Comment

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Is photonics the new electronics?

Mihaela Girtan discusses electronics and the rise of photonics, and asks what the future has in store for technology

Silicon dioxide, also known as silica, is commonly found in nature, in sand or quartz, and is one of the most abundant chemical compounds on earth. Humans discovered how to transform the silica into silicon, and today almost all of our modern technology is based on this single starting material.

The four basic elements of electronics are: (1) electrons as carrier vectors, (2) electrical cables and circuits, (3) the generators and (4) transistors. Progress in photonics provides the opportunity to replace electron flow, for transmission and computing, with a photonic flow or a *plasmonic flow*; harnessing the interaction between the surface electrons of nanostructured circuits and photons.

The information carrier vectors in photonics can be photons, solitons, light balls, or plasmons. The plasmon is a quasi-particle associated with the plasma oscillations of free electron density. The association of this particle, resulting from existing electrons present in the material and injected photons, offers at least two, unique, highly important benefits: (1) the possibility to transmit information with higher frequency (about $\sim$100 THz) and (2) the ability to confine light in very small dimension objects. Lasers and spasers are the optical equivalent of electrical generators; optical wave guides and optical fibers act as the transport cables; and plasmonsters and optical transistors are the equivalents of electrical switches and electronic transistors.

These new photonic structures are very similar to those found in electronics. For instance, in transparent flexible electronics and in third generation solar cells, new promising electrodes are composed of three-layer oxide/metal/oxide [1]. We find these same structures in photonics for plasmonic wave guides [2]. This is also the case for organic solar cells [3] and organic wave guides [4]. Electronics has also inspired photonics for optical circuits, and by combining these two sciences, plasmonics circuits have been realized in the last few years.

By comparing the basic elements from these two sciences – the electron in electronics vs the photon, soliton and plasmon in photonics; electrical cables vs optical fibers and plasmonic wave guides; electrical circuits vs optical circuits; electrical transistors vs optical transistors and plasmonsters; electrical generators vs pulsed lasers and spasers – we remark that photonics has built up, step by step, all the tools already available in electronics. These similarities lead to the idea that, in the future, we may be able to replace devices that use an electronic flow (mobile phones, computers, displays, etc.) with equivalent devices that use a photonic or a plasmonic flow. Furthermore, in the case of a photonic flow, it may be possible to take advantage of the ultimate photon generator as a power source: the Sun.

This presents a familiar problem faced in the application of photovoltaic systems: the night–necessitating the storage of energy. However, if we think on a global scale, there is always light available (earth rotates). Thus, one of the biggest challenges of taking advantage of solar energy won't just be to store the energy, but to create a global photovoltaic energy network. Indeed, optical fiber networks are already in place and could represent a first step in connecting future *plasmonic computers*.

While current electronics and photonics are based on sand (silicon and silicon dioxide), carbon, in both bulk and graphene form, might be the future element of choice. Graphene is a very interesting material for electronic applications, as a transparent electrode with very good mechanical properties, with new transfer techniques allowing deposition on large area flexible surfaces. Due to the absence of an optical band gap, graphene absorbs all photons at any wavelength. However, if incident light intensity becomes strong enough, due to the Pauli blocking principle, the generated carriers fill the valence bands, preventing further excitation of electrons at valance band. Hence this property could potentially be exploited to realize short and very intense light pulses lasers with a wide optical response ranging through

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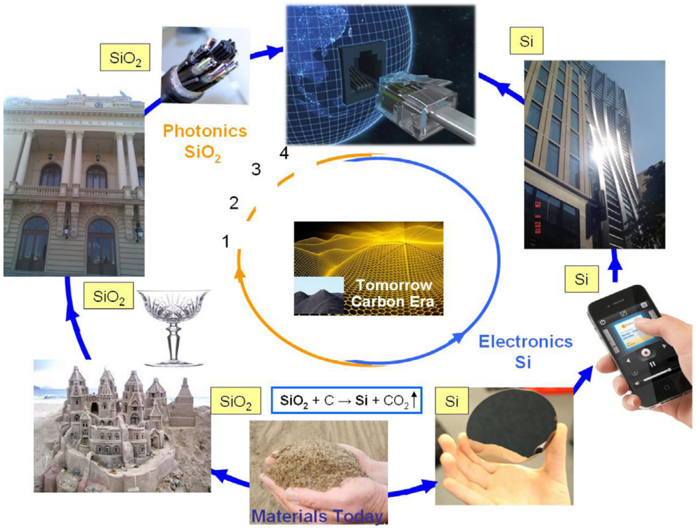
ultra-violet, visible, infrared to terahertz. These lasers might be the future of pulsed signal photonic generators. Moreover, graphene's structure specificity and charge transport properties open up new research possibilities through *graphene nanoplasmonics*.

While humanity has proved it can thrive on technologies derived from sand, it remains to be seen whether the same can be said of carbon. But perhaps the bigger questions are; if photonic informatics becomes a reality, will we still need electricity? And what will the solar powered devices of tomorrow resemble?

Today we transform different forms of energy into electricity to meet most of our needs. But, will it be possible to avoid the transformation of the energy in electricity and directly exploit solar energy for all our requirements? For heating, we can and often do already use solar energy directly, without transforming it. If light storage is possible through plasmons, laser cavities, or light trapping as in the black body model, it will be possible to directly use solar energy for lighting too. Optical manipulation and optical engine concepts have already been experimentally demonstrated [5], and the progress in photonics with optical circuits, optical transistors, etc. has shown that photonic or plasmonic informatics might be possible too. If laser propulsion can be achieved, and optical engines work, we may also have motors working with light.

Today we transform solar energy into electricity, but tomorrow we may be using solar energy directly, for all our technological needs.



Further reading

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