Introduction to Plasmonics: Harnessing the Power of Light

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Perspective Article

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DESCRIPTION

Plasmonics, also known as nanoplasmonics, is the study of the creation, detection, and control of optical signals at nanometer-scale metal-dielectric interfaces. Plasmonics, which draws its inspiration from photonics, continues the trend of optical device miniaturisation (see also nanophotonics) and finds use in sensing, microscopy, optical communications, and bio-photonics. Surface Plasmon Polaritons (SPPs), which are coherent electron oscillations that move along with an electromagnetic wave along the interface between a dielectric (such as glass or air) and a metal (such as silver or gold), are commonly used in plasmonics. Strong light-matter interactions result from the SPP modes' strong confinement to their supporting interface. In specifically, the metal's electron plasma oscillates in response to the electromagnetic pulse. Ohmic losses in plasmonic signals are typically high because moving electrons are dispersed, which restricts the signal transfer distances to the sub-centimeter range unless hybrid optoplasmonic light guiding networks or plasmon gain amplification are employed. Plasmonic modes include localised surface plasmon modes supported by metal nanoparticles in addition to SPPs.

The size efficiency of electronics and the data capacity of Photonic Integrated Circuits (PIC) are being combined in an effort to merge plasmonics with electric circuits or in an analogous electric circuit. The size of conventional PICs is constrained by diffraction, which acts as a barrier to greater integration even though the gate lengths of CMOS nodes used for electrical circuits are continuously reducing. This size disparity between the electrical and optical components could be overcome using plasmonics. In addition, since optical signals can be transformed into SPPs and vice versa under the appropriate circumstances, photonics and plasmonics can complement one another. The short surface plasmon propagation length is one of the main challenges in developing plasmonic circuits. Surface plasmons often only travel a few millimetres before damping reduces the strength of the signal. Ohmic losses, which become more significant the further the electric field travels through the metal, are mostly to blame for this. By examining different materials, geometries, frequencies, and attributes, researchers hope to minimise losses in surface plasmon propagation. Metal oxides, metal nitrides, and graphene are recent promising low-loss plasmonic materials. Improved fabrication methods are essential for greater design flexibility since they can also lower losses by reducing surface roughness. Heat is another obstacle that plasmonic circuits will likely have to overcome; it may or may not be higher than the heat produced by sophisticated electronic circuits. Designing plasmonic networks to support trapped optical vortices, which move light powerflow across the inter-particle gaps and reduce absorption and Ohmic heating, has recently been proposed as a way to reduce heating in these networks. It is challenging to reverse the direction of a plasmonic signal in a circuit without drastically affecting its amplitude and propagation length in addition to heat. The employment of Bragg mirrors to slant the signal in a certain direction or even to serve as signal splitters is a brilliant way to address the problem of bending the direction of propagation. Surface plasmon confinement and propagation length are two factors that optimal plasmonic waveguide designs aim to optimise in a plasmonic circuit. A complicated wave vector with components parallel and perpendicular to the metal-dielectric interface characterises surface plasmon polaritons. The wave vector component's imaginary portion, which defines the SPP confinement, has a relationship with the SPP propagation length that is inverse. The dielectric constants of the materials that make up the waveguide have an impact on the SPP dispersion properties. The surface plasmon polariton wave's confinement and propagation length are inversely proportional. Therefore, shorter propagation lengths are often the result of stronger mode confinement. A balance between propagation and confinement must be struck in order to build a useful and functional surface plasmon circuit. A plasmonic circuit will accept and send optical signals through its input and output ports, respectively. The optical signal must be coupled and uncoupled from the surface plasmon in order to do this. Because the surface plasmon's dispersion relation is completely below that of light, coupling must be accomplished by the input coupler in order to maintain the momentum conservation between incoming light and surface plasmon polariton waves generated in the plasmonic circuit. In order to help induce coupling by lining up the momenta of the incident light with the surface plasmons, one method is to use dielectric prisms, gratings, or localised scattering features on the metal surface.