Status update of the fast energy corrector cavity at FLASH.

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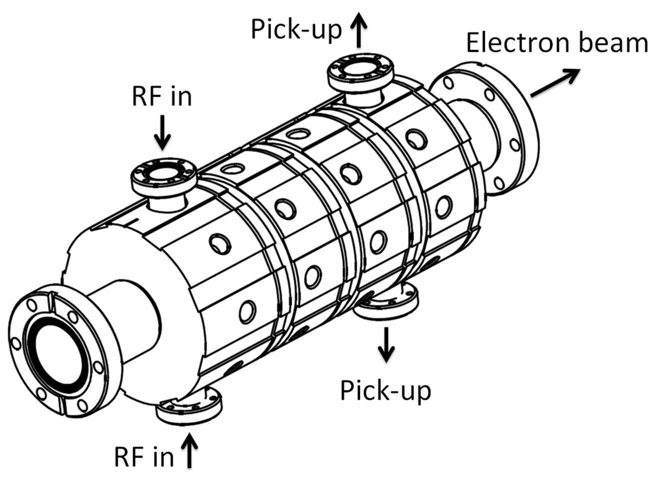
Abstract

Linear accelerator facilities driving a free-electron laser require femtosecond precision synchronization between external laser systems and the electron beam. Such high precision is required for pump-probe experiments and also for example for the electron bunch injection into a plasma bubble for laser plasma acceleration. An upgrade of the fast intra-train beam-based feedback system is planned at the Free-Electron Laser FLASH in Hamburg, Germany. This linear accelerator is based on superconducting (SRF) technology operating with pulse trains of maximum 1 MHz bunch repetition rate. Arrival time fluctuations of the electron beam are correctable by introducing small energy modulations prior to the magnetic bunch compressor. This contribution focuses on the design and the characterization of a normal-conducting RF (NRF) cavity with large bandwidth, mandatory to correct fast arrival time fluctuations. The cavity has recently been installed in the FLASH beamline. First measurements with the new cavity will be presented.

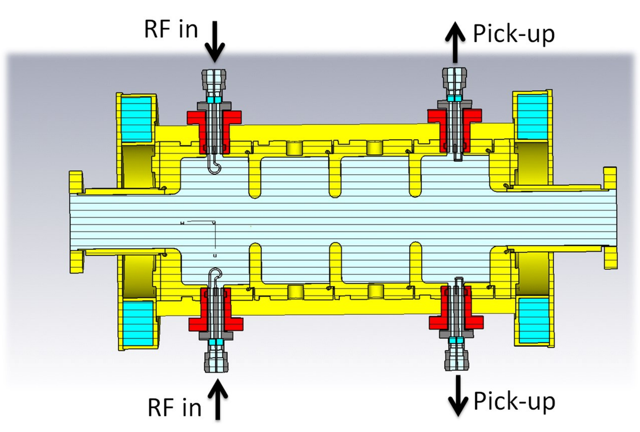
*B*unch *A*rrival time *C*orrector *CA*vity (BACCA) design and characterization

Specification and 3D design

- 2.998 GHz operating frequency
- Max. energy correction of ±50 keV corresponding to ±200 fs arrival time correction after first bunch compressor
- Max. feedback loop latency of 700 ns
- Corrector cavity half bandwidth of about 500 kHz
- Operating temperature above ambient temperature
- Longitudinal and transverse wakefields as well as orbit changes for multi bunch operation should not occur during operation

