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PSI

Fabio Marcellini on the behalf of PolariX TDS team :: RF section :: Paul Scherrer Institut

The PolariX TDS at PSI

a novel polarizable X-band Transverse Deflection Structure (TDS)

CLIC Project Meeting #42, Thursday 12 May 2022

Outline

- Motivation for high-resolution time-resolved
- PolariX TDS Collaboration Background
- Design, Bead-Pull and high Power Test
- Summary PolariX TDS system in SwissFEL at PSI

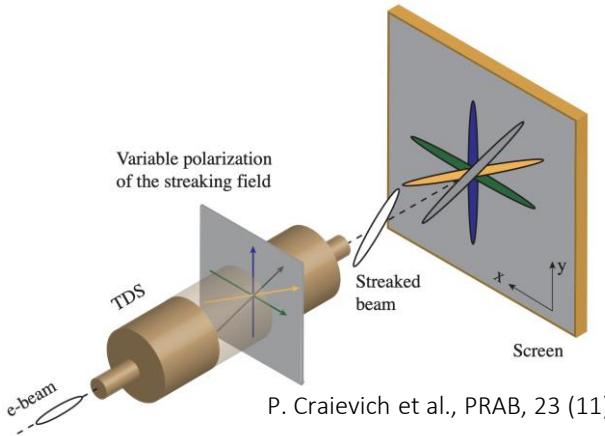
Motivation for high-resolution time-resolved diagnostics

- Diagnose both transverse and logitudinal slide proprieties for machine optmisation in e.g. FELs
- fs and sub-fs-level temporal resolution are required for optimisation of ultra-short bunches
- Diagnose multidimensional phase space of electron bunches to investigate complex beam dynamics (e. g. collective effects, beam correlations, …)
- 3D charge distibution reconstruction for novel high-gradient accelerator concepts

Tranverse Deflection Structure (TDS)

High-frequency (X-band) range

Variable polarization streaking



P. Craievich et al., PRAB, 23 (11):112001 (2021)

PolariX TDS Collaboration Background

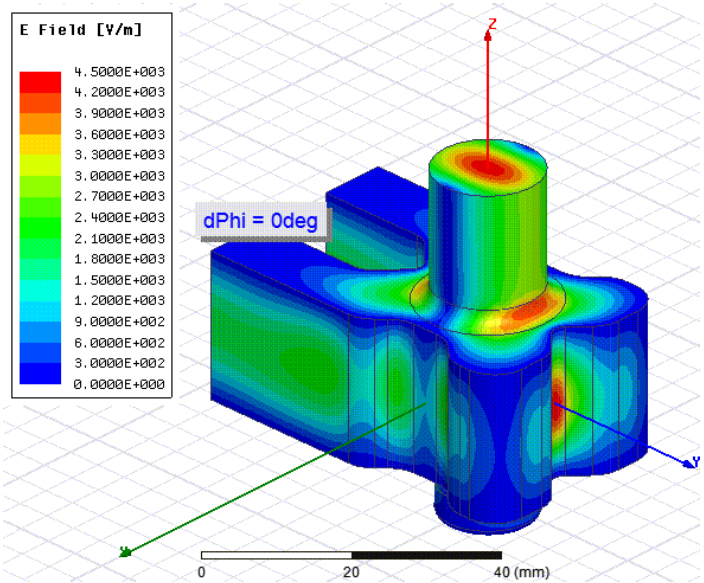
- Design of compact high-power RF components at X-band in 2016 by Alexej Grudiev [1]
- High-precision tuning-free assembly procedure developed at PSI [2, 3]
- New diagnostics requirements at four facilities:
  - FLASHForward (beamline at FLASH, DESY): fs-longitudinal diagnostics of driver/witness beams used in plasma- wakefield acceleration (PWFA) — One in operation
  - ARES-SINBAD (facility at DESY): sub-fs longitudinal characterisation of ultra-short electron bunches — Two installed
  - FLASH2 (beamline at FLASH, DESY): online longitudinal measurement with fs resolution of electron bunches for optimising FEL process and UV/soft X-ray photon-pulse reconstruction — Two in operation
  - *ATHOS (beamline at SwissFEL, PSI): online longitudinal measurement with sub-fs resolution of electron bunches for optimising FEL process and soft X-ray photon-pulse reconstruction* — Two installed

→ PolariX TDS Collaboration between CERN, PSI, DESY (2017)

[1] A. Grudiev, CLIC-Note No. 1067 (CERN, Geneva, Switzerland, 2016).
[2] U. Ellenberger, et al., 11th International Conference on Synchrotron Radiation Instrumentation 425, 072005 (2013).
[3] R. Zennaro, et al., in Proceedings of the 27th International Linear Accelerator Conference, pp. 333–335

