FLASH.
Free-Electron Laser FLASH

European XFEL

HOM-based Diagnostics in SC Accelerating Cavities at FLASH and the European XFEL

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DESY

on behalf of the international HOM-team

TTC Meeting, Japan, 26-29 June 2018

HELMHOLTZ GEMEINSCHAFT

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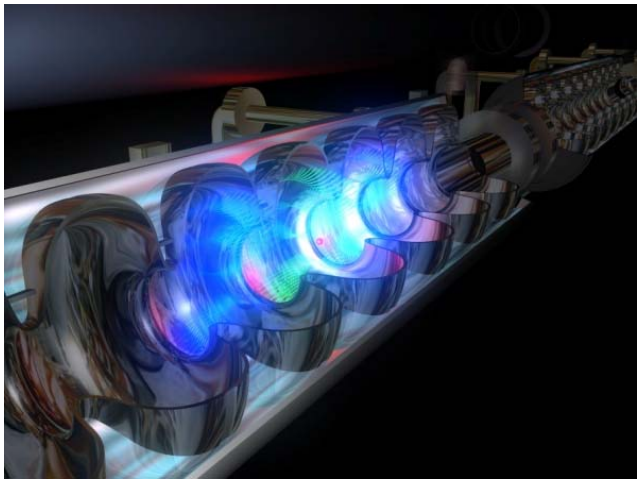
Outline

> Motivation

> HOM-BPM

(HOM-based Beam Position Monitoring)

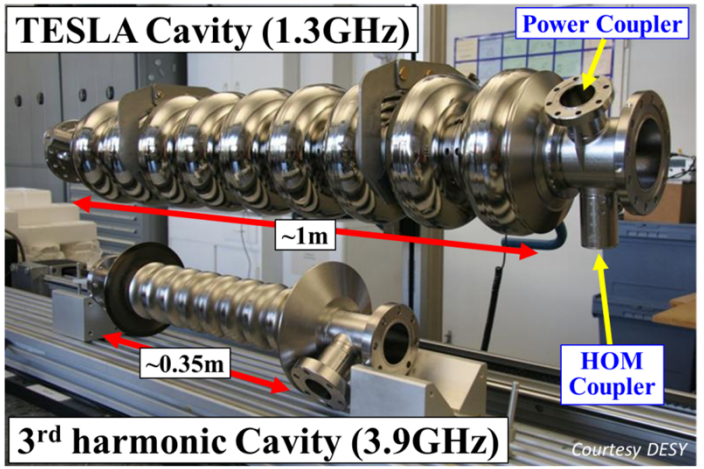
- Beam alignment
- Beam position measurement in 1.3 and 3.9 GHz cavities
- Cavity alignment measurement



> HOM-BPhM

(HOM-based Beam Phase Monitoring)

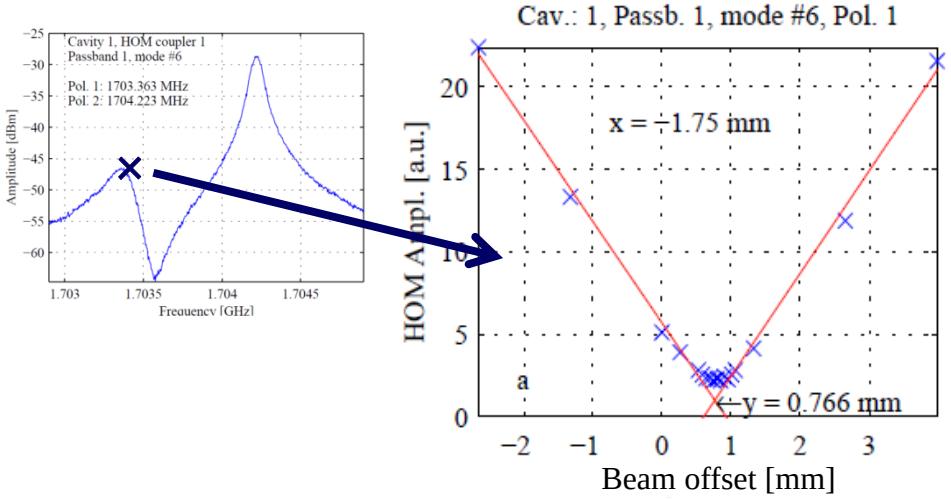
> Summary

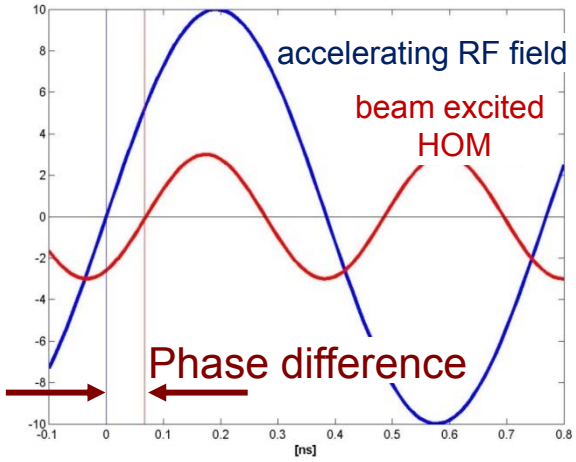


Motivation: Beam Diagnostics with HOMs

> HOMs carry information about the beam properties
⇒ they can be used to monitor the beam

