Supporting Information

All-Optical Full-Colour Displays Using Polymer Nanofibers

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1. CIE chromaticity of the spots

Normally, colour evaluation is related to the Commission International de l'Eclairage (CIE) chromaticity diagram. The colour coordinates x, y, and z are defined as[1] $x = X/(X + Y + Z)$, $y = Y/(X + Y + Z)$, and $z = Z/(X + Y + Z) = 1 - x - y$, where X, Y, and Z are the tri-stimulus values of one colour, which can be obtained by integrating the product of the power-spectral density and the corresponding colour matching function from wavelengths of 380 to 780 nm. Figure S1 shows the spot with colour coordinate of (x, y) = (0.27, 0.70) (yellowish-green colour), (0.45, 0.54) (greenish-yellow colour), (0.56, 0.43) (orange colour), and (0.64, 0.35) (reddish-orange colour) in the CIE chromaticity diagram.

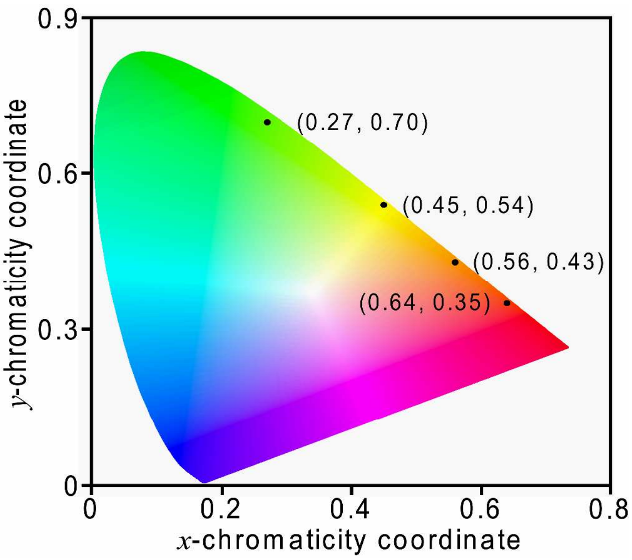


Figure S1. The CIE chromaticity diagram for the spots with colour coordinates of (*x*, *y*) = (0.27, 0.70), (0.45, 0.54), (0.56, 0.43), and (0.64, 0.35) for Figure 1c–f.

2. Optical microscope images of the mixed colors at the junction

To investigate the influence of the inputted power ratio of the blue and green lights on the mixed colours at the crossed junction of the nanofibers, the blue and the green lights with power ratios of about 8 : 17 (Figure S2a, total power of 25.4 μW), 15 : 16 (Figure S2b, total power of 36.6 μW), 19 : 15 (Figure S2c, total power of 35.1 μW), and 21 : 9 (Figure S2d, total power of 29.7 μW) were launched into the nanofiber 1 (diameter, 457 nm) and the nanofiber 2 (diameter, 486 nm), respectively. Accordingly, different colours at the crossed junction were obtained as shown in the insets of Figure S2a–d. With a change of the inputted power ratios, the mixed colours were changed from green (Figure S2a, b) to bluish-green (Figure S2c), and blue-green (Figure S2d). The respective spot radii are 295, 299, 301, and 304 nm while the colour coordinates in the CIE chromaticity diagram are (x, y) = (0.16, 0.56) (green), (0.15, 0.43) (green), (0.14, 0.42) (bluish-green), and (0.13, 0.26) (blue-green) for the Figure S2a–d. These results indicate that desired spot colours at the crossed junction can be easily obtained by adjusting the power ratios of the launched blue and green lights.

