Colour vision

Seeing in colour is something we take for granted. But achieving accurate colour discrimination in practice is not a simple task. *Nature Photonics* spoke to Thomas Ebbesen about his group's latest work, which makes it possible to sort light into its constituent colours using surface plasmons.

Photon sorters. From left to right: Thomas W. Ebbesen, Cyriaque Genet, Adi Salomon, Eric Laux, Frédéric Przybilla, Aurélien Drezet, Oussama Mahboub, Eloïse Devaux, Marie-Claude Jouaiti and Jean-Yves Laluet.

Tell us about your latest work.
The basic idea is to use surface plasmons to separate light into different colours. We do this rather simply: we structure a two-dimensional silver film in such a way that it contains a number of overlapping grooves (gratings). Each grating has a different period and is associated with a different nanohole in the surface. When incoming light hits the film, it is converted into surface plasmons that then guide different wavelength components to different holes, depending on the periodicity of the grooves. In this way, we can single out specific colours for transmission through different nanoholes. These colours are then picked up by light detectors placed below the film.

And what's the motivation for doing this?
The original idea for this work actually came from one of my co-authors, Torbjorn Skauli, who has done a lot of work on spectral imaging. He had heard me talk about surface plasmons and approached me to discuss the possibility of using them to improve spectral imaging. At present, digital imaging achieves full colour sensitivity either by having each pixel sensitive to only one colour, or through very complicated light separation using colour filter arrays and by sending different wavelengths to different detectors. This either results in bulky devices that produce high-resolution images, or compact ones with poorer resolution. We brainstormed and eventually came up with the metal structures that are described in our article. In the process, we came up against many problems that had to be worked out.

What sort of problems?
Once we had got our heads around the concept of using plasmons to achieve colour separation, there was a lot of engineering involved in actually building the metal structures. For instance, the film contains three overlapping gratings that are oriented in different directions. The key to ensuring a satisfactory light collection efficiency is to make sure that any one grating does not interfere too much with the others. Eric Laux achieved this by engineering a depth gradient within each grating so that it becomes very shallow far away from a given light-collection point.

How many colours can you filter in this way?
Well, it is a geometry issue (how a two-dimensional plane can be filled with repeating cells) and also a question of register (that is, the correct positioning of an image when superimposing one colour on another). There is a trade-off in register as the number of colours goes beyond three. The choice of colours is, however, very flexible and can be tuned to a given wavelength mostly by changing the period of the grating involved. Nevertheless the metal must be able to support surface waves at the desired frequencies. For instance, gold films will not work in the UV.

How do your results compare to existing spectral-imaging devices?
At present, the performance is similar to that offered by existing technology. The main advantage of our plasmonic approach is that it should be able to achieve better register between the different colours compared with digital spectral imaging because we are sorting the photons in the plane. This means that the overlap between different colours is better than if we used completely separate pixels for different colours. Our method of sorting photons is also fairly simple to implement, as structuring the metal is not too complicated. And because we use a nanostructured metal film, we can use a much smaller photodetector to collect the light. Smaller light detectors have faster response times, and this means we can obtain colour images much more quickly.

What next?
Our next goal is to build a real prototype device that will give us more realistic efficiency measurements. This will involve preparing photodetectors that are small and adapted to fit these plasmonic structures (which will be difficult), putting our metal structures on top where they will act as nanoantennas to guide the light, and measuring the overall output of the detector. I am sure we will face new challenges and will need to improve our light collection efficiency. We would also like to move into the near-infrared or infrared waveband, where spectral resonances are narrow and which, from an applications point of view, is potentially a more valuable wavelength regime to explore.

Ebbesen and his colleagues have a Letter on plasmonic photon sorters on page 161 of this issue.

Interview by Amber Jenkins.