# ELBE -Center for High-Power Radiation Sources

Michael Kuntzsch for the ELBE- team





### Introduction

- ELBE-accelerator
- Recent upgrade

### **RF-Infrastructure**

- > High-Power RF
- analogue LLRF controller
- µTCA-based solution

### **Stability analysis**

- Diagnostics
- Arrival-time jitter behavior
- Beam based feedback

## **Summary and Outlook**

- Summary
- Further steps regarding µTCA-LLRF





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# **ELBE -** Center for High-Power Radiation Sources





electron beam energy / MeV	8 – 40
average beam current / μA	1600
bunch charge / pC	
- thermionic injector	100
- SRF photo injector	100 (1000)
minimal Bunch length/ ps	0.2



# thermionic DC-Gun



# **Buncher**



# superconducting RF-Gun



# superconducting accelerator modules



# **User beams at ELBE**







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# **Solid State Amplifier**





# 10kW transmitter presented at SRF Berlin October 2009

- 42U cabinet
- WR650 waveguide output on top
- water cooled power modules
- water cooled driver
- built in 24kW 28V power supply

courtesy: Hartmut Büttig, HZDR

# Start Development 1/2009; Prototype 9/2009



# **Installation at ELBE**



courtesy: Hartmut Büttig, HZDR

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Assembly of two Solid State 10kW PAs

**SRF-GUN** with one 10 kW SSPA

SIDEVIEW (PRINCIPLE)

Cabinet R106 ELBE



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# **Solid State Amplifier- Bandwidth**



### courtesy: Hartmut Büttig, HZDR

# **~ 10 times higher RF bandwidth!**Bandwidth RF power at Pin=-3dBm





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# SSPA – Bandwidth – and the result



E. Vogel: High gain proportional RF control stability at TESLA cavities, Phys. Rev. S.T.-Acc. and beams, 10,052001 (2007)







# **LLRF-Controller Modification**





- courtesy: Hartmut Büttig, A. Buechner, HZDR
  - Hardware- Redesign of the LLRF-Controller  $\succ$
  - Loop filters with notches in both loops (amplitude, phase)
  - Stable operation with modified controllers



# **Analogue Controller**



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# μTCA.4 Controller







Courtesy: C. Schmidt, DESY

- Transition to µTCA.4- based solution
- strong collaboration with DESY (MSK) and ISE
- Four test runs at ELBE since 2012 (Hardware, Software and Firmware)
- ➢ November 2015 "all-µTCA-control" of ELBE LLRF

(4x SRF-cavities, 1.3 GHz-NRF-Buncher, 260 MHz-NRF-Buncher)

Main player: Igor Rutkowski → see talk tomorrow





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# **Beam diagnostics**





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# DC-Gun vs. SRF-Gun – fast arrival jitter **ELBE**.



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# Feedback – first attempt



- proof of principle with analogue controller (feedforward-scheme)
  - suppression of 50-Hz-Line
  - reduction from 300 fs RMS to 20 fs RMS



# Feedback – future structure



- incorporating compression-, arrival-time-, beam-energy- diagnostic
- changing amplitude and phase of NRF- and SRF- cavities
- NRF-Cavities can be used for high-bandwidth stabilization (suppressing gun-jitter)



PhD-student vacancy for implementing beam-based feedbacks into μTCA

### LLRF-control at ELBE





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# **Summary**



- ELBE is running as a user facility since more than 10 years
- replacement of CW-Klystron by solid state amplifiers
- For highly time resolved experiments improvement of phase and amplitude stability needed
- Fransition from analogue to digital LLRF ongoing
- reliable operation of all 6 cavies (4 SRF and 2 NRF) during test run

in November 2015



DOOCS-Panels while operating all 6 ELBE- cavities in parallel



# Outlook



# Iong-term test of µTCA.4-system at ELBE during user run (2016) integration into ELBE- control system WinCC (using OPC-UA ???)



training of ELBE staff for μTCA.4 hardware and software!

- integration of beam based feedback systems
- integration of drift compensation module (compensating for drifts in detector path)



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# ... to the ELBE-team...

Thank you...

BREADER IS AC MARKED

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# ...and all partners.

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