Supplementary Material

Square Maxwell's fish-eye lens for near-field broadband achromatic super-resolution imaging

Numerical analysis of the super-resolution information transmission channel composed of the solid immersion square MFELs

To design a super-resolution information transmission channel with a better transmission performance, the influence of the air gap between the components (solid immersed square MFELs) of the super-resolution information transmission channel on the transmission channel is discussed and numerical analysis is carried out by using the full-wave simulation method in this section. Three solid immersion square MFELs is arranged in a row to make up a super-resolution information transmission channel, and the spacing d (air slot) between each square MFELs is taken as a variable, as shown in Fig. S1(a). Here the air gap between each solid immersion square MFELs is the same, which is equal to d. In the figure, the red dotted line is the observation position of the imaging point ($y=-100\sim100$ mm), which is in the middle of the gap of lens A, B and C respectively. It is the same distance from the imaging boundary of each lenses. The red dots represent a point source which is placed at $x=-100$ mm and $y=0$ mm to excite the TE cylindrical wave at frequency of 12GHz. According to the super-resolution information transmission channel structure diagram composed of three solid immersion square MFELs as shown in Fig. S1(a), the relative FWHM value is obtained by calculating the electric field intensity distribution along the red dotted line of each square MFELs with the spacing d increasing as shown in Figs. S1(b)-(d). It is clearly observed that the variation curve of FWHM value at each solid immersion square MFELs imaging position concerning air gap spacing d from 0mm to 1.8mm is calculated respectively. Fig. S1(b) indicates the relative value FWHM of solid immersion square MFEL A increases slowly with the increase of air gap d, which are basically all below 0.18λ. This is because the coupling between solid immersion square MFELs decreases with the increase of air gap d, thus, when the air gap d is large, the FWHM of lens A is mainly influenced by total internal reflection (TIR) which is closer to the value of a single solid immersion square MFEL. In Fig. S1(c), it can be seen that the relative value FWHM of the solid immersed square MFEL B reveal a similar "s"-shape change trend when the air gap d increases, that is, the FWHM curve increases firstly and then decline, immediately it rises again, which is affected by the coupling effect between square MFELs and the TIR mechanism. The FWHM's variation trend of solid immersed square MFEL C concerning air gap d is similar to that of lens B.

Through the comprehensive observation of Figs. S1(b)-(d), it can be found that when d is 0 and 0.6mm, the total transmission effect of the super-resolution information transmission channel is relatively good. At the same time, when the air gap is 0.6mm, the channel not only has better information transmission capabilities, but also has super-resolution capabilities. Thus, when the optimal spacing d is 0.6mm, a super-resolution information transmission channel composed of three solid immersion square MFELs is designed. The corresponding FWHM obtained for three solid immersion square MFEL of A, B and C is less than 0.18λ, which is less than the diffraction limit. In the main text, Fig. 6 shows the electric field intensity of the designed super-resolution information transmission channel excited by the two point sources. This design has a good optical applications prospect, not only can realize the multi-points source resolution information transmission, but also has the advantage of long-distance transmission.

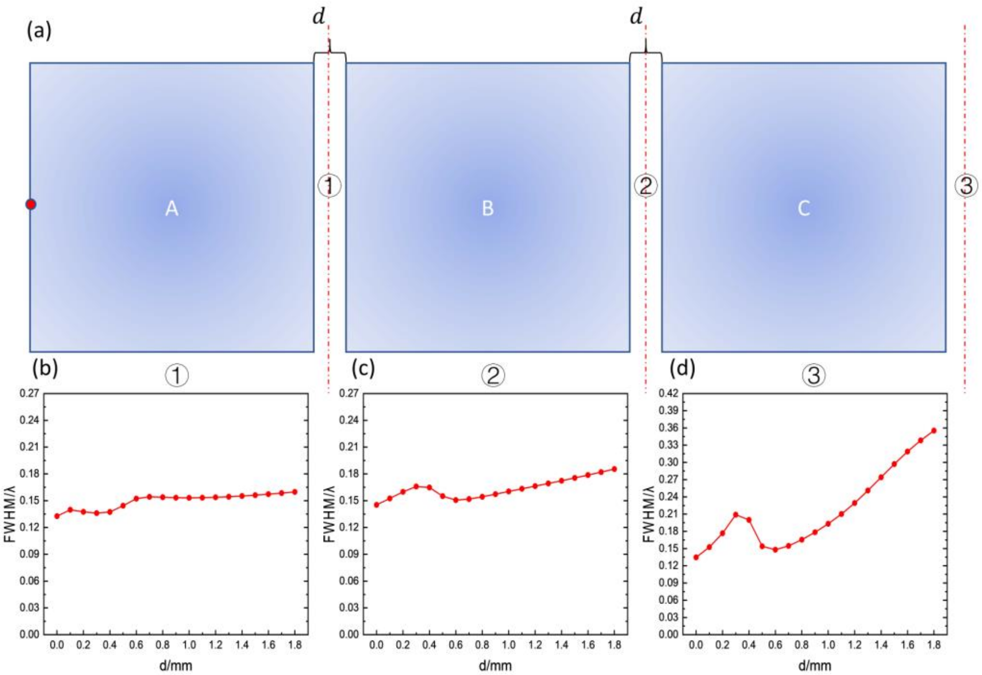

Fig. S1. (a) A super-resolution information transmission channel. (b) The curve of FWHM value corresponding to the solid immersion square MFEL A with air spacing d. (c) The curve of FWHM value corresponding to the solid immersion square MFEL B concerning air spacing d. (d) The curve of FWHM value corresponding to the solid immersion square MFEL C concerning air spacing d.