First Results of the High Resolution Wire Scanners for Beam Profile and absolute Beam Position Measurement at the TTF

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Abstract

In the TESLA Test Facility (TTF), wire scanners are used to measure the electron beam profile and position. The intended use of the wire scanners (to center the electron beam in the Free Electron Laser (FEL) undulator) requires an especially precise alignment of the wire scanners with respect to the undulator axis. The wire scanners should define a reference axis with respect to the external reference system of the undulator with an accuracy better than 30 μm. The wire scanners allow a beam profile measurement, which will be used to optimize and match the beam optics for the undulator. First experimental results of beam position and profile will be presented and discussed.

1. Introduction

The undulator at the TTF-FEL consists of three undulator modules. The narrow spaces between and at both ends of the undulator modules are used for diagnostics. Two types of monitors are included in a so-called "diagnostic block". RF type cavity monitors for horizontal and vertical beam position measurement and vertical and horizontal wire scanners allow a measurement of the beam profile and position [1]. The beam position can be measured with respect to external reference marks so that the position of the beam before, after, and between the undulator modules at several fixed points is known. Figure 1 shows a photograph of the diagnostic block between two undulator sections. The principle set-up of the wire scanners is sketched in Figure 2. Each wire scanner fork (wire holder) is equipped with three wires: one tungsten wire of a diameter of 20 μm, and two carbon wires with a diameter of 5 μm. This allows one to select the wire as a function of beam size, beam intensity and required resolution. Electrons hitting a wire in turn produce scattered electrons, which are detected by scintillation counters. Behind each pair of wire scanners, a scintillation counter is installed covering nearly 360 around the beam tube [2].

The main difficulties that had to be overcome were:

The cleaning and assembly of the complicated diagnostic block. Together with the attached components (like RF feedthroughs), the assembly had to take place under clean room conditions according to TTF specifications (clean room better than class 100) [3].

The alignment and stretching of wires. The tightening of the wires in the fork is critical. It is difficult to stretch the wires to a straight line and fix them. After installation, the wires have to pass the narrow RF shielding slit (width 1.5 mm) in the diagnostic block during the scan of the beam profile. The alignment is extremely crucial since small deviations from the center of the slit result in the damage of all wires.

The calibration of the wire scanner in the diagnostic block. The goal of this calibration is block with an accuracy of better than 30 μm in both planes. This calibration was done using a vertical coordinate measuring machine (CMM). A local clean room was installed in front of the machine. The diagnostic block was under clean room conditions during the entire calibration measurement. To measure the wire position a microscope was mounted on the CMM. It allowed one to see the thin wires and to measure the distance from the wires to the reference planes. Reproducibility was achieved using a linear encoder connected to the linear driving system of the wire scanner.

2. Results

Figure 3 presents the results of all eight wire scanner measurements recorded during FEL operation of the TTF linac. The electron beam profile measurements were made with the 20 μm thick tungsten wire, which was chosen to ensure sufficient intensity on the scintillation counter; the signal from the carbon wires, on the other hand, was too small to be detected. By reducing the background (less beam loss before and inside the undulator area) and reducing the electron beam spot size, the signal-to-noise ratio can be improved.

The measured profiles indicate that the beam offset along the entire undulator stays below 300 μm during SASE operation. The spot size is somewhat larger than expected. Measurements have shown that a part of the spot size is generated by dispersion.

Each undulator has a superimposed FODO structure of 10 quadrupoles per undulator [4] In addition to the wire scanners, ten beam position monitors (BPM), which allow the measurement of the beam position inside the quadrupoles, are installed along the undulator chamber [5].

Figure 4 gives a comparison between the beam position measured by the wire scanners and the BPMs inside the first two undulators. It is clear that the BPMs show some random position deviations, due to the fact that they had not been calibrated. The fit of a betatron motion to both the 20 BPMs and the four wire scanner readings results in a similar betatron amplitude and phase of the beam motion.

The measurement of a difference orbit, implemented by a kick before the undulator, allows one to verify the beam optics inside the undulator by a comparison of the expected and measured betatron motion. Figure 5 shows good agreement between the measured and calculated difference orbits. The betatron motion is only fitted in amplitude and phase to the measured difference orbit. Both measurements (wire scanner and BPMS) result in the same difference orbit. The agreement with the calculated betatron motion is very good (~50 µm).

3 Conclusions

The eight wire scanners allow one to measure the beam profile and the beam position with high reproducibility and accuracy (better than 30 µm). Good agreement between the calculated and measured phase advance inside the undulator was observed. The position measurements of the wire scanners are also in good agreement with the 20 distributed BPMs.

4 REFERENCES

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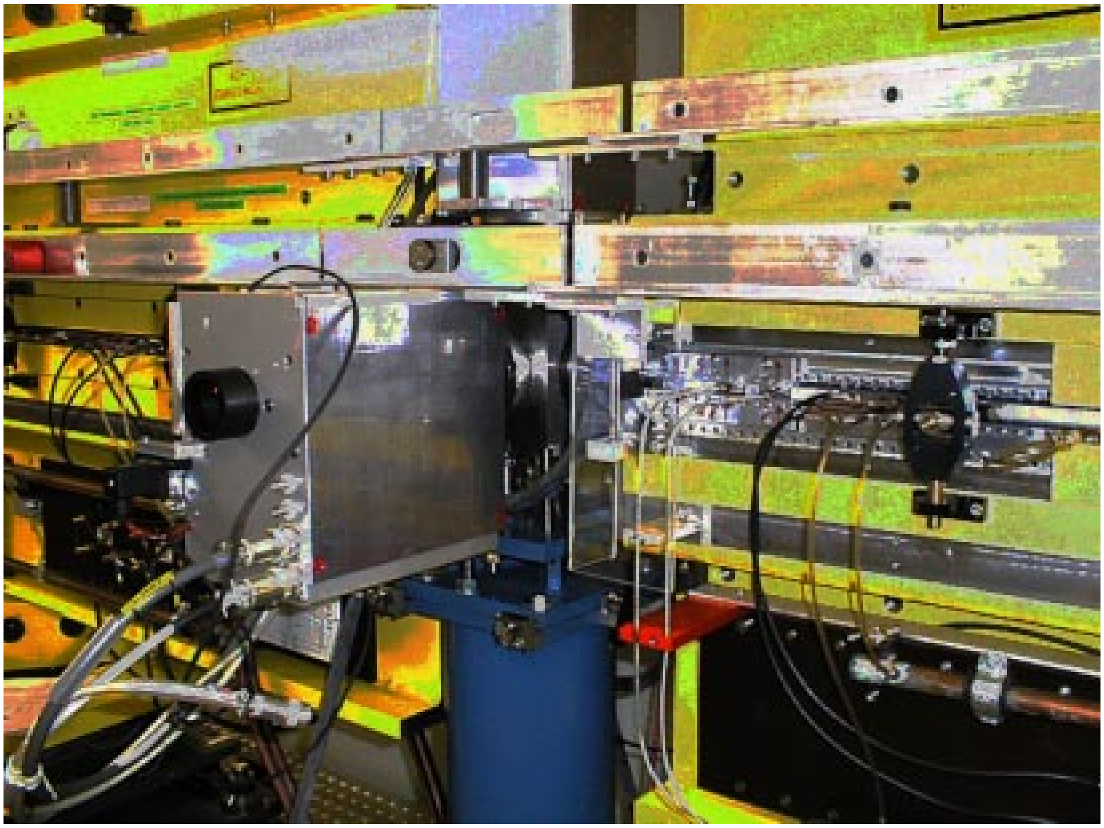

Fig.1: Diagnostic block between two undulator sections.