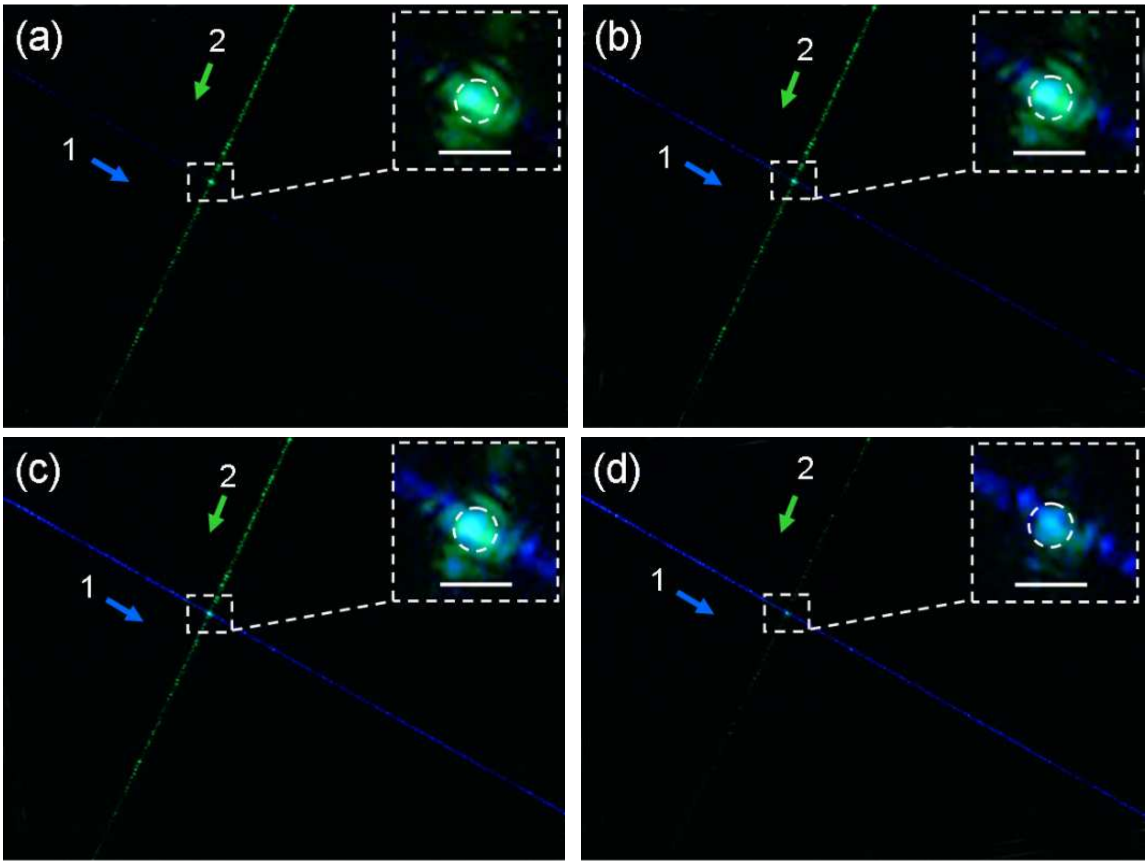


Figure S2. Optical microscope images of the mixed colours at the junction of the nanofibers. The insets show a zoomed (×10) view of the spots at the crossed junction. The arrows show the propagation directions of the launched lights. Scale bars in the insets of the **a–d** are 10 μm.

Similarly, if change the launched power ratios of the red and blue lights from 9 : 10 to 13 : 6, 21 : 4, and 22 : 3, the mixed spot colours at the crossed junction can be also easily changed from purple (Figure S3a, total power of 42.2 μW) to reddish-purple (Figure S3b, total power of 58.8 μW), purplish-red (Figure S3c, total power of 70.2 μW), and purplish-red (Figure S3d, total power of 70.5 μW). The respective spot radii are 251, 282, 285, and 287 nm while the corresponding coordinates are (0.25, 0.12), (0.37, 0.16), (0.52, 0.21), and (0.58, 0.23). Above demonstrations indicate that, by changing the power ratios of the launched red, green, or blue lights, a desired colour can be obtained at the crossed junction of the nanofibers.

