LLRF Developments for CW Control of SRF Cavities

at Cryo-Module Test Bench@DESY

Radosław Rybaniec (DESY/ISE WUT)
on behalf of the DESY MSK LLRF Team

2. Annual Matter and Technologies Meeting
Karlsruhe, 8-10.03.2016

HELMHOLTZ
ASSOCIATION

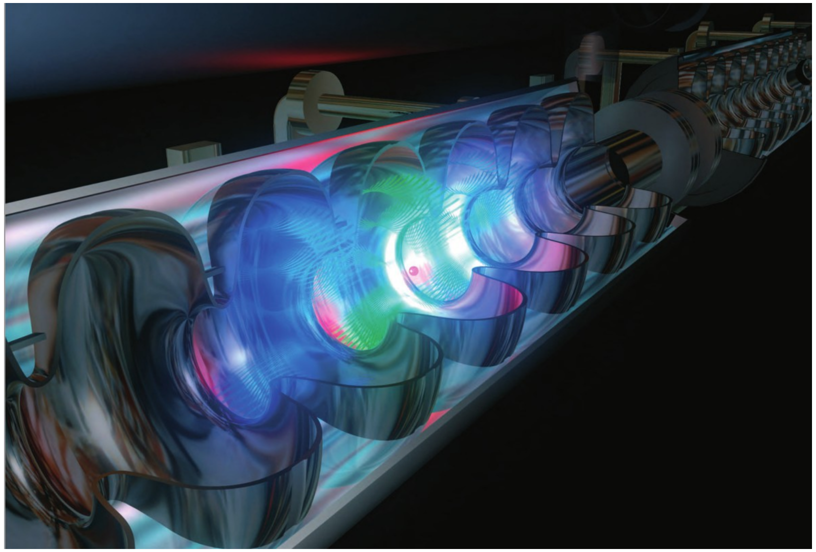
ise

DMCS

DESY

Table of contents

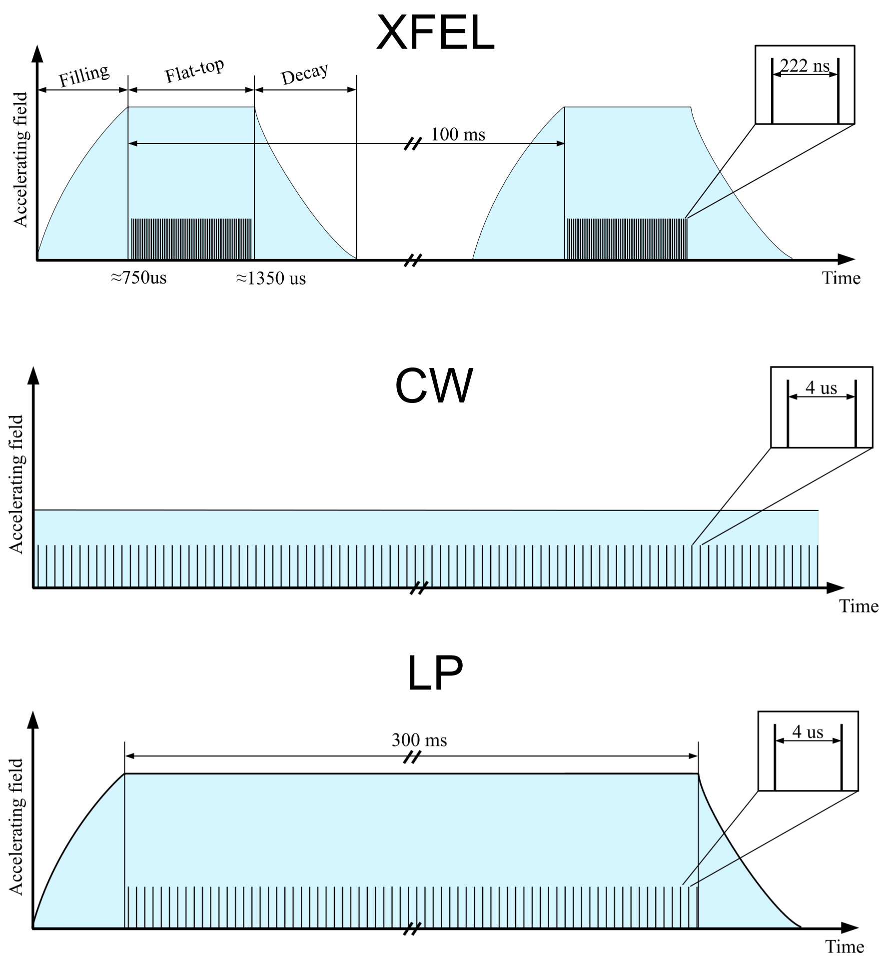
- Motivation
- CW tests at CMTB
- CW/LP control issues
- Microphonics control
- Results
- Future plans



