IMAGE SOURCE

MILESTONE 20

Small and beautiful

The 'diffraction limit' of classical optics does not allow the localization of light into regions that are much smaller than its wavelength. As a result, the level of integration and miniaturization of photonic circuits is not even close to that achievable in electronics. The technology that might close this gap is known as 'plasmonics'. Plasmonic structures have beaten the diffraction limit, and led to advances in spectroscopy and sensing, imaging, cancer therapy, integrated nano-optics and solar cells, to name just a few.

Modern plasmonics started with a publication in 1998 by Thomas Ebbesen and colleagues, who observed a surprisingly efficient light transmission through a thin metal film with holes ten times smaller than the wavelength of light. Additionally, more light was transmitted through the film than was incident onto the area of the holes. Eventually, Ebbesen was able to explain his observations with the properties of surface-plasmon polaritons (SPPs).

SPPs consist of photons that interact with the surface motions of free electrons in metals. Plasmonic effects have inadvertently been exploited by glass makers since at least the fourth century, for example to generate the colours used in stained-glass windows in medieval cathedrals.

The scientific investigation of plasmonic effects began as early as 1899 with theoretical studies by Arnold Sommerfeld and experimental observations of plasmonic effects in light spectra by Robert Wood in 1902. Later that decade, J. C. Maxwell Garnett and Gustav Mie developed theories explaining the scattering effects by metallic nanoparticles. However, it was not until a number of theoretical studies in the 1950s that a more complete understanding of SPPs was reached. The foundation for the systematic experimental study was then laid in 1968 by Erich Kretschmann and Andreas Otto, who devised methods to excite SPPs with prisms attached to metal surfaces.

In the late 1970s, the technological exploitation of plasmons began with the pioneering discovery by Martin Fleischmann and Richard Van Duyne of significant enhancements in the Raman scattering of light by molecules attached to a rough silver surface. This effect is explored for devices that detect molecular concentrations down to the single-molecule level.

For applications in photonic circuits, the Ebbesen discovery has led to efforts aimed at exploiting the highly localized nature of plasmons to guide light on the nanoscale. Furthermore, a plasmon-based analogue to the laser, the spaser, could provide a source of coherent light below the diffraction limit.

In addition, SPPs are exploited in a number of areas, such as metamaterials (MILESTONE 21). Similarly, plasmonic light concentration can not only enhance light absorption in solar cells, but also improve the efficiency of light-emitting devices.

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