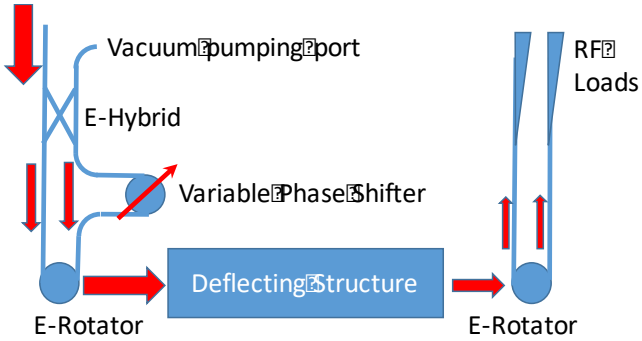
Novel Concept with Variable Polarization

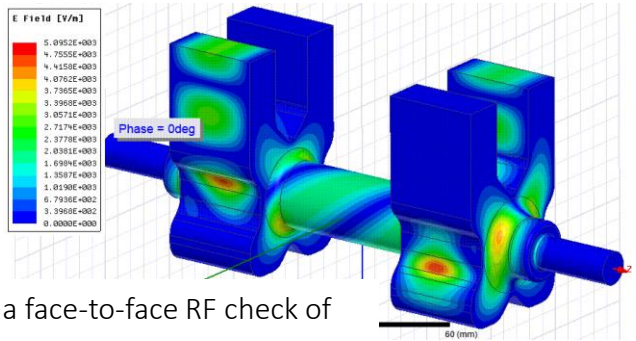
Variable polarization circular TE11 mode launcher: E-rotator



Phase difference between port 1 and port 2:

- 0 degree -> vertical polarization
- 180 degree -> horizontal polarization

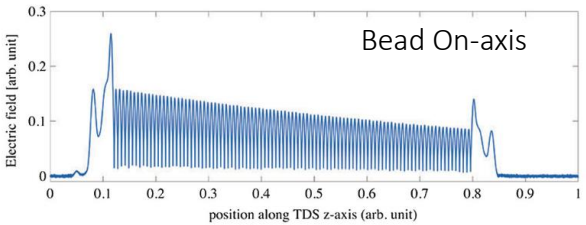


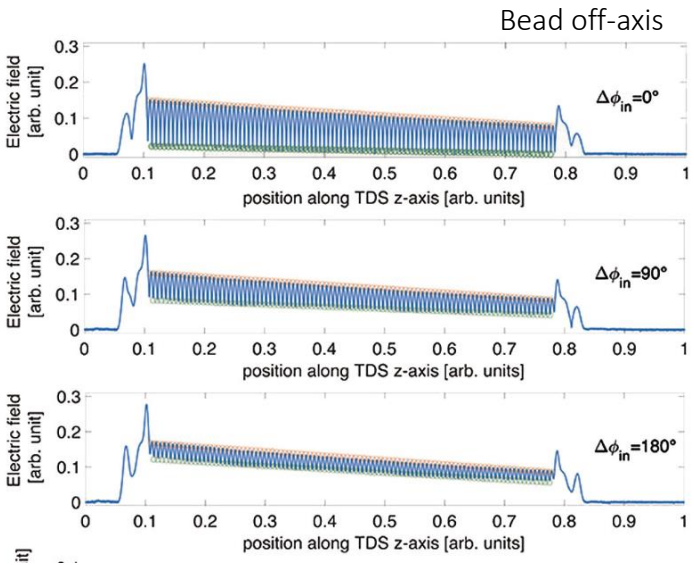


Full geometry for a face-to-face RF check of two E-rotators

A. Grudiev, CLIC-note-1067 (2016)

RF characterization at PSI – bead pull measurements

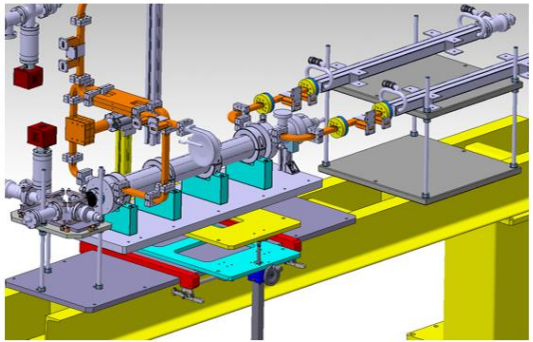


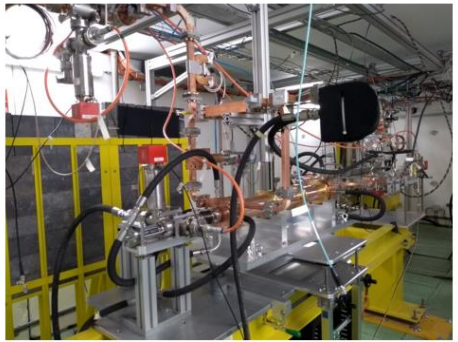


+ Marcellini and Fortunati

Excellent results of the RF measurements on the prototype and similar results for the following TDSs

