Supplementary Information (SI) for Nanoscale.

Continuous wave laser fabrication of small pitch/size perovskite pixels realizes high-resolution color conversion Micro-LED display

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Material synthesis and Experimental Section

Chemicals: 1-Octadecene (ODE, 90%), n-hexane (C_6H_{14}, 97%), ethyl acetate ($C_4H_8O_2$, 99%), acetone (C_3H_6O, 99.5%), toluene (C_7H_8, 99.5%) were purchased from Macklin. Lead bromide ($PbBr_2$, 99.9%), lead chloride ($PbCl_2$, 99.99%), lead iodide (PbI_2, 99.99%), cesium carbonate (Cs_2CO_3, 99.9%), oleic acid (OA, 85%), and oleylamine (OLA, 90%), ethanol (C_2H_6O, 99.5%) was purchased from Aladdin. All chemicals were used as received without further purification.

Synthesis of PQDs solution: $CsPbClBr_2$, $CsPbBr_3$ and $CsPbBrI_2$ PQDs solutions were synthesized according to the hot injection method. The first step is to synthesize the cesium oleate precursor solution. Cs_2CO_3, 1-octadecene and oleic acid were placed in a three-necked flask, and Ar gas was introduced to isolate the air. The solution was magnetically stirred and heated to 150°C. After the solute was completely dissolved, a precursor Cs-oleate solution was formed. The second step was to synthesize $CsPbX_3$ (X=Cl, Br, I) solution by hot injection. PbX_2, 1-octadecene, oleic acid and oleylamine were placed in a three-necked flask, and Ar gas was introduced. The solution was magnetically stirred and heated to 120°C. After the solute was completely dissolved, the mixture was heated to 170°C. The Cs-oleate solution preheated to 140°C was injected into the three-necked flask, cooled in an ice-water bath, and the product was collected by centrifugation and dispersed in toluene to obtain a $CsPbX_3$ (X=Cl, Br, I) solution.

PQDs film formation: Prepare PQDs film on quartz glass substrate (SiO_2). Ultrasonic clean SiO_2 with acetone, ethanol and deionized water for 30 minutes in sequence, remove surface moisture with Ar air gun, and then place SiO_2 in a UV cleaner for further cleaning for 15 minutes to better prepare the film. Use a glue homogenizer, set its parameters (2000 r/min, 45 s), take 70 μL $CsPbX_3$ solution with a pipette, and start the homogenizer to spin coating the required perovskite film.

Laser direct writing: Build an optical path to introduce the laser beam into the microscope system (OLYMPUS-BX43), focus the laser on the PQDs film through a focusing lens (NA=50×/0.80, Olympus), set the power parameters of the 405 nm CW laser (COHERENT-OBIS) on the computer, and control the moving path and speed of the three-dimensional electric translation stage (MARZHAUSER WETZLAR-MFD2) through software programming to complete the laser direct writing process on the PQDs film.

Blue Micro-LED chip: The chip was purchased from Lattice Power (Jiangxi) Corporation. The size is 0.5 inches, the main peak of luminescence is 450 nm, and the pixel center pitch is 50 μm. The red/green perovskite solution is suspended-coated on the glass cover of the blue Micro-LED chip. According to the pixel size and pitch of the chip, the laser parameters (laser power, moving speed and off-focus position) are set and prepared red/green array on the glass cover. Then turn on the power of the blue Micro-LED chip to complete color conversion.

High-resolution projection platform and its components: Composed of 320 nm CW laser, beam expander, attenuator, focusing lens, arrayed QDs film, filter and CCD. The projection platform is scanned by a laser beam and can project a focused image of any template. Using a 320 nm laser as an excitation light source, it passes through the template and excites the array on the PQDs film to achieve color conversion.

