THz autocorrelation measurements at the Metrology Light Source

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***Abstract*—We have developed a flexible Martin-Puplett Interferometer setup utilizing broad band coherent terahertz (THz) synchrotron radiation provided by the Metrology Light Source (MLS). In order to obtain frequency resolved measurements we combined the Martin-Puplett setup with a Fourier transform spectrometer (FTS). Frequency resolved autocorrelation measurements for beam diagnostics will be presented.**

I. INTRODUCTION

COHERENT synchrotron radiation (CSR) provides stable, broadband, short (< 10 ps), and powerful pulses (up to 60 mW average power) with high repetition rates (up to 500 MHz) [1]. The Metrology Light Source (MLS) is the first storage ring with a dedicated electron optics for low-alpha operation and an optimized THz beamline. Both are necessary for the generation of stable high power THz CSR [2]. The emitted CSR spectrum extends up to 1.5 THz with a CSR power depending on the length and shape of the electron bunch [3], [4]. Therefore the properties of CSR make it suitable for beam diagnostics. We will report on autocorrelation measurements at the MLS, the electron storage ring of the PTB.

II. SETUP & RESULTS

The MLS provides THz pulses with repetition rates up to 500 MHz. The pulse length is 1 to 15 ps depending on the setting of the storage ring beam optics.

In order to obtain the autocorrelation function from the THz synchrotron pulses we utilize a Martin-Puplett interferometer type approach. As shown in Fig. 1 the incident horizontal polarized beam (blue) enters a grid rotated to 54.7° (45° in beam projection) acting as a beam splitter. The transmitted (red) and reflected parts (green) are polarized perpendicular to each other. Both are reflected at the rooftop mirror and reach the beam splitter again. The polarizations of the partial beams are flipped at the rooftop mirrors. The previously transmitted beam is now reflected at the wire grind and vice versa. In this setup the superposition of both beams yields a linear polarization only at zero phase shift between the two partial beams and elliptical polarization at non-zero phase shift. The phase between the two beams depends on the time delay, i.e. the optical path difference (OPD) between both and the wavelength. The transmitted signal therefore contains information on the time-dependent electric field of the initial THz pulse, i.e. the pulse shape. The OPD is set by a delay line to negative and positive delay that matches the pulse length.

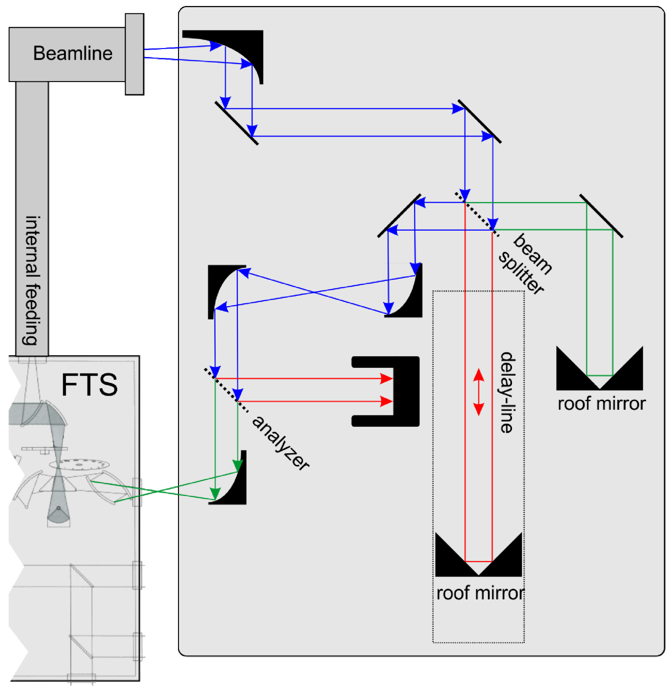

Fig. 1. Sketch of the Martin-Puplett interferometer setup at the MLS THz beamline. The analyzed part of the autocorrelation function is fed into the FTS.