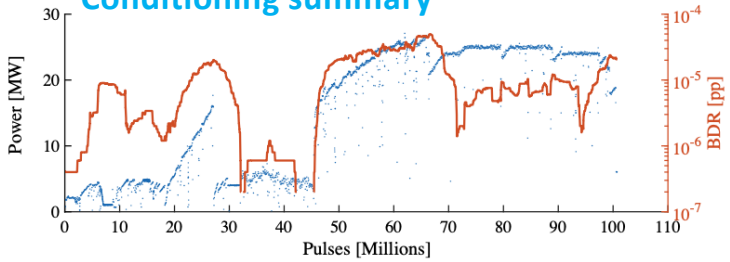
High-Power tests at CERN

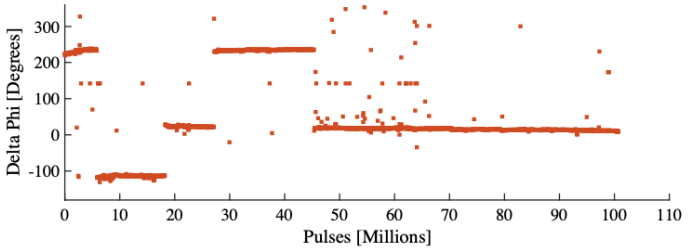




Riccardo's XBOC

Conditioning summary

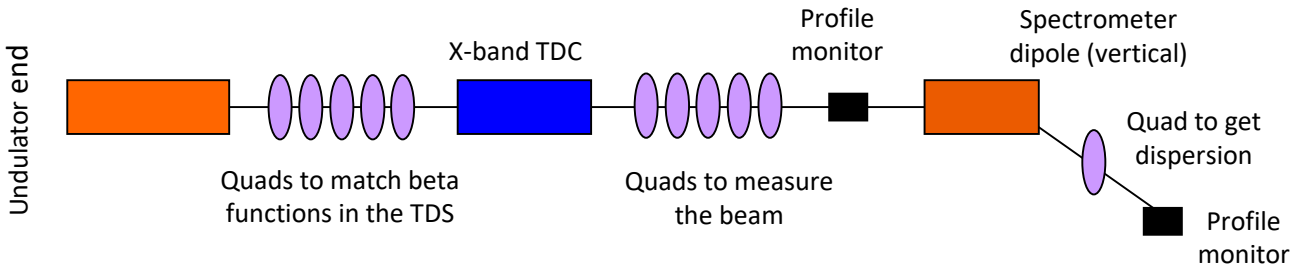




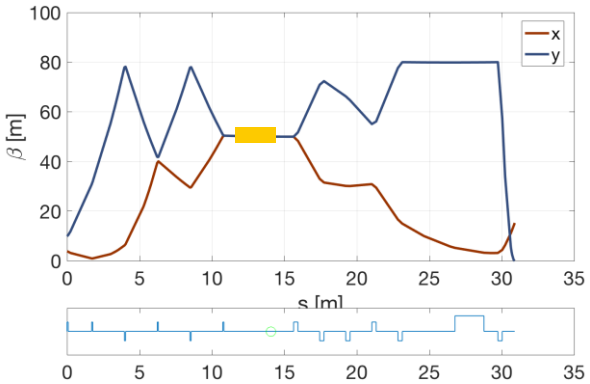
- End of February 2019, PolariX-TDS Prototype N1 has been installed in Xbox2 at CERN
- It has been conditioned up to 25 MW input power at 100ns pulse within few weeks
- End of April, 2019, High power testing has been stopped
- 1st week of May (last week), Prototype has been dismounted and made ready for shipment to DESY