- The strength of the excited dipole modes depends linearly on the beam charge and transverse position: $q \cdot r \cdot (R/Q)$
- The timing of excited modes depend on beam arrival time (beam phase)





Motivation: Benefits of HOM-based Diagnostics

> HOM-BPM (HOM-based Beam Position Monitoring)

- Enable the alignment of the beam based on the signals which can damage beam quality, therefore reduce the wakefield effects
- Measure the transverse beam position
- Measure the transverse cavity alignment in the cryo-module

> HOM-BPhM (HOM-based Beam Phase Monitoring)

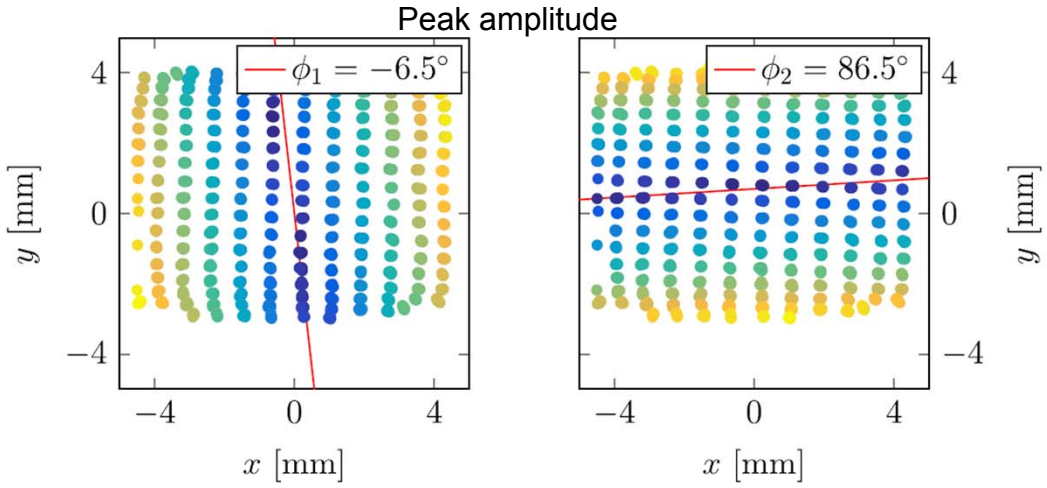
- Direct, on-line measurement of beam phase wrt accelerating field phase

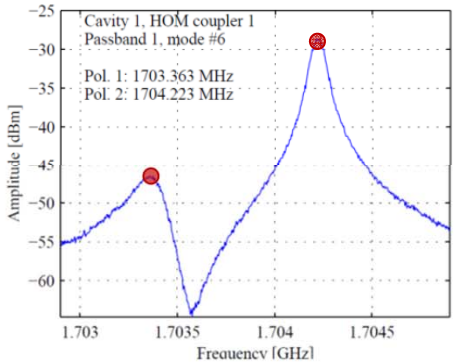
> Does not require additional vacuum component, therefore relatively cheap

HOM-BPM: Dipole Modes

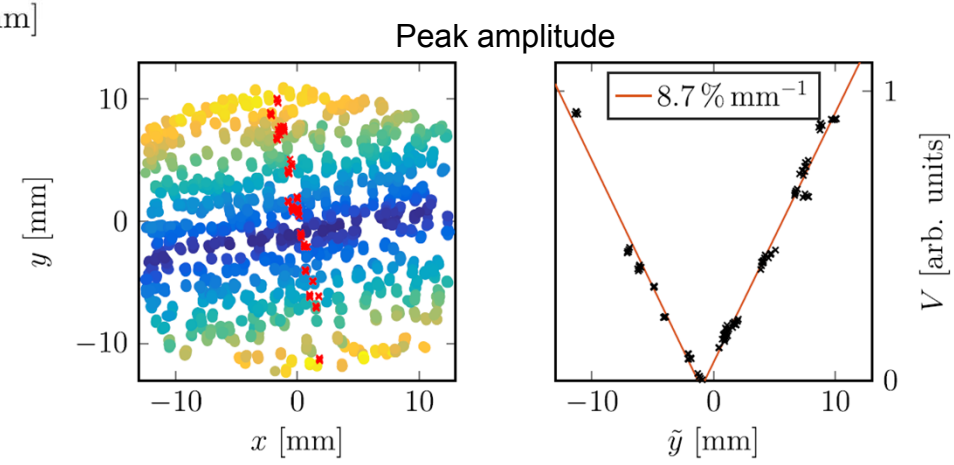
> HOM amplitude vs. (x,y) (example)

- Rotated polarizations (different for each cavity)