HELMHOLTZ
ASSOCIATION

Motivation

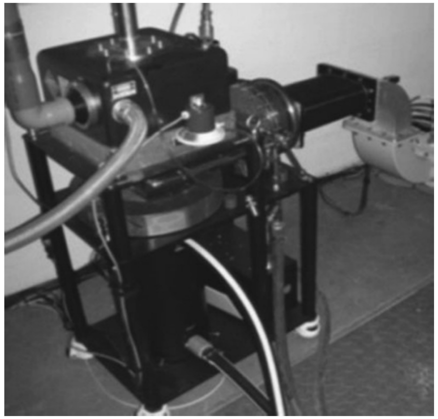
- CW XFEL upgrade
- RF field profile put constrains on beam patterns
- Continuous Wave and Long Pulse (quasi-CW) modes
  - XFEL bunch repetition. freq. 4.5 MHz
  - CW/LP bunch repetition freq. 250 kHz
- Higher number of bunches can be delivered
  - slow detectors
- 17.5 GeV → 7.8 GeV @CW, 10 GeV @LP



XFEL CW upgrade

> Required XFEL modifications

- higher QL=2e7
- cryo-plant upgrade (ca. 5kW@1.8K)
- new RF power source (IOT)
- CW capable electron gun
- LLRF upgrade