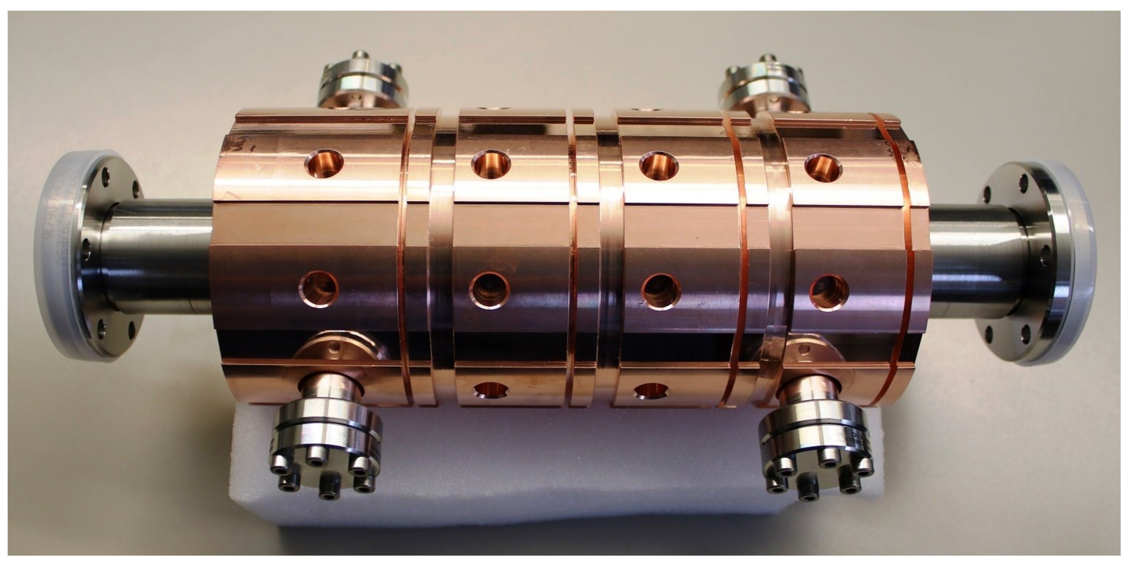


- Simulation of thermal stress to the input loop has been simulated justifying the power distribution to BACCA with 2 input loops
- Two output loops, i.e. the probe pick-ups, for symmetry reasons



Fabrication

- Cavity cells were produced at the Hansa Press- und Maschinenbau GmbH in Hamburg, Germany
- Assembly and the soldering of all parts were done at DESY
- Quality control and leak test passed

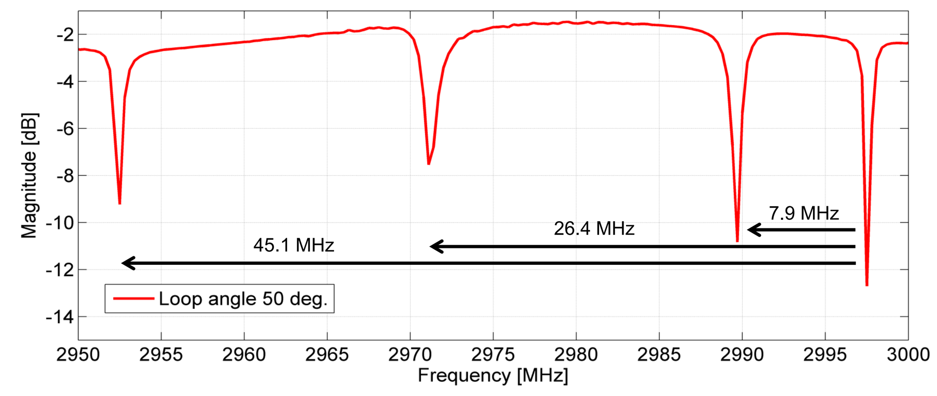


- 4 feedthroughs, where 2 are used for in-coupling and 2 for the pick-up antennas
- Loops can be rotated to adjust the magnetic coupling to the field
  - Adjustment of half bandwidth by coupling change for both inputs
  - Adjustment of RF coupling for the pick-ups (-48 dBm)