Material characterization: The fluorescence images of the PQDs film and the array part were captured by the CCD camera (MSHOT-MSX2) integrated inside the microscope, and the light source used was an optical fiber light source (COLDSPOT-PCS MH375RC). Atomic Force Microscope (AFM) images were taken by an atomic force microscope (Bruker-Diension Icon). Scanning Electron Microscope (SEM) images were taken by a field emission scanning electron microscope (FEI Quanta 250FEG and Hitachi Regulus 8100). Energy Dispersive Spectroscopy (EDS) spectrum tested by Hitachi Regulus 8100. Photoluminescence (PL) spectra were collected on a Varian Cary Eclipse instrument. The absorption spectrum was collected using the (SHIMADZU UV-3600) instrument. The photoluminescence quantum yield (PLQY) was collected using the (HAMAMATSU PMA-12) instrument. The XRD data pattern was measured by an X-ray diffractometer (Bruker-AXS D8 Advance). The fluorescence lifetime spectrum is detected by the fluorescence lifetime test system (SPC-130EM).

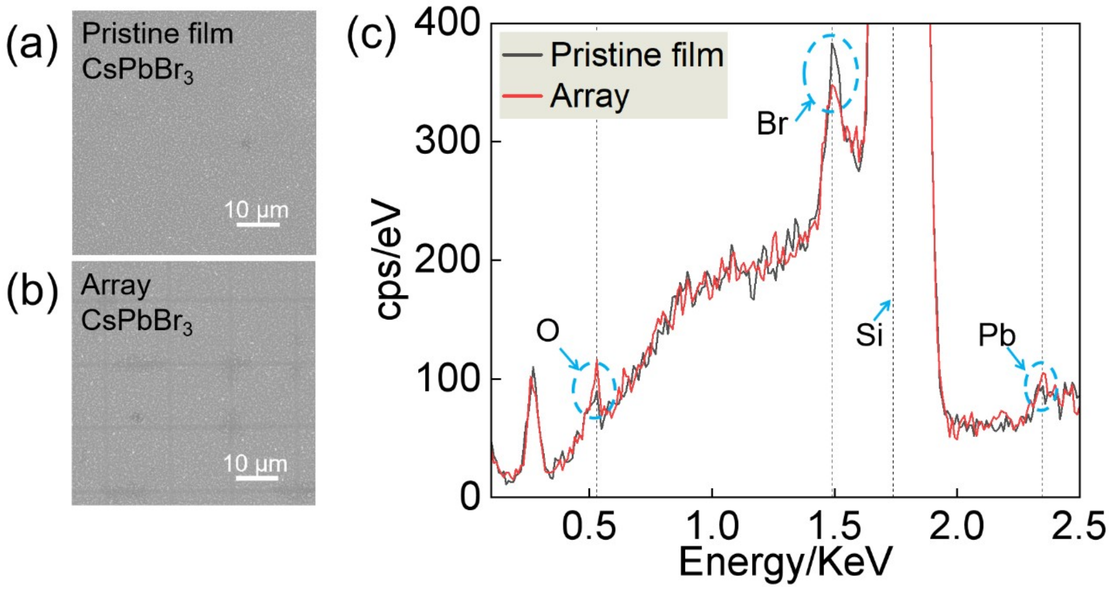

Fig. S1 (a) and (b) are SEM images of the pristine film and array on a silicon substrate, respectively. (c) EDS surface scan energy spectrum of (a) and (b).

Table S1 The EDS spectra were analyzed to obtain the proportions of Cs, Pb, Br and O elements in the pristine film (a) and array (b).

Element (wt%)	Cs	Pb	Br	O
Pristine film	9.52	9.87	75.7	4.91
Array	10.8	16.68	61.31	11.21