PolariX TDS diagnostic beamline @3GeV

Measurement concept



$\beta_x = \beta_y = 50$ m → **optics for both polarizations**

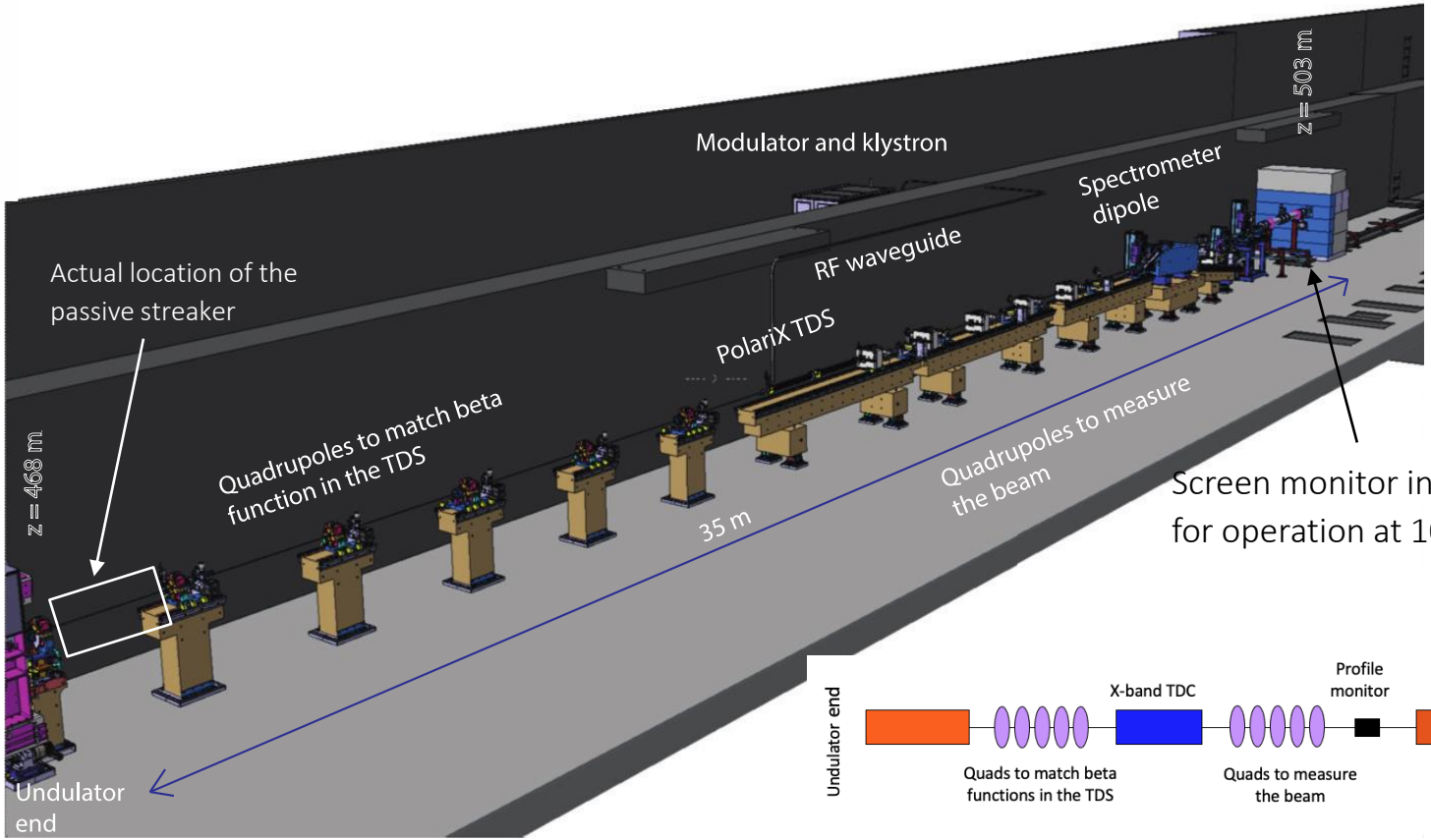


Beam measurements:

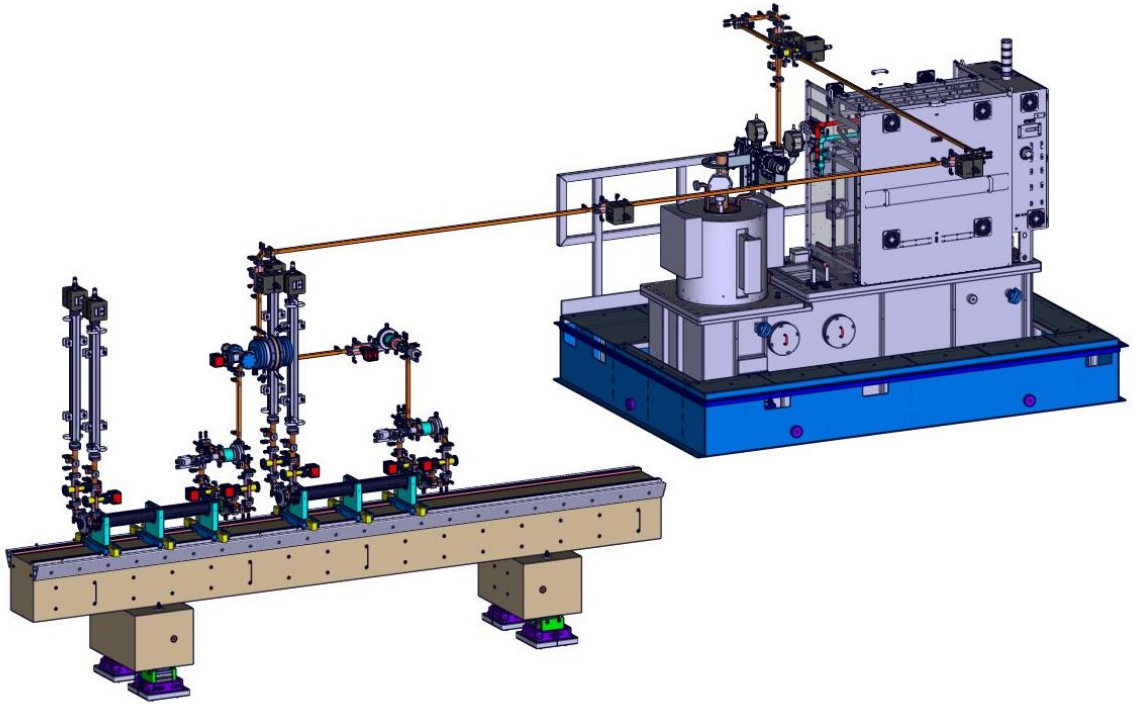
- ❑ Slice emittance on both planes
- ❑ Electron and photon pulse length with the energy spread induced by FEL

