</sub>P<sub>0.5</sub> nanowire heterojunction after 5 min growth of InAs<sub>0.5</sub>P<sub>0.5</sub> section with different diameters: (a) 50 nm, (b) 300 nm (c) 700 nm. These results show the lateral growth of InAsP leads to nanowire bending in small diameter and an irregular large head at top for the large diameter nanowires. This growth is due to the asymmetric lateral growth induced strain and the non-preferential growth of InAsP along the  $\langle 111 \rangle\text{A}$  polar direction. The growth conditions for InP nanowires are  $T=730$   $^{\circ}\text{C}$ , TMIIn flow is  $4.048 \times 10^{-6}$  mol/min with V/III ratio of 143. The scale bars are 500 nm.

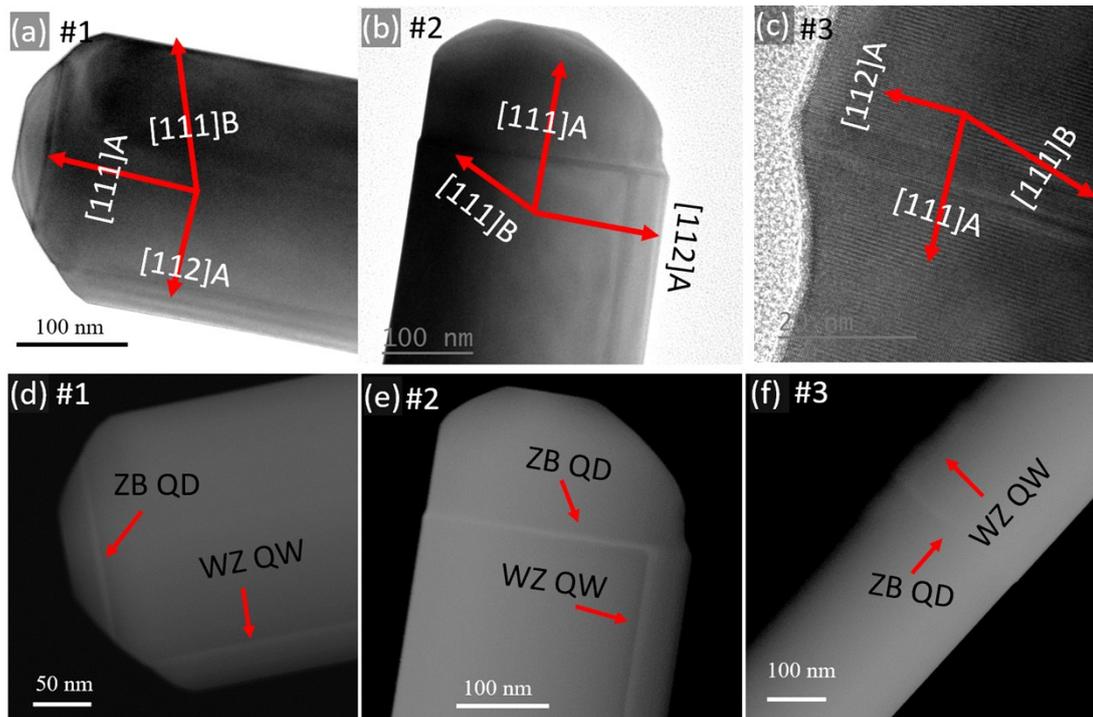


Figure S4. TEM images of more examples show that WZ InAsP QW selectively grow at the  $[11\bar{2}]A$  polar side of ZB QD. (a-c) TEM images viewed along  $[11\bar{2}0]$  zone axis of different samples. (d-f) corresponding HAADF images from (a-c) with indication of the QW position. The inset directions in (a-c) are determined through the FFT analysis of the InAsP QD. The InP nanowire growth conditions are the same as the reference sample in the main text. Sample #1 and #2, InAsP QW with nominal composition of  $\text{InAs}_{0.5}\text{P}_{0.5}$  is grown for 5 s while sample #3 are exactly the same as the reference sample in the main text.