Often signal from one polarization dominates signal from one HOM coupler

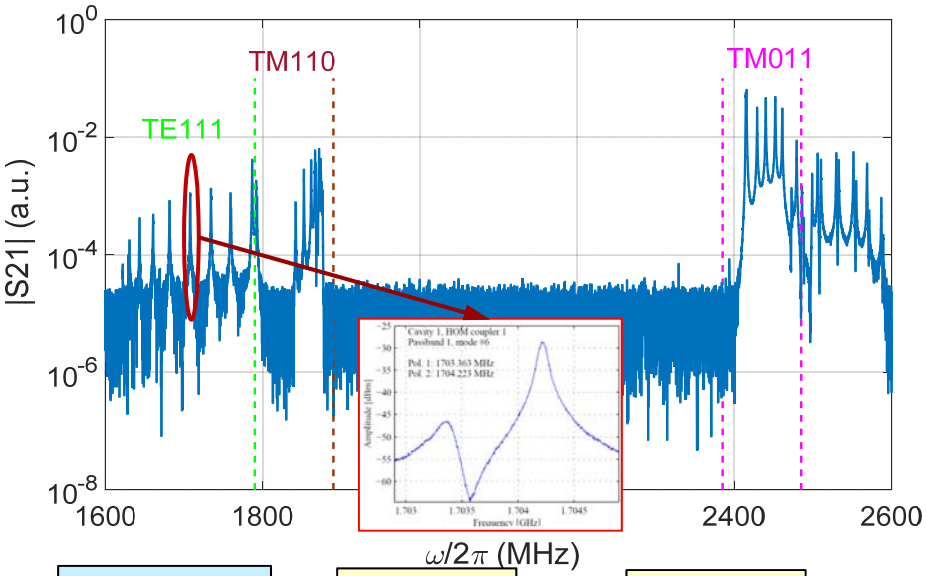


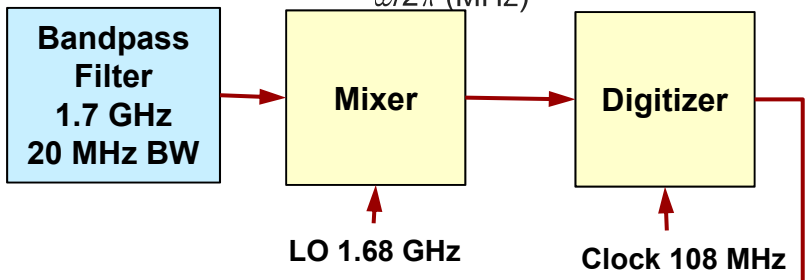
- Linear dependence on beam offset (and charge)

HOM-BPM: 1.3 GHz Cavities

- HOMBPM-electronics installed in FLASH
  - Use 1 dipole mode at 1.7 GHz, which has higher R/Q
  - Used as operator tool for beam alignment (ACC1-5)
  - Used for measurement of cavity alignment

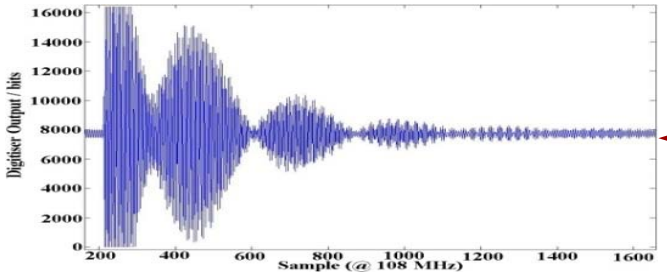
Joe Frisch, SLAC





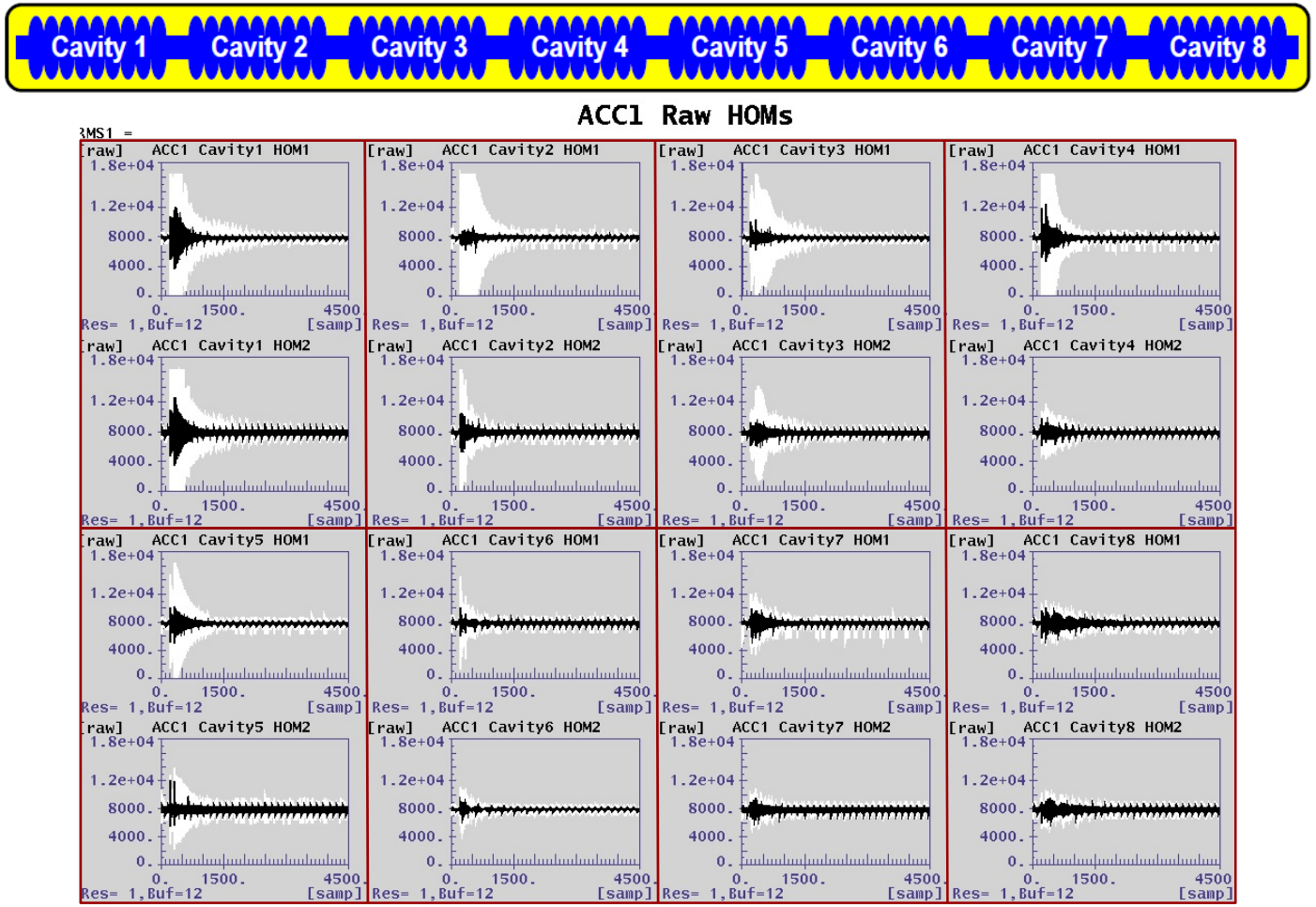
- Electronics under development for the E-XFEL

