Phase noise investigation in terahertz Time-Domain Spectroscopy measurements

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***Abstract*—We present a detailed study of the influence of time jitter in terahertz time-domain measurements. It proves to be particularly important in TDS based imaging measurements and can strongly influence the quality of the images.**

I. Introduction And Background

NOISE is one of the fundamental limitations in physics measurement, and it has of course been extensively reviewed in the terahertz domain. In terahertz Time-Domain Spectroscopy (TDS) setups, additional concepts must also apply to take into account the pump-probe-like measurements [1-3]. In TDS, a femtosecond optical pulse is split into two. The first is sent to a photoconductive antenna or a nonlinear crystal to produce a terahertz sub-cycle pulse. The second is sent to the detector that samples out the terahertz electric field which is then reconstructed in the time domain by varying the delay τ between the two pulses. The key point is the measurement in the time domain followed by a Fourier transform to obtain spectral information. Here, we extended this analysis to take into account the temporal jitter between the two femtosecond pulses which can arise for instance from air turbulence or mirror vibrations.

II. Results

The following results are based on the measurement of the standard deviation in a TDS recording (see Fig. 1), and on the simple model of the phase fluctuation during measurements:

$$s_t(\tau,t) = s\left(\tau + n_\phi(t)\right)[1 + n_s(t)] + n_b(t),$$

where s_t is the total recorded signal for a delay τ, n_ϕ the time jitter, n_s the emitter noise and n_b the detector noise. Using standard deviation measurements at precise delays $\tau_- \ll 0$, τ_0, τ_s and τ_{Max} given by fig. 1, we can extract the different noise sources, and n_ϕ in particular. We can notice the non-uniform standard deviation (fig. 1 red) in the time domain. Switching to the frequency domain, it can also be shown under this model that the standard deviation linearly increases with respect to frequency, whose slope provides the amplitude of the phase jitter. Using fig. 2, we then extract that the optical path fluctuation amplitude is 625±80 nm, corresponding to a time jitter of 2 fs. This amplitude is compatible with the air refractive index fluctuation in a laboratory room [4] which is expected to be much larger than the mechanical mounts vibrations.

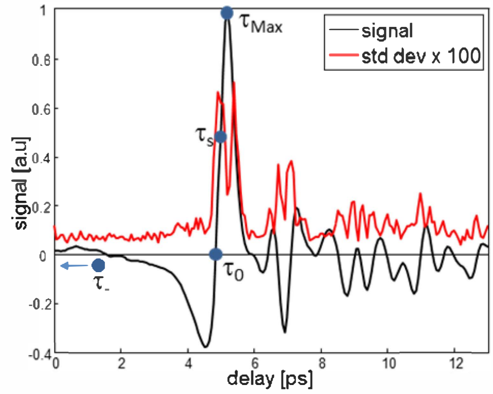

Figure 1: TDS signal (black) and s (red). Dots are spatial delays.

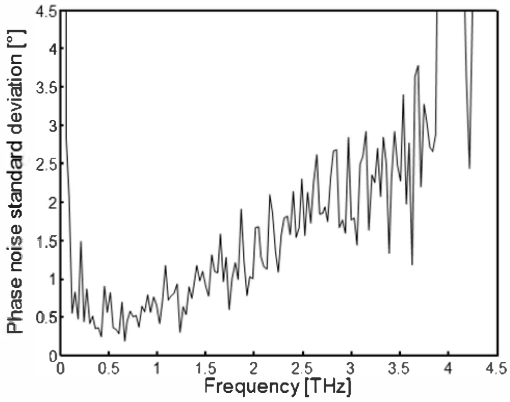

Figure 2: Standard deviation versus frequency.

III. Conclusion

We show that noise level is not uniform in TDS measurements. Precise time jitter can be obtained. This jitter is of first importance in TDS based imaging techniques [5] where the delay between the optical pulses remains constant for which an optimum recording range can be chosen.

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