Background document for non-specialist attendees at first TERANET meeting

When the astronomer and musician William Herschel placed a thermometer beyond the red light, obtained when sunshine fell on a glass prism, he observed a small rise in temperature which he attributed to *infrared* energy. As the nineteenth century progressed, major scientific breakthroughs took place in understanding further the nature of light. Heinrich Hertz's observation that so-called *radio waves* could travel in space helped to complete the picture and emphasised that electromagnetic radiation possessed wave-like properties with basic characteristics such as wavelength and frequency, by analogy with waves on the surface of water. The drive to produce more efficient incandescent electric light bulbs, at the end of the Victorian era, led experimenters to begin to study a region of the spectrum that lay between the infrared and radio regimes that were then beginning to become reasonably well-defined. This region, which is termed the terahertz (THz) frequency region, is characterised by wavelengths of the order from tenths of a millimeter up to around one millimeter. In frequency terms, we normally define the region's limits as 100 GHz – 10 THz (but this definition is a little elastic!). Remember that the giga- and terahertz (abbreviated GHz and THz) stand for *one thousand million* and *one million million* respectively. Confusingly, although the wave-like nature of light, and indeed all electromagnetic radiation, forms the basis of our everyday understanding physicists have also found it useful to highlight its particle-like nature. From this standpoint, the light particle, or *photon*, that is characteristic of THz radiation has an energy (measured in the 'traditional' units of electron-volts (eV)) of a few milli-electron volts (meV). By comparison the infrared emitted by, say, a television remote control unit has photons with characteristic energy of a few electron volts and, correspondingly, much shorter wavelengths.

So: why is this THz radiation so useful? The answer lies in the size of the photon energy we are dealing with, which makes it ideal for interacting with some aspects of the behaviour of electrons in materials, with the fundamental vibrations and jostlings of molecules (including molecules in living matter) and other, more subtle, phenomena. Moreover, THz radiation is emitted by, or associated with, a variety of astronomical phenomena such as the famous background radiation of the Universe. In practical terms, THz radiation can penetrate many materials, but not metals or (significantly) water. It has been used in recent years in medical diagnostics (where its characteristic low-energy is advantageous), together with security and surveillance and a variety of non-destructive testing applications.

It soon became apparent that THz radiation was not easy to generate. There are several good reasons for this, but the essential problem is that THz radiation cannot be easily and efficiently produced either by the type of source that generates, for example radio waves (usually described as an *electronic* source); or infuriatingly, can it easily be produced by the (normal) type of compact infrared laser source that has become familiar in recent years (usually described as an *optical* source). Fortunately, the scene is changing rapidly and over the last two decades significant strides have been made in the generation of THz radiation and the bridging of the so-called *THz gap* between electronic and optical sources. There have been several 'landmarks' in the progress towards more convenient THz sources, including the so-called Quantum Cascade Laser (which harnesses quantum mechanics to make it work) and the use of so-called THz time domain spectroscopy (THz-TDS). In this technique, it is possible to create bundles or pulses of THz photons which can not only be used to analyse materials but also (by analogy with RADAR) can be deployed to provide depth information by measuring the time the bundle takes to return to a detector after reflection at a boundary or defect.

We hope you will enjoy meeting the UK THz community at these TERANET events which are designed to assist non-specialists evaluate the possibilities of applying THz radiation to solve their problems. In addition to a very active academic membership, the UK is fortunate to have fostered a number of SMEs specialising in THz instrumentation and they will, wherever possible, also be present at our events.

For more information on TERANET, please visit http://terahertz.network.