courtesy of E. Prat

Installation of the PolariX-TDS full RF system



HV modulator, klystron and waveguide network



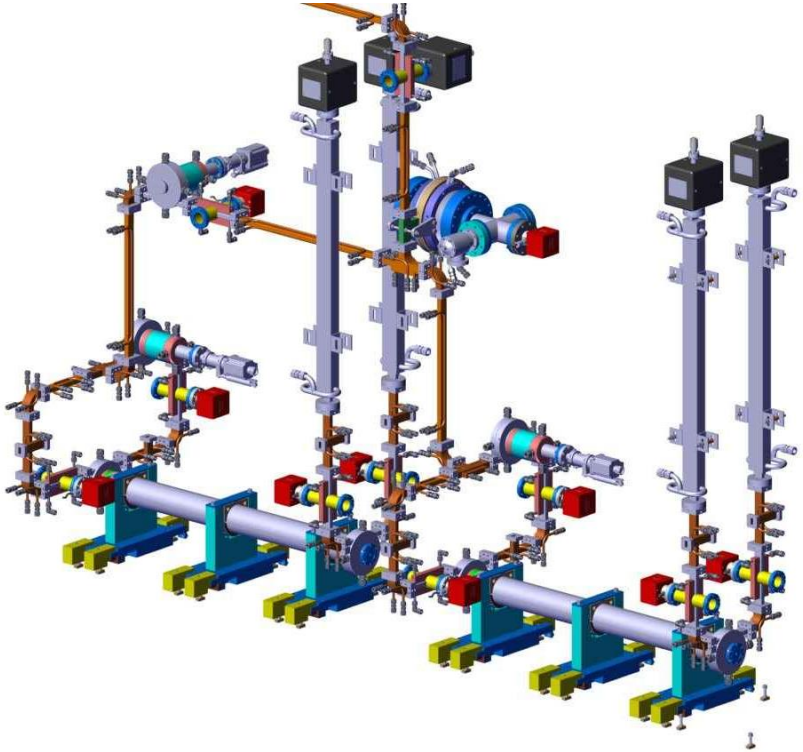
HV Modulator development:

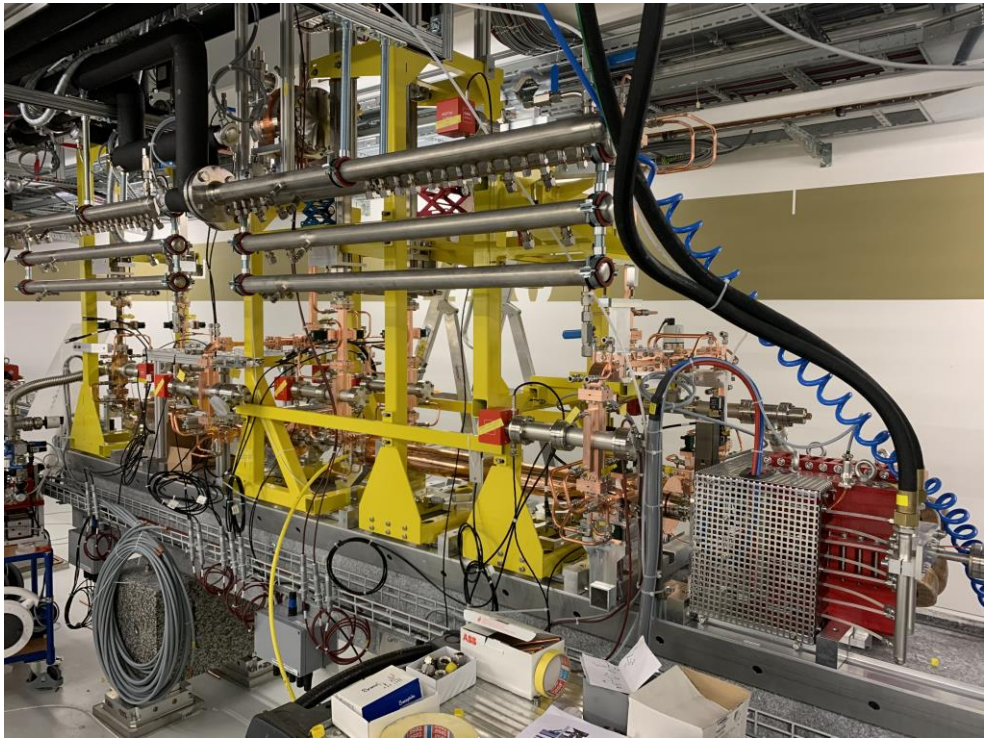
- PSI decided to build the X-Band modulator for Athos in house
- new modulator is based on the Linac 1 and 2 design (Ampegon)
- Investment for late renewal of the injector modulators (S-band and X-band)

