What does diffraction limit limit?

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Diffraction limit has been addressed and studied intensively, and more recently, owing to the driving needs in super-resolution imaging and its correlated applications, a lot of breakthroughs have been achieved by breaking the diffraction limit in different wave natures. Nevertheless, the myth of what is the diffraction limit per se, at least to our knowledge, is not yet fully understood well. It is crucial to define what diffraction limit is, in a given physical system rather than benchmarking against the given diffraction limit formula throughout. In this work, we will discuss how to approach the system's diffraction limit in imaging, in a conservative fashion, and then how to break it in the farfield air ambient without any assistance of environmental refractive index or evanescent wave. It is of great importance to achieve even subwavelength focusing and imaging in the far field of air ambient, because this leaves enough space for optical characterization behind the lens from practical concerns, as well as imposing minimal requirements on industrial applications. In addition, such a noninvasive and optical way would cause no modification or harm to the samples to be tested, while STED usually needs to dye the molecule and use pumping.

We will take some recently finished works in our group as examples to demonstrate. We start from some planar meta-lens to discuss some alternative ways to deem whether the achieved focus or imaging is beyond the diffraction limit, and then study how to design and experimentally realize super-resolution focusing and imaging in far field of air, via the theory of super oscillation at a sacrifice. We further develop a design method to manage tens of thousands of nano-holes to experimentally achieve polarization-independent subwavelength focusing in our predefined niche, and this design method is also verified to achieve subwavelength-pixel hologram. Breaking the diffraction limit is not limited to the creation of a focused spot in the far field, and instead it could open up more promising applications to realize a super-narrow needle with long focal length and depth of focus. Thus, it shows a high tolerance for industrial applications such as super-resolution imaging and nano-lithography.

On the other hand, to deal with the resolution of two active sources placed very closely, we report another fabricated dielectric magnifier made of metamaterials to resolve two radiating RF sources from RCS pattern. To conclude, it is very challenging, if not impossible, to approach the diffraction limit of the system per se, and it usually comes with some price to break the limit.