ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPAL068

STATUS OF THE PolariX-TDS PROJECT

P. Craievich*, M. Bopp, H. Braun, R. Ganter, T. Kleeb, M. Pedrozzi, E. Prat, S. Reiche, R. Zennaro
Paul Scherrer Institut, 5232 Villigen PSI, Switzerland
A. Grudiev, N. Catalan Lasheras, G. McMonagle, W. Wuensch
CERN, 1211 Geneva 23, Switzerland
B. Marchetti, R. Assmann, F. Christie, R. D'Arcy, U. Dorda, M. Foese, P. Gonzalez Caminal,
M. Hoffmann, M. Huening, R. Jonas, O. Krebs, S. Lederer, V. Libov, D. Marx, J. Osterhoff,
F. Poblotzki, M. Reukauff, H. Schlarb, S. Schreiber, G. Tews, M. Vogt, A. de Z. Wagner
DESY, 22607 Hamburg, Germany

Abstract

A collaboration between DESY, PSI and CERN has been established to develop and build an advanced modular X-band transverse deflection structure (TDS) system with the new feature of providing variable polarization of the deflecting force. This innovative CERN design requires very high manufacturing precision to guarantee highest azimuthal symmetry of the structure to avoid the deterioration of the polarization of the streaking field. Therefore, the high-precision tuning-free production process developed at PSI for the C-band and X-band accelerating structures will be used for the manufacturing. We summarize in this paper the status of the production of the prototype and the waveguide networks foreseen in the different facilities.

INTRODUCTION

Electron beam diagnostic based on a transverse deflection structure (TDS) placed downstream of the undulators (post-undulator TDS) in conjunction with an electron beam energy spectrometer can indirectly measure the pulse length of these ultra-short photon beam analyzing the induced energy spread on the electron bunch due to the FEL process [1]. Furthermore, complete characterization of the electron beam 6D phase space by means of meas-urements of the bunch length, energy and of the transverse slice emittances (vertical and horizontal) are also important tasks for commissioning and optimization of the FEL process [2–5]. More complete characterizations of bunch proprieties, such as the reconstruction of the 3D charge density distribution [6], will be important diagnos-tic tools for the new acceleration techniques based on plasma and/or dielectric wakefield generation. Several experiments at DESY (FLASH2, FLASHForward, SIN-BAD) and PSI (ATHOS at SwissFEL) are interested in the utilization of such a high gradient X-band TDS systems for high resolution longitudinal diagnostics. In this context, a collaboration between DESY, PSI and CERN has been established to develop and build an advanced modular X-Band TDS system with the new feature of providing variable polarization of the deflecting force [7]. In this paper we summarize the status of the collaboration focusing on the integration of the X-band TDS in the different facilities.

THE POLARIX-TDS PROTOTYE

The prototype of the novel X-band TDS [8], the Polarizable X-band (PolariX) TDS, is under production at PSI following the high-precision tuning-free production process developed for the C-band Linac of the SwissFEL project [9] and already used for the fabrication of the tuning-free X-band structure prototypes for CLIC [10]. Bead-pull rf measurements will also be performed at PSI in September 2018 in order to verify that the polarization of the dipole fields does not have any rotation along the structure. Figure 1 shows the detail of the input and out-put couplers (left), the whole TDS prototype (middle) and the basic disk geometry (right). The main RF parameters of the TDS and rf pulse compressor are summarized in Table 1.

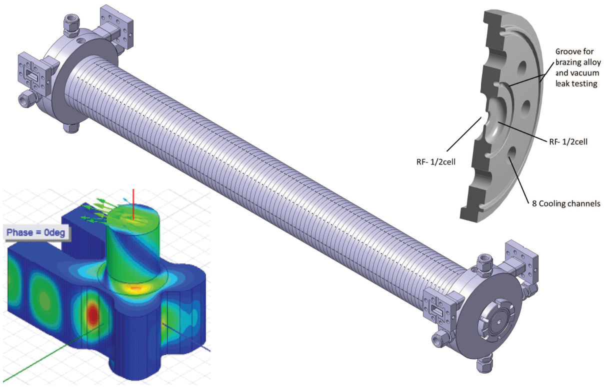

Figure 1: Left: detail of the input/output coupler. Middle: whole TDS prototype. Right: basic disk.

TDS LAYOUTS AND RF NETWORKS

In this section we will briefly introduce the integration of the PolariX TDS including the concept for the rf wave-guide networks in the different facilities.

