HOM-based Beam Position Monitoring

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FLASH Workshop, DESY, Hamburg, Oct. 4, 2011

FLASH
Free-electron laser FLASH

Universität Rostock
Traditio et Innovatio

The Cockcroft Institute
of Accelerator Science and Technology

MANCHESTER 1824
The University of Manchester

Fermilab

DESY

Overview

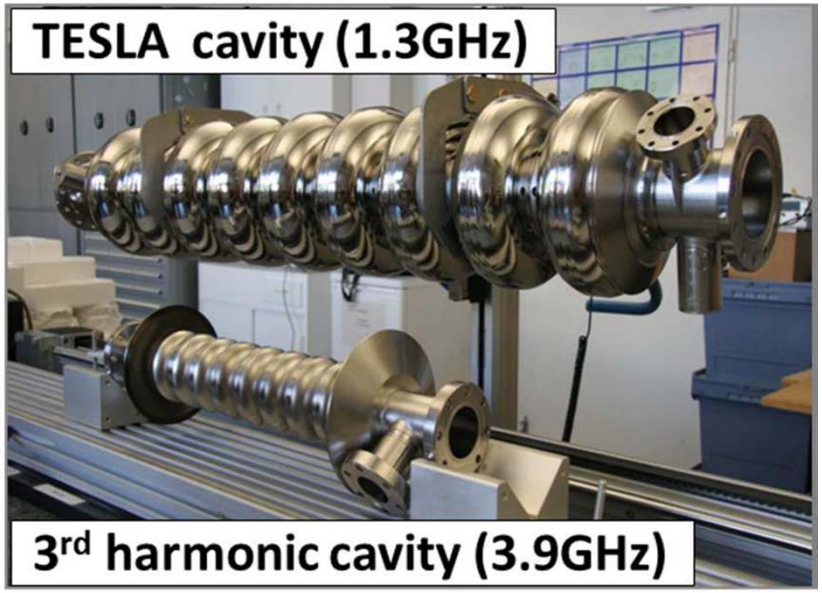
- Principle of HOM-BPMs
- Current work:

  HOM-BPMs for 3.9 GHz cavities at FLASH
- Future plans (tentative):

  HOM-BPMs for 3.9 GHz cavities at the XFEL

  HOM-BPMs for 1.3 GHz cavities at the XFEL

  Improvement of HOM-BPMs at 1.3 GHz cavities at FLASH
- Summary and Outlook

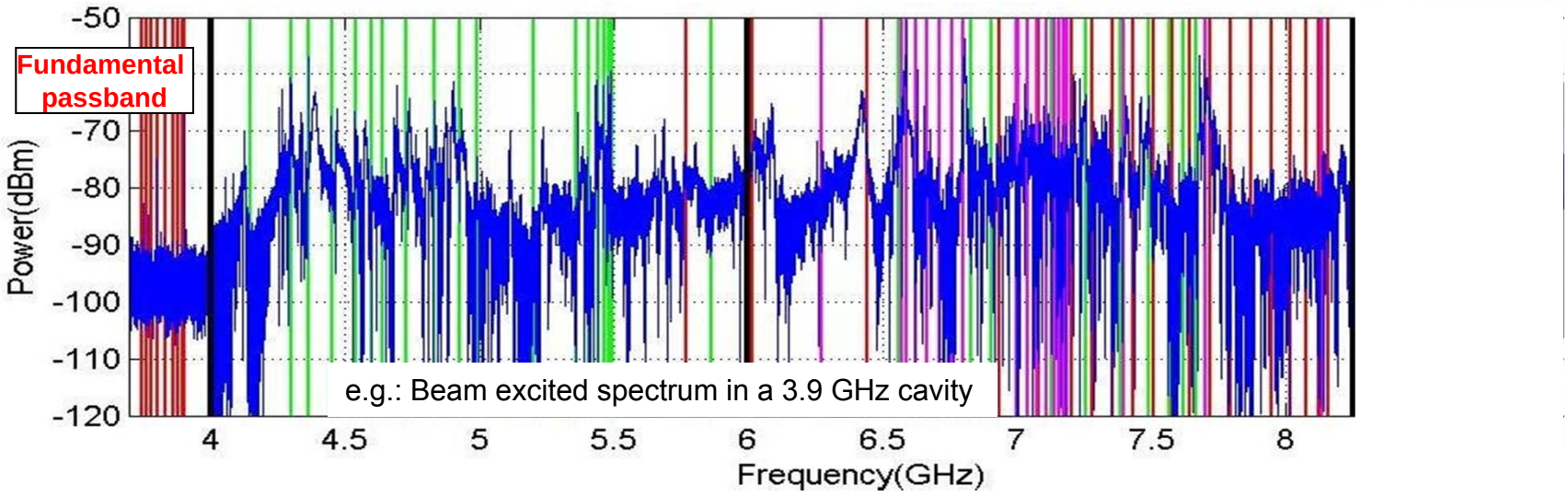


Principle of HOM-BPMs: Higher Order Modes (HOM)

