A cost efficient and scalable THz-QTDS system

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***Abstract*—In this work we present a low-cost and compact terahertz quasi time domain spectroscopy (QTDS) system based on inexpensive and commercially available components. The novel scheme allows for a compact and robust system design at the lower end of the price segment.**

I. Introduction

QUASI time domain spectroscopy technology shows potential for building low-cost systems as alternatives to regular THz TDS systems [1], [2]. The technique exploits cheap multi-mode laser diodes (MMLD) instead of rather expensive femtosecond lasers. The resulting signal is a pulse train, similar in shape to the pulses of a TDS system, but with a rather small spectral bandwidth and discrete frequency components. Still, THz QTDS can be used for non-destructive testing, imaging and industrial process monitoring [1], [3]. To fully exploit the financial advantage of using a MMLD, an overall cost-effective system is mandatory.

In this paper a new system concept is proposed and characterized which allows to improve the standard THz QTDS systems in three ways. Firstly, the MMLD and the beam splitter are moved directly onto the mechanical delay line. Secondly, the measurement and control electronics were replaced by a Raspberry Pi with an additional sound card. The Raspberry Pi single board computer enables signal detection and processing. Furthermore, the sound card is modified to drive and control the delay line. As a third step, two different delay lines were compared and characterized. The combination of these three improvements should allow for THz QTDS systems at the lower end of the price segment.

II. System concept and setup

Our improved setup is shown schematically in Fig. 1. The MMLD, beam splitting optics and delay line have been combined into one compact package, reducing the size of the optical assembly. Instead of varying the length of only one arm of the spectrometer, the length of both emitter and detector arms with lengths l_E and l_D, respectively, are modified simultaneously when the delay line is moved by Δx:

$$\begin{aligned} & l_\mathrm{E} \mp \Delta x + l_\mathrm{THz} = l_\mathrm{D} \pm \Delta x \\ \Leftrightarrow \quad & l_\mathrm{E} + l_\mathrm{THz} = l_\mathrm{D} \pm 2 \cdot \Delta x \end{aligned} \tag{1}$$

The length conventions thus match the standard scheme. The new approach offers the ability of a more compact design and further improves the system's costs factor.

All other external hardware was replaced by a Raspberry Pi single board computer with an additional high quality sound card, functioning as an all-in-one data acquisition and system controlling device. The custom built software handles lock-in detection, delay line movement and data display without resorting to external hardware, except for two compact signal amplifiers.

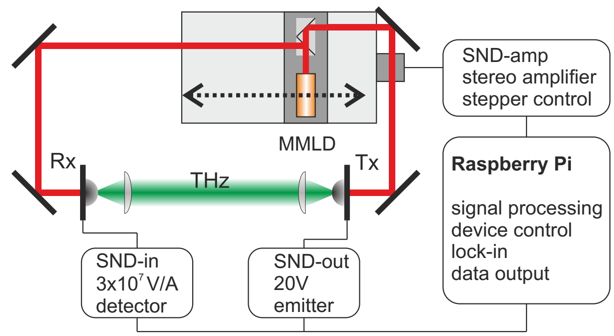

Fig. 1: Compact system setup and signal processing scheme based on a Raspberry Pi computing unit. Data acquisition is done with the sound card input (SND-in), emitter modulation with the sound card output (SND-out) and stepper motor control with the on-board sound amplifier (SND-amp).

III. Measurement and results

A further significant cost reduction affects the delay line. We have compared different types of stepper motor driven delay lines. The cheapest and most compact stage that we tested was a modified CD drive, using the sled that contained the optics as the linear translation unit. Additionally, a Thorlabs LNR50S/M delay line is used as a reference to characterize the low cost device.

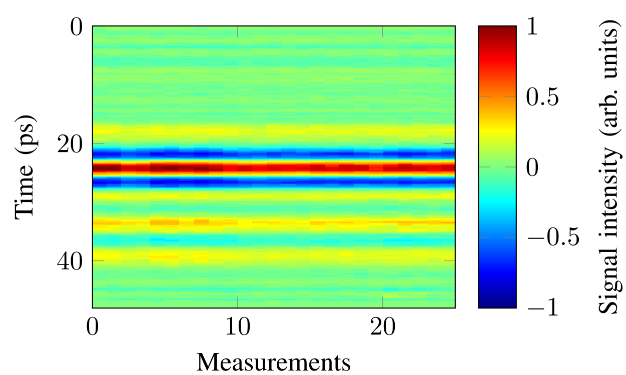

Fig. 2: Top-down view on 25 THz QTDS pulses recorded with the CD drive stage, showing very good positional reproducibility.

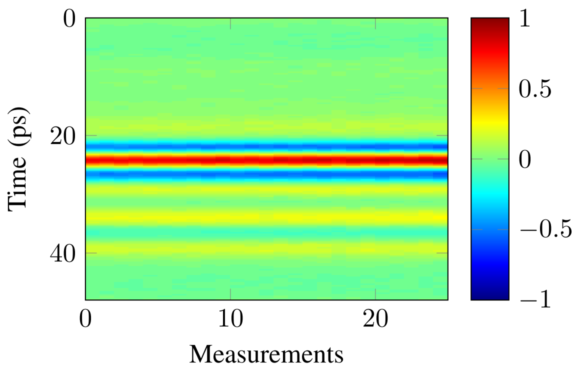

Fig. 3: Top-down view on 25 THz QTDS pulses recorded with the TL stage, showing very good positional reproducibility.

The measurement over 25 single scans with the low cost stage are depicted in Fig. 2. For comparison, the same measurement was done with the Thorlabs stage, see Fig. 3. Both delay lines show a good reproducibility in their temporal position; the amplitude stability of the high quality stage is slightly better than that of the low cost device.

While the CD drive sled achieves a very good positional reproducibility (cf. Fig. 2), the deviations from linear movement are significant. This can be remedied by recording the movement profile with an interferometer and correcting the time axis with this information.

IV. Conclusion

The cunning system approach reveals the potential of THz QTDS technology and paves the way for affordable THz systems capable of real world applications in a very low price segment. Still, more development has to be done mainly to improve stability, performance and footprint of the setup. Taking all this into consideration, using ultra low-cost delay lines may well be an option in the future.

References

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