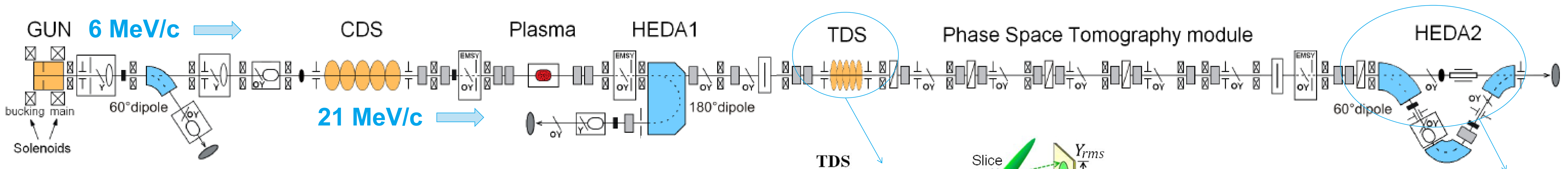
First Results of Commissioning of the PITZ Transverse Deflecting Structure.

H. Huck#, P. Boonpornprasert, A. Donat, J. Good, M. Gross, I. Isaev, L. Jachmann, D. Kalantaryan, M. Khojoyan,
W. Koehler, G. Kourkafas, M. Krasilnikov, D. Malyutin, D. Melkumyan, A. Oppelt, M. Otevrel, M. Pohl, Y. Renier,
T. Rublack, J. Schultze, F. Stephan, G. Trowitzsch, G. Vashchenko, R. Wenndorff, Q. Zhao (DESY, Zeuthen, Germany)
D. Churanov, L. Kravchuk, V. Paramonov, I. Rybakov, A. Zavadtsev, D. Zavadtsev (INR of the RAS, Moscow, Russia)
M. Lalayan, A. Smirnov, N. Sobenin (MEPhI, Moscow, Russia)
C. Gerth, M. Hoffmann, M. Hüning (DESY, Hamburg, Germany)
O. Lishilin, G. Pathak (Hamburg University, Hamburg, Germany)
C. Hernandez-Garcia (Jlab, Newport News, USA)
G. Asova (INRNE, Sofia, Bulgaria)
M. Bakr (Assiut University, Assiut, Egypt).
holger.huck@desy.de

Abstract and Introduction

For successful operation of X-ray Free Electron Lasers, one crucial parameter is the ultrashort electron bunch length yielding a high peak current and a short saturation length. In order to effectively compress the bunches during the acceleration process, a detailed understanding of the full longitudinal phase space distribution already in the injector is required. Transverse deflecting RF structures (TDS) can shear the bunch transversely, mapping the longitudinal coordinate to a transverse axis on an observation screen downstream. In addition to the bunch length, the slice emittance along the bunch as well as the full longitudinal phase space can be obtained. At the Photo Injector Test Facility at DESY, Zeuthen site (PITZ), an S-band traveling wave TDS is under commissioning since 2015. This cavity is a prototype for the TDS in the injector part of the European XFEL and has been designed [1] and manufactured by the Institute for Nuclear Research (INR RAS, Moscow, Russia). In this paper, first commissioning results of the system at PITZ are presented and discussed.



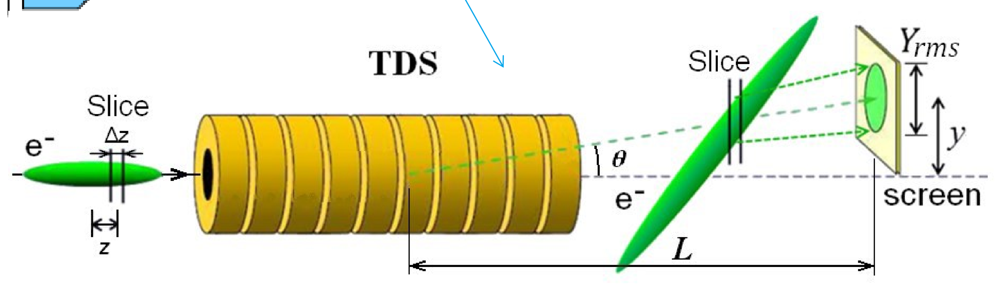


Fig.1: Current PITZ beamline with TDS. Depeding on their position, electrons are deflected by transverse RF fields and observed on a downstream screen. When combined with a dipole, the full longitudinal phase space can be observed.