ATHOS beamline at SwissFEL

The SwissFEL project at PSI consists of an accelerator complex and two undulator beam lines: Aramis [11] and Athos [12] for hard and soft X-rays, respectively. The latter is designed to operate in advance modes of operation different to standard SASE operation and will produce FEL radiation

---

[*] paolo.craievich@psi.ch

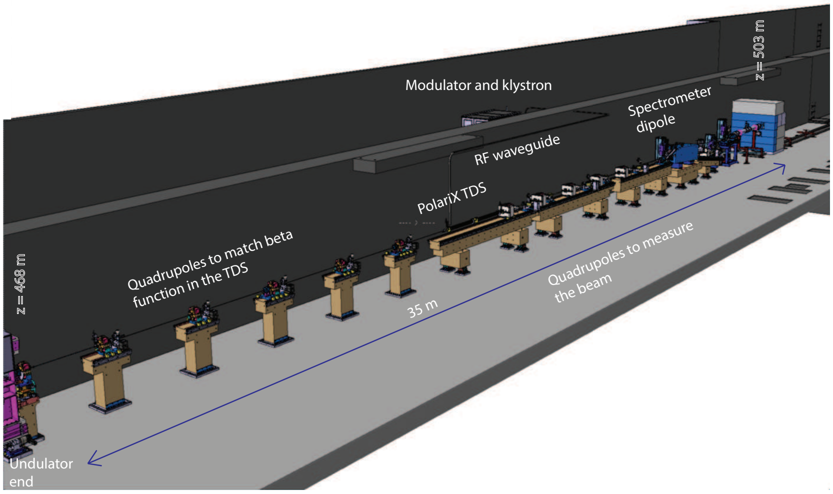

Figure 2: Layout of the Athos post-undulator diagnostic section.

Table 1: RF parameters for short and long X-band TDS. Both structures are constant impedance and backward traveling wave structures. t_k is the klystron pulse width and the frequency corresponds to an operational temperature of 30°

Cell parameter		**Unit**	
Frequency	11995.2	MHz	
Phase advance/cell	120	°	
Iris radius	4	mm	
Iris thickness	2.6	mm	
Group velocity	-2.666	‰c	
Quality factor	6490		
Shunt impedance	50	$M\Omega/m$	
TDS parameter	**Short**	**Long**	**Unit**
n. cells	96	120	
Filling time	104.5	129.5	ns
Active length	800	1000	mm
Total length	960	1160	mm
Power-to-voltage	5.225	6.124	$MV/MW^{0.5}$
TDS + BOC	**Short**	**Long**	**Unit**
BOC Q_0	145000	145000	
BOC β@t_k=1.5μs	7	7	
Power-to-voltage	12.010	13.626	$MV/MW^{0.5}$

with pulse durations ranging from a few to several tens of femtoseconds. Figure 2 shows the layout of the Athos post-undulator diagnostic section where a long PolariX TDS will be installed in mid-2019. Figure 3 shows a conceptual sketch of the PolariX TDS rf power distribution system including a Barrel Open Cavity (BOC) pulse compressor that is actually also under development at PSI.

FLASHForward and FLASH2

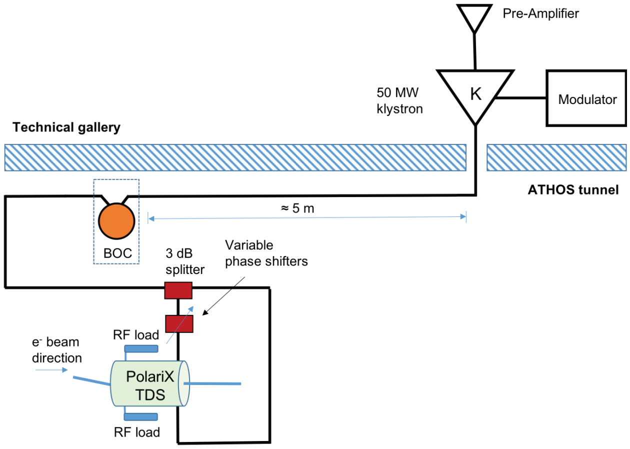

Figure 3: Concept for RF power feeding scheme with a 50 MW CPI klystron for one long PolariX TDS.

