Nanoplasmonics: Towards efficient light harvesting

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The control of light is vital to many applications, including imaging, communications, sensing, cancer treatment, and even welding processes for automobile parts. Transformation optics is an emerging field that has revolutionized our understanding of how to control light by constituting an effectively curved electromagnetic space. This revolutionary strategy not only revisits the fundamental physics of light-matter interactions, but also renders trivial the design of optical functions that may otherwise be difficult or virtually impossible, such as an "invisibility cloak," which could only previously be found in science fiction. When compared with ray optics, the new transformation optics technique provides a picture that is equally intuitive, but that is much more accurate in its description of the wave nature of light by using the electric and magnetic field lines as its basis.

Therefore, the validity of this method is not restricted to the macroscopic regime, but can also be extended to the subwavelength scale. In a recent review paper published by *SCIENCE CHINA Information Sciences*, Yu Luo and colleagues from Imperial College London illustrate how the general capabilities of the transformation optics technique can be used to treat the subwavelength fields that occur in plasmonic systems and review the latest developments in transformation optics as applied to nanophotonics.

In plasmonics, metallic structures with sharp corners can trap light into nanometric volumes, thus giving rise to strong near-field enhancements. This effect can be used to detect single molecules, generate high harmonic signals, and even improve absorption in photovoltaic devices. Further developments using these techniques need to be guided by accurate and versatile theoretical modeling. However, modeling of this type can be difficult, because various aspects associated with the sharp plasmonic structures can hinder provision of accurate and convenient solutions to the problem at hand. First, the size of the sharp metallic point structure is normally much smaller than that of the device overall, which makes it difficult to create meshes for numerical simulations. Second, the strong contrast in the dielectric functions at the metal-dielectric interfaces leads to slow convergence of the field expansions.

Yu Luo and colleagues deploy the theory of transformation optics to circumvent these problems. Their idea is to transform a complex plasmonic system with little intrinsic geometrical symmetry into a canonical structure with translational or rotational symmetry, which is then relatively easy to study using conventional theory. For example, two touching nanowires can be transformed into two flat metal surfaces that are separated by a gap, and a sharp metal edge can be related to a periodic array of metal slabs. Other structures that can be studied using transformation optics include pairs of metallic nanospheres, asymmetric core-shell structures and rough metal surfaces. In fact, using transformation optics techniques, we could reverse engineer the optical properties of complex plasmonic nanostructures and redesign these structures based on the requirements of the desired applications.

Practical issues with the realization of plasmonic devices, such as the effects of edge rounding at sharp boundaries on the local field enhancement and resonance properties, can also be considered theoretically using transformation optics and provide useful guidance for the fabrication of these devices. In particular, the necessary conditions are highlighted for both broadband light absorption effects and large field enhancements. Experimental evidence for phenomena that have been predicted by transformation optics has also been reviewed, indicating potential applications in biosensing and broadband solar photovoltaics. These studies demonstrate the accuracy and versatility of transformation optics methods and are expected to encourage more researchers to enter this field.

More information: Luo Y, Zhao R K, Fernandez-Dominguez A I, et al. Harvesting light with transformation optics. Sci China Inf Sci, 2013, 56(12): 120401(13). info.scichina.com:8084/sciFe/E … abstract512908.shtml

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