Jablonski, Szymon, DESY

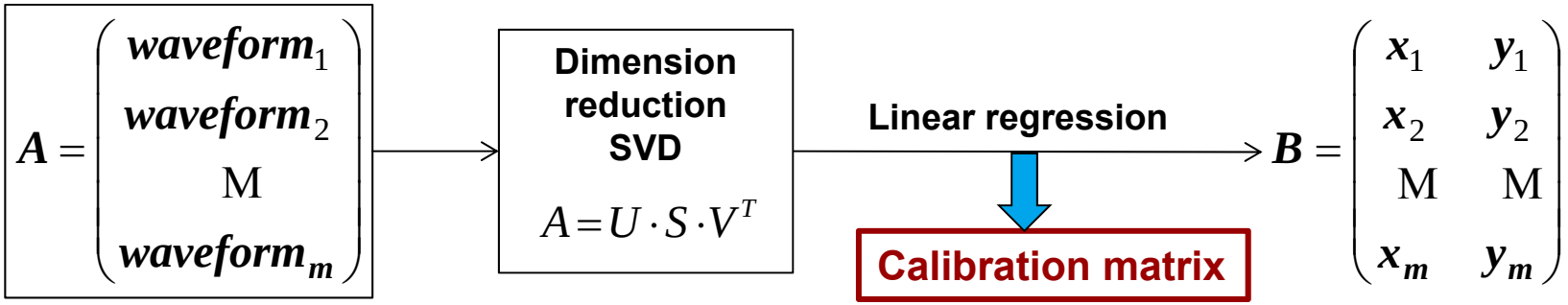


HOM-BPM: Beam Alignment

> Used for beam alignment, mainly during commissioning



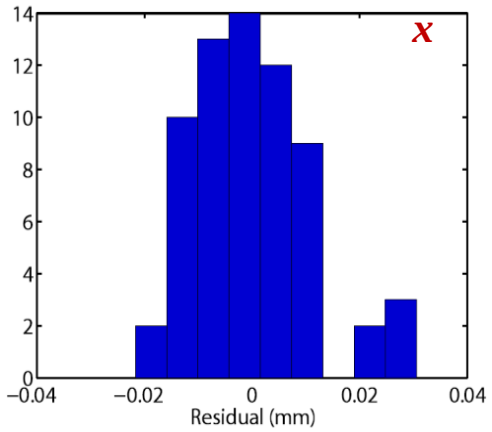
HOM-BPM: 1.3 GHz Cavities Calibration



> Calibration more complicated than in standard cavity BPMs
  - Split modes
  - Polarization direction is usually not horizontal or vertical, and, generally unknown
  - Different frequency in each cavity (1.7 GHz ± 10 MHz)

> Demonstrated use as BPM
  - 10 μm rms resolution

Resolution: 9μm



Stephen Molloy, SLAC (now ESS)

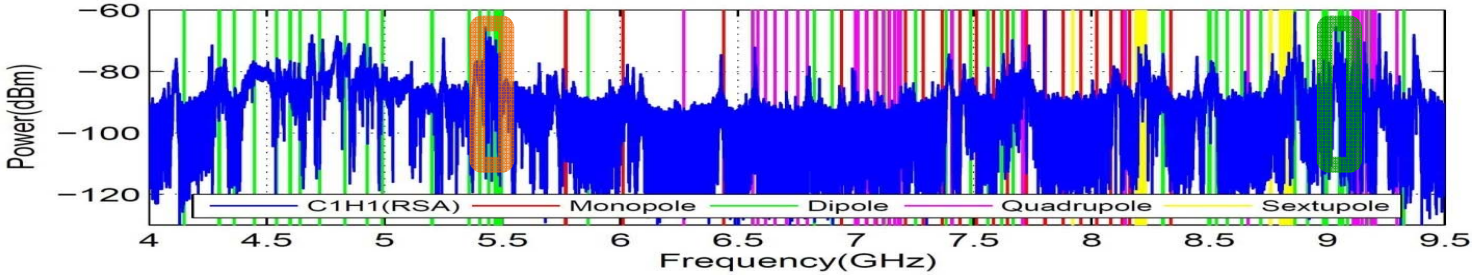
HOM-BPM: 3.9 GHz Cavities

> HOMs in 3.9 GHz cavities have higher impact on the beam

> No trivial copy of system for 1.3 GHz cavities, due to:

