NON-INVASIVE BUNCH LENGTH DIAGNOSTICS BASED ON INTERFEROMETRY FROM DOUBLE DIFFRACTION RADIATION TARGET*

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Abstract

Reliable and precise non-invasive beam diagnostics technique to measure length of sub-picosecond electron bunches are required for new accelerator facilities (FEL, et al.). Investigations of coherent radiation spectra generated by such bunches using interferometer allow to determine a bunch length [1].

The bunch length may be reconstructed using the inverse Fourier-transform. Here we report the results of the proof-of-principle experiment where the same information has been obtained without usage of conventional interferometer.

INTRODUCTION

Non-invasive methods of the sub-picosecond bunch length diagnostics are very important nowadays for such accelerator facilities as free electron lasers with typical bunch lengths of a few hundreds of femtoseconds.

The spectral distribution of the coherent radiation generated by short bunches contains information about its longitudinal distribution.

The interference pattern formed by two diffraction radiation beams from two shifted plates (double DR target) may be used instead an interferogram measured by interferometer.

Measuring a dependence of radiation yield intensity from two diffraction radiation targets on a distance between them (the intrinsic DR interferogram), it is possible to determine a bunch length. Such a non-invasive technique can be directly used for ultra-short bunch length measurements [2].

Recently the first investigations of such interferograms with a double DR target were carried out at the SINAP facility with fs bunches [3].

EXPERIMENTAL SETUP

Accelerator

The accelerator providing femtosecond electron bunch facility consists of an S-band thermionic cathode rf-gun, an alpha magnet and a SLAC-type accelerating tube [4]. The alpha-magnet is applied to change the duration of electron bunches from a few hundreds of ps to few hundreds of fs. The parameters of electron beam are presented in Table 1.

Table 1: Parameters of Electron Beam

Beam energy	23MeV
Beam charge	0.068 nC
Normalized emittance	~ 10 mm·mrad
Macro-bunch repetition frequency	6.25 Hz
Micro-bunch repetition frequency	2856.2 MHz
Macro-bunch duration	3 µs
Micro-bunch duration (FWHM)	0.3 – 3 ps

Experimental Setup

To measure the interferograms of the coherent diffraction radiation from double DR target the parabolic mirror with focal distance L_d was used (see Fig. 1). Coherent DR was extracted through a toughened glass window with thickness 4 mm and diameter 40 mm which suppressed a high-frequency part of spectra.

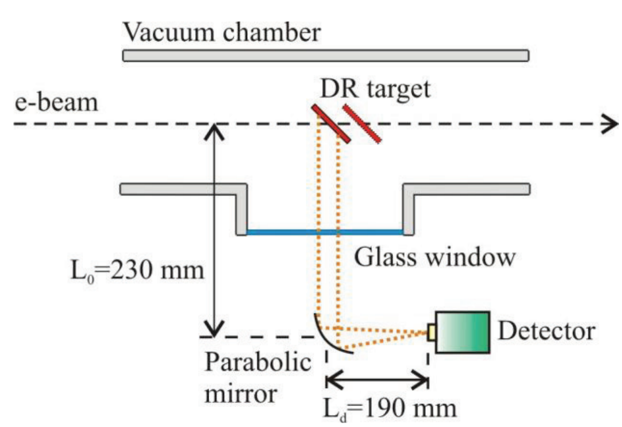

Figure 1: The scheme of experimental setup.

Detector

To detect CDR a room temperature broadband $LiTaO_3$ pyroelectric detector SPI-D-62 THZ (Gentec-EO) was applied with the aperture diameter 2 mm which are optimized for usage in THz region of radiation. Other detector parameters are following: sensitivity range is

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0.01 – 3 mm, response is 150 kV/W and maximum average power is 200 mW.

Target

The DR target was consisted of two plates (with sizes 46×20 mm^2) made from the 2 µm aluminum foil covered on the 0.3 mm polyamide film. Both plates were fixed on the holder with a possibility to move one plate relative other one along the beam direction with a step less than 16 µm. During such a movement we measured coherent DR intensity for each position (interferogram).

In Fig. 2 the side view of doubled DR target is shown which illustrate the location of the two parallel plates relative to each other when they are shifted along beam to a distance d, $\theta_0 = 45°$ is the tilt angle to the beam trajectory, β is the particles speed.

