Production of Cavity BPMs for the European XFEL

A large production with small tolerances

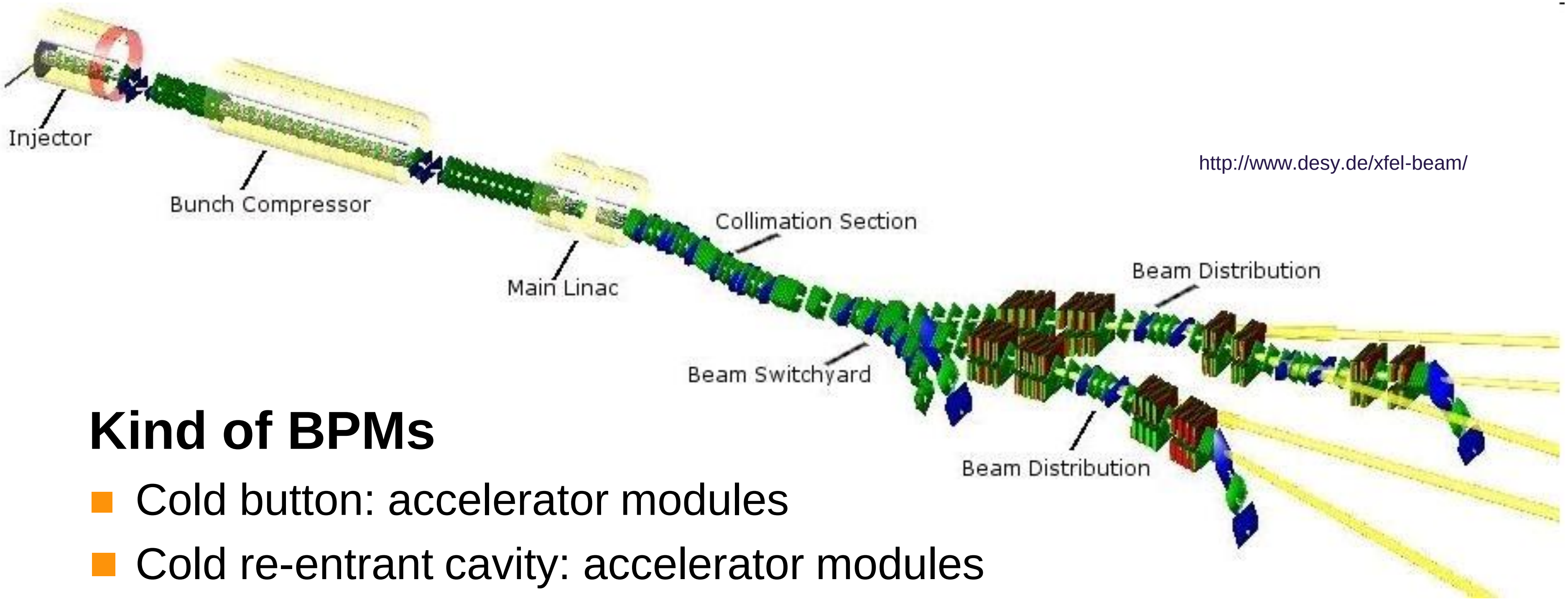
IBIC 2013 Satellite meeting Sep. 20: Cavity BPMs; Oxford

D. Lipka, D. Nölle, S. Vilcins; MDI department, DESY
Hamburg, Germany

Content

- Overview
- Requirements
- Design
- Prototypes
- Feedthroughs
- Undulator Cavity BPM Pre-production and selection
- Series production of Undulator Cavity BPMs
- Series production of Beamline Cavity BPMs
- Summary

Overview



http://www.desy.de/xfel-beam/

Kind of BPMs

- Cold button: accelerator modules
- Cold re-entrant cavity: accelerator modules
- Warm button: distribution system, compressors
- **BPMF: Beamline type (26)**: Intra Bunch Feedback system (IBFB), Fast energy feedback, positions with higher resolution required
- **BPME: Undulator type (98)**: undulator

Overview

BPM system for European XFEL (cold and warm) as an In-Kind contribution

Collaboration (institutes and task)