- Coupling of the cavities (4 at FLASH, 8 at the E-XFEL)

  Beam pipe cut-off: 4.39GHz → basically no local modes

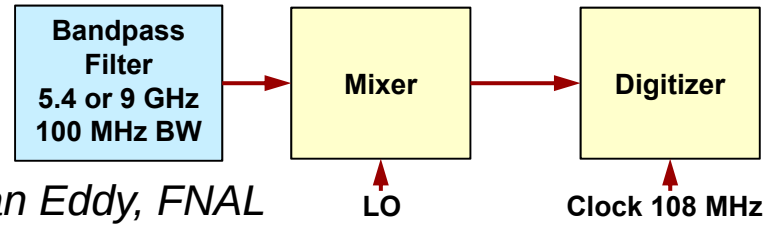


- Use 2 bands:

  Pei Zhang, DESY (now IHEP)

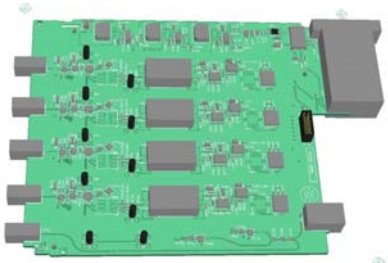
Dipole band	Beam Position meas.	Resol. (rms)
2nd, ~5.4GHz	Global position over the module length	~20 μm
5th, ~9GHz	Local position in each cavity	~50 μm