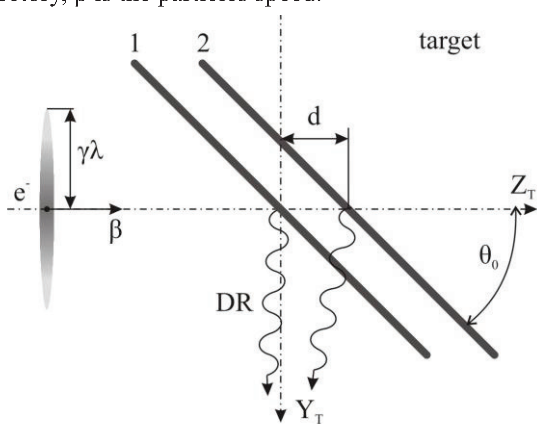

Figure 2: The shifted two plates of double DR target.

SIMULATION

In Fig. 3 are shown the calculated spectra from one plate for two rms values of bunch length: a red solid curve is 0.3 mm and blue dashed one is 0.6 mm. The simulation was performed for parameters of experiment, but for impact parameter h = -10 mm (see Fig. 4), for ideal case (without window attenuation but with effect of target finite size).

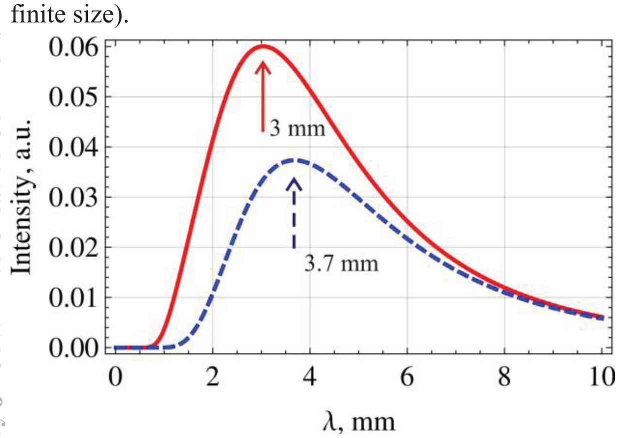

Figure 3: The calculated spectra of coherent DR from single plate of a target.

RESULTS

In Fig. 4 the dependence of intensity from impact parameter for one plate is shown.

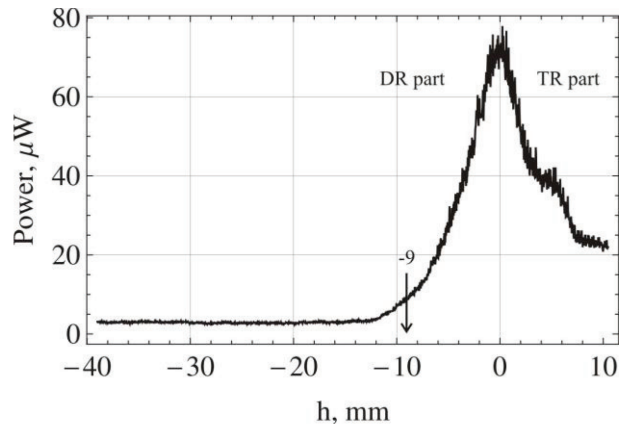

Figure 4: Intensity dependence from impact parameter for one plate.

The left part of this dependence refers to the case of diffraction radiation and the right part to the case of transition radiation.

We have measured the interferograms using the coherent diffraction radiation interferometry. In Fig. 5, the whole interferograms for equal value of impact parameter measured in experiment for the various current of alpha-magnet I_α is presented in distance domain.

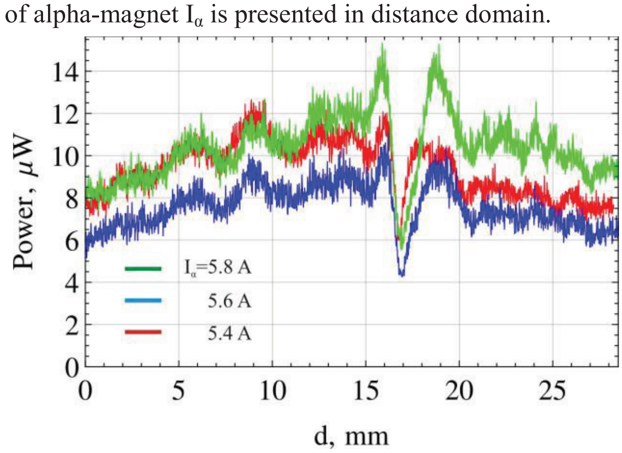

Figure 5: The measured double DR interferograms.