RF structures and components:

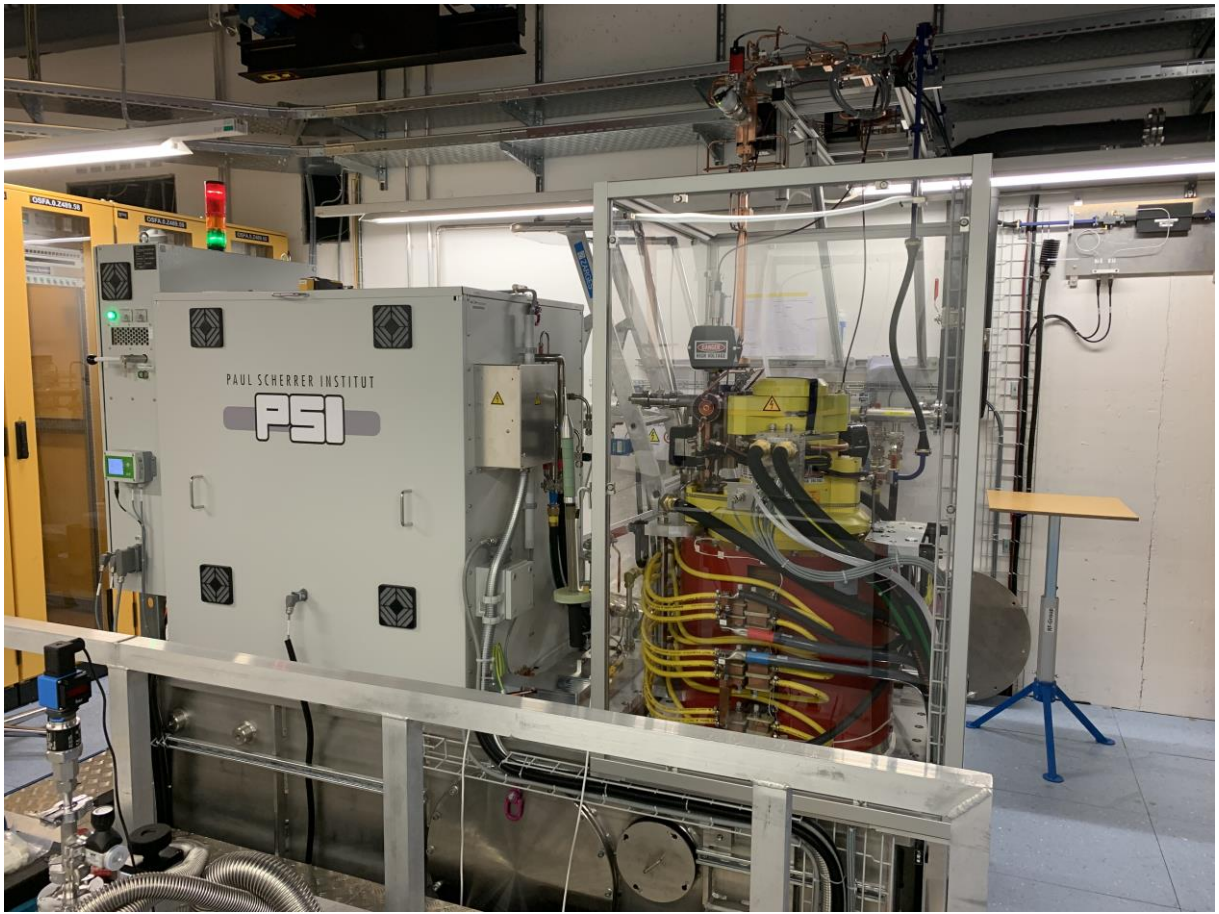
- 2 TDS are installed with the waveguide network and rf components
- RF components: design, engineering and production at PSI (we have a catalog now!)
- XBOC installed