The FLASH facility [13] at DESY operates two SASE beamlines in parallel: FLASH1 and FLASH2. The electron pulses of FLASH come in trains of several hundred pulses with a repetition rate of 10 Hz. The pulses of a train are shared between the two beamlines providing FEL radiation for two experiments at the same time - with the full repetition rate of 10 Hz. Moreover a third beamline for plasma acceleration experiments FLASHForward is currently undergoing commissioning. The FLASH2 and FLASHForward beamlines are located in the same tunnel (see Fig. 4). Both beamlines require fs-level longitudinal diagnostics to establish fs scale photon pulses [14] and to characterise beams driving or being driven by a plasma wakefield [15], respectively.

The beamlines share a common design of the rf station constituted by a 6 MW Toshiba E37113A klystron and an Ampegon Type-μ M-class modulator. The klystron will be installed inside the tunnel, whereas the modulator rack will be located in an external adjacent corridor. This beamline will be installed in two stages.

For the PolariX TDS prototype commissioning only the elements shown in Fig. 5 will be available and the maximum deflecting voltage in the TDS will be about 14MV. In the second stage of the installation an rf pulse com-pressor will be installed allowing for an increase in peak power by a factor of 4.

Figure 6 shows the integration of the PolariX TDS with the waveguides, vacuum pumps and mechanical support. The latter will allow for precise remote adjustment of the position of the structure.

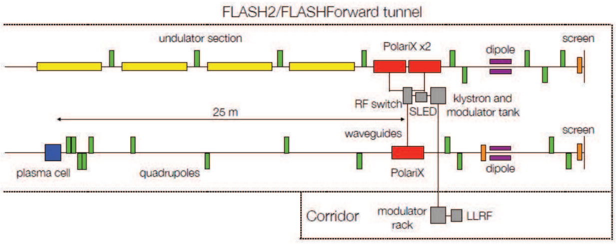

Figure 4: Final layout of the X-band RF station shared be-tween the FLASHForward and FLASH2 beamlines. An RF switch is incorporated in the design in order to send power exclusively to one of the two beamlines at a time.

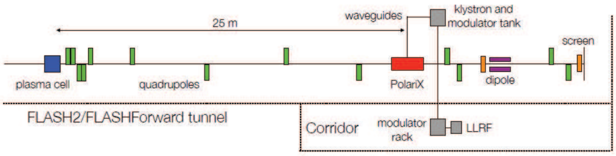

Figure 5: Setup of the RF station for the commissioning of the PolariX prototype in the FLASHForward beamline.

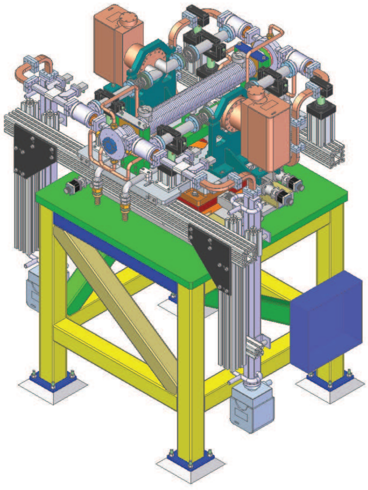

Figure 6: Integration of the PolariX TDS in the beamline. The support will allow for precise remote adjustment of the cavity position.

SINBAD

Two short PolariX TDSs are also planned to be in-stalled in the SINBAD facility at DESY. The ARES accelerator at SINBAD requires indeed sub-fs longitudinal resolution for the characterization of ultra-short electron bunches for testing novel acceleration methods [6, 16–18].
At SINBAD two independent PolariX TDSs fed by in-dependent rf stations will be installed. The two TDSs can be operated in series (as foreseen in their commissioning phase) or installed at two different locations of the beam-line. A similar rf station design (with 6MW klystron and pulse compressor) to that at FLASH is foreseen to be implemented. Figure 7 shows a sketch of the RF stations and TDS positions in the SINBAD tunnel for the com-missioning of the two cavities.

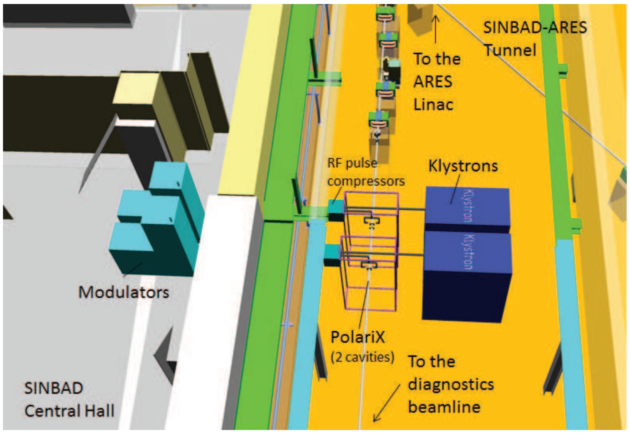

Figure 7: Sketch of the PolariX TDSs and relative rf stations at SINBAD-ARES.

