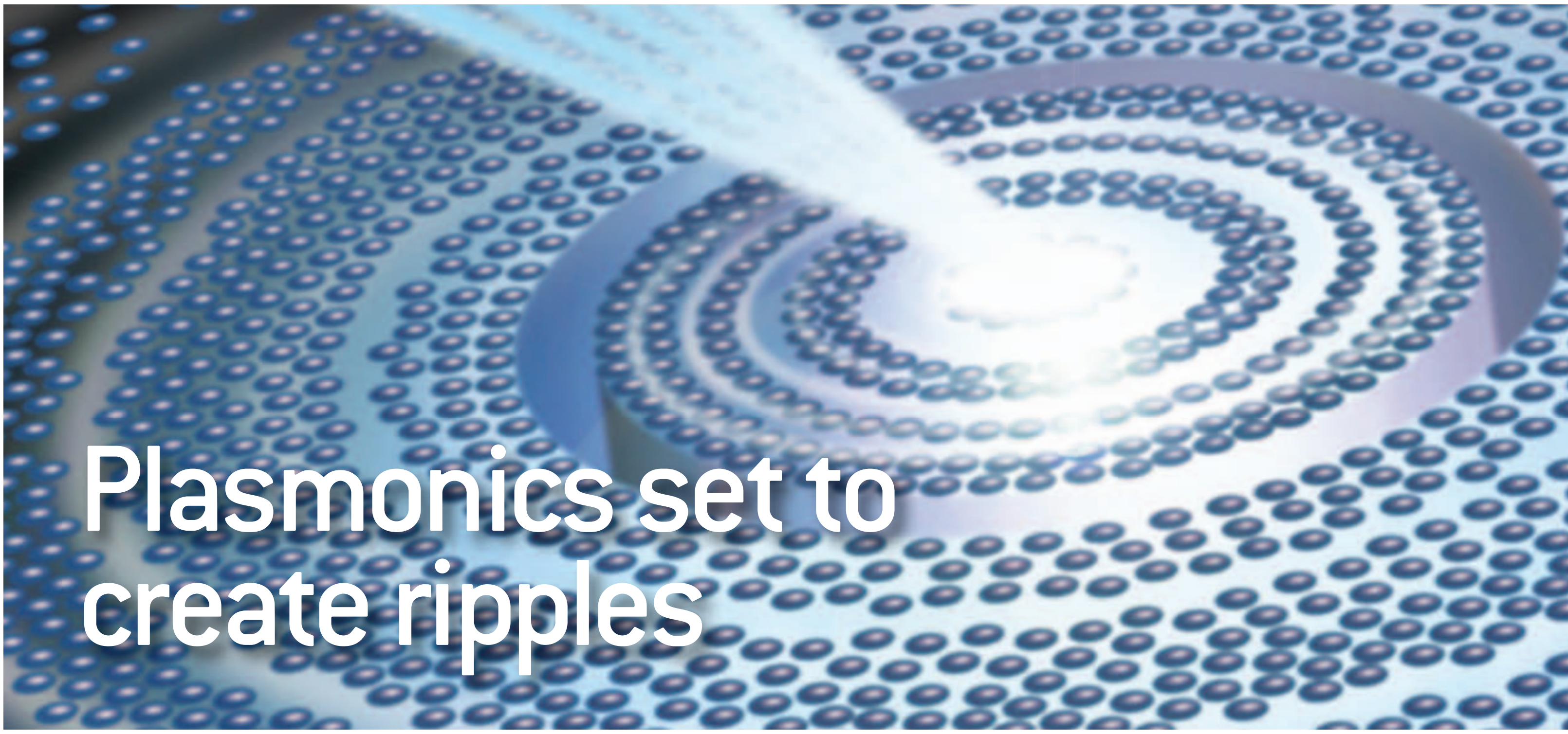

Plasmonics set to create ripples

Will surface plasmons provide the breakthrough that enables the next generation of computers? By **Graham Pitcher**

In general, electronic components can be made to extremely small dimensions, but the downside is that they can't support very high data bandwidths. By contrast, optical fibres can provide the data capacity our thirst for information requires, but at a cost: optical components are bulky.

What if there could be a blending of the two approaches that supports the creation of extremely small, extremely high bandwidth devices? That, essentially, is the aim of researchers around the world exploring the possible applications of plasmonics.

While you might think that plasmonics is a new field of research, you would be wrong. In fact, the concept was first mooted in 1899 by German physicist Sommerfeld. He was investigating how radio waves were guided along a metal rod, but it wasn't until the 1960s until their existence was proved during the conduction of energy loss experiments.

Stefan Maier is professor of photonics at Imperial College. He's recently embarked on a research project, in association with Professor Anatoly Zayats of Queen's University Belfast, to understand the basic science associated with nanoplasmonics.

According to Prof Zayats: "This is basic research into how light interacts with matter on the nanoscale. But we will work together with, and listen to, our industrial partners to direct research in the direction that hopefully will lead to new improved products and services that everyone can buy from the shelf."

The £6million project, which is planned to last for six years, has been funded by the Engineering and Physical Sciences Research Council and is supported by Intel, Seagate, Ericsson, Oxonica, IMEC and the National Physics Laboratory. The project is looking to develop devices that bring the data carrying capacity of light, but with the dimensions associated with microelectronics components.

