The Beams and Applications Seminar Series

Terahertz pulsed spectroscopy: a new tool in medical, security and pharmaceutical applications

Phil Taday, *Teraview Inc., UK*

Bldg. 401, room B2100, Thursday, Mar. 11, 10:00 am

Host: S. Biedron, Energy System and National Security

Terahertz pulsed spectroscopy is a promising new technique which may have much relevance to the many application areas. Until recently, working in the terahertz region (0.1 THz to 3 THz) was difficult with researchers having to use low sensitivity pyroelectric detectors or helium-cooled bolometers and weak blackbody sources. In the early 1990s there was a revolutionary development in ultra-short pulse lasers which allowed the production of stable femtosecond pulses. Today, this mature technology is sufficiently developed to allow turnkey ultra-fast lasers to be incorporated into commercial terahertz instrumentation. Terahertz technology relies on the fact that when an ultra-short pulse is focused onto a suitable semiconductor, a short-pulse of coherent terahertz radiation is emitted. The technique works at room temperature and, as a result of the very short time gate provided by pulsed laser, it is possible to readily obtain very high signal-to-noise ratios (>10^5). In addition, because it is a coherent technique both amplitude and phase information are measured from which both spectral absorption coefficients, $\alpha(\omega)$ and the refractive indices, $n(\omega)$ of the material under investigation can be extracted.

As the terahertz radiation is emitted from a diffraction-limited point source it is easy to manipulate, and this has lead to the application of terahertz imaging. The TeraView group [1] have used terahertz pulsed imaging to investigate basal cell carcinomas and shown that there is a significant difference between the tumour and healthy tissue in this spectral region. Another possible medical application is the terahertz imaging of teeth [2].

The terahertz pulses generated from the semiconductor are broadband in nature, and can thus be used for spectroscopic applications. Kemp *et al.* [3] have shown that all the major plastic explosives have discrete, well-described spectral signatures and hence may be useful in security screening applications. There is also interest in combining the imaging capability of terahertz radiation with the full spectroscopic data for non-destructive testing of illicit drugs [4].

In the terahertz region the spectral information comes from the collective modes of lattice structure (or phonon vibrations) in solid materials. This makes the technique very sensitive to both the crystalline conformation and polymorphic form [5] of the material in the solid phase, and to some higher frequency molecular rotations in the gas phase. The liquid phase spectroscopic information is a complex mixture of rotational and transitional modes.

The talk will review recent results in areas of medical imaging, security and pharmaceutical applications.

[1] (a) R. M. Woodward, V. P. Wallace, R. J. Pye, B. E. Cole, D. D. Arnone, E. H. Linfield, and M. Pepper "Terahertz pulse imaging of ex vivo basal cell carcinoma", *J. Invest. Derm.*, 120 (1) 72-78 (2003); (b) V. P. Wallace, P. F. Taday, A. J. Fitzgerald, R. M. Woodward, J. Cluff, and D. D. Arnone, "Terahertz pulsed imaging and spectroscopy for biomedical and pharmaceutical applications", *Faraday Discuss.*, 126, in press (2004).

[2] D. Crawley, C. Longbottom, V.P. Wallace, B. Cole, D. Arnone, and M. Pepper "Three-dimensional terahertz pulse imaging of dental tissue", *J. Biomed. Opt.*, 8 (2) 303-307 (2003).

[3] M. C. Kemp, P. F. Taday, B. E. Cole, J. A. Cluff, A. J. Fitzgerald, and W. R. Tribe, "Security applications of terahertz technology", *Pro. SPIE*. 5070, 44–52 (2003).

[4] K. Kawase, Y. Ogawa, Y. Watanabe, and H. Inoue,"Non-destructive terahertz imaging of illicit drugs using spectral fingerprints", *Opt. Express*, 11, 2549-2554 (2003).

[5] P. F. Taday, I. V. Bradley, D. D. Arnone, and M. Pepper, "Using Terahertz Pulse Spectroscopy to study the crystalline structure of a drug: A case study of the polymorphs of ranitidine hydrochloride", *J. Pharmaceutical Sciences*, 92 (4) 831-838 (2003).

For more information visit

http://www.aps.anl.gov/asd/physics/seminar.html

Visitors from off-site please contact Yuelin Li

(ylli@aps.anl.gov, 630-252-7863) to arrange for a gate pass.

This ANL seminar series is a CARA activity and focuses on the physics, technology and applications of particle and photon beams. It is sponsored jointly by the ASD Division, the AWA group of the HEP Division, and the ATLAS group of the PHY Division.