CONCLUSION

A collaboration between DESY, PSI and CERN has been established to develop and build an advanced modular X-band TDS system. A prototype of this novel TDS, the Polar-izable X-band (PolariX) TDS, is actually under production at PSI and the bead-pull rf measurements are also foreseen for September 2018. In this paper, we have summarized the status of the collaboration focusing on the integration of the X-band TDS in the different facilities.

REFERENCES

[1] C. Behrens *et al.*, *Nature Communications,* vol. 5, no. 3762, April 2014.

[2] D. Alesini *et al.*, *Nucl. Instrum. Meth. Phys. Res. A*, 568 (2006), pp. 488–502.

[3] R. Akre *et al.*, “A Transverse RF Deflecting Structure for Bunch Length and Phase Space Diagnostics ”, in *Proc. PAC’01*, in *Proc. Particle Accelerator Conf. (PAC’01)*, Chicago, IL, USA, Jun. 2001, pp. 2353–2355.

[4] H. Ego *et al.*, *Nucl. Instrum. Meth. Phys. Res. A*, 795 (2015), pp. 381–388.

[5] P. Craievich *et al.*, *IEEE Transact. on Nucl. Science*, vol. 62, no. 1, pp. 1-11, 2015.

[6] D. Marx *et al.*, “Reconstruction of the 3D charge distribution of an electron bunch using a novel variable-polarization transverse deflecting structure (TDS)”, *J. Phys.: Conf. Ser.*, vol. 874, p. 012077, 2017.

[7] B. Marchetti *et al.*, “X-Band TDS project”, in *Proc. IPAC’17*, Copenhagen, Denmark, May 2017, paper MOPAB044, pp. 184–187.

[8] Craievich *et al.*, “Sub-Femtosecond Time-Resolved Measurements Based on a Variable Polarization X-Band Transverse Deflecting Structures for SwissFEL”, in *Proc. FEL’17*, Santa Fe, NM, USA, Aug. 2017, paper WEP040.

[9] U. Ellenberger *et al.*, “Status of the manufacturing process for the SwissFEL C-band accelerating structures”, in *Proc. FEL’13*, New York, USA, paper TUPSO17, pp. 246–249.

[10] R. Zennaro *et al.*, “High power tests of a prototype X-band accelerating structure for CLIC”, in *Proc. IPAC’17*, Copenhagen, Denmark, May 2017, paper THPIK097, pp. 4318–4320.

[11] C. J. Milne *et al.*, “SwissFEL: The Swiss X-ray Free Electron Laser”, *Appl. Sci.*, vol. 7, no. 720, July 2017.

[12] “Athos Conceptual Design Report”, PSI, Switzerland, Rep. Nr. 17-02, Sep. 2017.

[13] `https://flash.desy.de`

[14] F. Christie *et al.*, “Generation of Ultra-Short Electron Bunches and FEL Pulses and Characterization of Their Longitudinal Properties at FLASH2”, in *Proc. IPAC’17*, Copenhagen, Denmark, May 2017, paper WEPAB017, pp. 2600–2603.

[15] R. D’Arcy *et al.* , “Longitudinal Phase Space Reconstruction at FLASHForward Using a Novel X-band Transverse Deflection Cavity (XTDC)”, presented at IPAC’18, Vancouver, Canada, April-May 2018, paper TUPML017.

[16] U. Dorda *et al.*, “Status and objectives of the dedicated accelerator R&D facility SINBAD at DESY”, *Nucl. Instr. Meth. Phys. Res. A*, to be published.

[17] D. Marx *et al.*, “Lattice considerations for the use of an X-band transverse deflecting structure (TDS) at SINBAD, DESY”, *J. Phys.: Conf. Ser.*, vol. 874, p. 012078, 2017.

[18] D. Marx *et al.*, “Longitudinal phase space reconstruction simulation studies using a novel X-band transverse deflecting structure at the SINBAD facility at DESY”, *Nucl. Instr. Meth. Phys. Res. A.*, 2018.