> HOM: fields excited by the beam in the accelerating cavities

- Bad effect on beam, but also
- Can be used for beam (and cavity) diagnostics

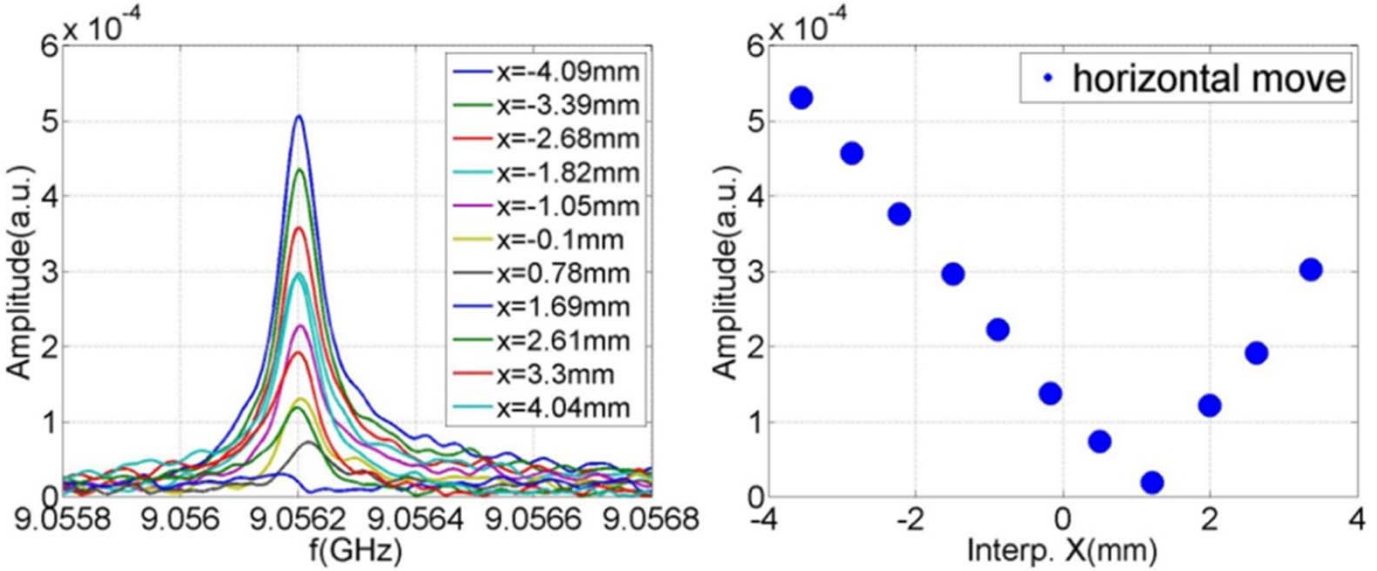
  Because properties depend on accelerating cavity and beam properties



- Spectrum includes: monopole, dipole, quadrupole etc. modes

Principle of HOM-BPMs: Dipole Modes

> Dipole modes have linear dependence on beam offset and charge



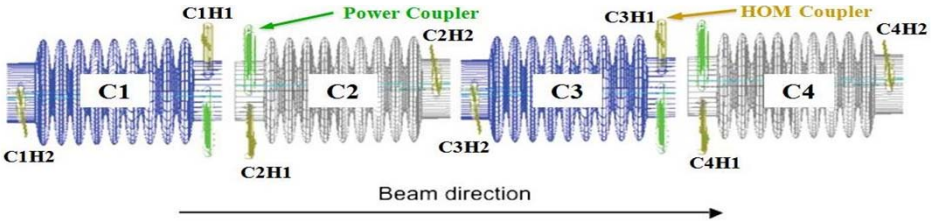
⇒ Idea: Use dipole HOMs for beam position monitoring (HOM-BPM)