- CEA-Saclay: re-entrant cavity BPM for cold module including front end electronics
- DESY: button and cavity BPM mechanics
- PSI: front end electronics (button and cavity BPM) and digital electronics (all): see talk B. Keil

Subject of this talk:

Cavity BPMs organized by DESY

Photo: D. Nölle

Requirements

Cavity BPM performance:

- Undulator: 1 μm for charge range 0.1 to 1 nC (optional down to 20 pC) and ±0.5 mm dynamic range; with 10 mm pipe diameter
- Beamline: 10 μm for same charge range and ±1 mm dynamic range with 40.5 mm pipe diameter

Have to fulfill following accelerator parameters

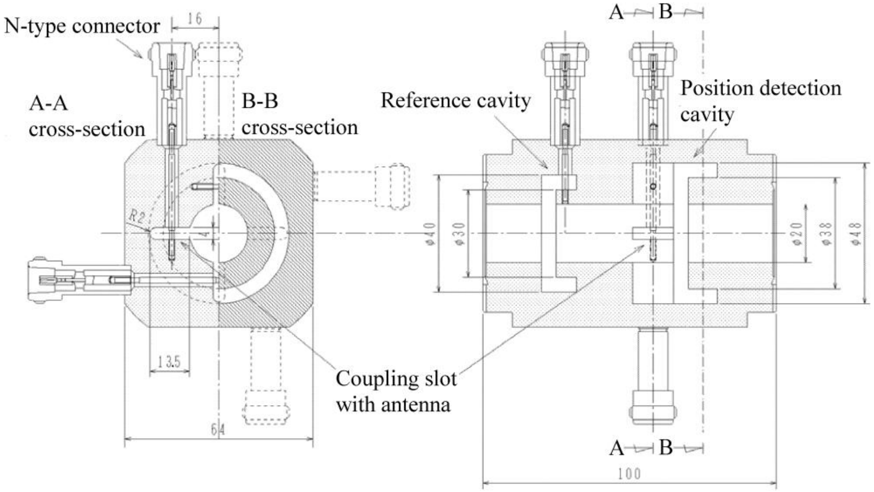
- Bunch spacing: ≥222 ns, single bunch measurement
- Macro pulse length: 600 μs
- Number of bunches within 1 pulse: 1 – 2700
- Macro pulse repetition rate: 10 Hz

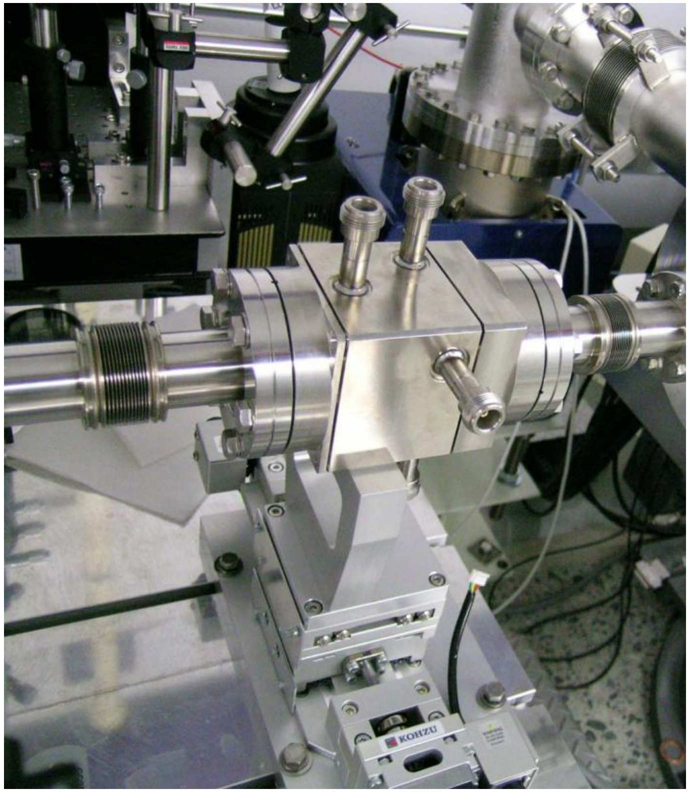
Design basis

Photo by:
D. Nölle

Design obtained from T. Shintake

His design for SPring-8 Angstrom Compact free electron Laser (SACLA)