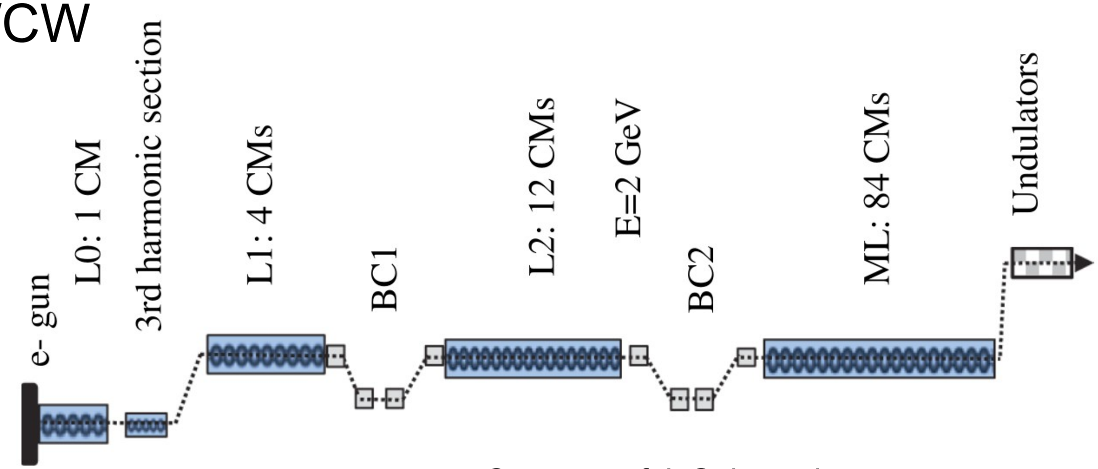


Courtesy of J. Sekutowicz

> Easily switch between SP/LP/CW modes

> Control Issues

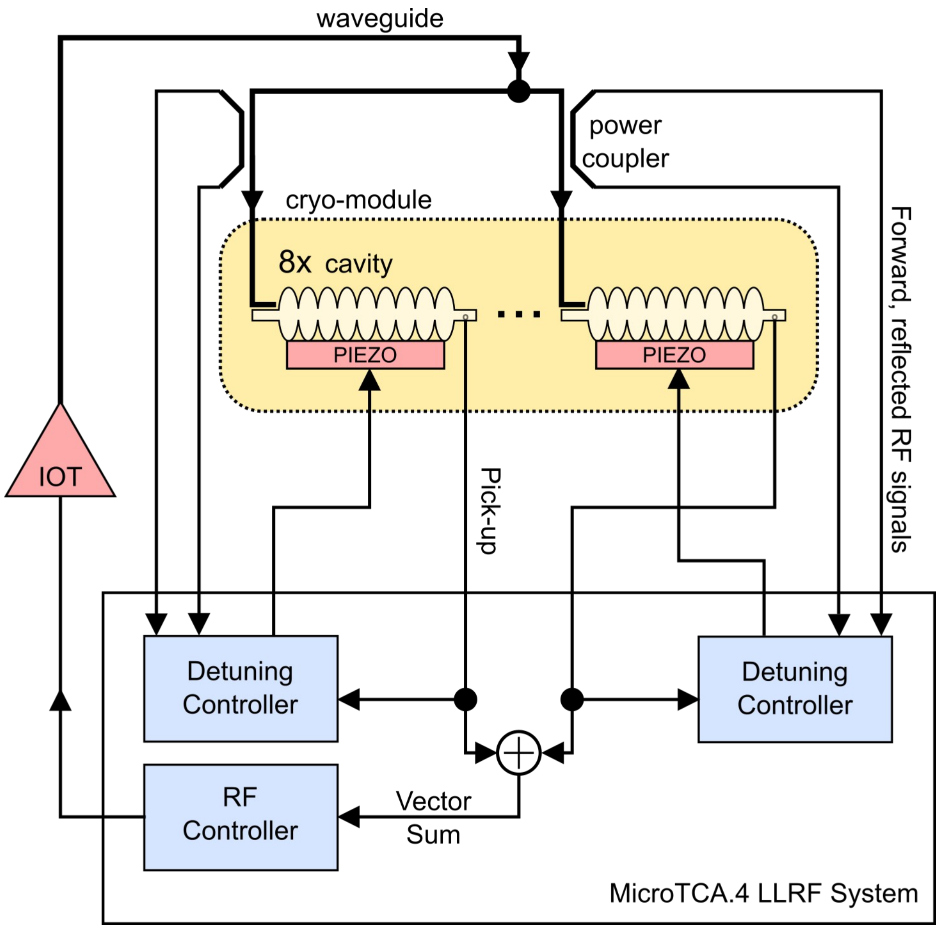
- higher QL
  - microphonics
  - Lorentz Force detuning
- IOT control
  - nonlinearities
  - transients during filling



Courtesy of J. Sekutowicz

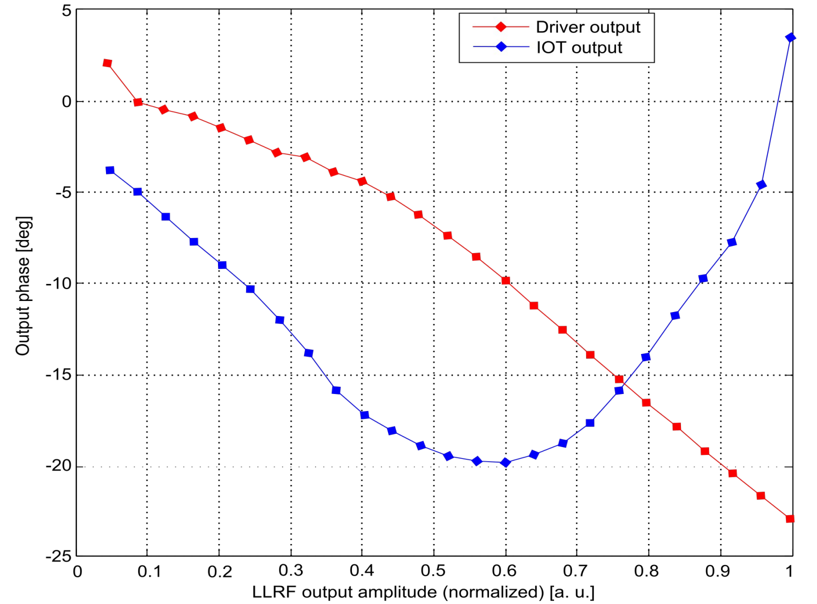
CW/LP tests at Cryo-Module Test Bench (CMTB)

- **Cryo-Module Test Bench**
  - single superconducting module
  - 8 TESLA cavities 1.3 GHz
- **MicroTCA.4 LLRF system**
  - Vector Sum control
  - piezo tuning of individual cavities
- **IOT RF source**
  - prototype produced by CPI (105kW)
- **Parallel single cavity system**
  - out of loop measurements
  - single-cavity development

