Piezo Control
at ACC1, ACC3, ACC5-7

Mariusz Grecki for LLRF collaboration
Agenda

- Lorentz Force Detuning (LFD) and it's compensation by piezo
- Upgrade of FLASH and piezo control system in 2009/2010
- Piezo control
- Experience at FLASH
- Conclusion
LFD vs Gradient

![Graph showing the comparison between Low-field (LFD) and Gradient fields over time. The graph indicates a FLAT TOP period and highlights the differences in behavior at various electric field strengths.]
RF Power Excess due to LFD

\[ \phi_b = -3 \gamma \]
\[ I_{b0} = 8 \, \text{mA} \]
\[ E_{acc} = 25 \, \text{MV/m} \]
\[ Q_L = 3 \cdot 10^6 \]

![Graph showing klystron power per cavity vs. detuning]
Goal of Piezo Control system

- Drive the piezoelements assembled in fast tuners frames to minimize the Lorentz force and microphonics effects
- On-line frequency detuning calculation
- Microphonics measurement

Dimensions: 10x10x30mm
Manufacturer: NOLIAC

Dimensions: 10x10x36mm
Manufacturer: PI
## Piezos Installed in ACC1,3,5,6,7

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Noliac</th>
<th>PI ceramic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producent ratings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model:</td>
<td>SCMAS/S1/A/10/10/30/200/42/6000</td>
<td>P-888.90</td>
</tr>
<tr>
<td>Cells:</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Voltage:</td>
<td>&lt; 200 V</td>
<td>&lt; 120 V</td>
</tr>
<tr>
<td>Blocking force:</td>
<td>6 kN</td>
<td>3 kN</td>
</tr>
<tr>
<td>Size:</td>
<td>10 mm x10 mm x 30 mm</td>
<td>10 mm x10 mm x 35 mm</td>
</tr>
<tr>
<td>Capacitance:</td>
<td>6 μF</td>
<td>12 μF</td>
</tr>
</tbody>
</table>
Piezo tuners at FLASH
Piezo Control at ACC3,5,6,7
Piezo Control

- Piezo drive
- RF pulse (probe)
- offset
- slope
- flat-top
- time position vs RF
- detuning

Amplitude vs time position graph with labeled axes and key points.
Transfer function (ACC5 cav. 8)
Piezo Control Panel

System ON/OFF

Piezo Timing

Detn State

Freq[Hz] No. Pulses Delay[ms] Amp[V] OFF SEL[1V]

Detn / PZS Cav1: 250 + 1 ± 0.00 ± 11.00 ± 13.00
DetnC1 PzC1 Cav2: 200 + 1 ± 0.30 ± 8.00 ± 34.00
DetnC2 PzC2 Cav3: 200 + 1 ± 0.00 ± 13.00 ± 35.00
DetnC3 PzC3 Cav4: 200 + 1 ± 0.00 ± 10.00 ± 56.00
DetnC4 PzC4 Cav5: 230 + 1 ± 0.00 ± 12.00 ± 69.00
DetnC5 PzC5 Cav6: 220 + 1 ± 0.00 ± 17.00 ± 27.00
DetnC6 PzC6 Cav7: 200 + 1 ± 0.00 ± 8.00 ± 63.00
DetnC7 PzC7 Cav8: 200 + 1 ± 0.00 ± 17.00 ± 70.00
DetnC8 PzC8

Fill line [m]

Latte line

Calc on/off

Caverry DETONING [V]

Lorentz force detuning

FLASH Seminar, 26.10.2010

M. Grecki
Automatic control algorithm

\[ \Delta \omega = -\frac{1}{2 \cdot \pi} \left( \frac{d\phi_{\text{probe}}}{dt} - 2 \cdot \omega_{1/2} \cdot \frac{|U_{\text{forward}}|}{U_{\text{probe}}} \right) \cdot \sin \left( \phi_{\text{forward}} - \phi_{\text{probe}} \right) \]

- Detuning computation \( \Delta \omega(t) \)
- Correction \( k_p \cdot \{\omega_1(t) - \omega_2(t)\} \)
- Driving signal update \( u(t) = u(t-1) \pm \text{correction} \)

- a) \( u(t) = u(t-1) + \text{corr.} \)
- b) \( u(t) = u(t-1) \)
- c) \( u(t) = u(t-1) - \text{corr.} \)
ACC6 (SP = 20 MV/m, rep = 5 Hz)
ACC6 (SP = 20 MV/m, rep = 5 Hz)
LFD during 9mA tests

ACC3 - Lorentz Force detuning compensation

pre-detuning [Hz]

cavity number

1  2  3  4  5  6  7  8

10  1  7  10  10  21  6  5

piezo off
piezo on
ACC3 cav. 4 (no beam)
ACC1 cav.1 (with beam)
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.

![Pulse amplitude vs time before RF](image)
Piezo operation influence on SASE level
Cavity vibrations

Detuning without and with LFD compensation by piezo

Piezo sensor - only RF

RF plus LFD compensation by piezo

RF plus LFD compensation by piezo plus active attenuation
Active vibration attenuation (ACC7C5)
Conclusion

● LFD has negative influence on cavity operation but can be compensated with fast piezo tuners.

● Fast tuners with piezos are installed at FLASH (ACC1,3,5,6,7) and are operable. ACC1 control needs a special fibre connection due to overloaded CPU in ACC1 crate.

● Piezo control system was developed, implemented and installed. The implemented functionality was tested and works well.

● There is a lack of automation. The experts are needed to operate piezos.

● The influence of piezo operation on SASE is still not clear. More experiments needed.
Thank you for your attention