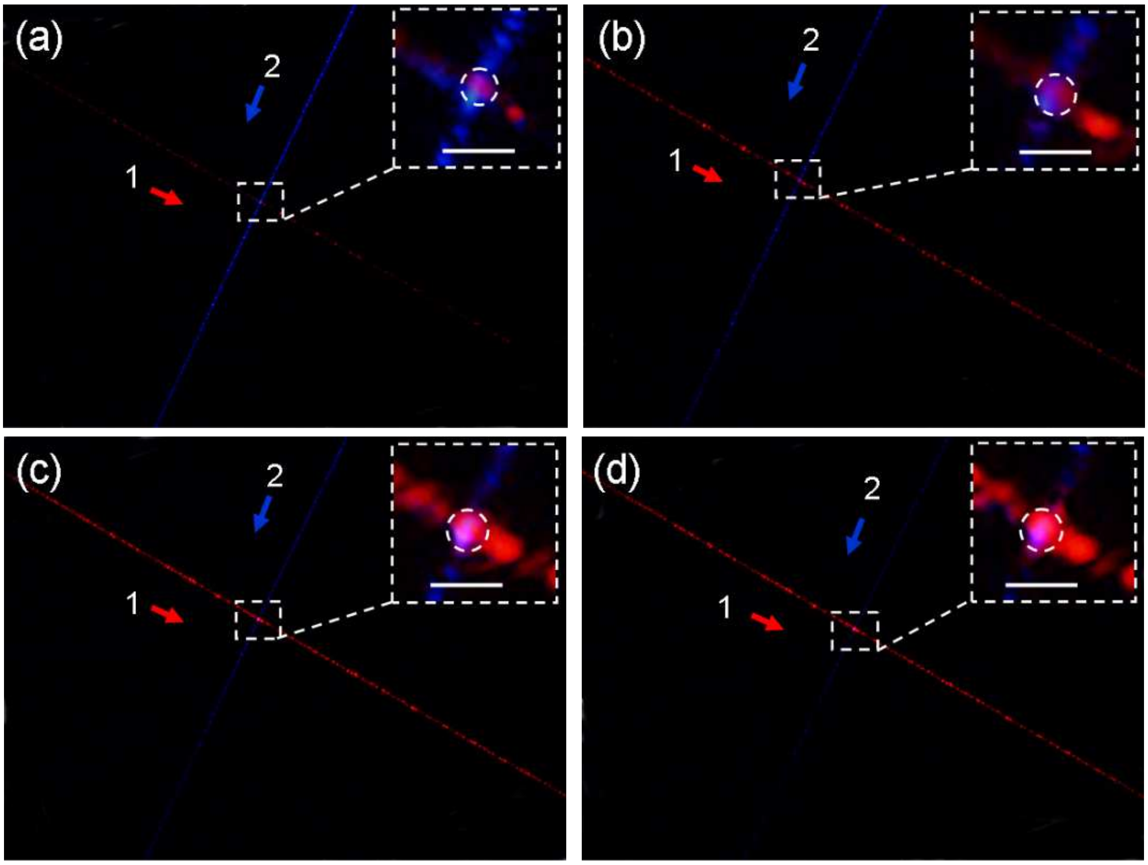


Figure S3. Optical microscope images of the mixed colours at the junction of the nanofibers. The insets show a zoomed (×10) view of the spots at the crossed junction. The arrows show the propagation directions of the launched lights. Scale bars in the insets of the **a–d** are 10 μm.

3. CIE color coordinates of spots at the junctions

Figure S4 shows the CIE coordinates of the spots at the crossed junction in Figures S2 and S3. The coordinates locate in somewhere along a straight line linking two point (coordinates of mixed two lights) in the chromaticity diagram, which is in conformity with colour-mixing theory[2]. Moreover, the colour coordinates of these spots lie far outside the current National Television System Committee (NTSC) standard colour triangle, which indicates this nanodisplay would provide a significantly larger colour triangle in the CIE chromaticity diagram[3].