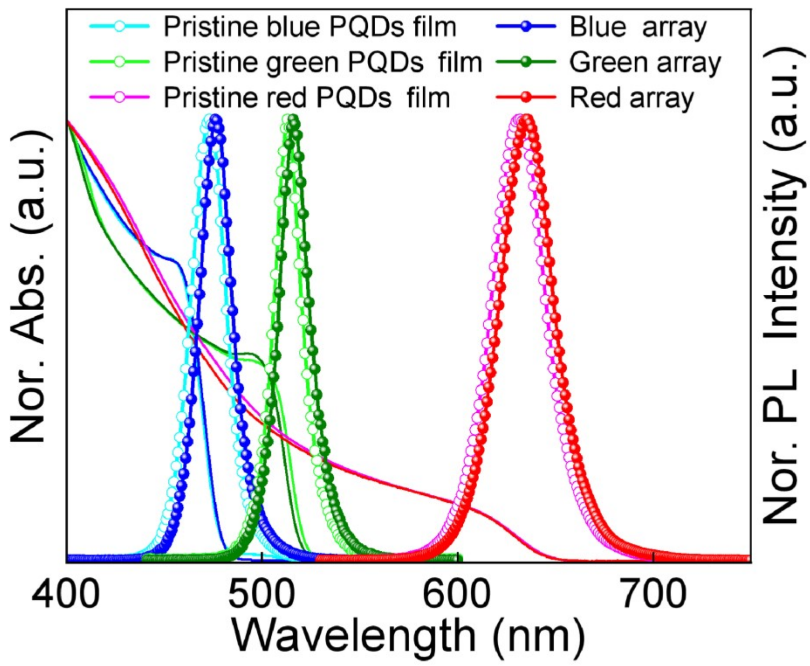

Fig. S2 Normalized fluorescence spectra and absorption spectra of three-color film and array area.

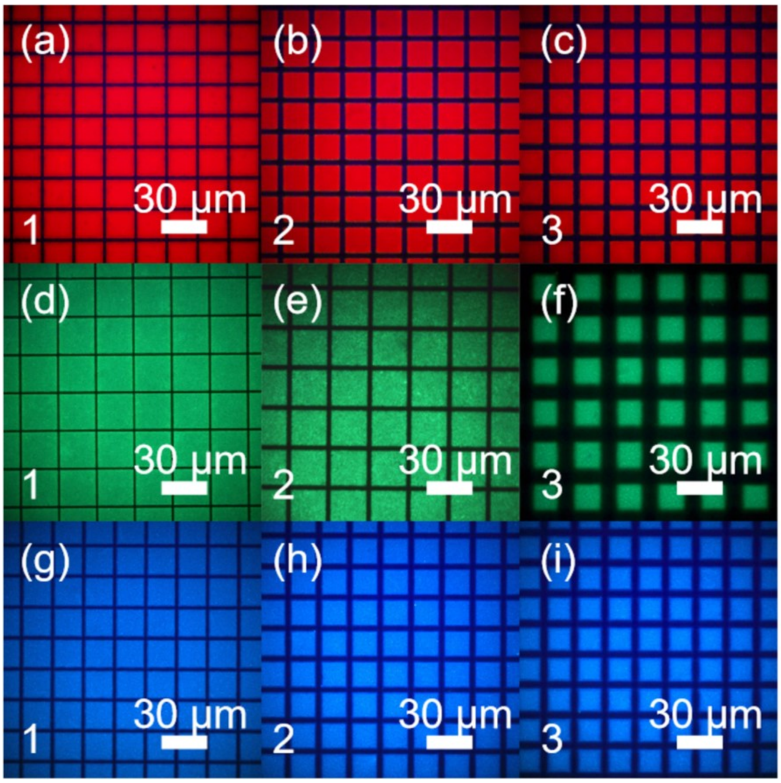

Fig. S3 (a)-(c) $CsPbBrI_2$ arrays with different pixel pitch. (d)-(f) $CsPbBr_3$ arrays with different pixel pitch. (g)-(i) $CsPbClBr_2$ arrays with different pixel pitch.