- Center beam (therefore reduce wakes)
- Measure cavity misalignment

> Same idea as for cavity BPMs, but much more complicated

Current Work: HOM-BPMs for ACC39 at FLASH

- ACC39
  - Built at Fermilab in collaboration with DESY



- **EuCARD**: Partially supporting our work
  - Sub-tasks
    1: HOMBPM
    2: HOMCD (HOM Cavity Diagnostics)
    3: HOMGD (HOM Distributions and Geometrical Dependencies)
  - Several PhD students involved

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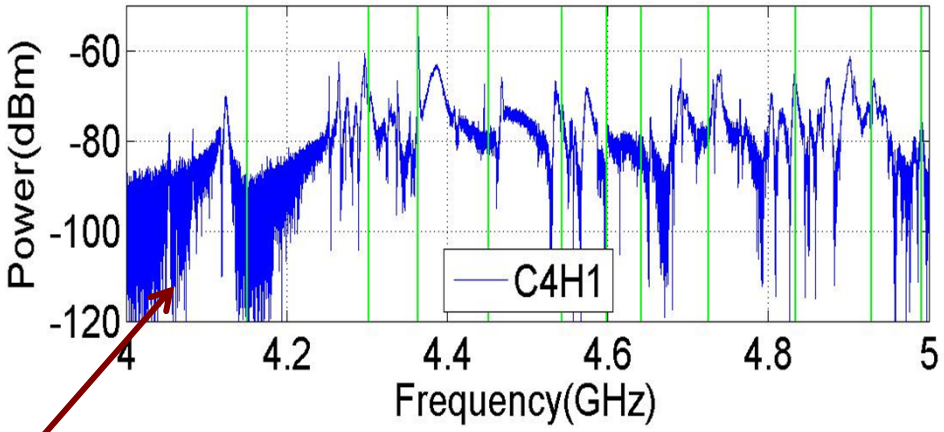
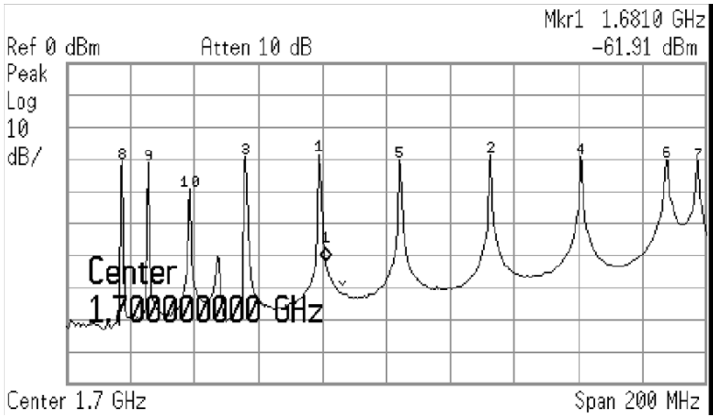
HOM-BPMs for ACC39 at FLASH: 1st Dipole Passband

- Idea: use mode with high R/Q
- But, crowded spectrum
  - Practically all cavity modes above cut-off
  - Modes: not possible to identify
  - Modes are not localized
  - Idea: cut one portion of spectrum (several modes)
- Alternatives:
  - Beam-pipe dipole modes
  - Trapped cavity modes in 5th dipole passband
  - All options: advantages and diadvantages