- Material: Stainless Steel
- Pipe diam.: 20 mm
- Slots connected to tube

Measured resolution: < 0.6 μm at 0.1 nC

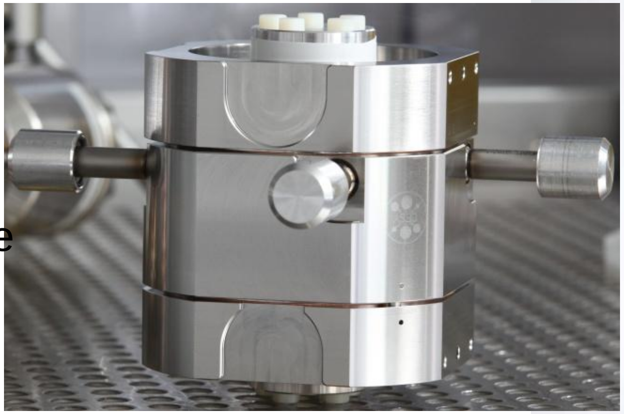
Courtesy H. Maesaka

Design Undulator Cavity BPM

- Stainless steel “discs” forms the cavities without any tuners: RF- properties depend on mechanical tolerances; these tolerances are calculated to match the requirements
- Coupling Slots without direct connection to tube
- Discs brazed together
- High performance feedthrough welded to the body

Requirements for electronics:

- Resonance frequency (loaded) 3.30 ± 0.03 GHz
- Q, loaded 70 ± 10
- Max. Frequency Difference between dipole and reference resonator: ≤ 30 MHz
- Crosstalk between resonators: < -100 dB



Photos: D. Nölle

Design Beamline Cavity BPM

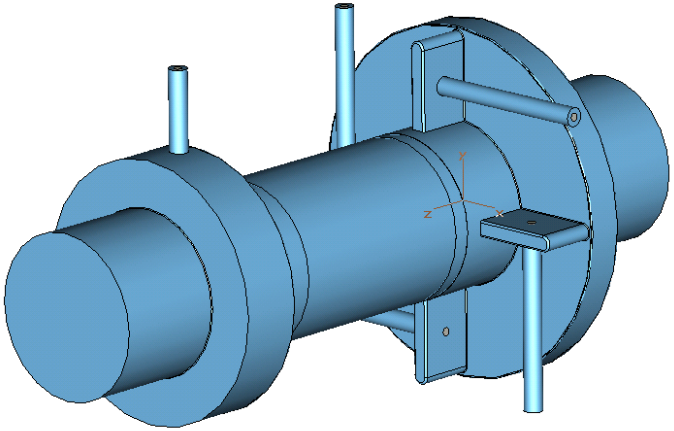
- Stainless steel "discs" form the cavities without tuners
- Slots with direct connection to tube
- Brazed together
- Distance between reference and dipole resonator = 190 mm
- High performance feedthrough flange mounted

Requirement for electronics:

- Frequency (loaded) 3.3 ± 0.03 GHz
- Q, loaded 70 ± 10
- Frequency Difference between dipole and reference resonator: ≤ 30 MHz
- Crosstalk between both resonators: < -100 dB

RF-properties Beamline and Undulator BPM types allow the use of the same electronics

Coupling between both resonators (defines distance): < -100dB



Reference and Dipole resonator

Vacuum view

Photo: D. Nölle

Prototypes

- 2008 produced 3 cavity BPMs with Shintake design and 4.4 GHz in the DESY workshops
- 2009 produced 6 Undulator BPMs with 3.3 GHz at DESY
- 2009 – 2010 produced 12 Undulator and 4 Beamline BPMs at different companies
- 2009 installation of 3 Undulator and 1 Beamline at FLASH
- Installation of 3 Undulator and Beamline at SwissFEL Test Injector

