Single Cavity and Piezo Controls

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Motivation

- Strong need to support high energy physics experiments and R&D programs
- Strong need for rapid setup of LLRF systems that will sense and actuate a single plant
- Strong need to use a modular and modern hardware architecture that will support a high availability, high digital and analog performance
- Strong need to use unified firmware and facility independent software
PRTM-PZDR4

More details at talk presented by M. Fenner:
“Improvements of the MicroTCA Piezo Driver DRTM-PZT4”

Also come and visit booth from our industry partner
dr. P. Jeanker from *Piezotechnics*
Software

More details at poster presented by M. Hierholzer:

“A Framework for Modern Control Applications at the Example of a Facility Independent LLRF Server”
LLRF System for CW at CMTB in DESY

Environment:
- 1.3 GHz 9-cell SRF cavities
- \( Q_L \sim 1.5 \times 10^7 \)
- Bdw. \( \sim 86 \) Hz
- CW operation up to several MV
- High voltage power source: 120 kW IOT tube
- Cavity mechanical tuner (Saclay II model)
  - Sanyo motorized stage for cavity coarse tuning
  - Physik Instrument piezo elements (\( \sim 4 \mu F \)) for cavity fine tuning

Goal:
- Stabilize RF field amplitude and phase
- Minimize microphonics effect
Microphonics Compensation Strategy

- Conventional PI control insufficient due to complicated piezo->detuning transfer function (<10Hz)
- Narrowband Active Noise Control algorithm for the dominating disturbances
  - Adaptive feed forward
  - LMS update: $w(i+1) = w(i) + \text{learning\_rate} \times \text{error} \times x(i)$
  - FPGA implementation based on the CORDIC algorithm
  - Optionally multiple frequencies compensation
  - Accurate transfer function is not required

Courtesy R. Rybaniec
Preliminary Results

> RF & Piezo feedbacks

RF & Piezo feedbacks

Piezo feedback

RF&Piezo FBs on: dA/A=0.014281%
RF&Piezo FBs off: dA/A=0.098702%

RF&Piezo FBs on: dP=0.019853 deg
RF&Piezo FBs off: dP=0.60017 deg
**LLRF System for BeRLinPro at HZB**

** Courtesy P. Echevarria **

<table>
<thead>
<tr>
<th>Basic Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>max. beam energy</td>
<td>50 MeV</td>
</tr>
<tr>
<td>max. current</td>
<td>100 mA (77 pC/bunch)</td>
</tr>
<tr>
<td>normalized emittance</td>
<td>1 μm rad (0.6 μm rad)</td>
</tr>
<tr>
<td>bunch length (straight)</td>
<td>2 ps or smaller (100 fs)</td>
</tr>
<tr>
<td>rep. rate</td>
<td>1.3 GHz</td>
</tr>
<tr>
<td>losses</td>
<td>$&lt; 10^{-5}$</td>
</tr>
</tbody>
</table>

**Schematic Diagram:**

- **LLRF** LO
- **Kly**
- **P**<sub>forward</sub>, **P**<sub>reflected</sub>, **P**<sub>transmitted</sub>
- **SRF Photoinjector**: 1.4-cell SRF cavity, $dE = 2$ MeV
- **Booster module**: 3 x 2-cell SRF cavities, $dE = 4$ MeV
- **Main LINAC**: 3 x 7-cell SRF cavities, $dE = 44$ MeV

**Key Parameters:**

- max. beam energy: 50 MeV
- max. current: 100 mA (77 pC/bunch)
- normalized emittance: 1 μm rad (0.6 μm rad)
- bunch length (straight): 2 ps or smaller (100 fs)
- rep. rate: 1.3 GHz
- losses: $< 10^{-5}$
Photoinjector Test in Gunlab

- Lab to demonstrate beam operation with electrons generated from multi-alkali photocathodes.
- One modified TTF coupler operation (currently 2 KW, up to 10 KW)
- Thermal short $\Rightarrow$ Only low fields possible
- $Q_L \approx 1.2e7 \Rightarrow f_{1/2} = 55$ Hz
- Gun 1.0 prototype cavity pre-tuned to 1.3 GHz - 400 kHz (need additional pre-tuning)
- Possible operation up to $\sim$2.1 MV/m
- Low proportional RF feedback gains possible ($<200$)
- New microphonics strategy based on Kalman filter in progress

Courtesy P. Echevarria
Preliminary Results Using Prototype Gun1.0 cavity

Gun cavity tuning with FMC-MOTDRV22

Frequency Vs. Stepper motor microsteps

\[
y = 0.28x + 1.3 \times 10^9
\]

Frequency (GHz)
Stepper motor microsteps

Open loop
Closed loop

RF feedback @ ~2.1 MV/m

Courtesy P. Echevarria
LLRF System for TARLA

- Facility is located in Ankara, Turkey
- 3-250 um FEL, usage of braking deceleration radiation and fixed target experiments – CW RF
- Additional piezo control system for microphonics suppression (double piezo stack)
- Cavities acceptance tests are planned for mid. of 2018

Integration Test at DESY Site

More details at talk presented by C. Guemues: “Design and Status of the MicroTCA.4 Based LLRF System for TARLA”

special thanks to Aleksey Sulimov
**Electro-Optical Bunch Length Spectrometer**

- **Environment:** XFEL Injector tunnel (No. of Bunches 10, Charge of 1 nC)

![Diagram of Electro-Optical Bunch Length Spectrometer](image)

- **Piezo fiber stretcher** (fine tuning)
- **Piezo motor** (coarse tuning)

![Graph of bunch resolved bunch length](image)

Courtesy by P. Peier

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Laser Cavity Coarse Tuning & Fine Tuning

> Phase noise (in-loop)

More details at talk presented by M.K. Czwalinna & B. Steffen:

“MTCA.4 Usage in Longitudinal Electron Beam Diagnostics at the European XFEL”
Thank You for Attention