Deflecting cavity: Bunch length mapped to the vertical axis [2,3]

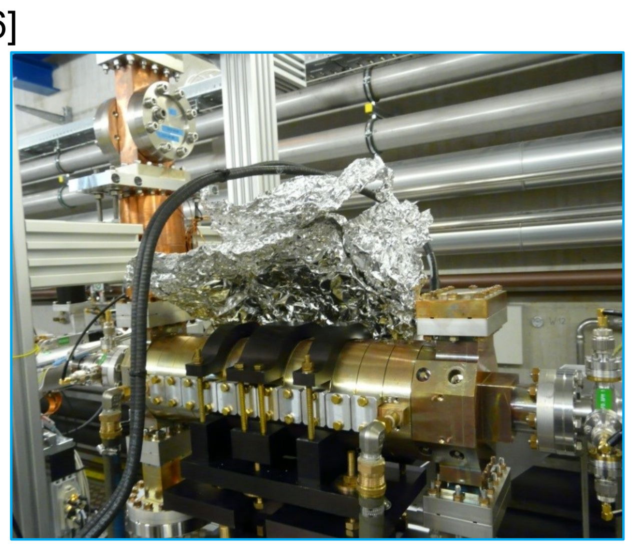
Horizontal spectrometer dipole

Layout at PITZ

The PITZ TDS is installed in the high energy section of the beamline, between the first emittance measurement station and the phase space tomography module (Fig.1). It is a traveling wave structure similar to the LOLA design [4]. The cell dimensions were selected to have the same cells for all three structures in the European XFEL TDS and are realized in its prototype for PITZ [5].

Table 1: Design parameters of the PITZ TDS [6]

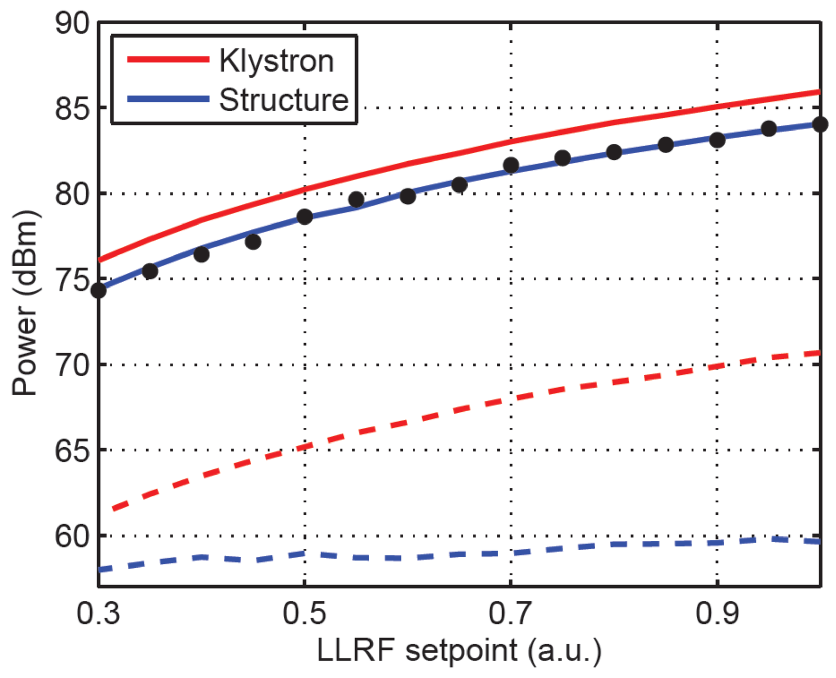
Deflecting voltage	1.7 MV
Input power	2.11 MW
RF Frequency	2997.2 MHz
Pulse length	3 μs
Structure Length	0.533 m
Number of cells	14+2
Phase advance per cell	$2\pi/3$
Quality factor at 20 °C	11780