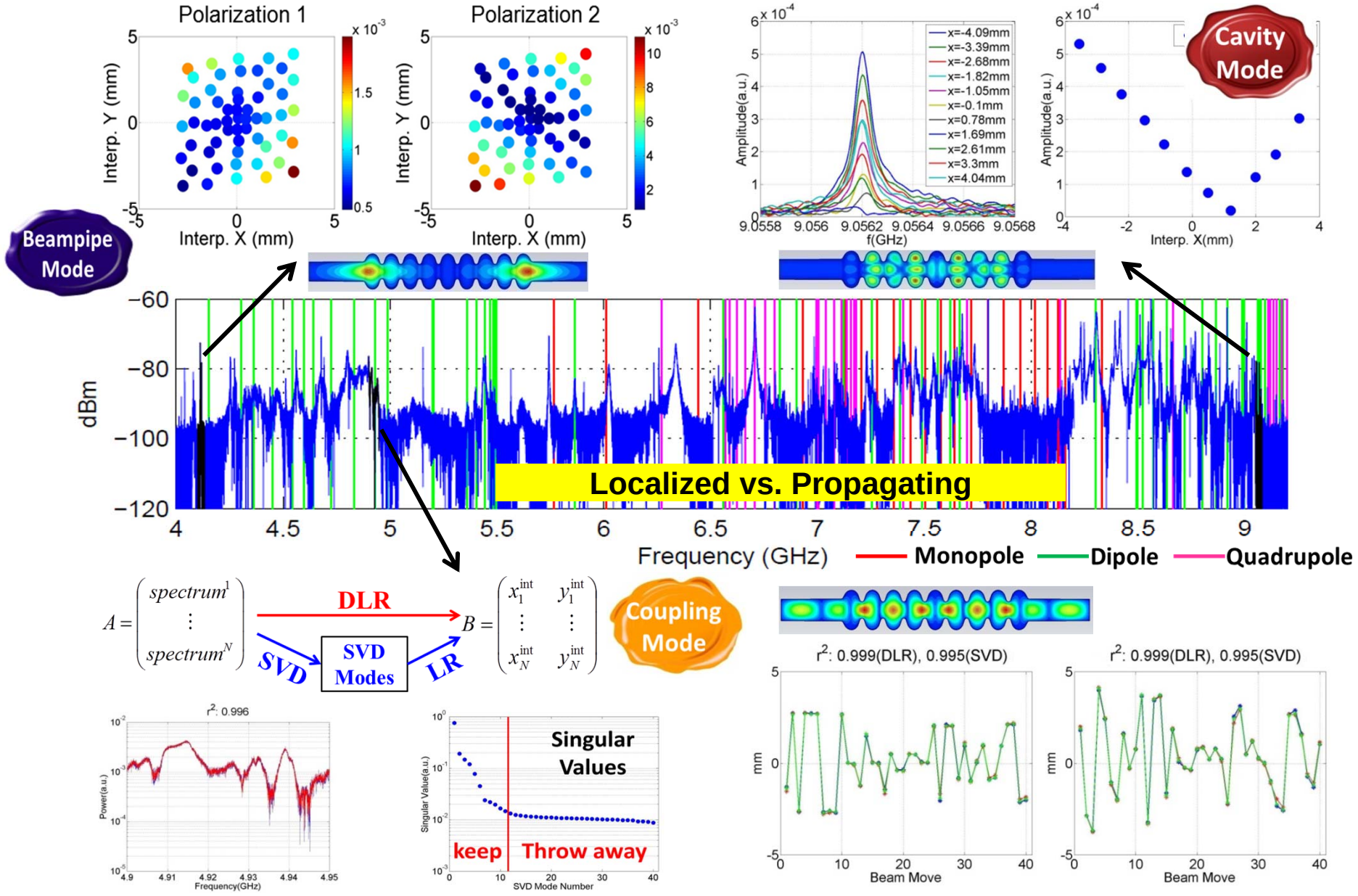
1st dipole band



Compare to TESLA cavity:



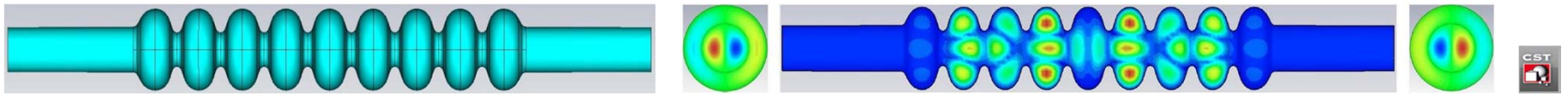
Localized and Propagating Modes in ACC39



