The Global COE Program

"The Next Generation of Physics, Spun from Universality and Emergence"

Bilateral International Exchange Program (BIEP, invite) report

Send report to: Your responsible Professor in Kyoto University

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(Year/Month/Day) 2008/12/03

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Research Project

Title	ATR terahertz spectroscopy on liquids
Duration	2008/09/01 – 2008/12/21

Please summarize your activities and results during your stay in Kyoto University .
You can add a sheet, if you need more space. You can also write any comments and requests to the GCOE program. We will appreciate them.

During my stay in the Solid State Spectroscopy Group at Kyoto University I have measured on various alcohol/water mixtures with ATR THz-TDS (attenuated total reflection terahertz time-domain spectroscopy).

The terahertz region bridges the gap in the electromagnetic spectrum covering the frequency range between radio waves and infrared light, see Fig. 1. This spectral range, broadly defined as 0.1-10 THz, gives, for one thing, information about intermolecular interactions, e.g. hydrogen bonds to surrounding molecules. Since its breakthrough about 20 years ago, THz Time Domain Spectroscopy (THz-TDS) has found many applications in a wide range of fields such as fundamental physics, chemistry and biology as well as more practical applications including the fields of pharmaceutics and security.

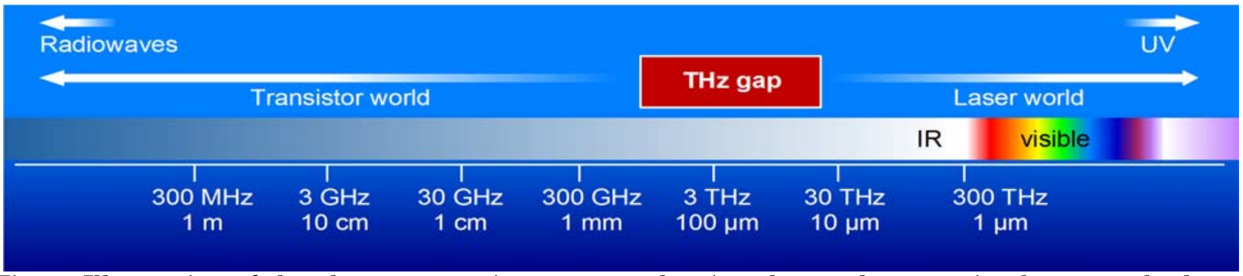

Fig. 1: Illustration of the electromagnetic spectrum showing the terahertz region between the longer electronic wavelength and the shorter optical wavelengths, also called the terahertz gap.

Broad banded THz radiation can be generated and detected by use of ultrashort laser pulses and two pieces of semiconductor material (one for generation and one for detection) like it is illustrated in Fig 2.

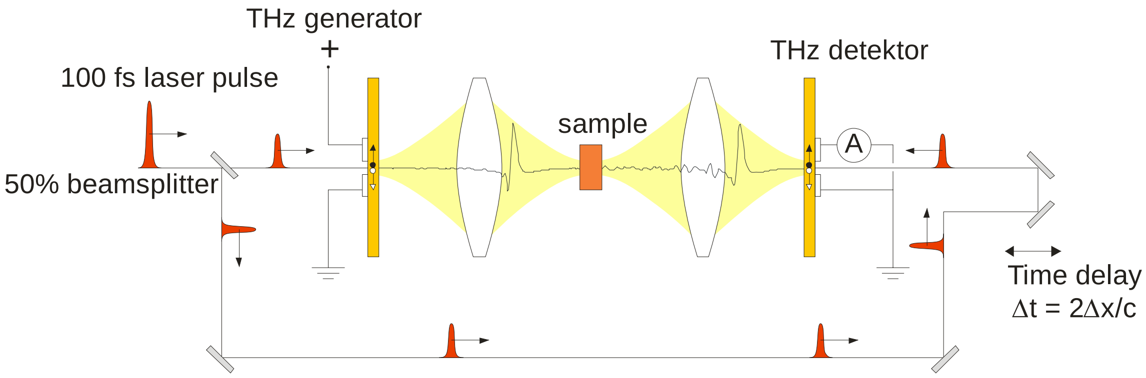

Fig. 2: Sketch of a typical THz setup. The 100 fs laser pulse is split, one part goes to the generator and the other part goes to the detector via a variable time delay. To generate THz radiation the laser pulse is focused on a biased semiconductor material. The short pulse generates electron-hole pairs which are accelerated by the bias field. This acceleration of charges leads to time dependent electromagnetic radiation. If the properties of the laser and the semiconductor material are right this radiation will be broad banded. A current proportional to the time dependent electric field - the THz field - is measured by the detector. By delaying the arrival of the laser pulse, the time dependent electric field of the THz pulse can be mapped.