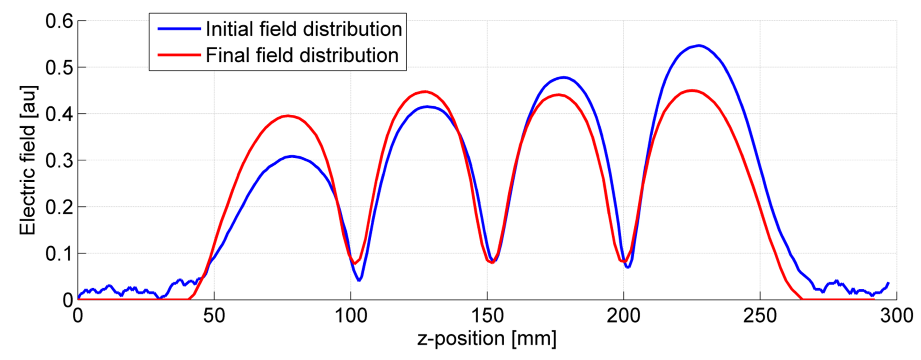
Characterization and tuning

- Measurements using network analyzer
  - BACCA driven by an adjustable test signal
  - Used the S11 (frequency dependent reflection coefficient) measurement
  - BACCA tuned to operating frequency (for op. temperature of about 40°C)

Parameter	Operating Frequency		Difference w.r.t. π-mode	
	Simulation	Measurement	Simulation	Measurement
π-mode frequency	2998 MHz	2997.6 MHz	0 MHz	0 MHz
2π/3-mode frequency	2989 MHz	2989.7 MHz	9 MHz	7.9 MHz
π/3-mode frequency	2971 MHz	2971.2 MHz	27 MHz	26.4 MHz
0-mode frequency	2954 MHz	2952.5 MHz	44 MHz	45.1 MHz