- Electronics for FLASH and the E-XFEL



Nathan Eddy, FNAL

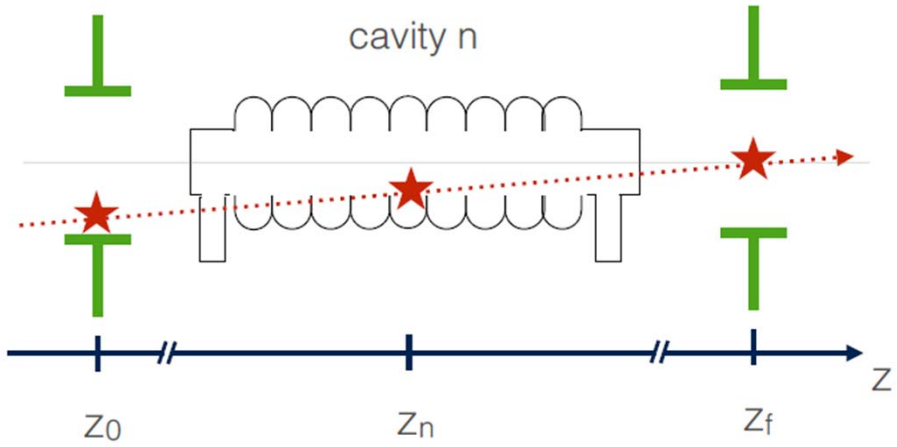
Thomas Wamsat, DESY



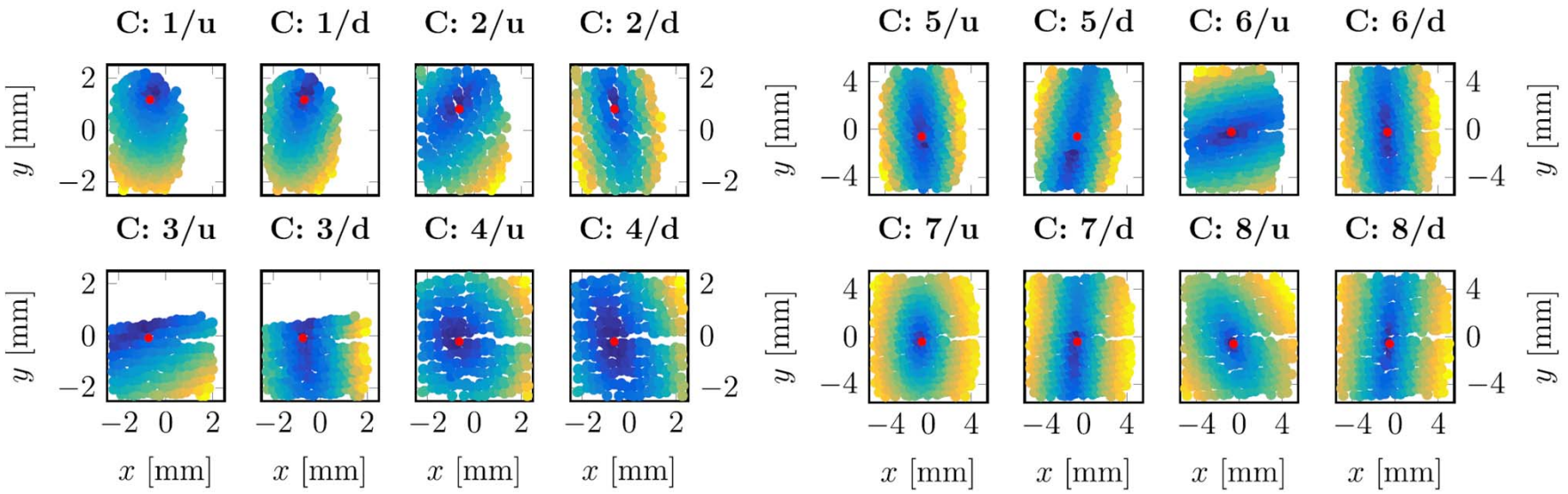
HOM-BPM: Cavity Alignment Measurement

> Cavity offset

- HOM(offset) >> HOM(tilt)
  ca. 200 µm ⇔ 1 mrad (theor.)
  confirmed by one measurement
- Work ongoing to measure tilt of cavities in one module



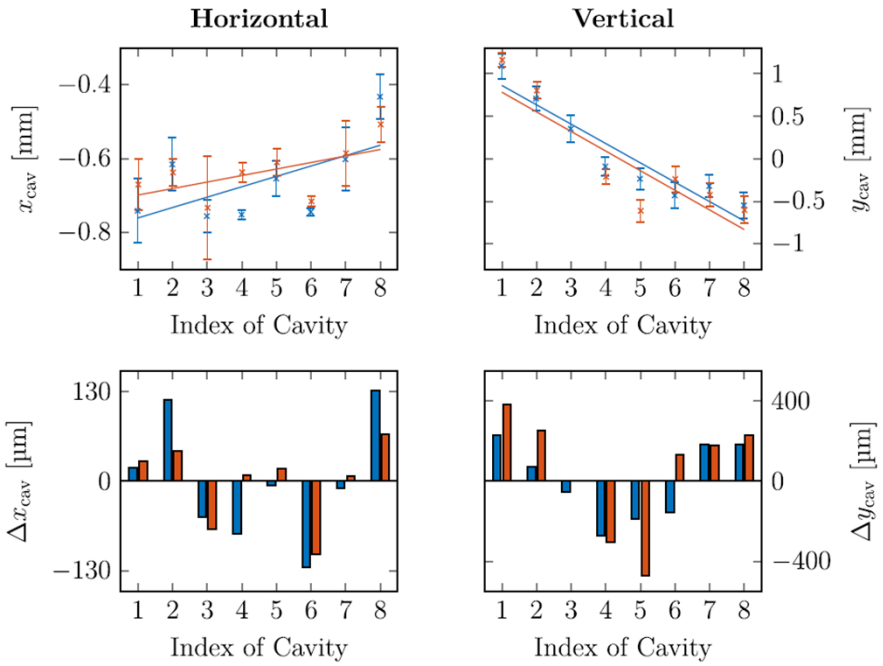
Mode power

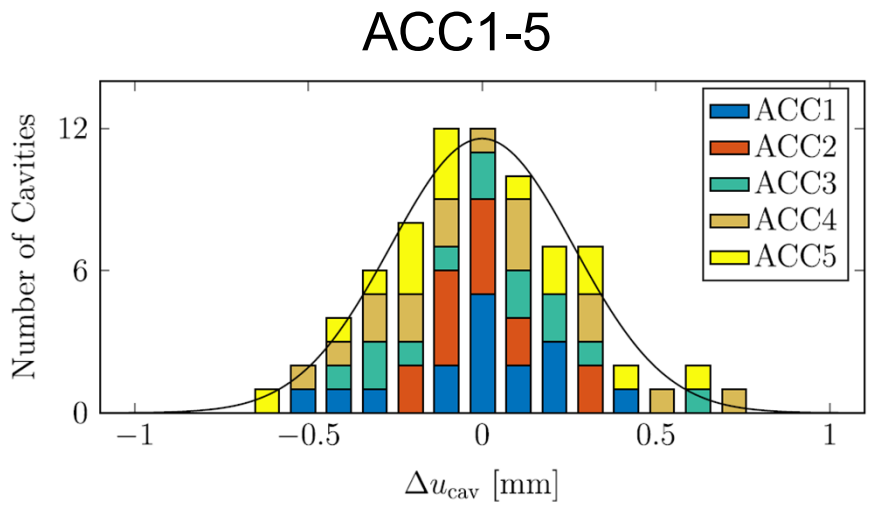


HOM-BPM: Cavity Alignment Measurement (2)

> Results

- 2 measurements are shown in the plot (ACC1)