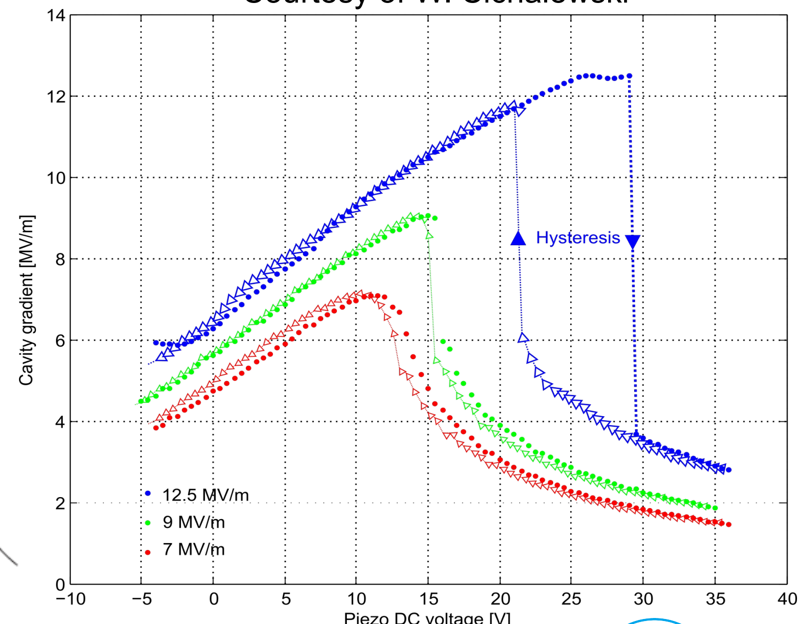


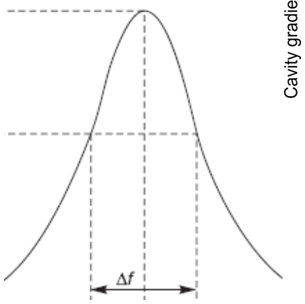
CW/LP control issues

- Observation time
- IOT control
  - non linearity
  - transients during pulse filling
- QL=2e7 → 65 Hz bandwidth
- Lorentz Force Detuning
  - excitation of mechanical modes
  - resonance curve deformation
- Microphonics
  - detuning of caused by mechanical interferences