The minimal step size corresponds to a delay well below 0.1 ps. An analyzer was used to select only the horizontal (*H*) or vertical polarization components (*V*) of the superimposed beam. A beam dump was used to avoid stray light coming from the reflected part of the beam. To measure a frequency resolved signal we fed the polarization components *H* (and *V*) into a Bruker Vertex 80v FTS. For detection a liquid helium cooled silicon bolometer was used.

The single channel spectra were measured stepwise after delaying one pulse against the other. Then we combined every interferogram pattern at a fixed frequency *f* of the horizontal polarization components and vertical polarization components to the frequency resolved autocorrelation using the following relation:

$$a(f,x) = \frac{H(f,x) - V(f,x)}{H(f,x) + V(f,x)}$$

Figure 2 shows the frequency resolved vertical polarization components of the autocorrelation function of the CSR. Shown are the single channel spectra in the range of 5 to 30 cm^{-1} versus the optical path difference of the two interferometer arms. The spectra were recorded at a spectral resolution of 1 cm^{-1}. During data acquisition the current in the storage ring decreased from 144 mA to 99 mA.

To avoid aliasing artifacts of the autocorrelation function at higher frequencies we chose a time resolution of 0.13 ps which corresponds to a maximum resolvable frequency of 50 cm^{-1}. A measurable THz signal is given in the range of 5 to 36 cm^{-1}. At low frequencies the CSR is attenuated exponentially by the shielding cutoff of the beamline while frequencies above 36 cm^{-1} are suppressed due to water vapor absorption within the free-standing Martin-Puplett setup. There are also water vapor absorptions visible in the spectra at 18.5 cm^{-1} and 25.1 cm^{-1}.

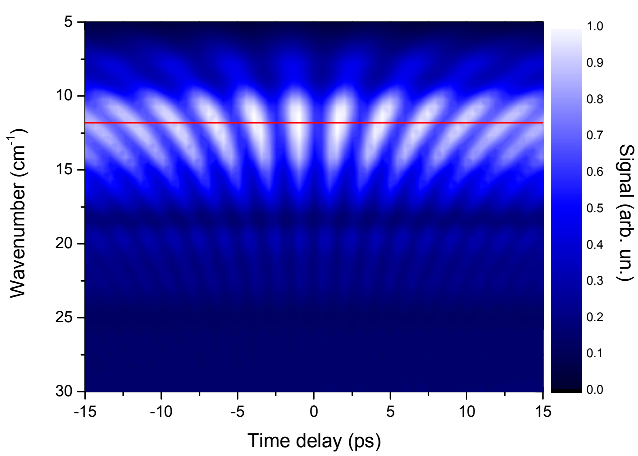

Fig. 2. Frequency resolved plot of the vertical polarization components of the autocorrelation function. At 18.5 cm^{-1} and 25.1 cm^{-1} water absorption is visible.

Figure 3 shows the cross section (red line in Fig. 2) of the vertical polarization component of the autocorrelation function at 12.1 cm^{-1}. It can be seen that the vertical component has a minimum at zero path difference (phase shift of 90°) whereas the horizontal component has its maximum at this position.

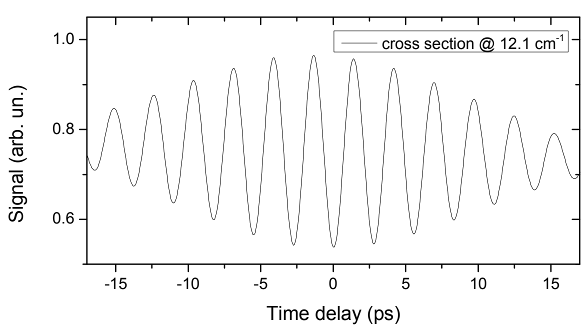

Fig. 3. Cross section of the frequency resolved autocorrelation at 12.1 cm^{-1}.

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