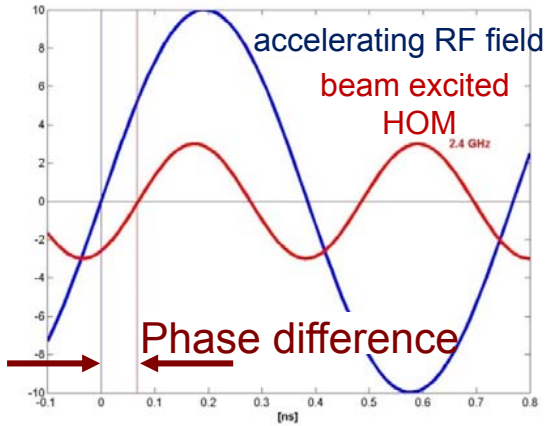


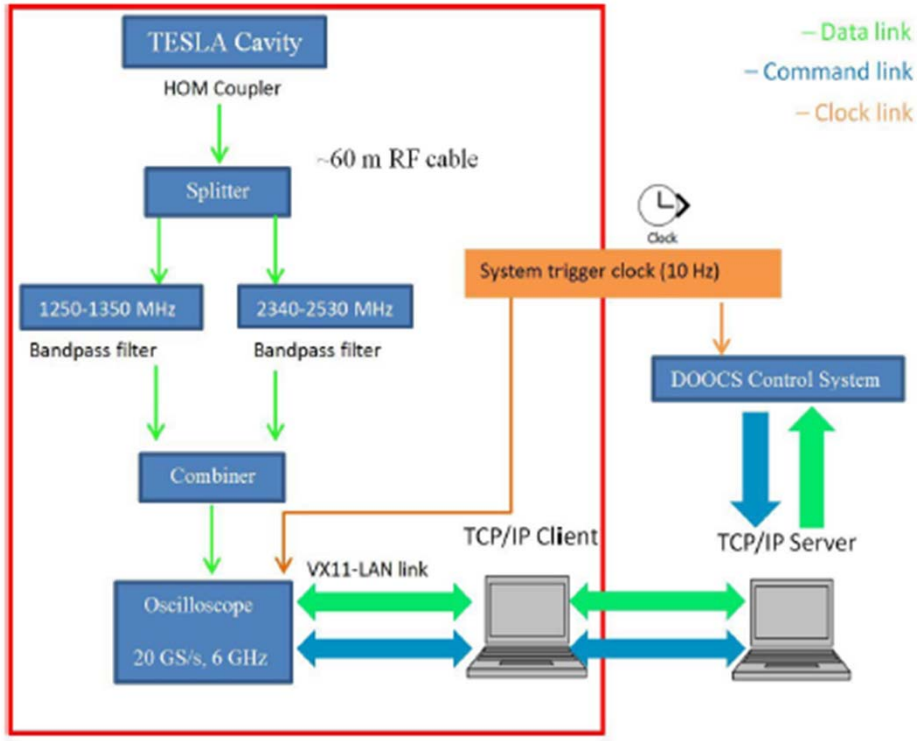
T. Hellert et al., Phys. Rev. Accel. Beams 20, 123501 (2017)