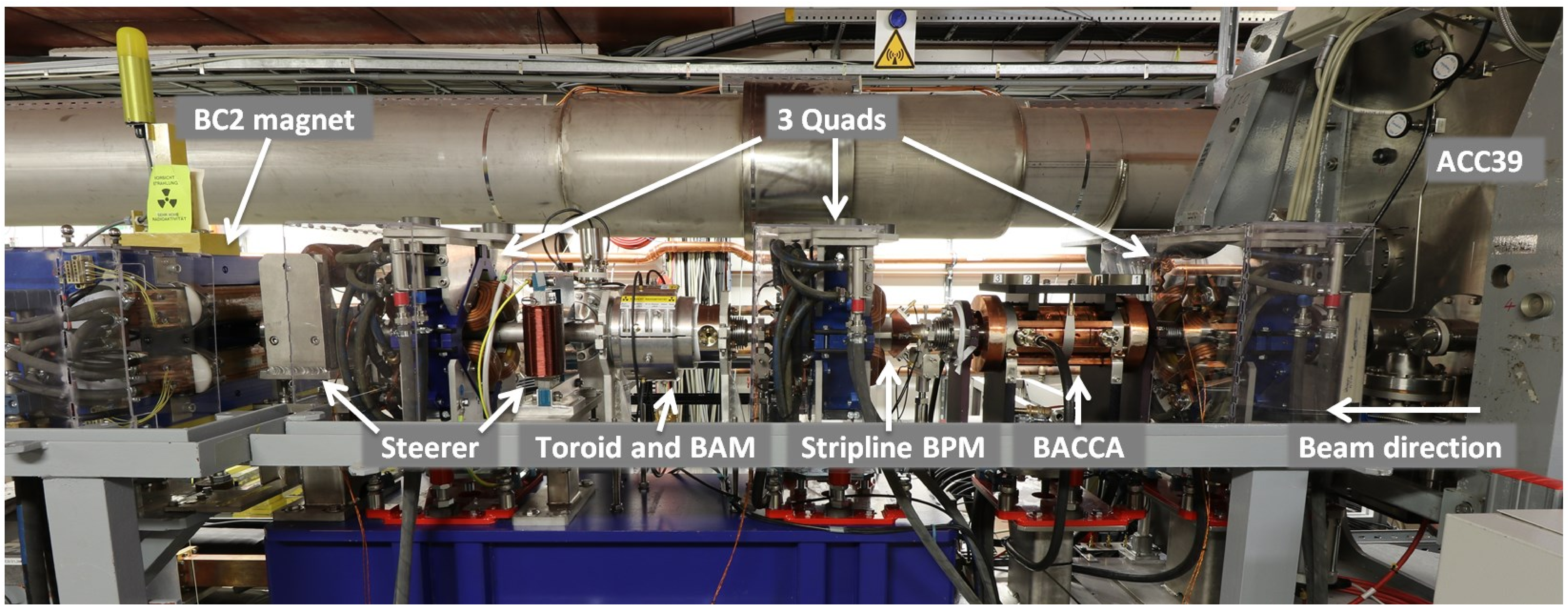


- Bead-pull measurement and tuning
  - Measure the profile of the electric field inside BACCA
  - Introducing a small metallic object (the bead) into the interior of the cavity will perturb the frequency proportional to the local fields at the location of the beat
  - The bead acts as a perturbation and causes a shift of the resonant frequency of the cavity which is proportional to the square of the local electric field
  - Tuned BACCA for flat electrical field distribution



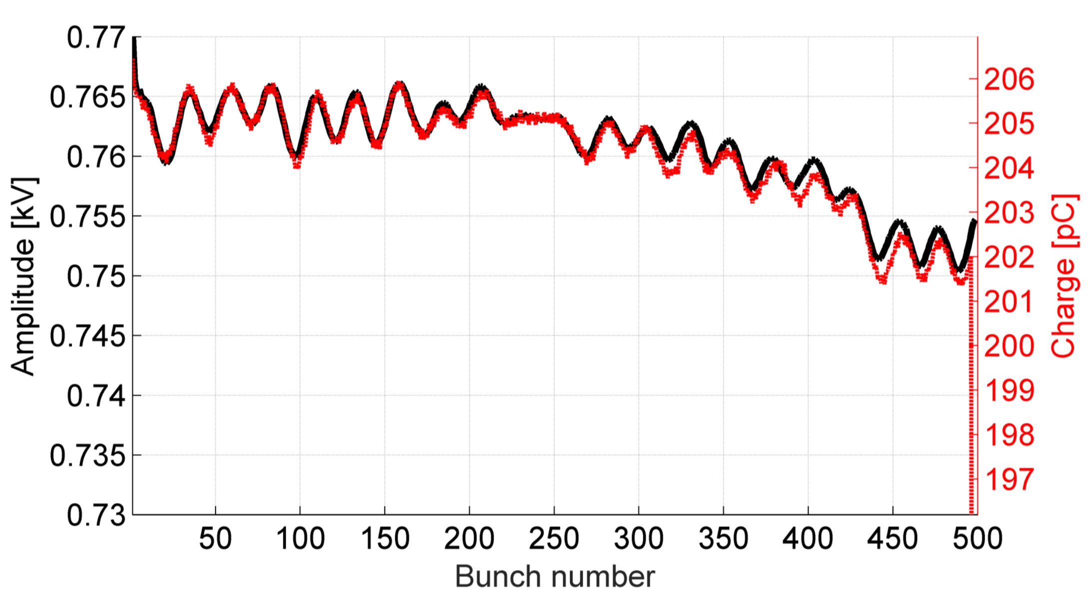
Upgrade 01/2018

- Complete renewal of upstream BC2 section at FLASH within 3 weeks
  - From ACC39 to first bunch compressor (BC2)
- 3 new quadrupoles installed
- BACCA installed
- Exchange of damaged first BC2 magnet
- New 40 GHz bunch arrival time monitor (BAM) body installed
- Installation of horizontal and vertical steerer
- Installation of beam diagnostic (Toroid, stripline beam position monitor (BPM))



First measurements

- The first measurements were done without RF and with beam loading only
- Cavity used as charge detector by analyzing bunch transients
- Black line shows the peak amplitude of the beam transient measured with one probe antenna of the cavity
- Red line shows the corresponding charge monitor information as independent measurement



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Conclusion & Outlook

- Cavity and the main components in the FLASH BC2 section were changed during the winter shutdown in 2018.
- Frequency generation module providing the operating and intermediate frequencies commissioned.
- MicroTCA.4 based LLRF system has been installed and commissioned.
- First RF measurements without and with beam (multi bunch operation) were performed.
- Outlook:
  - Interconnection with the bunch arrival time monitor (BAM) such that bunch arrival information can be used within a train of electron bunches for fast arrival time feedback.
  - Integration of fast feedback cavity into existing (to be updated) beam-based feedback scheme.
  - …

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