The upper green curve is for I_α = 5.8 A, the middle red curve is for 5.4 A and the lower blue one is for 5.6 A. The distribution minimum in the interferograms corresponds to the position when the two plates are located in one plane. The distance from beam trajectory to both of two target plates is equal to -9 mm according to Fig. 4.

DISCUSSION

Using the spectra reconstruction algorithm described in [4], we have obtained the spectra from double DR interferograms (see in Fig. 6). The reconstruction was especially performed for main central part of double DR interferograms.

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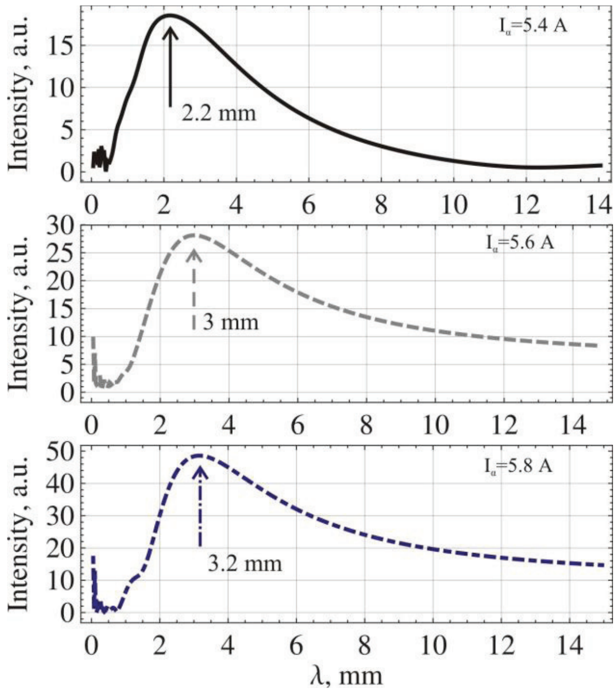

Figure 6: The reconstructed spectra from double DR target interferograms.

Upper solid spectrum is for $I_\alpha = 5.4$ A, then the middle dashed one – 5.6 A and lower dot-dashed one – 5.8 A. As we see there are visible differences in the short-wave part of spectra. Coherent radiation appears on the shorter wavelength for spectrum with a smaller value of current of alpha-magnet. Moreover the peak of distribution is shifted in the short-wave part of spectrum for a smaller value of I_α too. Not so considerable difference for $I_\alpha = 5.6$ and 5.8 A may be explain by the distortion of the beam trajectory relative to the target by the magnet system. Other parameter characterized bunch length is the full width at half minimum (FWHM) of each interferograms presented in Table 2.

Table 2: FWHM of Interferograms

Current of alpha-magnet, A	5.4	5.6	5.8
Double DR interferograms, mm	0.84	1.36	1.67

Applying the technique proposed in [5] for experimental double DR interferograms we estimated the bunch lengths about 0.12, 0.23 and 0.68 mm for currents of alpha-magnet equal to 5.4, 5.6 and 5.8 A respectively which corresponds to the order of femtoseconds.

As we see the calculated spectra have the similar behaviour for the shorter wavelength and peak. However the positions of peaks differ from the position in the spectra from the experimental interferograms. It can be explain also by the effect of vacuum chamber window which distort the spectrum of radiation from the target.

CONCLUSION

The first measurements of the sub-picosecond electron bunch lengths were carried out applying coherent diffraction radiation interferometry from double DR target (non-invasive beam diagnostics technique)

The obtained interferograms from double DR target demonstrate big dependence on a bunch length (in contrast to conventional Michelson interferogram from a single target)

From the measured interferogram the rms bunch length was found less than 0.7 mm, which confirms the ability of the proposed technique for non-invasive bunch length measurements in the sub-picosecond range

The developed technique doesn't need any complicate interferometer and additional optics elements.

In the future experiment we should take into account the suppression of output window material and exactly know the transmission properties of it.

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