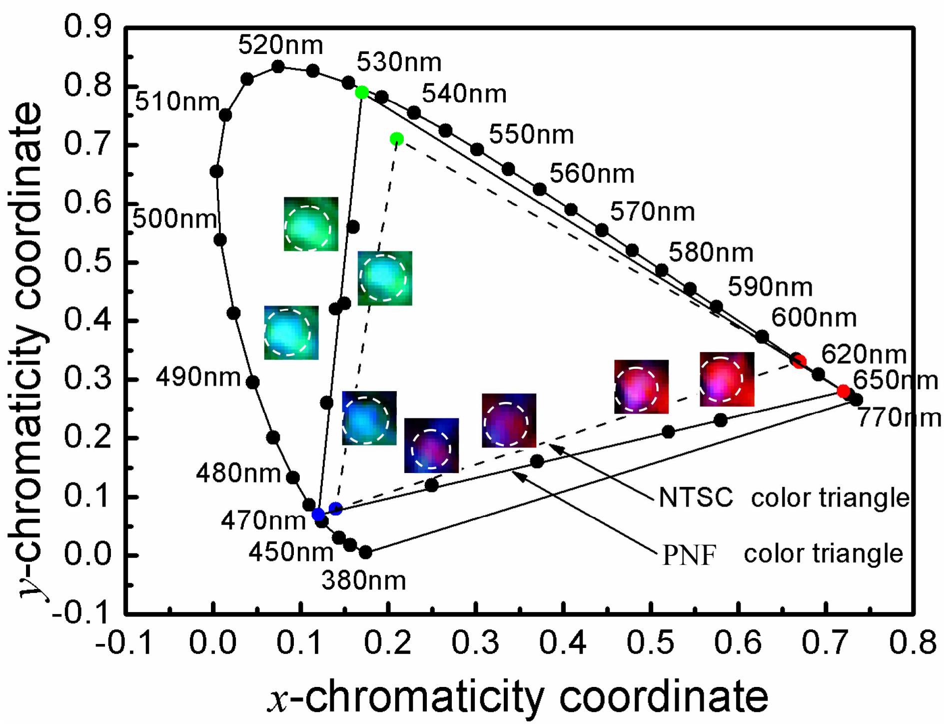


Figure S4. CIE colour coordinates of spots at the crossed junctions. The red, green, and blue dots in the colour triangle represent three primary colours. The NTSC colour triangle was included for comparison.

To investigate the effect of the red, green, and blue (RGB) lights on white colour generation, different power ratios of the RGB lights were launched into the structure. First, when a power ratio of about 65 : 19 : 10 for RGB lights (total power of 60.8 μW) were launched into the nanofibers 1, 2, and 3, respectively, a warm-white spot was observed at the crossed junction with a radius of 855 nm (inset of Figure S5a). The colour coordinate of the warm-white spot is (0.42, 0.36), correlated colour temperature (CCT) is 2915 K. Second, when the power ratio was changed to 37 : 10 : 11 (total power of 69.7 μW), a white spot was formed at the junction with a radius of 891 nm (inset of Figure S5b). Its colour coordinate is (0.37, 0.32) and CCT is 3861 K. Third, when the power ratio was decreased to 26 : 10 : 26 (total power of 93.5 μW), a cool-white spot was observed. The radius of the cool-white spot is 864 nm (inset of Figure S5c). Its colour coordinate is (0.26, 0.25) and CCT is 21883 K. It should be pointed out that, at around the white colour of the spot centre, red-green-blue mixed colour was occurred. This is due to the radii of the scattered RGB spots at the junction are different. Figure S5d shows the possibility of the tuning range of the CCT when plots of the

CIE coordinates were produced from Figure S5a–c. These demonstrations show that desirable colour coordinates of the generated white colour can be easily obtained by tuning the input power ratios of the RGB lights. The corresponding CCT also can be tuned from 2915 to 21883 K.

