16a-D4-8

Measurements using an OSREFM Fast-Scan Terahertz Time Domain Spectrometer

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1. Introduction

Terahertz time-domain spectroscopy (THz-TDS) conventionally employs a mechanical delay stage, which causes long data acquisition times. Another method avoiding the mechanical delay is the ASOPS technique (e.g. Ref. 1), which is based on an asynchronous optical sampling of two independent laser sources. However, the drawback of this method besides the high costs of two femtosecond lasers is the stabilization of the two lasers.

Recently, we demonstrated the implementation of an optical sampling method based on repetition frequency modulation (OSREFM) of one femtosecond fiber laser, resulting in a high-speed THz-TDS measurement system.[2] This method applies the same laser source for pump and probe pulses, while, a fixed time delay - corresponding to one base period of the laser pulse - is added in the pump beam line. Therefore, the pump and probe pulses are successive optical pulses, which are originally separated by one cycle. By continuously increasing the laser repetition frequency, the time delay between the pump and probe pulses is varied, resulting in an electronically controlled scan of the THz pulse with no need for mechanical delay components. In general, the scanned time-window, which determines the frequency resolution, depends on the chosen range of repetition frequency sweep. On the other hand, the temporal resolution, which determines the spectral bandwidth, is limited by the timing jitter of the laser pulses, which was estimated to be about 8 ps for the present system. To improve the timing jitter, we inserted a noise filter between the laser and the sweep generator, which provided the trigger for the repetition frequency modulation.

2. Results

We present first measurements of samples using the OSREFM technique. Figure 1 shows the THz signal versus time (and corresponding laser repetition frequency in the upper axis). The THz pulses were generated and detected by a pair of spiral photoconductive antennas, and a storage oscilloscope recorded the signal. The scan rate is tunable from 0.1 ms to 300 ms. A relatively low scan rate of 300 ms was used and accumulations of 100 scans was carried out to obtain the data shown in Figure 1. The black line represents the THz signal without insertion of a sample. Furthermore, the THz pulses for simple solid samples (silicon windows) are displayed. Due to the noise filter the time resolution and the signal to noise ratio (SNR) were improved compared to the previous report [2]. Because of the increased SNR, the lock-in amplifier was not necessary to use in these measurements. One can identify the retardation of the main pulse due to transmission through Si windows. For one and two Si windows (thickness of 3 mm), the retardation is 25 and 50 ps, respectively. This gives a refractive index of roughly 3.4 and demonstrates successful measurements of solid samples using our fast-scan THz-TDS measurement system.

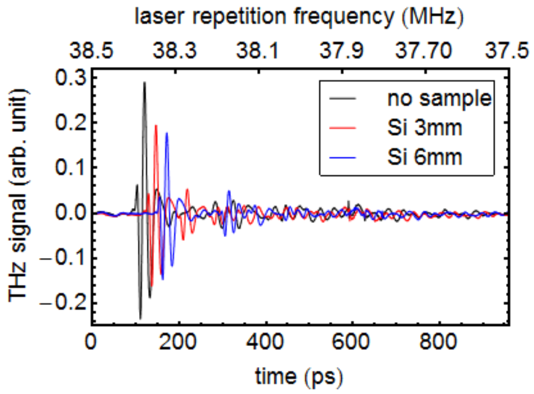

Figure 1: Time domain signals without sample, with one and two 3mm tick Si windows.

Furthermore, we will present measurements of liquid samples using the OSREFM spectrometer and resultant Fourier transform spectra.

3. Conclusions

We present the first demonstration of sample measurements using our fast-scan terahertz (THz) time domain spectroscopy system based on optical sampling by laser repetition frequency modulation (OSREFM). The results indicate that the technique is useful for fast measurement applications in the sub-THz frequency range (20-100 GHz).

References

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