Commissioning Status

A ScandiNova [7] modulator was installed and commissioned at PITZ in early 2015. The on-site acceptance tests were very successful, showing a pulse flatness of 0.24% within 3.3 μs and a pulse-to-pulse stability of approx. 66 ppm. In July, the TDS was conditioned up to intermediate power levels of about 0.5 MW within several days. Currently, the reflected power from the whole waveguide system precludes higher power levels.

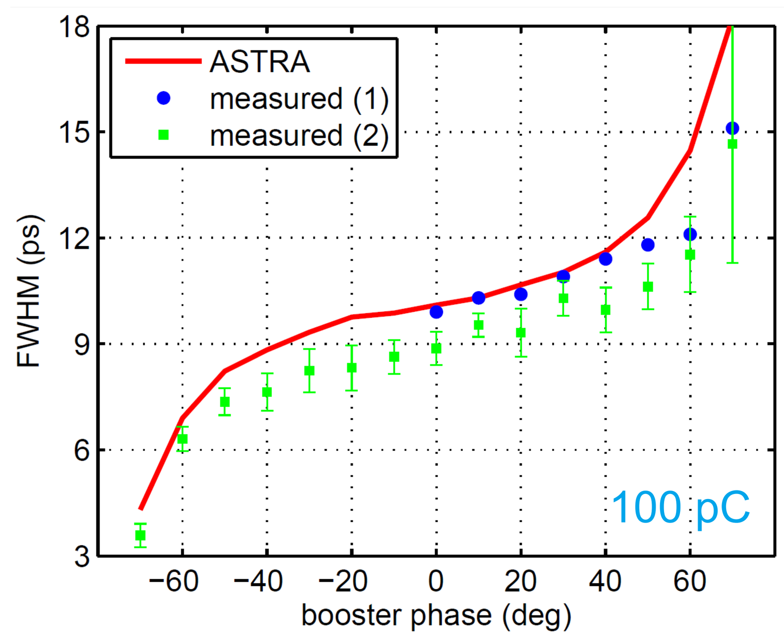
Power estimations based on the measured electron deflection fit very well to the coupler readings, however the ratio between forward power at the klystron and structure is unexpectedly large.

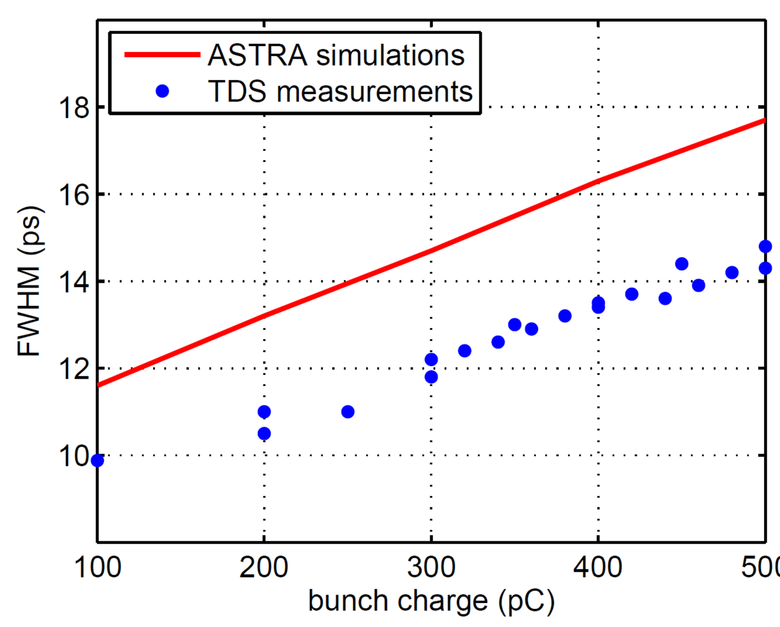


Left: Forward (full lines) and reflected (dashed lines) power readings from the directional couplers at the klystron and deflecting structure. The black dots are estimations of the power in the structure based on the measured electron beam deflection.)