Simulations of 3.9 GHz Cavities

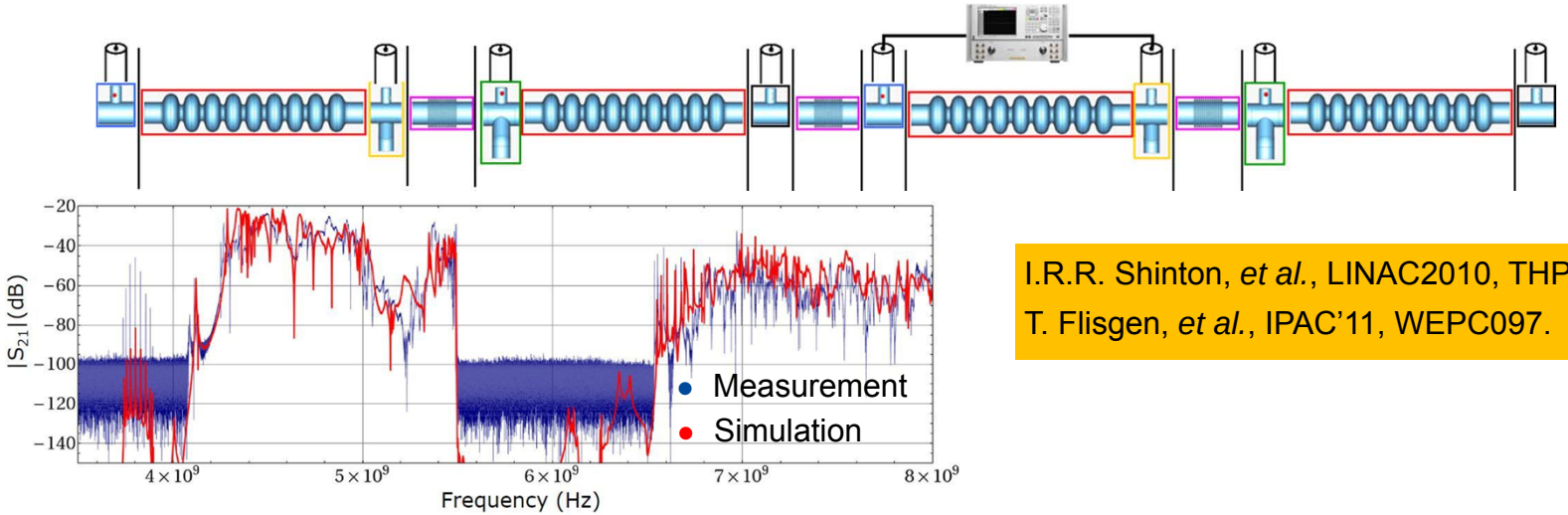
> Ideal cavity w/o couplers

P. Zhang, *et al.*, IPAC'11, THPPA00.



ω/2π: 9.058 GHz, R/Q: 2.17 Ω·cm^2

> Cascade scattering matrix calculation (GSM and CSC)



I.R.R. Shinton, *et al.*, LINAC2010, THP012.
T. Flisgen, *et al.*, IPAC'11, WEPC097.

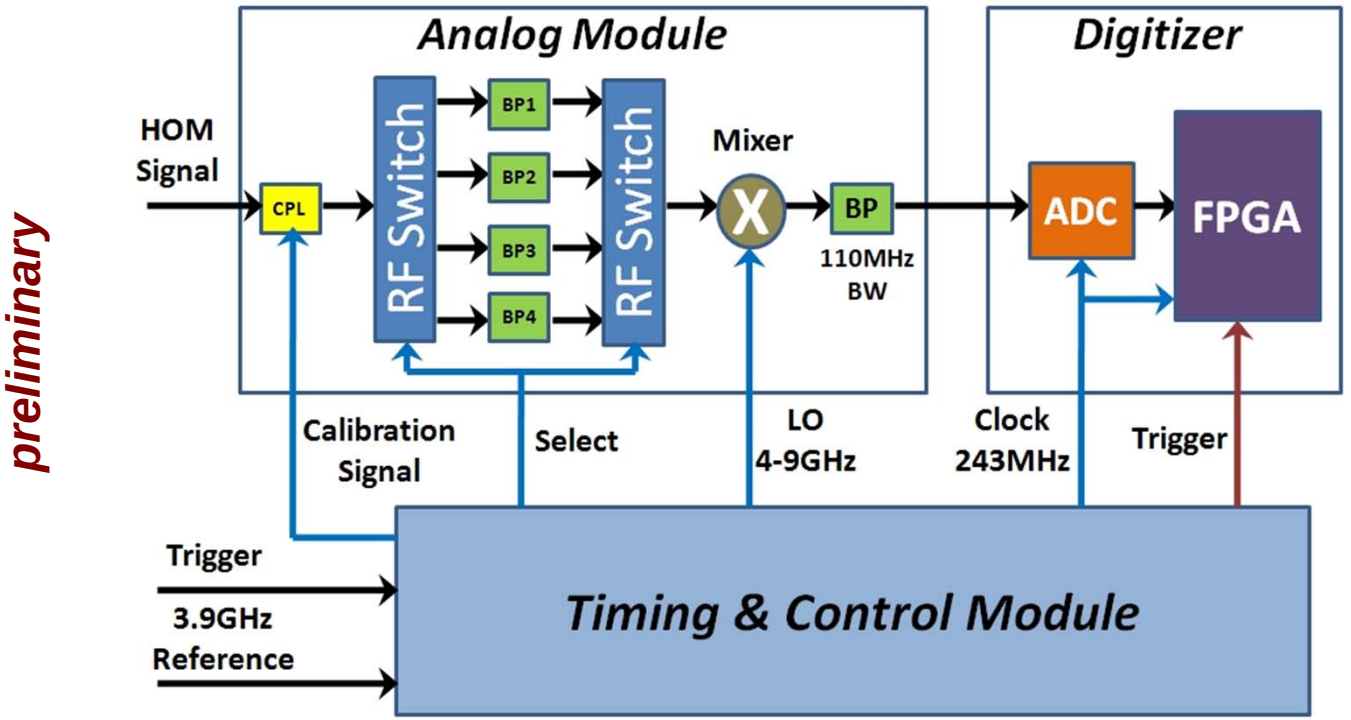
> Simulate the entire 4-cavity string (ACE3P@SLAC)