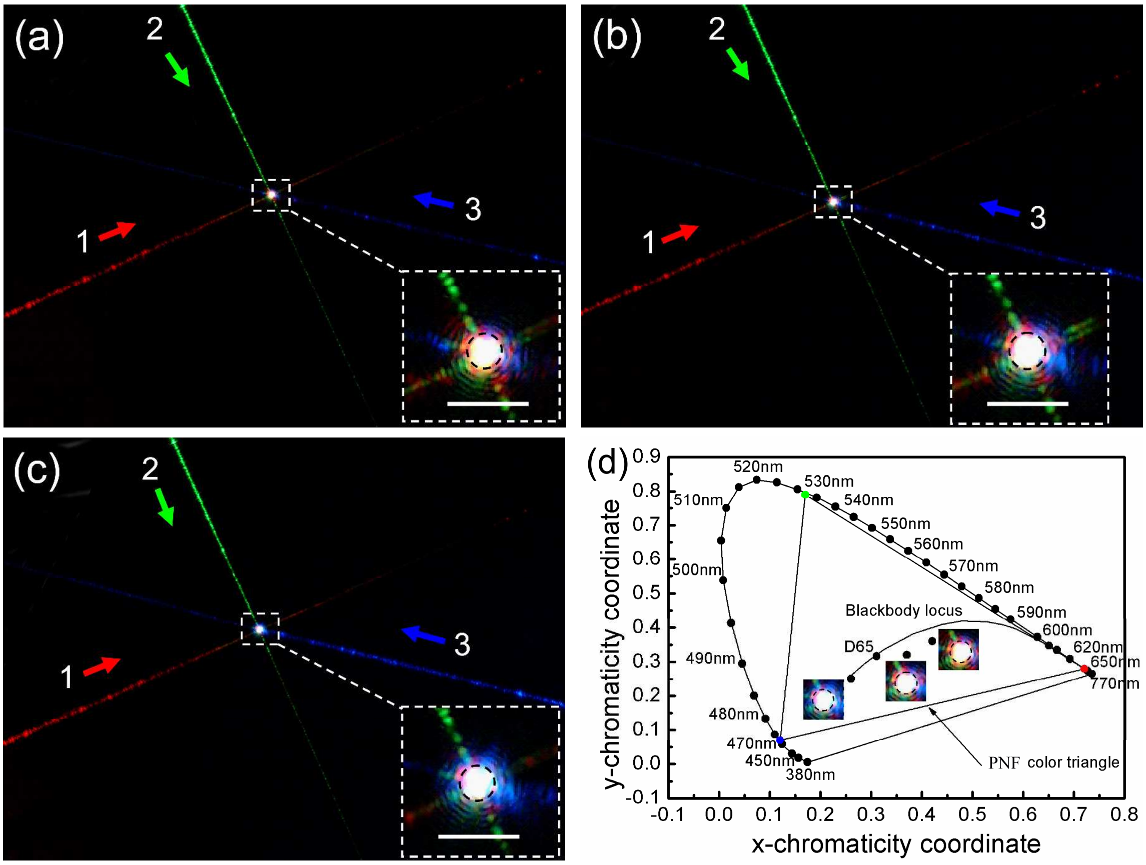


Figure S5. a–c, Optical microscope images of the mixed colours at the junction of the nanofibers. The inset shows a magnified (×5) view of the white spot at the junction. The arrows show the propagation directions of the launched lights. Scale bars in the insets of the **a–c** are 20 μm. **d**, CIE colour coordinates and CCT of the spot at the junctions. The red, green and blue dots of the colour triangle represents three primary colours. The standard light source D_{65} is included for CCT comparison.

4. Output and scattering efficiency dependence on nanofiber diameter and cross angle

Figure S6 shows the output efficiency dependence on the nanofiber diameter and cross angle while Figure S7 shows the scattering efficiency dependence on the nanofiber diameter and cross angle. It can be seen that, for fixed operating wavelength and fiber diameter, with an increase of the cross angle, output efficiency will decrease while scattering efficiency will increase. In other words, higher coupling efficiency can be achieved by using smaller diameter of fiber or smaller cross angle. Larger scattering efficiency can be achieved by using larger diameter of fiber or larger cross angle.

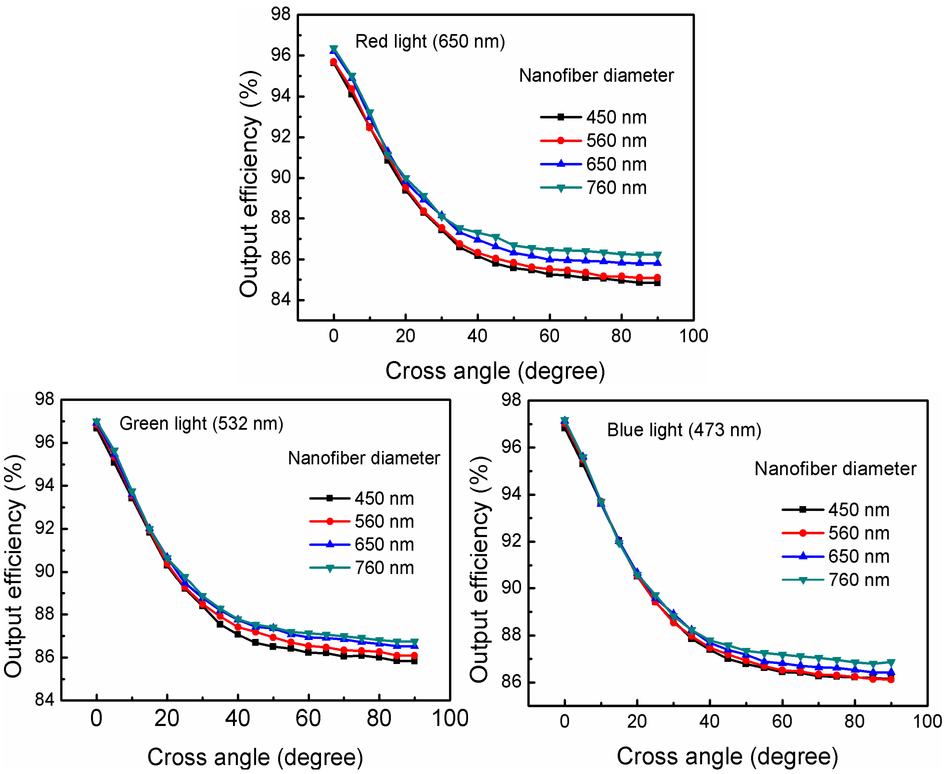


Figure S6. Output efficiency dependence on nanofiber diameter and cross angle.