Photo:

D. Lipka

Prototypes

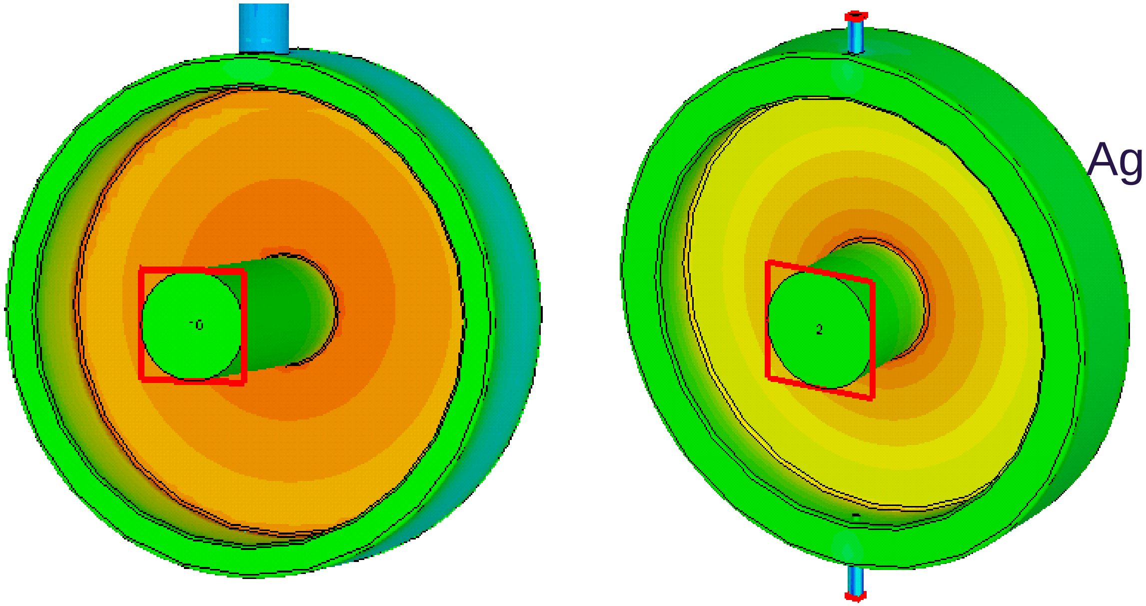
Difference of resonance frequency between expectation (simulation) and measurement of Undulator <u>reference resonator</u> by 6 MHz

Simulation view of reference resonator with

one antenna

two antennas

Disagreement between measurement and simulation



Agreement between measurement and simulation

Field distribution due to one antenna distorted, symmetry broken

But: a vacuum RF feedthrough is expensive. Therefore one antenna for the reference resonator. Outer radius is corrected in drawing to shift frequency by 6 MHz.

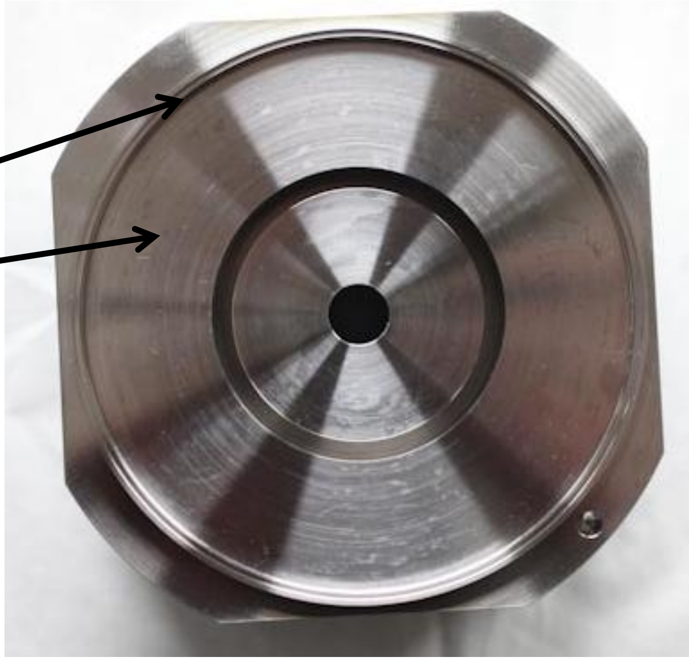
Prototypes

We found drop of quality factor at Undulator reference resonator with several prototypes.