I.R.R. Shinton, *et al.*, IPAC'11, WEPC125.

Trapped mode in the 5th dipole band: ω/2π: 9.061 GHz

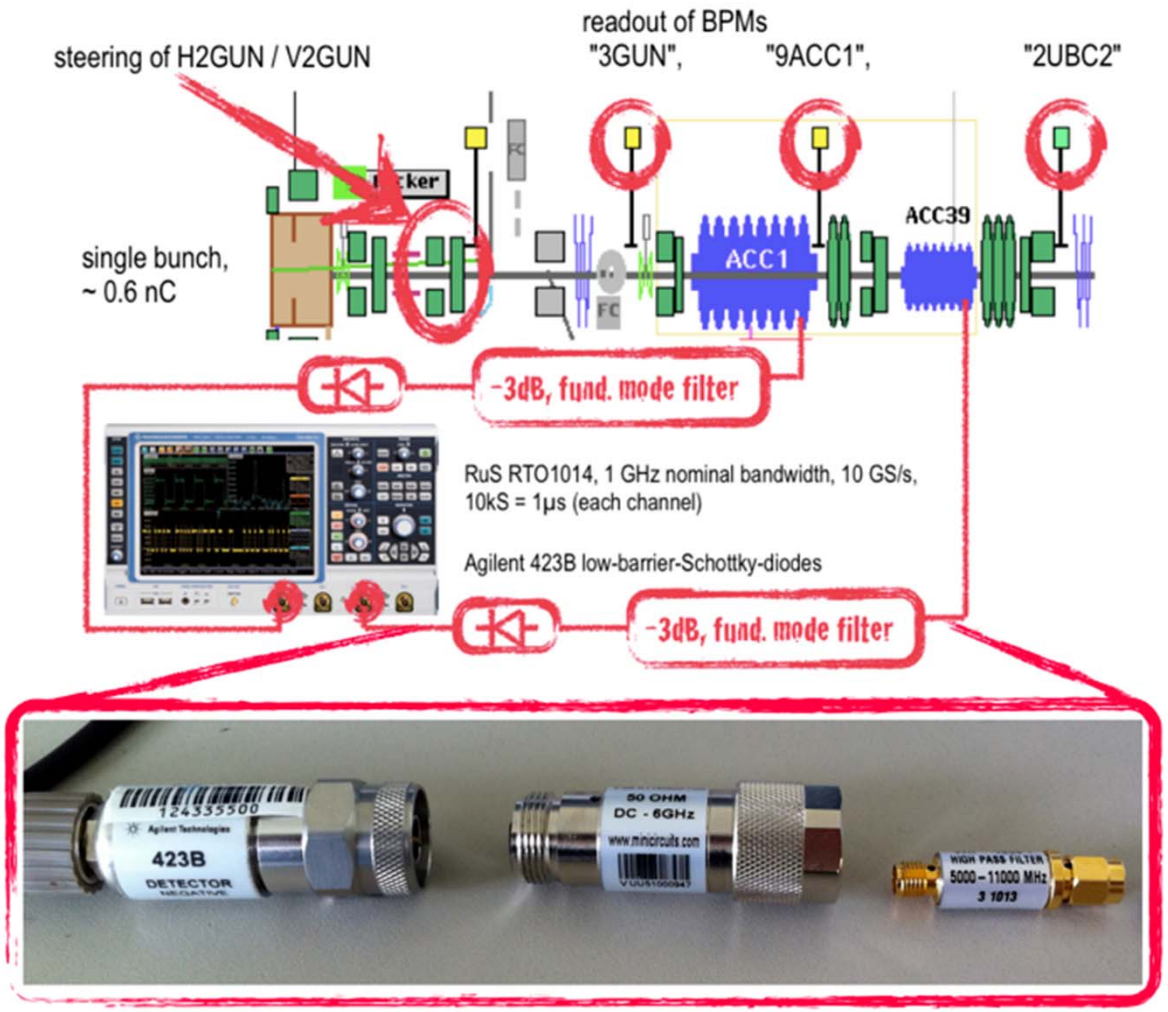
Electronics for ACC39 at FLASH

- To be built by Fermilab
- "Play"-electronics will be tested early next year
  - Test options



N. Baboi et al., SRF 2011, MOPO060, Chicago, IL, U.S.A.

Alternative Electronics: Diode-based Signal Capturing



- Alternative electronics
  - Already tested at ACC39 and ACC1
- Simple setup
  - Broad-band filter to suppress 3.9 GHz