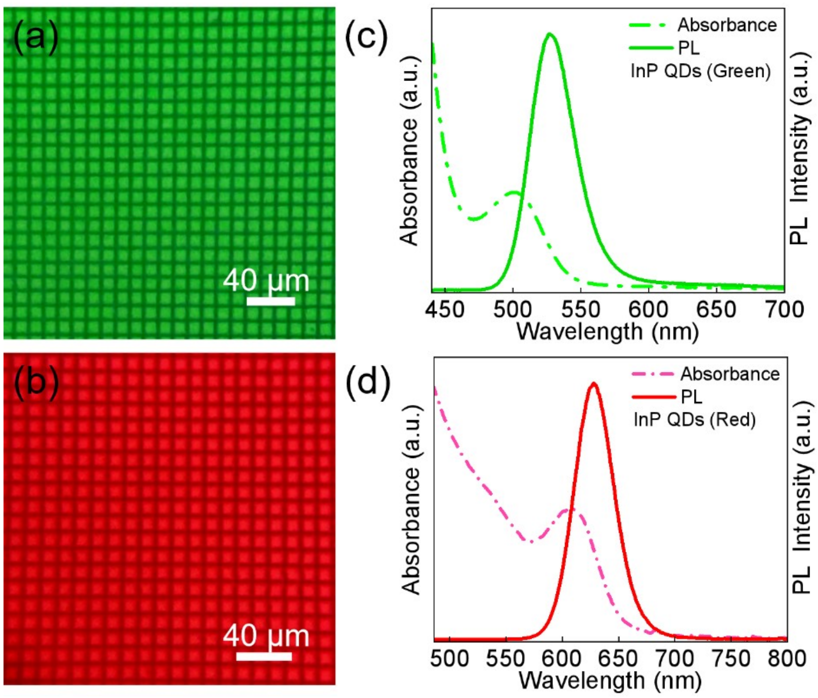

Fig. S4 (a) and (b) are fluorescence microscope images of InP (green) and InP (red) QDs arrays, respectively. (c) and (d) are absorption and PL spectra of InP (green) and InP (red) QDs.

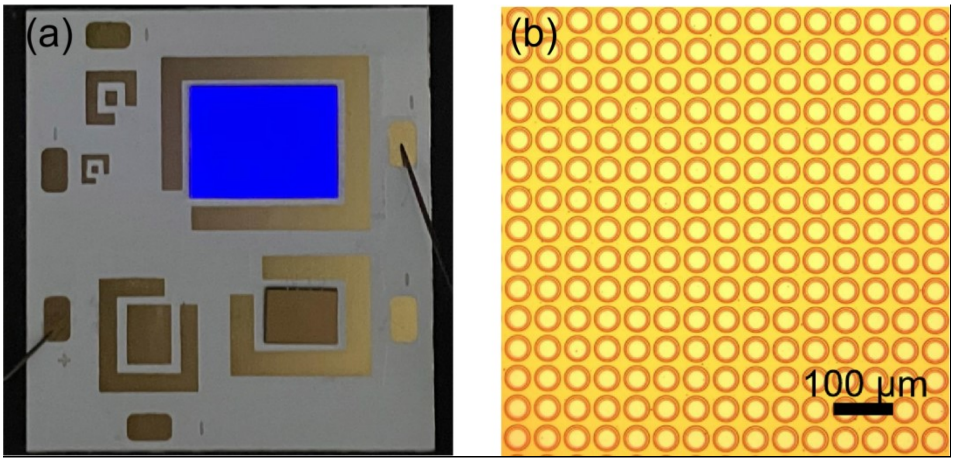

Fig. S5 (a) Photo of the blue Micro-LED chip when working. (b) Micrograph of the Micro-LED chip when it is not working.