Reason: bad electro-magnetic contact between discs after brazing causes higher resistance which decreases internal quality factor

(in simulation very hard to identify because ideal materials)

Change of brazing position from edge to plane with brazing foil instead of a wire



Photos: D. Nölle

Feedthroughs

Photo: D. Nölle

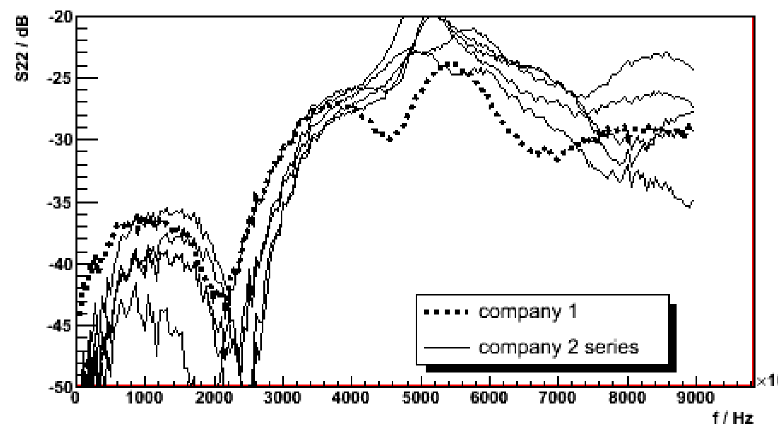
- Feedthroughs are bought from companies
- For 1. prototypes the SACLA type was used (Shintake Design)
- Need of cost reduction:
  - try different companies:
    - a larger reflection was measured at a 2nd company; this causes a shift of the external coupling of the resonator (loaded Q changed up to 30%), therefore a max. reflection of -25 dB at 3.3 GHz has been required.
    - -> design improvements, and match of specifications.
- Start 2 phase Tender process
  - Open Tender process
    - 3 companies selected to produce small series (Pre-series)
    - Test against specification
    - Get offers from successful pre-series producers for series production
    - Make the choice on price

Feedthroughs (Procurement Results)

- Pre-series: 180 feedthroughs ordered from 3 companies.
- One company did not fulfill the specification
- Two companies left
- Cheapest qualified company got the offer for the series production: 700 pieces


Feedthrough with measurement adapter

Photo:
D. Nölle



European XFEL

Pre-Production of Undulator Cavity BPMs

- Same 2 Phase Tender Process for the BPM body
  - Open EU Tender: Choose up to 3 companies to produce 18 Undulator Cavity BPMs before the series production for pre-selection of companies.

    Only two valid Bids
  - VACOM and FMB Berlin got offer to produce 9 pieces each in 2012

	VACOM	FMB
Dipole resonator	3299.8 ± 1.6 MHz 69.7 ± 1.4	3295.9 ± 2.0 MHz 68.9 ± 1.7
Reference resonator	3297.2 ± 2.0 MHz 77.8 ± 1.2	3299.0 ± 1.3 MHz 77.8 ± 1.0
Resonance frequency difference	3.0 ± 2.1 MHz	3.5 ± 2.2 MHz

Resonance frequency

and

loaded quality factor

Errors are standard deviation

- Both companies delivered BPMs well within specification and time.
- Decision for the series production of 122 pieces, based on price only

Series production of Undulator Cavity BPMs

- Installed a system to measure RF properties at FMB Berlin in November 2012 to observe status of each step:
  - before brazing,
  - after brazing and
  - after welding of feedthroughs
- A measurement takes few minutes with additional analysis
- A calibration has to be made beforehand which takes 0.5 h
- Measurement results are send to DESY for revision and to get permission for next step.
- Delivery of BPMs in small lots after final production each, second measurement system in DESY installed to check properties