  - + RF detector diode
- Signal output ~ total HOM power
- SVD-based signal analysis
  - Complicated, but it works

H.W. Glock, DIPAC2011, MOPD25

HOM-BPMs for ACC39 at FLASH: Future Plans

- Test “play” HOM-BPM electronics from Fermilab
  - Beginning of 2012
  - Evaluate results and decide final strategy
- Continue work with diode-based signal capturing
- Continue simulations
- Built and install final electronics

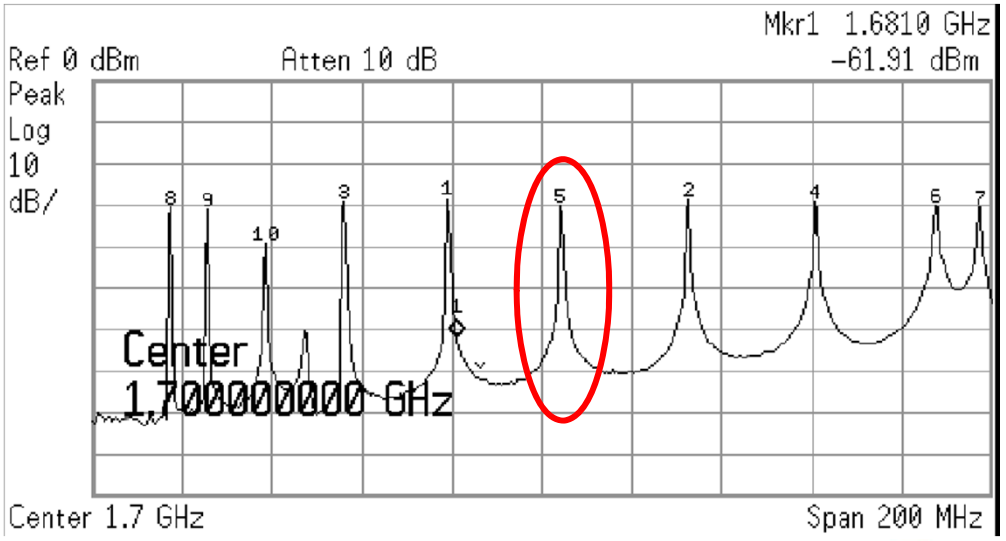
- Pei Zhang: Prize at IPAC 2011!

