Piezo Control for LFD compensation

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FLASH

RF gun
Laser 5 MeV

Diagnostics
Bunch Compressor 127 MeV

Accelerating Structures
Bunch Compressor 450 MeV

Collimator
Undulators

Bypass

FEL Diagnostics

260 m
Lorentz Force Detuning (LFD)

\[ K = 0.91 \frac{\text{Hz}}{(\text{MV/m})^2} \]

\[ K = 0.9 \frac{\text{Hz}}{(\text{MV/m})^2} \]
LFD vs gradient

![Graph showing LFD vs gradient with time in us and frequency offset in Hz for different field strengths.]

- Flat Top
- Low field
- High field

Legend:
- 37 MV/m
- 35 MV/m
- 33 MV/m
- 31 MV/m
- 30 MV/m
- 29.8 MV/m
- 26.7 MV/m
- 23.4 MV/m
- 20 MV/m
- 11 MV/m
Goals of Piezo Control System

- Drive the piezoelements assembled in fast tuners frames to minimize the Lorentz Force Detuning
- On-line frequency detuning calculation
- Microphonics measurement and compensation

PI Piezo
General Requirements of Piezo Control System for FLASH

- Dynamic Lorentz force detuning (LFD) during flat-top $\Delta \omega < 10$ Hz for field up to 30 MV/m (compensation up to 600 Hz with single pulse, up to 1 kHz with resonant excitation) providing constant offset of $\Delta \omega$ during flat top
- Piezo control must allow to tune/detune cavities in limited range instead of using step motor tuners
- Active attenuation of mechanical vibrations
- Maximum repetition rate of RF (LFD compensation) pulse 10 Hz
- Piezo control must assure piezo lifetime at least $10^{10}$ pulses (~20 years of operation), piezo must be protected and monitored (it is fragile to over current and over voltage; in particular caused by resonance in the cables)
- Possible microphonic compensation between the RF pulses (sensor/actuator mode)
Piezo tuners at FLASH

RF gun
Diagnostics
Accelerating Structures
Collimator
Undulators
Bypass
FEL Diagnostics

Laser
5 MeV
Compressor 127 MeV
Bunch Compressor 450 MeV
1000 MeV
Bunch

ACC3
ACC4
ACC5
ACC6 (double piezos)

DWN
ADC
CPU
SimconDSP
VME
DAC
ADC
Piezo Control Board

Piezo driver
Probe
Forward
DOOCS
## Piezos installed in ACC3,5,6

<table>
<thead>
<tr>
<th>Producent ratings</th>
<th>Noliac</th>
<th>PI ceramic</th>
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<tr>
<td><strong>Model:</strong></td>
<td>SCMAS/S1/A/10/10/30/200/42/60 00</td>
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<td><strong>Voltage:</strong></td>
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<td><strong>Blocking force:</strong></td>
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<td><strong>Size:</strong></td>
<td>10 mm x10 mm x 30 mm</td>
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<td><strong>Capacitance:</strong></td>
<td>6 μF</td>
<td>12 μF</td>
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### Piezos Capacitance at ACC3,5,6

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Piezodriver

- Suitable for both types of piezostacks up to 5µF:
  - Physik Instrumente (P-888.90 PIC255)
    \[ C_2 = 4.4 \mu F \]
  - NOLIAC (SCMAS/S1/A/10/10/20 /200/42/6000)
    \[ C_2 = 2.4 \mu F \]
- Maximal supply voltage up to ± 150 V (nominal operating voltage ±80V)
- Input voltage ± 1 V
- Amplifier gain \( G_u = 100V/V \),
- Operational temperature \( T_c < 75°C \) (\( T_j < 125 °C \))
- Pass-band frequency up to 5 kHz (for load 5µF)
- Monitoring of output voltage and current
- Single channel PZD with Apex PB51
- 8 channels on single board (Eurocard form factor)
- Up to 4 periods of sinus wave 80V, 200 Hz in 5µF load, 10 Hz repetition rate (thermal limit)
Piezo Control System at FLASH
ACC6 (SP = 20 MV/m, rep = 5 Hz)
ACC6 (SP = 20 MV/m, rep = 5 Hz)
ACC6 (SP = 20 MV/m, rep = 5 Hz)

Piezo off

Piezo on
Reduction of reflected power

![Graph showing the reduction of reflected power over time. The graph indicates three distinct power levels: ~3.9 kW, ~5.5 kW, and ~5 kW, marked at specific time points. The power is plotted on a logarithmic scale against time. Red and blue piezo states are also indicated.]
Piezo Driving Pulse

Piezo drive

RF pulse (probe)

time position vs RF

flat-top

detuning

offset

slope

amplitude
Piezo Control Panel
Microphonics

- Due to limited speed of acoustic wave propagation through the cavity it is not possible to react within the RF pulse for variable microphonics.
- Microphonics must be measured in advance (before RF pulse - either second piezo used as a sensor of some RF must be present before the pulse) and compensated as soon as possible.

![Graph showing Pulse amplitude vs time before RF with Δω = 300Hz]
Piezo sensors in ACC6

Without piezo drive

With piezo drive
Piezo operation influence on SASE level
ATCA integration

• Advantages:
  – No need for separate piezo crate (place, crate, power supply etc.)
  – The control link through the backplane

• Bigger form factor than Eurocard (2.5 more space) allows to integrate in the single board 16 channel piezo driver together with DACs and ADCs, probably it is also possible to put DC/DC converter (48V -> ±100V) in the board

• Special care for piezo connectors (high voltage, backside connection through customized RTM)
Conclusion

- Fast tuners with piezos are installed at FLASH and are operable.
- Piezo control system was developed and implemented. It is able to control piezos in 4 modules (32 cavities) simultaneously.
- Commissioning of the piezo control system is in progress and will be continued after shutdown.
- The integration of piezo control in ATCA looks possible and promising.
Thank you for your attention