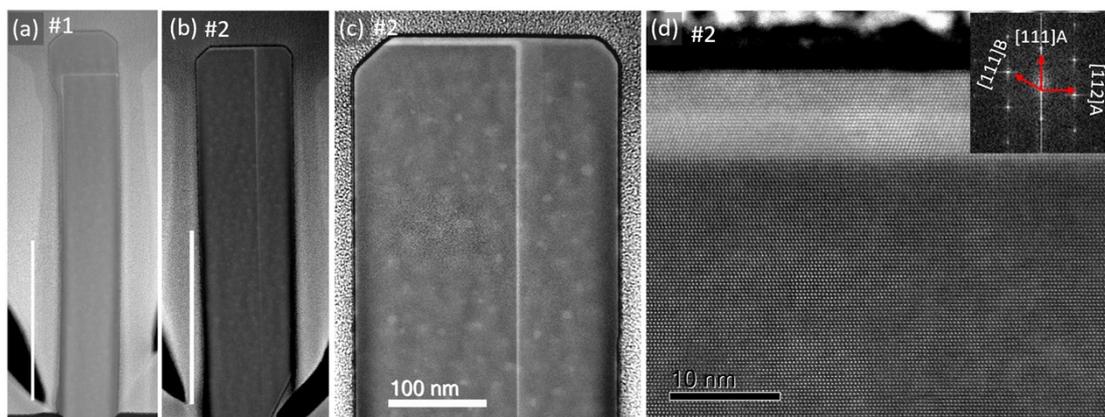


Figure S5. More STEM images of  $\langle 1\bar{1}0 \rangle$ -oriented InP/InAsP nanomembranes

demonstrate the nonuniform InAsP QW growth on the nonpolar  $\{1\bar{1}00\}$  facets. (a) Low magnification of the STEM of the sample shown in the main text. (b) HAADF images of another cross-sectional samples. The details of the QW structure is shown by the enlarged images at the top in (c) and atomically-resolved STEM image in (d). The inset FFT image confirms that InAsP QW grow selectively along the  $\langle 11\bar{2}\rangle$  A polar direction. In both samples, the lateral QW thickness is non-uniform and decreases from top to bottom. Scale bars are 500 nm in (a,b).

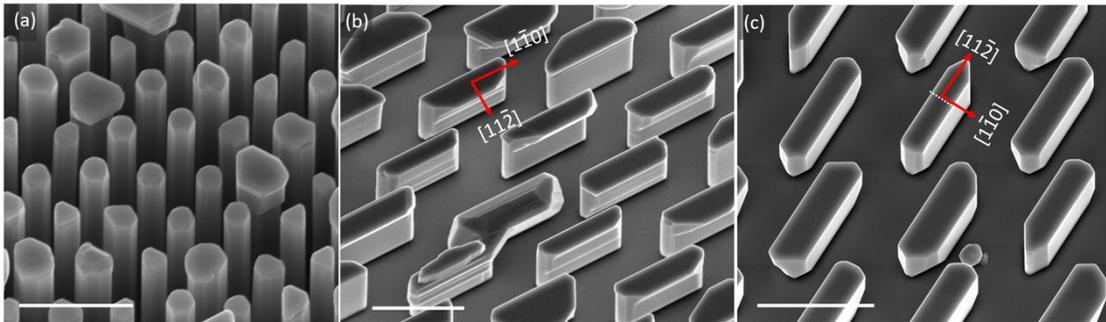


Figure S6. 30° tilted SEM images of InP/InAsP nanostructures with 5 InAsP QWs: (a) nanowires, (b)  $\langle 1\bar{1}0 \rangle$ -orientated nanomembranes, (c)  $\langle 11\bar{2} \rangle$ -orientated nanomembranes. Scale bars are 1  $\mu\text{m}$  in (a) and 2  $\mu\text{m}$  in (b-c).