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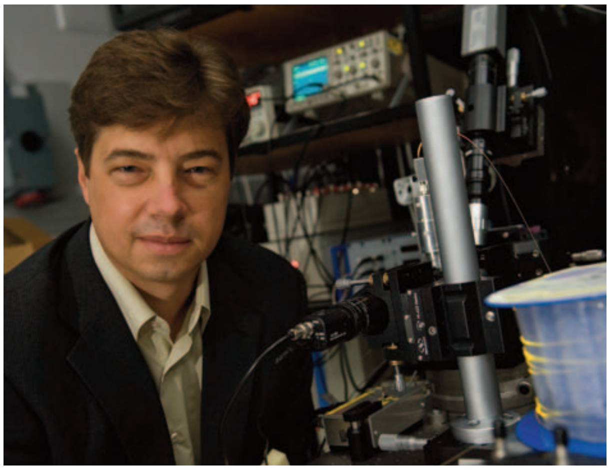
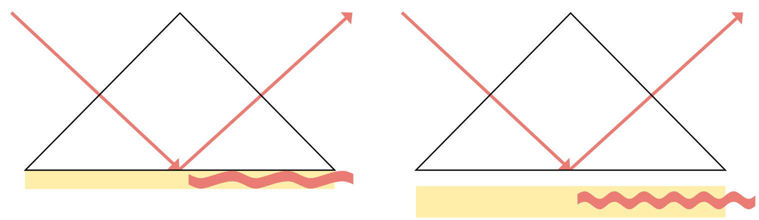


Prof Maier noted: "The fundamental problem is that light is a wave; it's a form of electromagnetic radiation distinguished only by its wavelength. Because light is a waveform, it doesn't matter whether it's in free space or in a beam guided in an optical fibre, you can't make the cross section of the beam any smaller than the wavelength of the light in question. It also means that you can't focus the beam to a spot smaller than the wavelength. This is called the diffraction limit."

And the diffraction limit is why the optical microscope can only provide so much magnification. "It also explains why you can't make light guides of the same size as the features on a chip," Prof Maier continued.

He gave the example of an Intel microprocessor. "The elements on the

Fig 1: How surface plasmons are created



The incident electromagnetic radiation is passed through an optically dense medium, which increases its wavevector. This beam then reflects off the boundary between the optically dense medium and either a less dense dielectric (in the Otto configuration, left) or a metallic layer (in the Kretchmann-Raether configuration, right). An evenescent field extends from this interface to 'drive' the electrons on the dielectric metal interface, producing a surface plasmon.

chip are of much smaller dimensions than a light guide. If you take an optical fibre and reduce its dimensions, you can't get any smaller than the wavelength of light being used. So what we are looking for is a way to make much smaller light guides." The reason? Light is fast, but electrons aren't.

Today's computers have reached something of a roadblock. Performance is dictated not by the clock speed, rather by the speed with which information can be routed between different points on the chip. Clock speeds can't be increased much further than they are because of heat issues. One solution to this is multicore processors. "But that means that even more wiring is needed on the chip and it will take even longer for information to get to where it's needed," Prof Maier continued.

The problem is that wires have a fundamental limit in the data rate that can be supported. "Smaller wires have higher resistivities," he explained, "meaning that it takes longer to transmit information."

A potential solution is to move from the electrical to the photonic domain because data could then be moved around the chip at speeds approaching that of light, with a much higher bandwidth. "It also holds the prospect of being able to apply wavelength division multiplexing techniques on chip," Prof Maier continued.

However, the problem of the diffraction limit remains; you can't make guides small enough. "And that holds for any guiding medium that is insulating," he noted.

But what if you moved to a guiding medium that isn't insulating? "Things get more interesting if you use metal," Prof Maier enthused.

While metals can be considered 'lossy' at visible frequencies, they can be constructed to make highly confined light guides. "And you may not need to take data very far with them," Prof Maier observed.

Step forward the surface plasmon.

Surface plasmons are, essentially, light waves that are coupled to the motion of conduction electrons at the interface between a conductor and an insulator. "The result," Prof Maier said, "is something that's half light and half electron motion."

It's an interesting concept which, Prof Maier explained, can be considered to be similar to the ripples created on a lake when the wind blows. "In the same way as the ripples are propagated by the wind, electrons are excited by light. But the interesting aspect is that these hybrid waves don't obey the diffraction limit, so you can constrain them into a diameter smaller than the wavelength of the light being used. If you were using green light at 500nm, it is possible to constrain surface plasmons into a 50nm guide."

However, it isn't quite that easy. "The problem is that the more you confine the plasmons, the greater the losses," Prof Maier continued, "so you need to design a metallic structure. It depends how far the data needs to travel, but there is a trade off." He also believes the principle will hold for a very small diameter optical fibre with a metal cladding.

What Imperial and QUB are looking to achieve in the project is to explore how to take light guiding a step further by adding active devices into the mix. "We're hoping to add all the devices that exist for light guides, but the rules of the game are completely different. What will be the active materials that excite surface plasmons and detect them?" Prof Maier believes that light emitting polymers are leading candidates.

Where Prof Maier and his colleagues Professor Donal Bradley and Dr Paul Stavrinou are looking at the fundamental physics and materials issues, Prof Zayats and his colleagues at QUB will be working on complementary aspects of the problem. "They will be looking at optical modulation and different kinds of waveguide geometries," said Prof Maier.

Although the main aim of the project is to create on chip links, the possibility remains that chip to chip communications may be possible. And a longer term prospect is using plasmonics to send data down existing cables. "While cables have a metal-dielectric interface, they aren't made of the right material," Prof Maier believed. "Surface plasmons don't like copper; they prefer silver or gold. But it's something we're looking into."

The team intends to produce prototype designs targeted at commercial semiconductor processes and the presence of Intel amongst the project sponsors is noteworthy. "But the main problems relate to materials and their compatibility with semiconductor processes," Prof Maier concluded.

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