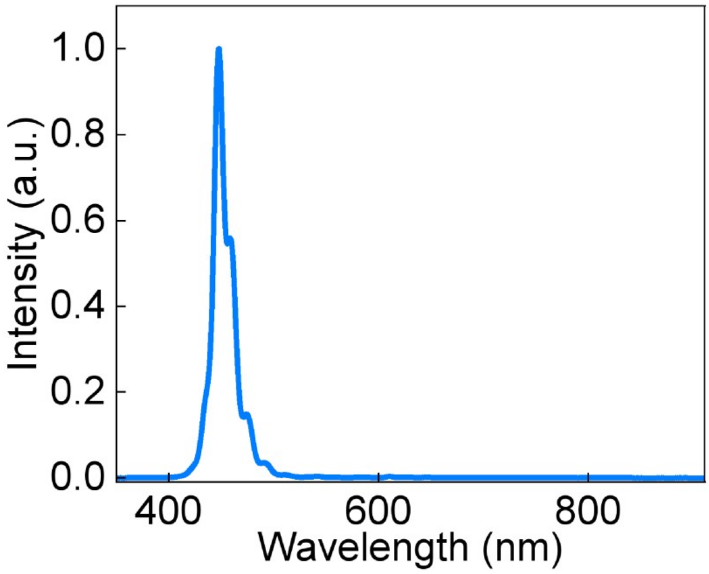

Fig. S6 The wavelength of light emitted by the blue Micro-LED chip during operation.

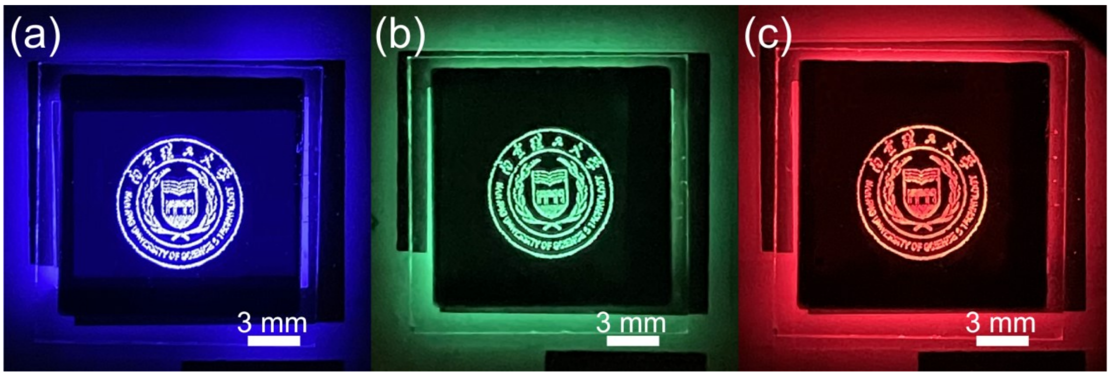

Fig. S7 (a) Blue Micro-LED chip pattern display. (b)-(c) Blue Micro-LED chip achieves patterned display through color conversion.

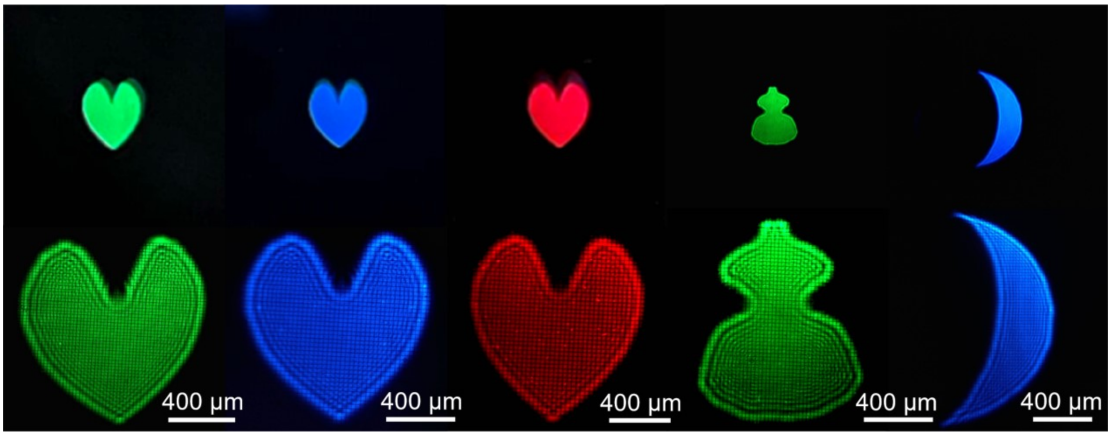

Fig. S8 Original projection image and enlarged image captured by CCD.