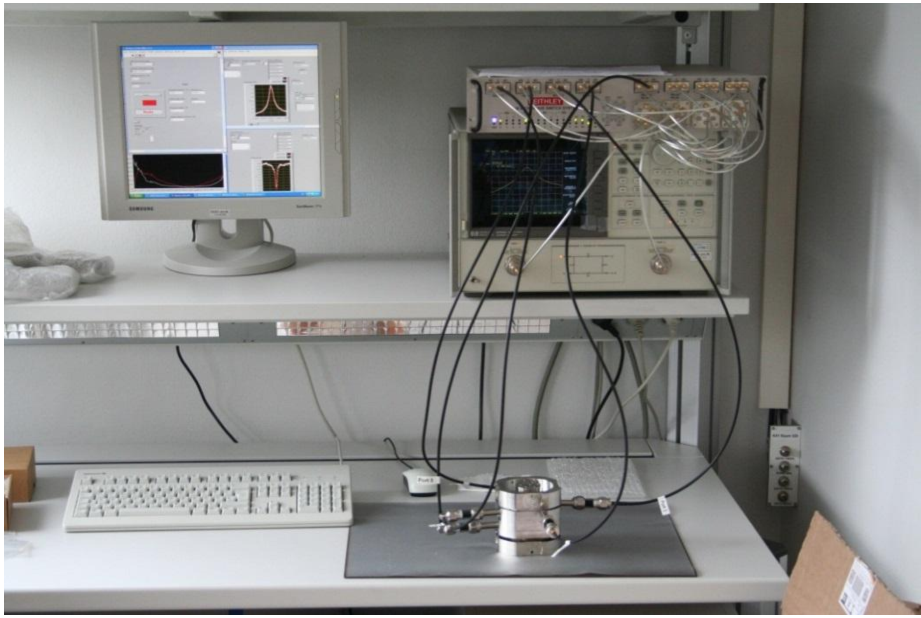
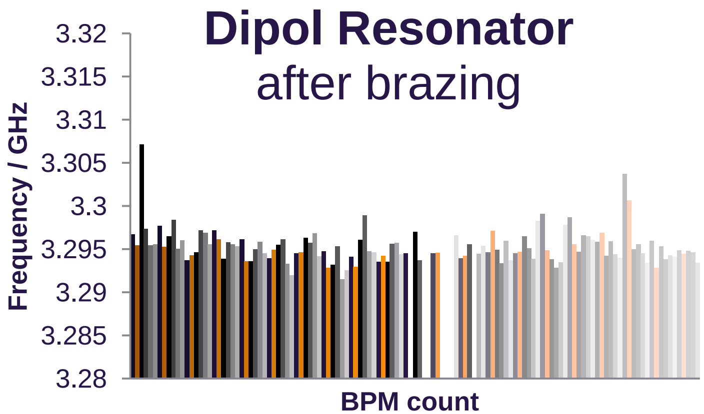
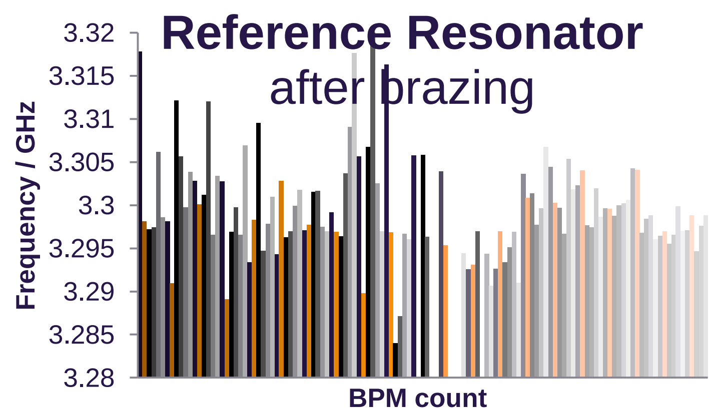