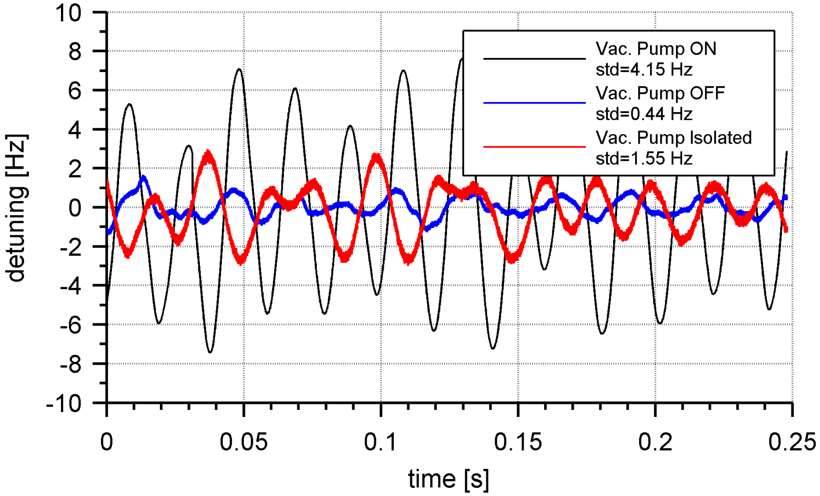
Courtesy of W. Cichalewski

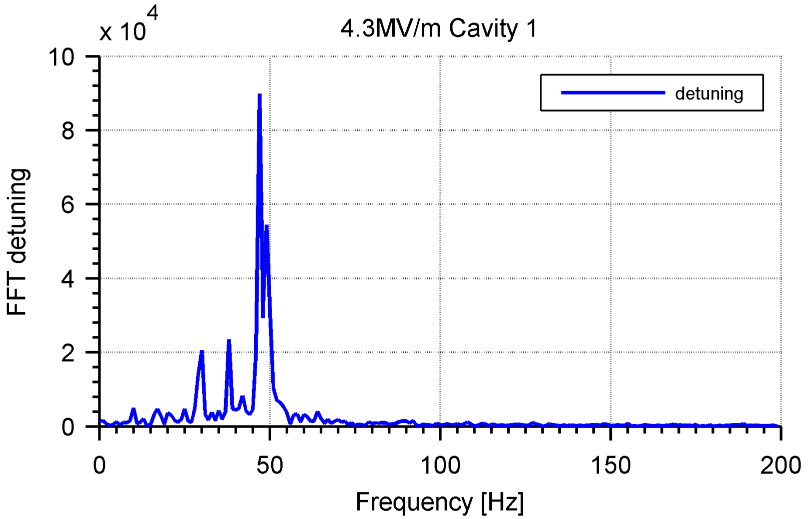




Microphonics

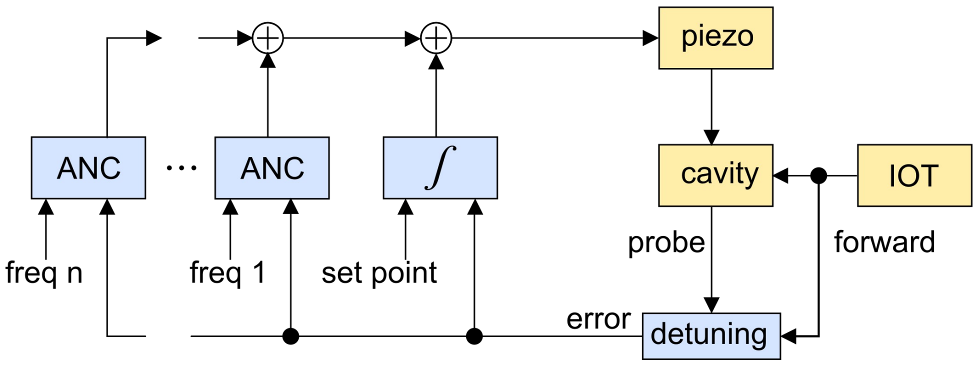
- Sources of microphonics
  - helium pressure change
  - vacuum pumps
  - other external sources
- Additional RF power needed to stabilize accelerating gradient
- Compensation
  - Passive vibration isolation methods
  - Piezo tuners
- RF signals can be used as a source of information

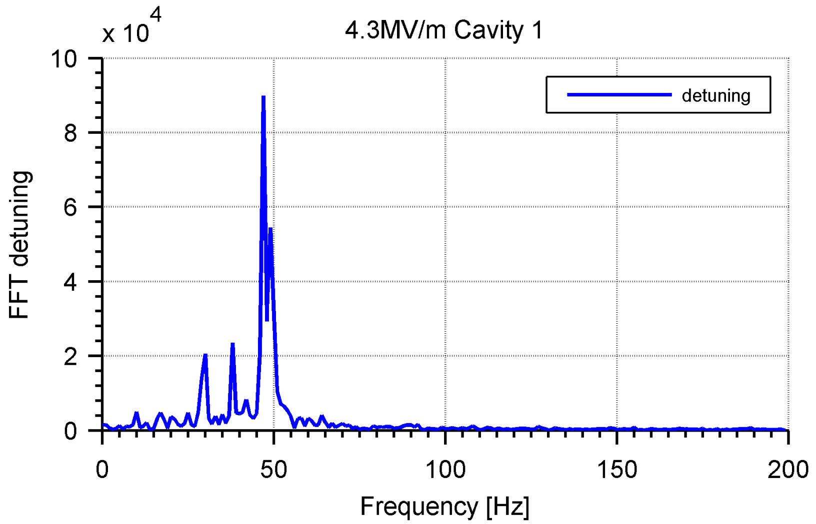


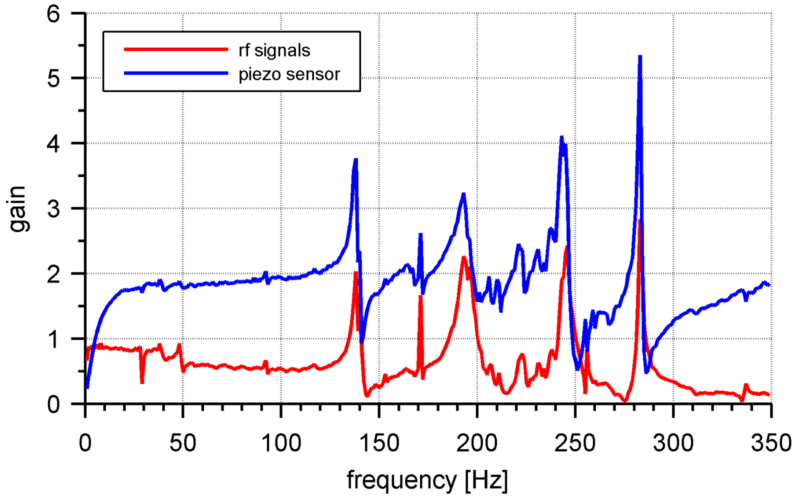


Microphonics compensation

- Microphonics around tens of Hz
  - ~49Hz peak
- Classic Proportional-Integral feedback insufficient
  - highly resonant transfer function
  - Active Noise Canceler algorithms developed