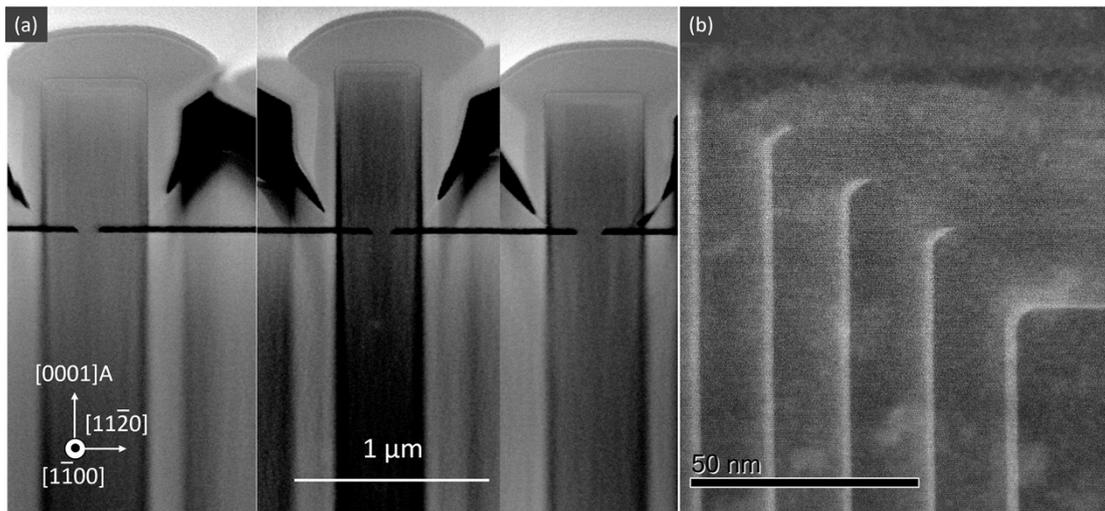


Figure S7. (a) More low magnification STEM images of  $\langle 11\bar{2} \rangle$ -orientated InP/InAsP nanomembranes with 5 InAsP QWs, showing the uniform lateral QW

distribution. (b) Enlarged HAADF image at the top, showing the nearly zero axial QW growth rate.

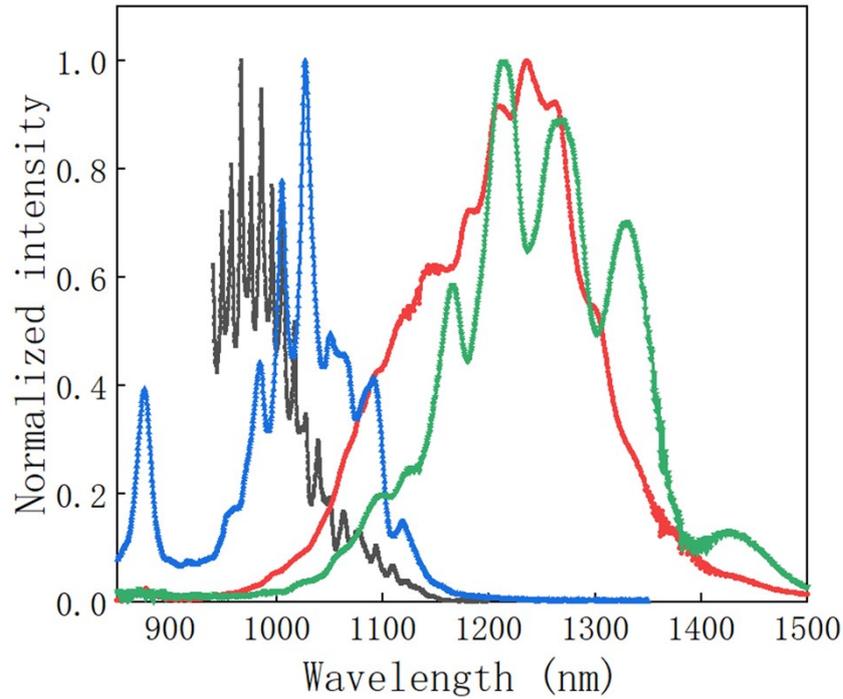


Figure S8. Selected PL spectra of different InP/InAsP QW nanowires showing the broad peak, tunable emission wavelength and amplified spontaneous emission. The nominal As/(As+P) ratio and growth time for the InAsP QW is: (black) 20%, 4s; (blue) 15%, 3s; (red) 33%, 5s; (green) 33%, 3s. Except for the black curve ( $T=740^\circ\text{C}$ ), all the other curves correspond to growth at  $730^\circ\text{C}$ . The PL measurements were performed by focusing the laser to an each vertical InP/InAsP QW nanowire.

