EFFICIENT COLOR CONVERSION FROM COLLOIDAL QUANTUM DOTS EMBEDDED IN RESONANT CAVITY

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Micro-LEDs have become essential in mobile display devices (e.g., XR glasses) due to their small pixel size. However, as pixel width decreases while thickness remains unchanged, current micro-LEDs face challenges with a high thickness-to-width aspect ratio, leading to fabrication complexities. Addressing this, efficient color conversion from a thin phosphor layer, which can significantly reduce pixel thickness, is highly desirable.

The authors' group has proposed and developed the concept of 'structurally engineered phosphors' for high color-conversion efficiency, using a two-dimensional photonic crystal platform in particular[1]. This involves integrating phosphor materials with a nanophotonic structure to achieve resonant absorption, which significantly increases the absorption of excitation photons, leading to stronger emission of converted photons.

In this study, we introduce resonant cavity (RC) as another platform for structurally engineered phosphors[2]. A colloidal quantum dot (CQD) film, only 40-nm-thick and inserted into a predesigned RC (Fig. 1), can effectively absorb a large portion of excitation photons through resonant absorption, a system we term 'RC phosphor'. Compared to the reference phosphor containing the same amount of CQDs, the RC phosphor exhibited 29 times higher fluorescence with moderately broad linewidth of 13 nm (Fig. 2).

To showcase practical application in micro-LEDs, red and green pixels were fabricated based on the RC phosphor, and excited using an LED-like blue source. These pixels, in the CIE 1931 color space, achieved a color volume approximately 121% of the sRGB standard. This marks a significant step towards replacing the traditional 10-μm-thick CQD films used in the present displays.