The measurement of the sample can be done in different configurations, e.g. transmission, reflection or attenuated total reflection (ATR). In Fig 3 the principle of ATR is shown. Water is heavily absorbing terahertz radiation and thus, when dealing with samples containing water, it is preferred to use reflection and/or ATR. The Solid State Spectroscopy Group at Kyoto University is one of a few groups in the World that combine liquid measurements with ATR THz spectroscopy.

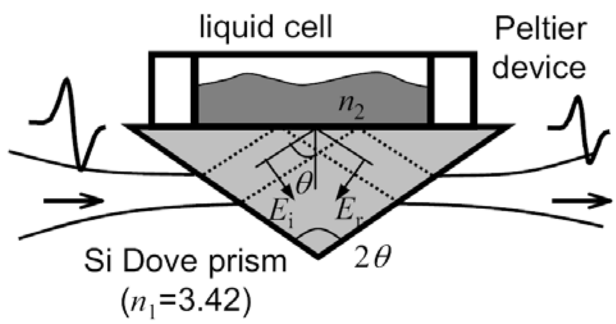

Fig. 3: Principle of ATR on liquids with temperature control

From a scientific point of view alcohol/water mixtures are interesting for several reasons. Alcohol/water mixtures are the simplest yet typical prototype of bio molecules and micelle forming systems and have been subject to a number of studies. Alcohol interacts with water through hydrogen bonding and therefore it is influences the dielectric relaxation properties of water when added. Measurements on alcohol/water mixtures have previously been done in other frequency regions and the dielectric relaxation processes has been modeled. However, the fastest of these relaxation processes, the intramolecular vibrations, are in the (sub)picosecond timescale and thus in the THz region, and THz-TDS (terahertz time-domain spectroscopy) can be used to probe these ultrafast processes. By combining the previous measurements done at other (lower) frequencies with measurements done with ATR THz spectroscopy it should be possible to obtain a more complete picture of these relaxation processes. In Fig. 4 the dielectric function of different ethanol/water solutions are shown.

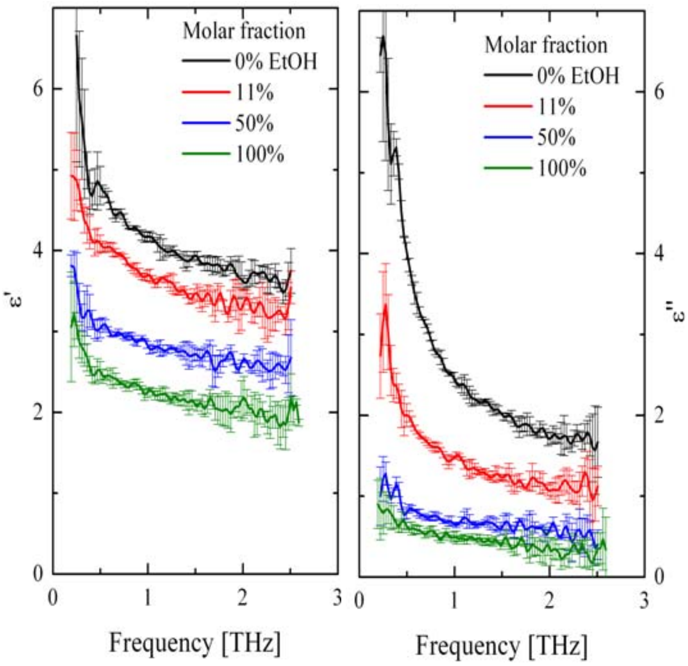

Fig. 4. The real (left) and imaginary (right) part of the dielectric function of pure water, neat ethanol and mixtures of 11% and 50% ethanol, respectively.

The activities during my stay have already resulted in submission of one scientific conference contribution:
U. Moeller, H. Yada, T. Arikawa, J.R. Folkenberg, P.U. Jepsen, and K. Tanaka, "Dielectric relaxation processes in ethanol/water mixtures measured with attenuated total reflection terahertz time-domain spectroscopy", International Workshop on Optical Terahertz Science and Technology March 7-11, 2009, Fess Parkers Doubletree Resort, Santa Barbara, California, USA.

A scientific publication on this subject is expected to be published in early 2009.

The obtained data can also be used in a different context: Hydrated water in ethanol/water solutions, i.e. when ethanol is added to water, some of the water will be 'bound' to the ethanol molecules and the rest of the water will behave like bulk water.

I would like to acknowledge the GCOE-BIEP programme for financial supporting my stay at Kyoto University.