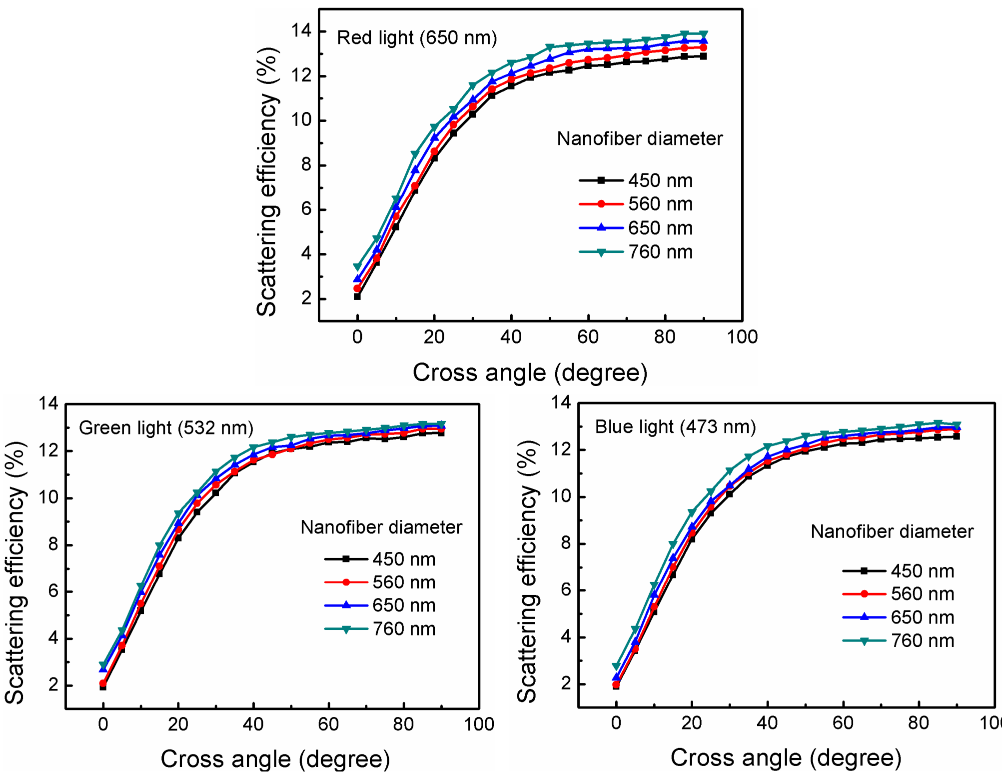


Figure S7. Scattering efficiency dependence on nanofiber diameter and cross angle.

5. Flexibility demonstration of the devices

Since the PTT nanofiber has an excellent flexibility as shown in the following Figure S8 (also see Opt. Express 16(2008)10815-10822). Therefore, the structures can also be assembled on flexible substrates such as plastic (Figure S9) and paper (Figure S10).

