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Design roadmap and physical nature of super-oscillation theory in super-resolution imaging system

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1. Introduction

Super-oscillatory lens has been demonstrated to focus the light into subwavelength spots in the farfield, without the assistance from evanescent wave [1]. It empowers realistic applications in super-imaging due to its farfield operation, with the price of strong sidelobes though. So far, the design of the super-oscillatory lens is more optimization-oriented and the harmonic contribution of every fine feature to the imagine plane is still unclear. In this talk, we will propose, for the first time, the explicit physical nature of super-oscillation theory in designing a super-oscillatory lens. Thus it enables us to accomplish nanosieving plates which is experimentally demonstrated to have improved super-resolution imaging. Another important issue of dealing with strong sidelobe of super-oscillatory lens is tackled by zero stitching and the sidelobe, though not being able to eliminate, can be pushed far away from the super-resolution spot in the center. It paves a new scheme in farfield super-imaging which can be obtained and integrated in conventional microscope.

2. Theory

Assuming that we want to realize the electric field $\mathbf{F}=[f_1,f_2,\ldots,f_M]^T$ at the prescribed position $\mathbf{r}=[r_1, r_2,\ldots, r_M]^T$ by using the interference of light from the given spatial frequencies $\mathbf{v}=[v_1, v_2,\ldots, v_N]^T$, the problem of determining the unknown amplitude $\mathbf{C}=[C_1,C_2,\ldots,C_N]^T$ can be expressed by

$$\mathbf{SC}=\mathbf{F} \qquad (1)$$

where **S** is an M×N matrix that has its matrix element $S_{mn}=J_0(k_0r_mv_n)$. Fiugre 1 shows the constructed optical pattern by the inverse problem of super-oscillation which is described by Eq. (1). One can see that the super-oscillation can be generated by solving the Eq. (1) with the number 2 or 9 of spatial frequencies. The method proposed here is enough to deal with the general problem that is relative with super-oscillation.

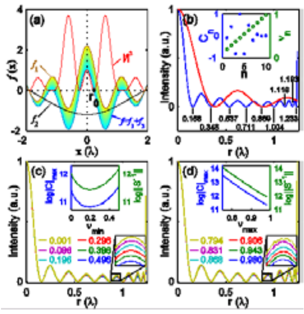

Fig. 1 The constructed optical pattern by inverse problem of super-oscillation.

3. Discussion

We have just considered Eq. (1) as a linear matrix equation with the unknown **C** and the given **S** and **F**. However, it is more meaningful to solve the spatial frequency in **S** for realizing the super-oscillatory pattern with **F** because the amplitude **C** usually has the strong dependence on the spatial frequency in real optical system. In the case of solving the spatial frequency with frequency-dependence $C_n(v_n)$ and $S_{mn}(r_n,v_n)$, Eq. (1) can be considered as a non-linear matrix equation. Eq. (1) is numerically solvable for its approximate solution by using the widespread methods based on Newton theory for non-linear problem, which makes our theory of manipulating the super-oscillation by its inverse problem more useful in application

4. Conclusion

We have demonstrated that the inverse problem of super-oscillation can be described by a matrix equation that is relative with the given spatial frequencies, the customized intensity and position. One can construct a super-oscillatory pattern by solving the matrix equation with analytical or numerical methods. Our method proposed here is not only suitable to the case of super-oscillation but also the general focusing issue with super-resolution size

References

[1] Rogers, E. T. F.; Lindberg, J.; Roy, T.; Savo, S.; Chad, J. E.; Dennis, M. R.; Zheludev, N. I. Nat. Mater. 2012, 11 (5), 432−435.

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