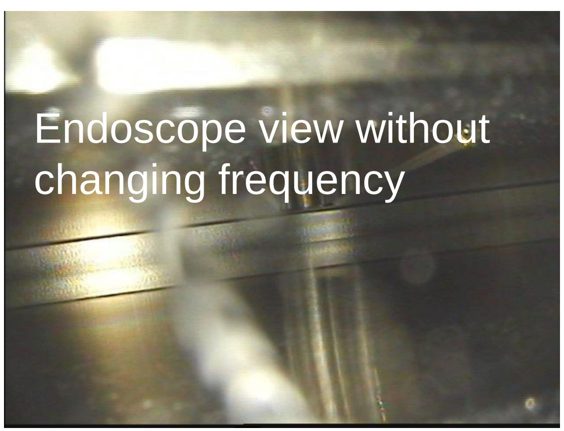
Photo:
D. Lipka

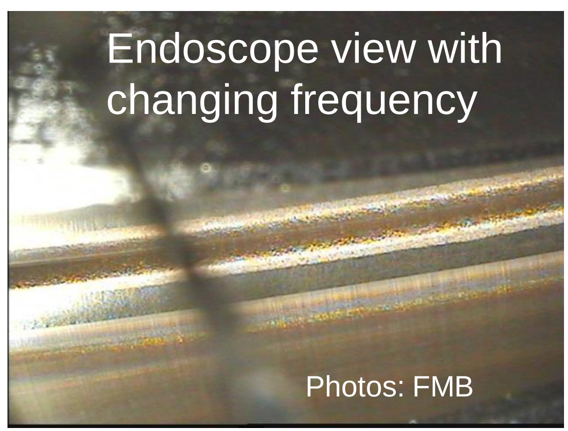
Series production of Undulator Cavity BPMs

- After some pieces we observed a larger frequency variation at the reference resonator after brazing









Larger resonance frequency difference before and after brazing is correlated with brazing material in the resonator; in the following we increased brazing foil inner diameter

Series production of Undulator Cavity BPMs

- Statistics after production of 122 Undulator Cavity BPMs

Dipole resonator	3295.4 ± 1.6 MHz 69.3 ± 1.1
Reference resonator	3301.3 ± 5.4 MHz 75.5 ± 1.2
Resonance frequency difference	6.4 ± 4.7 MHz

Photo: D. Lipka

6 Undulator BPM in a transport box

- Larger deviation of reference frequency due to brazing problem
- After correction of brazing foil this effect disappears
- Good communications between DESY and FMB Berlin to solve problems
- RF-properties of all BPMs within specifications
- Production according to planning; finished July 2013

Series production of Beamline Cavity BPMs

- In parallel to Undulator BPMs a call for tender for the Beamline Cavity BPMs was presented
- FMB Berlin got the offer to produce 30 Beamline Cavity BPMs at a similar time with the Undulator Cavity BPMs
- In this case FMB used the measurement setup for both types of BPMs

Photo:
D. Nölle

Series production of Beamline Cavity BPMs

- Statistics after production of 30 Beamline Cavity BPMs

Dipole resonator	3295.1 ± 1.3 MHz 87.6 ± 1.9
Reference resonator	3298.9 ± 2.4 MHz 54.3 ± 2.4
Resonance frequency difference	3.9 ± 2.1 MHz

Picture by D. Nölle

- Frequencies match better to specification compared to Undulator Cavity BPM
- Loaded quality factor shift observed: higher for dipole and lower for reference resonator; reason not understood; electronics can cope with the difference
- Good communications between DESY and FMB Berlin to solve problems
- Production within proposed time duration; finished similar to Undulator production in July 2013

Summary

- Production of 152 Cavity BPMs for the European XFEL is finished
- Design was guided on accelerator requirements and based on Shintake BPMs
- Produced few prototypes without tuners to minimize the series production effort; correction of design radius and brazing due to experience with these prototypes
- Investigation of feedthrough influence and selection of companies who can deliver them with the required performance
- Pre-production of Undulator Cavity BPMs to qualify companies for the series
- Close follow up of the production using RF measurements at and by the company to detect problems as soon as possible
- FMB Berlin produced both kind of Cavity BPMs in parallel within timeline and good performance and good communications (including RF measurements)