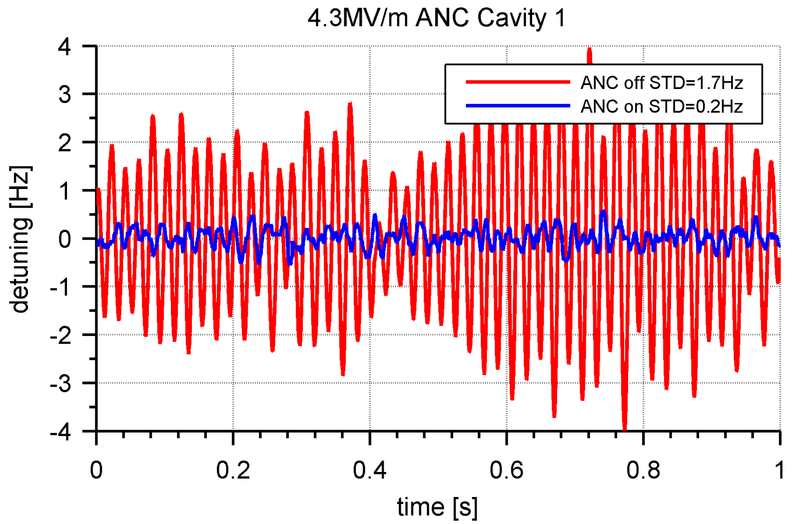


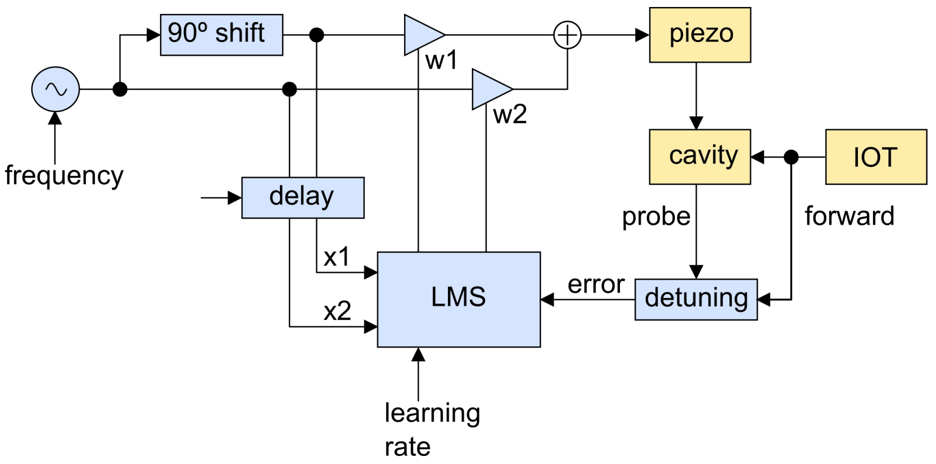


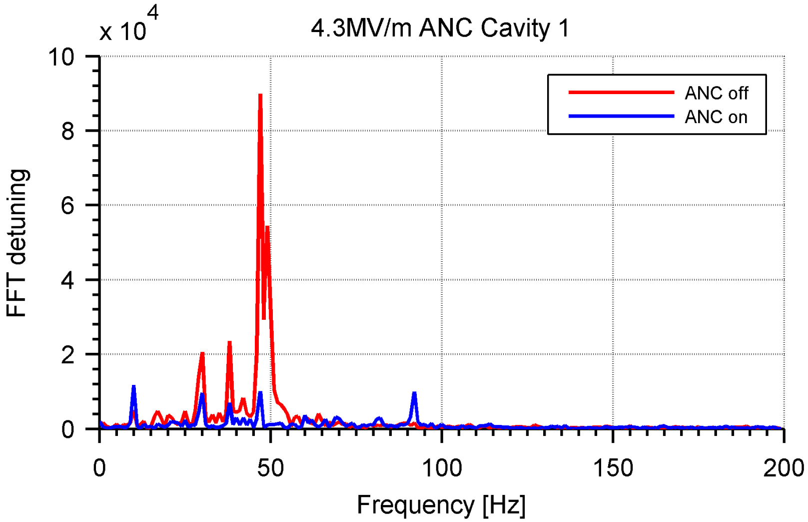
Active Noise Canceler

Active Noise Canceler

- adaptive algorithm
- Least Mean Squares
- implemented in the FPGA
- piezo→ detuning transfer function is not required