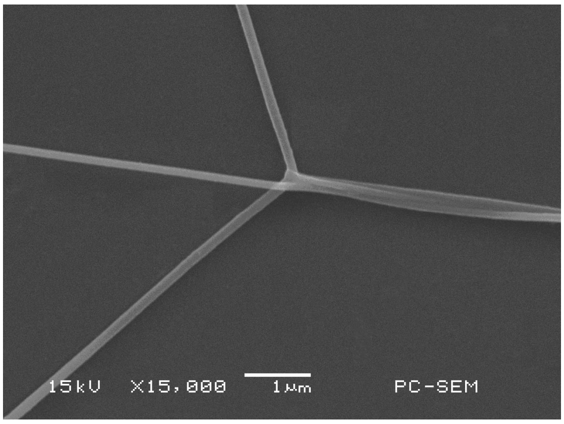
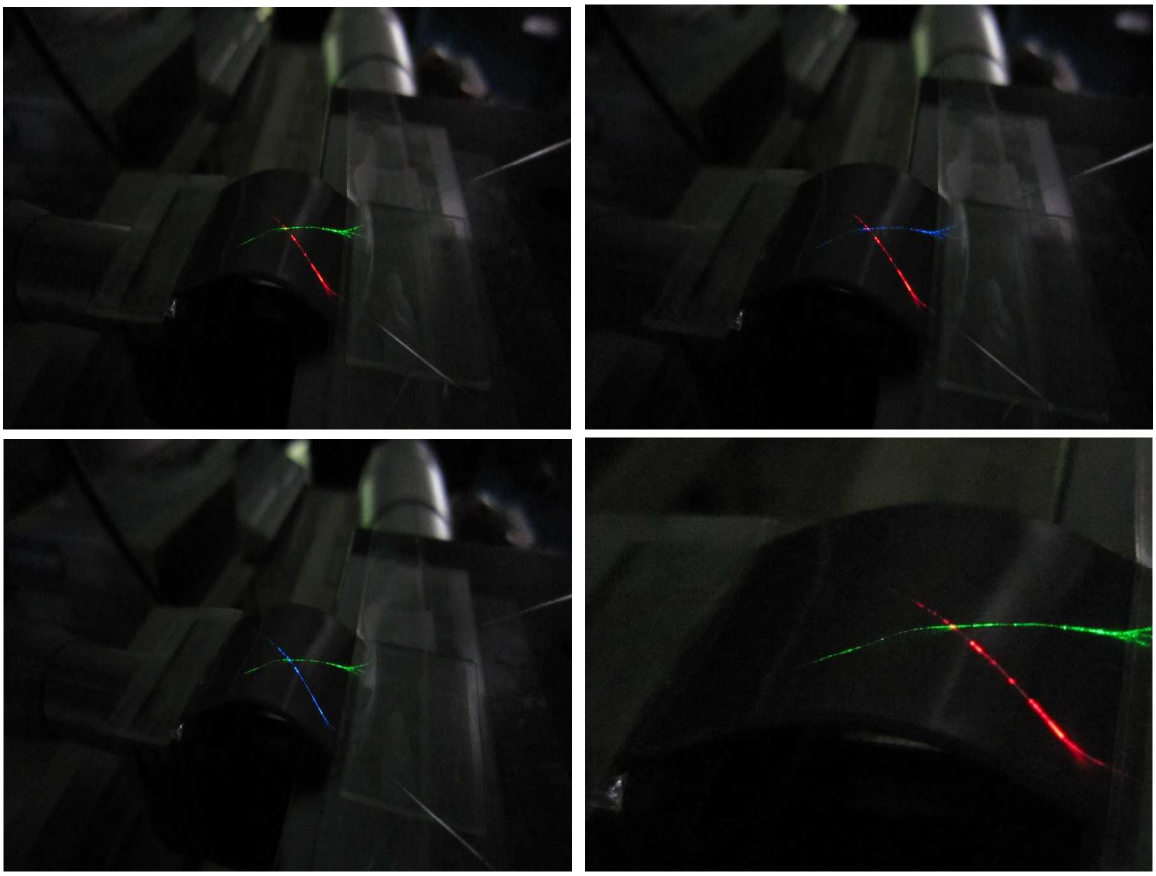


Figure S8. Flexible and elastic nanofiber connection with diameters of 140 and 170 nm.



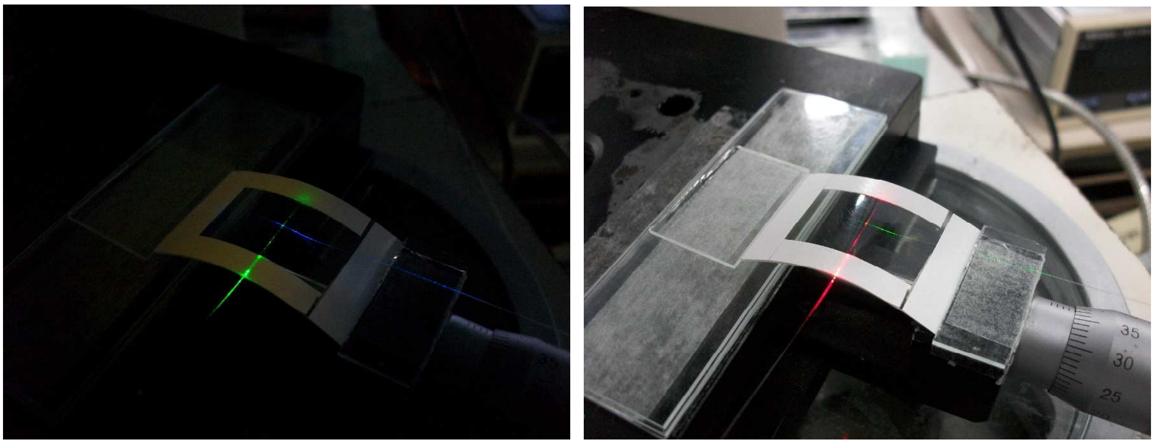


Figure S9. Optical microscope images of the display structures on flexible plastic substrate.

