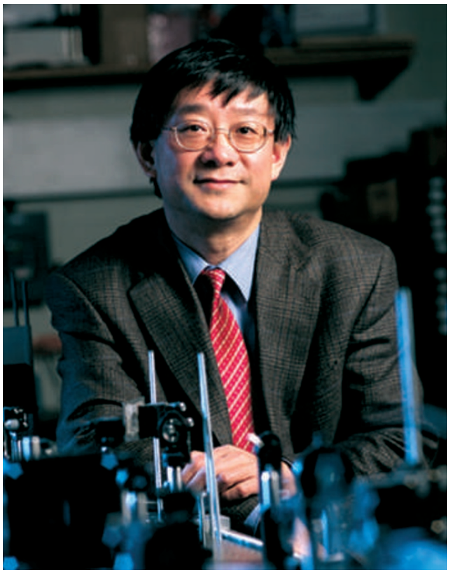
Searching for terahertz waves

A scheme for the remote sensing of terahertz waves over distances of tens of metres could have important applications in security and biology. Xi-Cheng Zhang from the Rensselaer Polytechnic Institute spoke to *Nature Photonics* about his group's latest work in this field.

What is the motivation behind your work on the remote sensing of terahertz waves?

Performing remote sensing of a hidden, unknown object — particularly one that might be dangerous — has been an important issue for many years. Fortunately, many materials have a characteristic and unique absorption spectrum in the terahertz (THz) wavelength region that acts as a 'signature' and so allows them to be identified. The biggest advantage of using THz waves for sensing is their high transparency through materials such as paper, plastic and cloth. The big problem, however, is that THz waves are strongly absorbed by water, including by moisture in the air. As a result, it has so far been impossible to transmit THz waves over a significant distance from their source. Indeed, ten years ago I gave up trying to transmit broadband THz waves over a long distance in free space, but I didn't give up on finding a way of remotely sensing them. The unsolved issue was how to obtain the transmission spectrum of a THz wave without having to place a detector near the sample. Our work helps to answer this question.



RENSSELAER POLYTECHNIC INSTITUTE

Xi-Cheng Zhang from the Rensselaer Polytechnic Institute in the USA explains his breakthrough in the remote sensing of THz waves in ambient air.

What is the mechanism behind your sensing scheme?

My group found that the information describing the field of the THz wave — that is, its amplitude and phase — can be translated to the intensity of ultraviolet (UV) fluorescence, which is only weakly absorbed in ambient air. The key point is that the plasma formed near the focusing point of visible and invisible lasers is used for the THz wave detection. The major constituent of ambient air is nitrogen molecules; in the plasma creation process these molecules become ionized by the highly intense lasers. The motion of the free electrons and population of the excited molecules in the plasma is influenced by the external electric field, thus offering a way of communicating information of a coexisting THz wave through plasma fluorescence. To be honest, the idea of somehow usefully using the UV fluorescence of ionized molecules was inspired by the study of corona between high-voltage electrodes, which was reported at the International Symposium on Filamentation in Paris, 2008. My group found that the intensity of the UV light emitted from the plasma is in fact modulated by the THz wave. It was not straightforward, however, to gather experimental evidence of this effect. However, thanks to many dedicated experimental trials and careful analysis by my students and senior researchers, we have now been able to experimentally demonstrate for the first time that the UV fluorescence intensity at 357 nm depends on the amplitude and phase of the electric field of the THz wave. This means that by collecting and analysing the UV light, which can indeed travel much longer distances than THz waves in ambient air, remote sensing of THz waves can now be realized.

What are the potential applications?

Homeland security would be an immediate application, such as for the remote detection of explosives or drugs. One can obtain transmission and reflection spectra of the THz wave in the frequency domain by measuring the time-resolved UV fluorescence intensity before and after the target, respectively, and then performing a Fourier transform on the data. It is important to note that the proposed remote sensing technique is done by an all-optical measurement. In our study the distance of the remote sensing was 10 m, but this was limited by the configuration of the experimental set-up. The signal of the UV fluorescence intensity was not strongly attenuated, and so I feel that the remote sensing of THz waves is possible over distances of 20–30 m or more.

What are the challenges and future work?

We demonstrated the remote generation (up to 30 m) and remote sensing (10 m) of THz waves in two separate experiments, and are therefore now working towards the development of a remote THz spectroscopy system. I would like to be able to use this detection concept as a biological sensor. The movement of cells in an organism is related to the flow of ions such as potassium and sodium in the cell fluid. There might therefore be ultraweak standing fields inside cell membranes that result from the ion distribution. Of course, we need to investigate the feasibility of the non-contact detection of THz waves in biological systems to allow information at the micrometre or submicrometre level to be extracted. It is an ambitious project, but remember that the remote sensing of THz waves was thought to be technically impossible before our work — to achieve what is considered to be impossible is really challenging. Fortunately, I have lots of opportunities to be involved in many international workshops, and I believe face-to-face communication among researchers is very important for finding inspiration for technological breakthroughs.

INTERVIEW BY NORIAKI HORIUCHI

Xi-Cheng Zhang and his co-workers have a Letter on the remote sensing of THz waves through the coherent manipulation of fluorescence on page 627 of this issue.