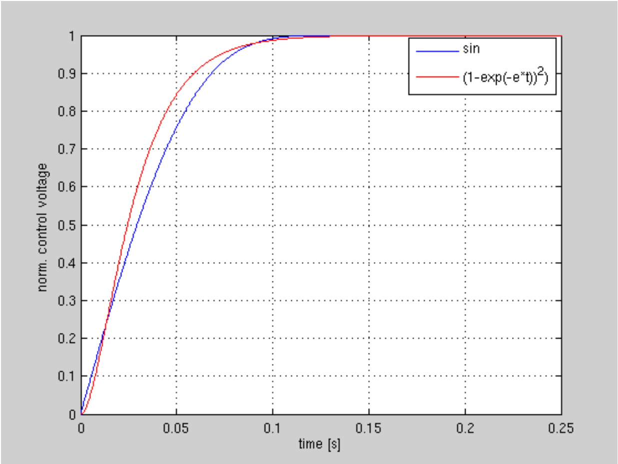




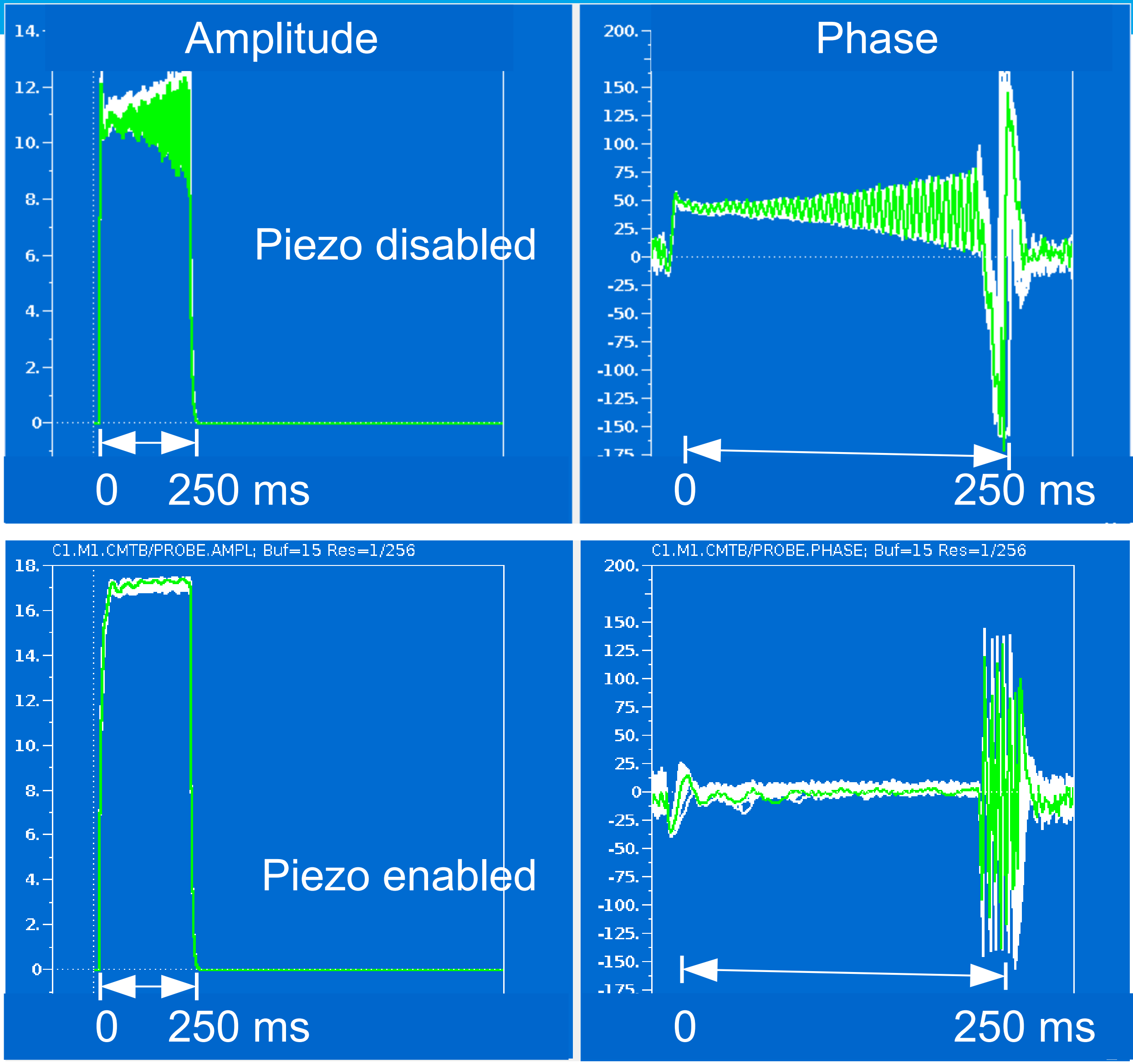


Lorentz force detuning during LP

- Lorentz force detuning in LP operation
- Precompensation signal for piezo actuators
  - iterative learning methods