Installation into the bunker



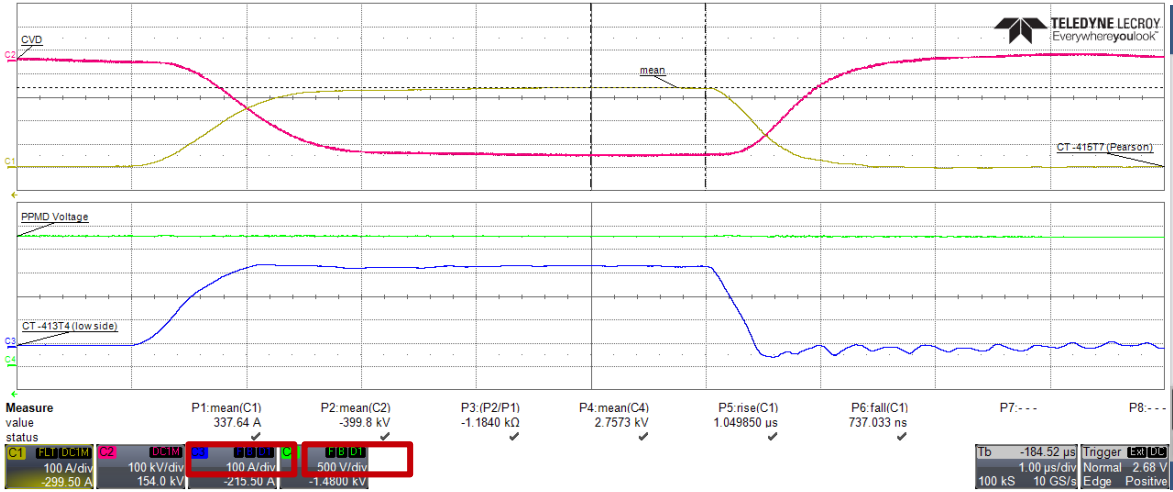


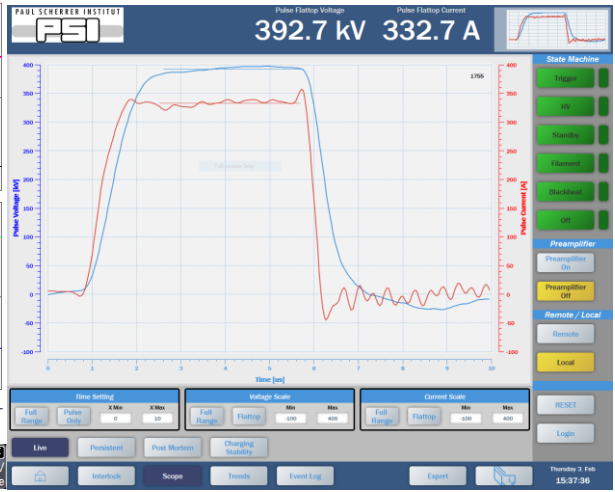
HV Klystron modulator: status



HV Klystron modulator: Commissioning status

- Achieved ~400 kV pulse voltage on the resistive load





- Now the klystron is installed and commisisoning in diode mode started this week
- In the next week we will start with the first RF.
- RF conditioning on the horizontal polarization. We need beamtime to find the right phase in the three phase shifters.

Credits and contributions

P. Craievich, J. Alex, H.-H. Braun, R. Ganter, Z. Geng, R. Kalt, T. Kleeb, T. G. Lucas, F. Marcellini, R. Menzel, M. Pedrozzi, E. Prat, S. Reiche, K. Rolli, R. Sieber, W. Tron, R. Zennaro,

Grudiev, W. L. Millar, N. Catalan-Lasheras, G. McMonagle, S. Pitman, V. del Pozo Romano, K. T. Szypula, and W. Wuensch

B. Marchetti, R. Assmann, F. Christie, B. Conrad, R. D'Arcy, M. Foese, P. Gonzalez Caminal, M. Hoffmann, M. Huening, R. Jonas, O. Krebs, S. Lederer, D. Marx, J. Osterhoff, M. Reukauff, H. Schlarb, S. Schreiber, G. Tews, M. Vogt, A. de Z. Wagner, and S. Wesch

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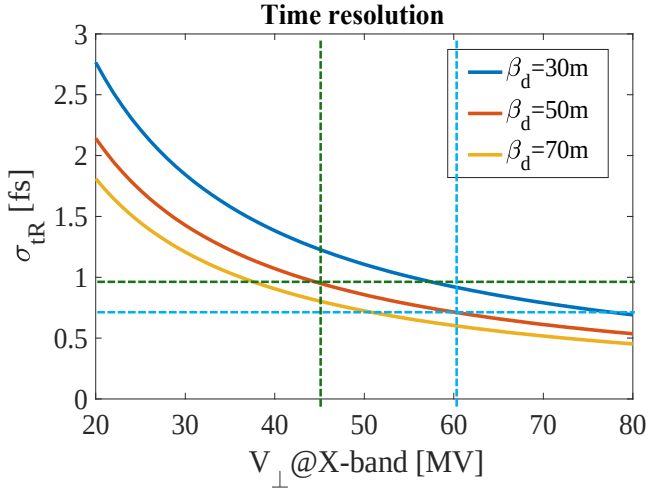
Some more slides