First Measurements with Electron Beam

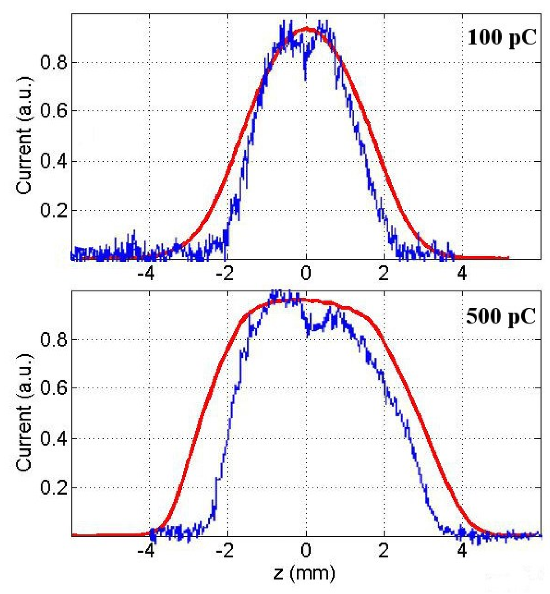
All measurements were done at machine conditions compliant to the emittance measurements [8] and stability tests for the commissioning phase of the European XFEL (5-MW, 640-μs RF pulses in the gun and 11-12 ps long Gaussian laser pulses [9,10]). The beam momentum after the booster was 21.5 MeV/c. An observation screen 1.3 m downstream the TDS was used.

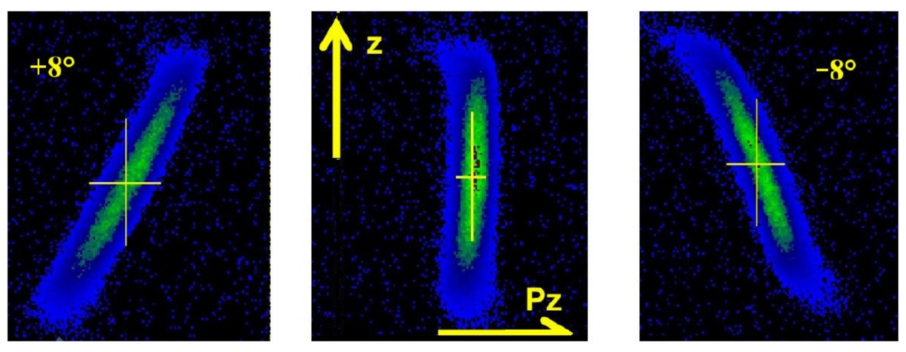




Top right: Preliminary bunch length measurements and simulations assuming a perfect transverse laser profile.
Right: Corresponding electron bunch profiles.

Top left: Bunch length versus RF phase of the booster, showing velocity bunching for off-crest acceleration of 100-pC bunches. Here, the measured transverse laser distribution from the first data set (blue dots) was used as input for more realistic simulations („core+halo“ model). The second data set was taken one month later, during which the quantum efficiency of the cathode and the transverse laser profile changed, resulting in different space charge forces during emission.





Left: First low-resolution images of the full longitudinal phase space in the HEDA2 section for different booster phases. Once the nominal TDS power is reached, a temporal resolution of ~0.3 ps is expected (~100 fs for pure temporal profile measurements).

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HELMHOLTZ GEMEINSCHAFT

PITZ Photo Injector Test Facility Zeuthen

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