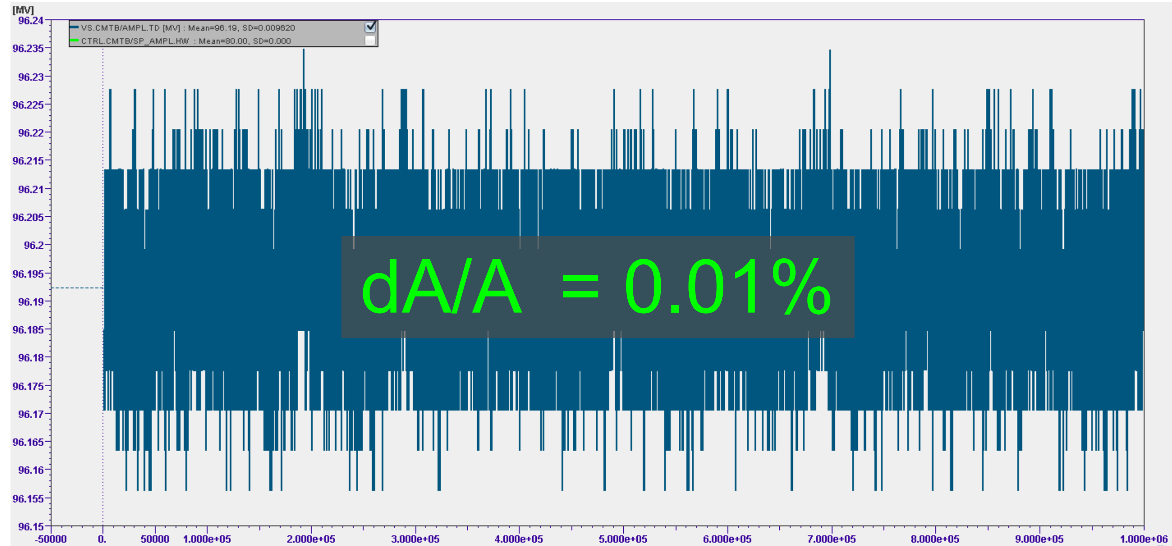


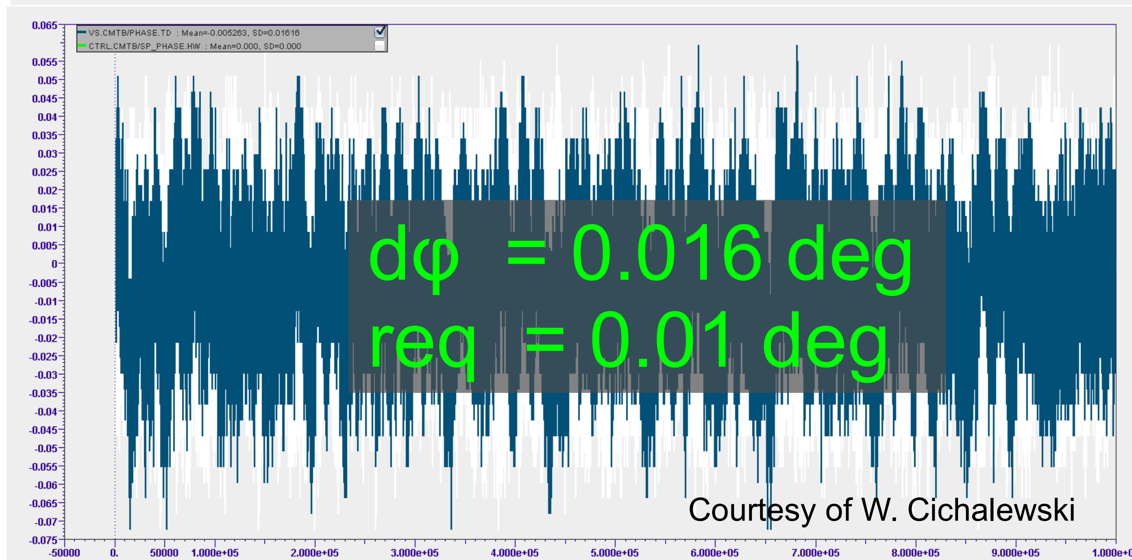
Piezo signal profile



RF + Piezo controller results

- CW XFEL requirements almost met
  - amplitude stability already met
  - phase stability almost as required
- IOT linearization algorithms
- MIMO RF controller





Future plans

- Improve RF feedback
  - MIMO controller
  - IOT linearization
- Long pulse operation
  - apply ANC methods
  - iterative learning LFD compensation
- High Level Software update
  - automation
- Share the knowledge with different facilities
  - bERLinPro, TARLA, ELBE, FLASH CW
- Thank you for attention!