Future Work: HOM-BPMs for 3.9 GHz Cavities at E-XFEL

- Tentative plans
- Use results from current work at FLASH
- Some experimental and theoretical studies needed
  - 8 cavities per module
  - Different arrangement of cavities in module
  - Smaller bunch spacing than now in FLASH etc.
- Electronics: XFEL-conform
- WP 46

Future Work: HOM-BPMs for 1.3 GHz Cavities at E-XFEL

- Tentative plans
- Collaboration with the University of Warsaw
- Sample dipole mode at 1.7 GHz
  - Profit from development of fast ADC card for LLRF (EuCARD WP 10.6)
- Electronics XFEL-conform: needs to be designed
- WP 17

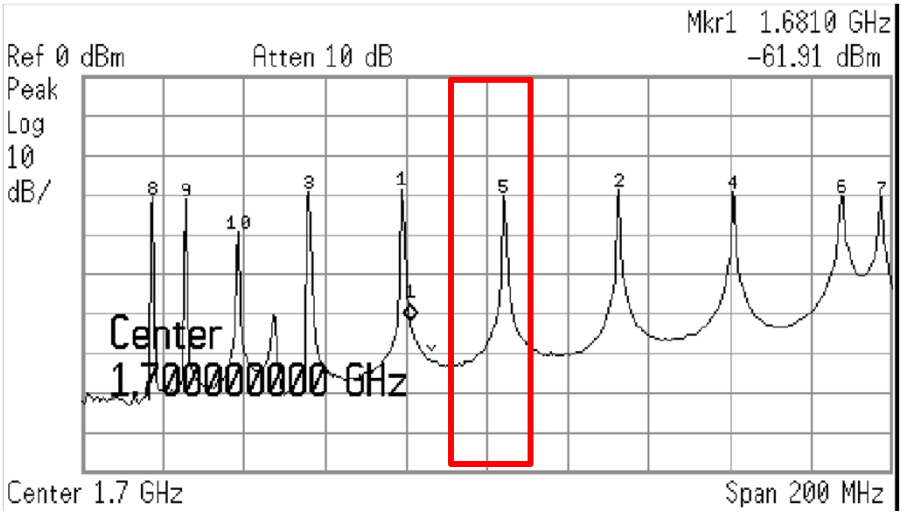


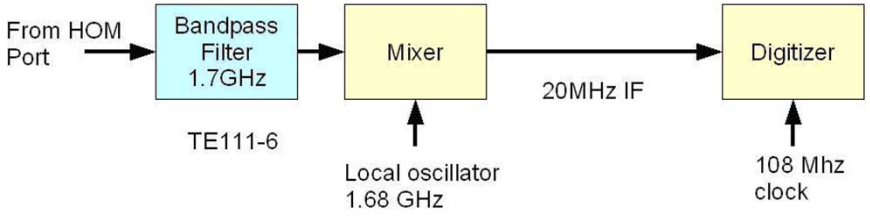
Future Work: HOM-BPMs at 1.3 GHz Cavities at FLASHs

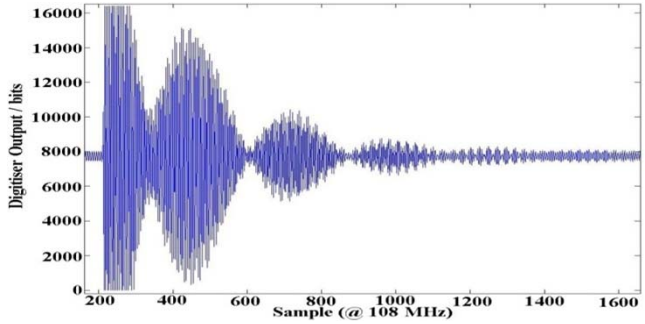
- Current electronics
  - Built by SLAC
  - Proof-of-principle made
  - Resolution for the 1st bunch
    ~10 μm
  - Problem with calibration stability
  - Raw signals used for commissioning

    S. Molloy et al., PRST-AB 9, 112802 (2006)

    J. Frisch et al., EPAC 2006, TUYPA02, Edinburgh, Scottland
- Idea: improve or replace current electronics
  - Work correlated to work on HOM-BPMs for the XFEL







Summary and Outlook

- Current work: HOM-BPMs for ACC39 at FLASH
  - PhD students: Uni. Manchester/DESY, Uni. Rostock, RHUL
- Future Work (tentative):
  - Design HOM-BPMs for 3.9 GHz cavities at the XFEL
  - Design HOM-BPMs for 1.3 GHz cavities at the XFEL
  - Improve HOM-BPMs at the 1.3 GHz cavities at FLASH
  - Possibly HOM-based beam-phase measurement wrt RF
  - Need to clarify financial aspects, man power
- Beam time
  - Both for FLASH and the XFEL
  - Fermilab: interested to build similar electronics for their SC test facility
  - Not easy to separate, therefore we need both FEL and machine studies
- EuCARD2: HOM-based beam diagnostics for the XFEL