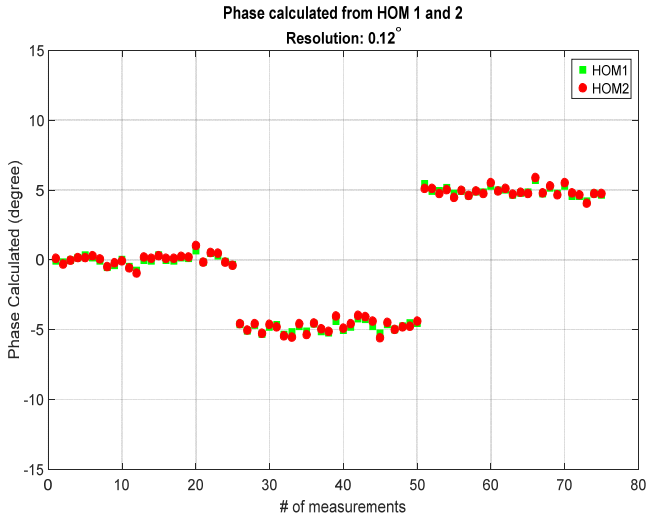
HOM-BPhM: Beam Phase Measurement

> Experimental setup

- Can trace RF phase change of -5 and +5deg
- Resolution: 0.12deg rms





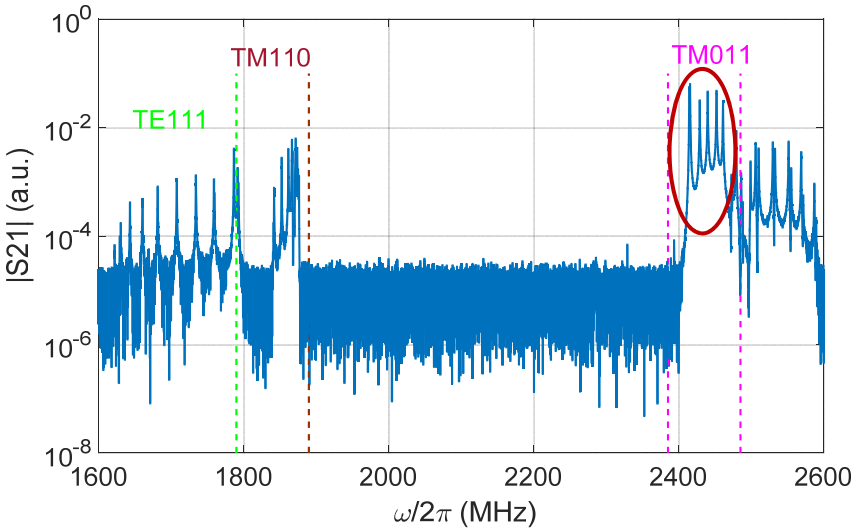


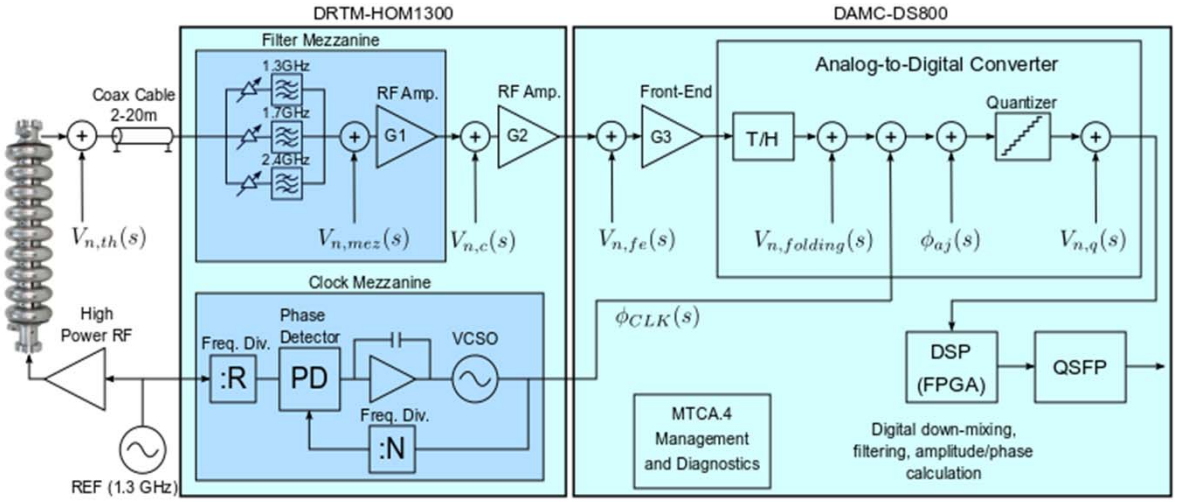
Liangliang Shi, DESY

HOM-BPM+BPhM: Electronics for 1.3 GHz Cavities

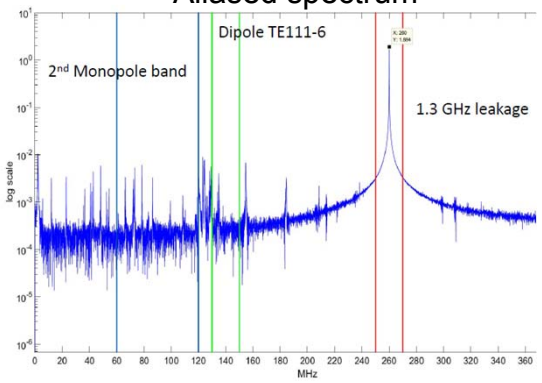
> Multiple filter
  - Selects 1.3 and 2.4 GHz monopole modes from the HOM spectrum
  - Also 1.7 GHz dipole mode for beam position monitoring

> Direct sampling





Aliased spectrum



Szymon Jablonski, DESY

Summary

> Motivation
- HOMs contain information about the beam and cavity, low cost monitors.
- Monitors built or being built for FLASH and E-XFEL, for 1.3 and 3.9 GHz cavities

> HOM-BPM
- Beam alignment → reduction of transverse wakefield effects
- Transverse beam position, like a cavity BPM

  1.3 GHz cavities:

  Resolution ca. 10 μm rms measured

  Currently work on stability in time

  3.9 GHz cavities:

  Resolution ca. 20 μm rms measured

  More challenging due to cavity coupling, higher frequency

  Extra challenges at the E-XFEL: longer cavity-chain, different cavity orientation
- Cavity alignment measurement

> HOM-BPhM
- Experimental setup: Resolution of ca. 0.1 deg rms measured

Outlook

> Current work:

- Long-term phase measurement
- Cavity tilt measurement
- Stability of beam position measurement in time
- Electronics for the E-XFEL being built

For 1.3 GHz cavities: beam position and phase
For 3.9 GHz cavities: beam position

Acknowledgements

> Talk based on work of many people from several institutes
(only main part of the work is mentioned)

- CEA: studies in TESLA cavities in FLASH
- SLAC: studies and electronics in TESLA cavities at FLASH
- FNAL: electronics for 3.9 GHz cavities in FLASH
- University of Rostock: measurements and simulations 3.9 GHz cavities
- University of Manchester/Cockcroft Institute: studies and simulations, 1.3 and 3.9 GHz cavities at FLASH
- TEMF: cavity simulations
- DESY

> Part of the work has been made under EuCARD and EuCARD-2

Thank you for your attention!

More Info

https://indico.cern.ch/event/465683/contributions/2269313/attachments/1325170/1990289/HOM_WORKSHOP_2016.pdf

https://indico.cern.ch/event/465683/contributions/2269230/attachments/1325164/1992713/2016.08.22-24_HOMinXFEL_HOMSC16_Rostock.pdf

https://indico.cern.ch/event/465683/contributions/2269311/attachments/1325882/1990314/160823_HOMSC_thellert.pdf

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