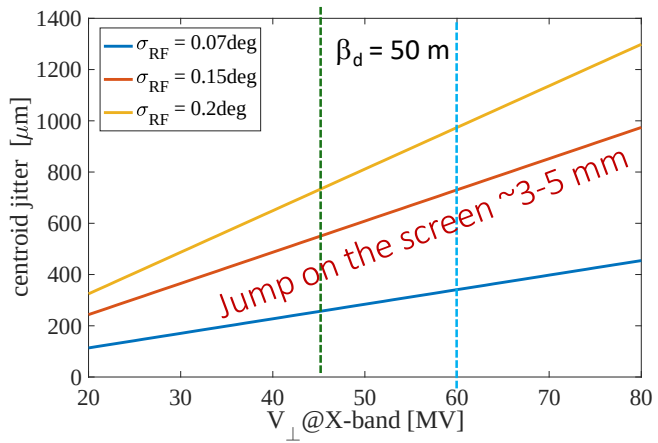
PolariX TDS – resolution in ATHOS @3GeV

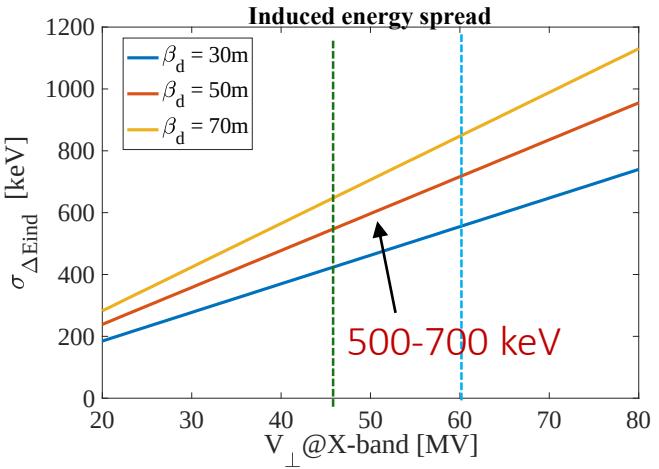


$$\sigma_{t,res} = \frac{\sqrt{\varepsilon_N} \cdot E_0 \cdot \sqrt{\gamma}}{\sqrt{\beta_y} \cdot \sin \Delta\psi_{ds} \cdot eV_\perp \cdot c \cdot k_{rf}}$$

Resolution 0.95 fs @45MV and β_d = 50 m

Resolution 0.7 fs @60MV and β_d = 50 m



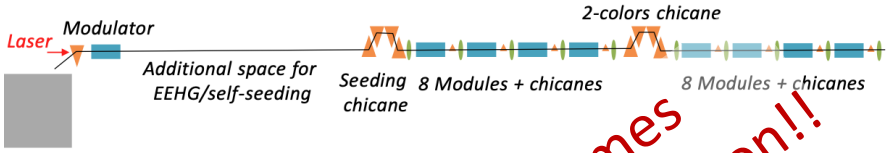


$$\sigma_{\Delta Eind} = \frac{E_0 \cdot \varepsilon_N}{c \cdot \sigma_{t,res}}$$

Requirements for the PolariX TDS

Requirements for Athos beamline

- Characterize and optimize the electron beam quality (compression, slice emittance, beam tilt, etc.)
- Time-resolved (i.e. longitudinal) information and control of these parameters
- Measure and monitor shot-to-shot FEL performance and improvement of performances looking at the FEL power profile (Athos Special Features, see Eduard's SPM talk on 24.11.2020):



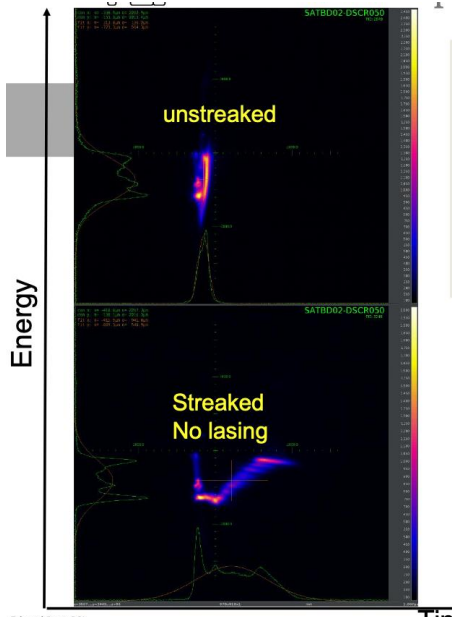
Flexible & short undulator modules
(variable polarization, transverse gradient)

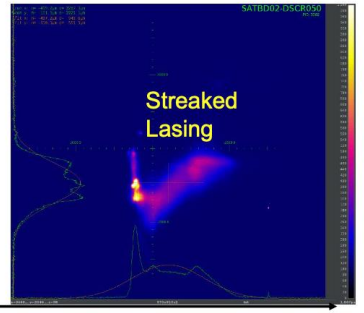
Inter-undulator chicanes

→ new operation modes to control FEL properties:

- Long. coherence and bandwidth: high-brightness SASE, large bandwidth.
- Multiple colors
- Pulse duration and power
- With external laser: slicing, phase-locked pulses, EEHG, etc.

Some of these schemes require a sub fs resolution!!





- Corrugated structure installed after the undulator
- Demonstration of streaking and time-resolved measurement of FEL profile (also in Aramis)
- Next: tool to reconstruct power profile in both Aramis and Athos