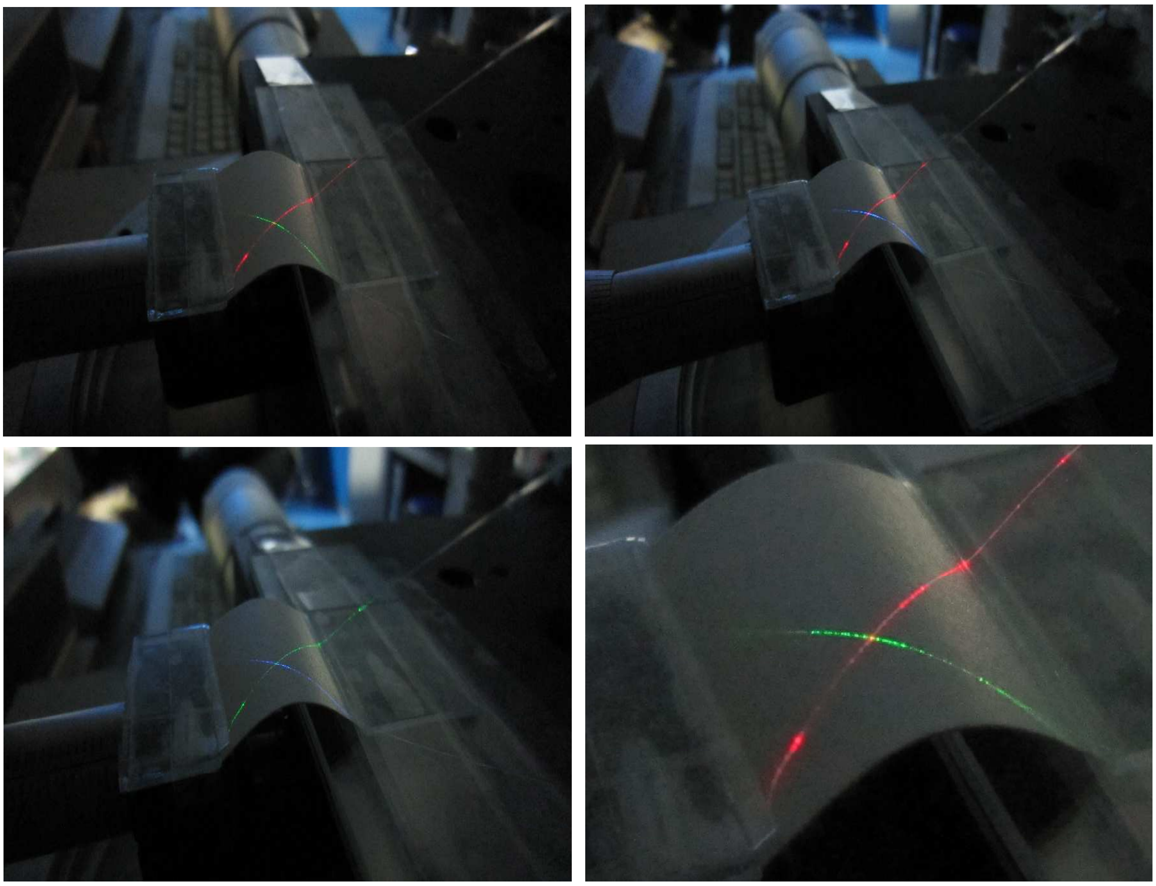


Figure S10. Optical microscope images of the display structures on flexible paper substrate.

References

1. Schubert, E. F. *Light Emitting Diodes* (Cambridge Univ. Press, Cambridge, UK, 2003), pp. 293–294.

2. Overheim, R. D.; Wagner, D. L. *Light and Color*, Wiley, New York, 1982.
3. Steckel, J. S.; Snee, P.; Coe-Sullivan, S.; Zimmer, J. P.; Halpert, J. E.; Anikeeva, P.; Kim, L.-A.; Bulovic, V.; Bawendi, M. G. Color-Saturated Green-Emitting QD-LEDs. *Angew. Chem. Int. Ed*. **2006**, *45*, 5796–5799.