Terahertz transfer

Terahertz sources are already hitting the market as parts of imaging systems. *Nature Photonics* spoke to Carlo Sirtori from the University of Paris-Diderot and Thales Research and Technology about the implications of merging terahertz and telecommunication technologies.

Why are terahertz sources so important?
Terahertz light has been valuable for many years; its sensitivity to molecular absorption has made it of interest to astronomers and also scientists investigating the troposphere. Gas lasers perform quite well at these wavelengths, and they have been available for the past 30 years. For example, you can pump methane with a carbon-dioxide-based laser and produce a decent amount of terahertz power — a few tens of milliwatts. However, it is difficult to develop a new technology based on such lasers as they are expensive and take up a lot of lab space. The real revolution at the moment is terahertz technology based on semiconductors — the drive to produce a compact terahertz source. In the region between 0.5 THz and 5 THz, there exists a so-called terahertz gap at which semiconductor sources and detectors are not available at present.

What are the typical applications for terahertz radiation?
One application is spectroscopy, which is getting more and more important for law enforcement and for environmental uses. Some examples of security applications are the detection of certain kinds of explosive or metal or some types of very hard plastic that can be used to make weapons. Other important uses include imaging, high-resolution radar technology and communication, where terahertz technology could broaden the available bandwidth.

What are the challenges involved in developing a new type of terahertz source that is attractive to potential end users?
To be honest, the difficulty is that there is probably an alternative technology for most of the applications that I have mentioned. In some cases, the alternative is already established and there is a tremendous inertia in the way of replacing it. The important aspect of our approach, and that of a number of other research groups around the world, is that we are finally introducing terahertz devices by exploiting and pushing further the technologies that are used today to produce transistors and laser diodes.

Carlo Sirtori is working to bring the worlds of telecoms and terahertz technology together.

These materials and their fabrication processes have been developed, and continue to be developed, for many other technologies. This is a key point: we are not starting from scratch — we are inserting our ideas into a technological platform that is well established. Semiconductors offer a compact size and are a planar technology, meaning that many devices can be produced on the same wafer.

You have just demonstrated that it is possible to transfer terahertz light onto an optical carrier in the infrared telecoms waveband. What is the significance of this?
There are two main reasons. The first is that we see the up-conversion of terahertz light into the telecom range as a simple way of detecting and analysing terahertz radiation. Measuring a spectrum in the terahertz range can be difficult: you need liquid helium to cool down a bolometer, which can be expensive, and a large spectrometer. But in our technique, by looking at the sidebands, we know exactly what is going on in the terahertz range, by simply plugging a fibre into a telecom spectrum analyser. Hence we bring all the signal analysis into the world of telecoms, which is obviously a well-established technology, making detection and testing much easier.

But this is probably not the most important reason. What I think is very interesting is that putting a terahertz wave on an optical carrier allows it to be transported over a long distance. Terahertz propagation in the air is limited to distances of about 100 m, owing to water-vapour absorption. Once it is in a fibre, however, you can transfer it over kilometres. You can also distribute it into many different devices, and they can then be phase-locked to the original oscillator. Today, such a task is done very well with transistor technology at frequencies up to 200 GHz. However, it is difficult to further increase the frequency of your system, and researchers don't know how to do it. Our technique may offer a solution to this.

So what is next?
The next important question, which we already have data on, is how you then convert the signal back into terahertz radiation. You can transfer the terahertz radiation along a fibre but then at the end, if you have an application, you have to be able to recover the radiation. Now the way to do this, as is hinted at in our paper, is to re-inject (or seed) another terahertz laser with the sidebands, so that the laser will start oscillating with the original phase. I think this idea is very important: the possibility of transferring terahertz radiation along a fibre, but then also having the ability to recover it.

Another experiment that we are working on now is putting sidebands on the sidebands. Quantum-cascade lasers are extremely fast because of the intrinsically short lifetime of the upper state of the laser transition, so you can directly modulate them at up to hundreds of gigahertz. This is important because by modulating the terahertz laser, we are essentially coding information that is then transferred on an optical fibre. This is a non-trivial point: a rapid direct modulation is important for transmission at very-fast data bit rates. Now we have a tremendous bandwidth, in principle we can modulate up to terahertz frequencies, but we don't know how to do that yet. The future of this technology lies in fulfilling this potential.

Interview by David Gevaux.

Sirtori and his co-workers have a letter on transferring terahertz signals to an optical carrier in the near-infrared telecoms window on p411 of this issue.