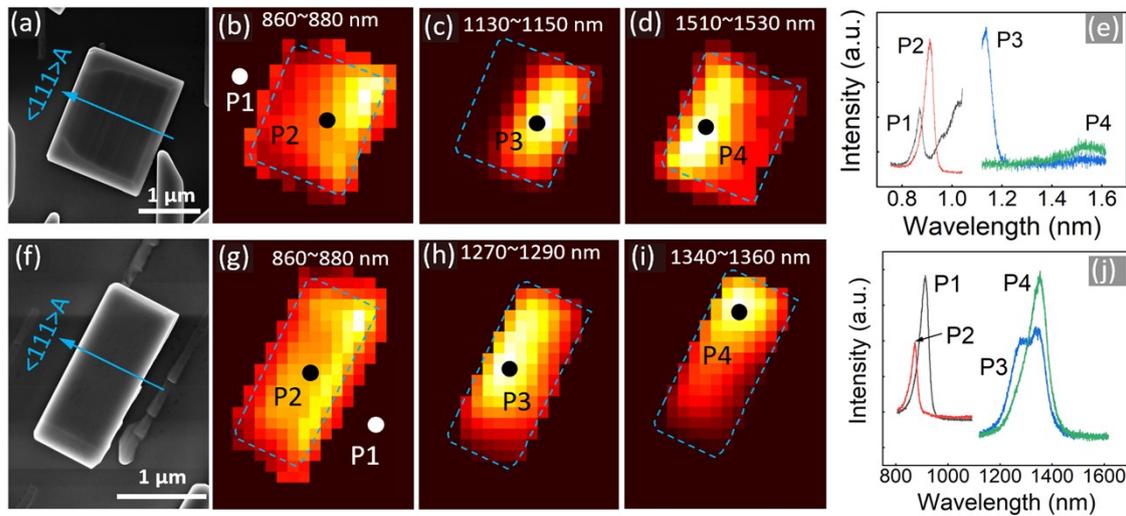


Figure S9. More CL mapping studies of (a-e)  $\langle 1\bar{1}0 \rangle$ - and (f-j)  $\langle 11\bar{2} \rangle$ -oriented

InP/InAsP QW nanomembranes. (a,f) Corresponding SEM images show the morphologies of the different QW nanomembranes. (b-d) and (g-i) are the corresponding normalized CL intensity mappings at different wavelength range. (e,j) are the extracted CL spectra at different positions.

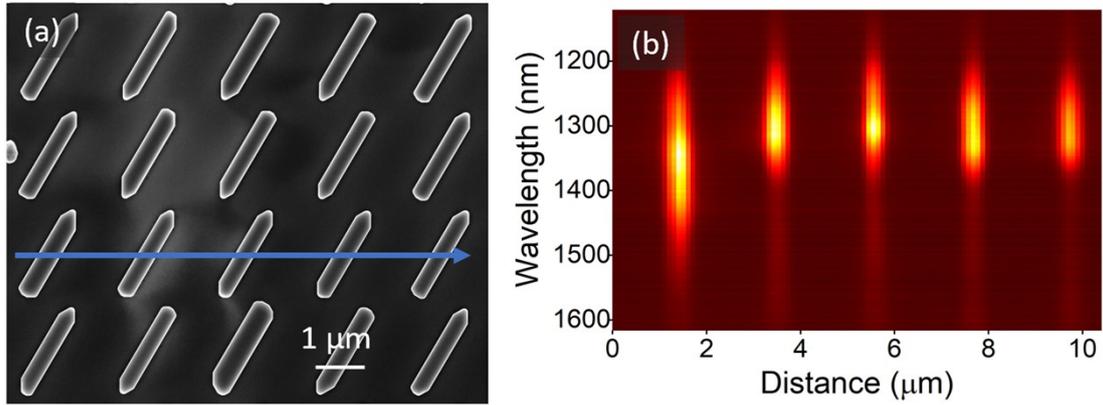


Figure S10. CL line scan of  $\langle 11\bar{2} \rangle$ -orientated InP/InAsP single-QW nanomembranes showing the uniform CL emission.