Our research group is mainly focused in the following broad research areas:

- Terahertz medical imaging and spectroscopy
  - Protein conformation
  - Hydration shell determination
  - Tumour margin identification
  - Novel techniques to speed up terahertz acquisition
- Spectroscopy of novel materials and systems
  - Liquid crystals
  - Vanadium dioxide
  - Conductive polymer thin films
  - Graphene
  - Metamaterials
- Terahertz optical devices
  - Broadband terahertz metamaterials
  - Efficient low-cost thin-film polarizers
  - Low-cost terahertz AR coatings and ND filters

Recent Research Highlights

**Preservation of fresh biological samples using gelatin**

Shuting Fan, Benjamin S.-Y. Ung, Edward P. J. Parrott and Emma Pickwell-MacPherson
DOI: 10.1088/0031-9155/60/7/2703 Link to article

Terahertz light is strongly absorbed by water; this is both a blessing and a curse! It means that terahertz light is very sensitive to subtle changes in water content, such as those that occur in biomedical tissues due to the presence of a tumour or other abnormality. Excised medical samples need to be preserved in some way and both formalin fixing and freezing are among those routinely used. However such techniques irreversibly change the water content of the sample, and given that relative water content is an important contrast mechanism for terahertz imaging this can be an issue. Our group has pioneered the technique of embedding fresh tissue directly onto an imaging surface and the covering it in a gelatin coating. We found that this preserved the water content very well, resulting in reproducible terahertz images with little change over as long as 35 hours.

**Broadband antireflection coatings and neutral density filters for terahertz frequencies**

Fei Yan, Edward P. J. Parrott, Benjamin S.-Y. Ung and Emma Pickwell-MacPherson
DOI: 10.1021/acs.jpcc.5b00465 Link to article

The terahertz frequency range suffers from a lack of basic optical components, particularly those that can be fabricated at a fairly low cost. Neutral Density (ND) filters and antireflection (AR) coatings in particular are incredibly useful optical components that are not readily available at a sensible price point. We turned to thin films of an organic conducting polymer (PEDOT:PSS) to see whether anything could be done with this.

To produce a broadband, frequency independent device requires an optical conductivity that is also frequency independent. Pure PEDOT:PSS does not have this; like many partially conducting materials is has an increasing conductivity with frequency. However, we found that doping with 6% DMSO could produce an almost flat response. Furthermore, by varying the dopant concentration and material we were able to show that the enhancement mechanism was a product of both decreased localisation of the charge carrier and increased charge screening. This charge screening effect only increased conductivity to a certain degree, which limits
the possible conductivity enhancement by doping.

We have fabricated both ND filters and AR coatings using this technique, and have shown that the ND filters have optical densities between 0.14 and 0.53 depending on thickness across the terahertz frequency range. Our AR coatings are close to the absolute theoretical limit of what can be achieved using conductive thin films.

**Thin-film, low-cost broadband terahertz polarizers**

Optical characterisation of materials almost always requires a good understanding of the polarization state of the measuring radiation. To this end, devices such as polarizers are an indispensable device, particularly for techniques such as ellipsometry.

With collaborators at City University, we have designed, fabricated and characterised thin film wire grid polarizers where we embed metal wires into a transparent terahertz material. This has the advantage of sealing them from the environment and also produces no discernable multiple reflections. Using this technique we have fabricated both single-layer and double-layer polarizers with extinction coefficients of 30+ dB and 50+ dB respectively for the TE mode whilst retaining a high transmission of the TM mode. We are working with our collaborators to further improve these results.

**Revealing the mechanism of Aggregation Induced Emission using THz-TDS**

Most fluorescence compounds only emit in a relatively dilute state, as they have loss mechanisms that are enhanced by aggregation, resulting in Aggregation Caused Quenching (ACQ). In the early 2000s our collaborators discovered a class of compounds that only weakly fluoresce in a dilute state but display a large enhancement in emission upon aggregation. These Aggregation Induced Emission (AIE) molecules have been extensively studied but their mechanism of fluorescence was not fully understood. A number of mechanisms have been proposed, and there was some indirect evidence to support that the restriction of intramolecular rotations played an important role. Using temperature resolved THz-TDS, we were able to show that there is a subtle reorganisation of the AIE molecule with temperature, and this reorganisation was correlated with the change in the photoluminescence intensity.