Statement on the XFEL 3rd harmonic inner module design the as of December 2010

WPLs of WP46:

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Technical feasibility

Since the meeting of February 2009 we discussed in several personal meetings all technical consequences also with experts, for example K. Jensch (WPL of WP03 - Accelerator Modules) or H. Brück (WPL of WP11 - Cold Magnets) and could not identify technical obstacles which cannot be solved by modifying already existing and proven designs.

Beam dynamical questions

Examinations performed under the supervision of W. Decking and T. Limberg (the MLCs) of the transverse beam emittance measured after the first bunch compressor (BC2) section in FLASH didn't show beam emittance with ACC39 larger than the ones measured without ACC39 while steering the beam on trajectories with significant transverse offsets through ACC39. Hence, there are no additional measures required reducing a potential serious negative influence of high frequency HOMs than those already taken.

Statement

The subsequent table of elements is the conceptual design of the inner XFEL 3rd harmonic module.

XFEL 3.9 GHz Module 12/2/2010

length [mm]	min. diameter [mm]	component	change of diameter
75.00	78.00	valve	
107.00	78.00	drift	
60.00	78.00	HOM absorber	
0.00	78.00	pump	
133.00	78.00	bellow	
75.00	78.00	valve	
170.00	78.00	BPM	
297.50	78.00	QA	
22.50	40.00	reducer 78-40 mm	step
101.40	40.00	bellow	
80.00	40.00	drift	
38.60	30.00	cavity 1 cell 1	
38.40	30.00	cavity 1 cell 2	
38.40	30.00	cavity 1 cell 3	
38.40	30.00	cavity 1 cell 4	
38.40	30.00	cavity 1 cell 5	
38.40	30.00	cavity 1 cell 6	
38.40	30.00	cavity 1 cell 7	
38.40	30.00	cavity 1 cell 8	
38.60	30.00	cavity 1 cell 9	
80.00	40.00	drift	
102.00	40.00	bellow	
80.00	40.00	drift	
346.00	30.00	cavity 2	
80.00	40.00	drift	
102.00	40.00	bellow	
80.00	40.00	drift	
346.00	30.00	cavity 3	
80.00	40.00	drift	
102.00	40.00	bellow	
80.00	40.00	drift	
346.00	30.00	cavity 4	
80.00	40.00	drift	
102.00	40.00	bellow	
80.00	40.00	drift	
346.00	30.00	cavity 5	
80.00	40.00	drift	
102.00	40.00	bellow	
80.00	40.00	drift	
346.00	30.00	cavity 6	
80.00	40.00	drift	
102.00	40.00	bellow	
80.00	40.00	drift	
346.00	30.00	cavity 7	
80.00	40.00	drift	
102.00	40.00	bellow	
80.00	40.00	drift	
346.00	30.00	cavity 8	
80.00	40.00	drift	
75.00	40.00	valve	

5,503.40		complete module

Minutes of Meeting on the inner module design at 2009-02-10

Participants:

Winfried Decking (WD), Torsten Limberg (TL), Yauhen Kot (YK), Jacek Sekutowicz (JS), Martin Dohlus (MD), Klaus Floettmann (KL), Elmar Vogel (EV)

Agenda

- Required rf voltage and the cavity string
- Quadrupole magnet position
- Beam pipe and vacuum diameters
- Trapped HOMs and beam pipe HOM absorber

1. Required rf voltage and the cavity string

Shifting the 3.9 GHz section form the previous position at the end of the injector linac and 0.5 GeV beam energy to the end of the injector and 130 MeV beam energy requires a minimum 3.9 GHz voltage of 40 MV (see Minutes and transparencies of the 205th XFEL Meeting at 17th December 2008). Eight 3.9 GHz cavities each with a 15 MV/m operational gradient are required to build up this voltage.

> The basic module design remains unchanged. It consists of a string of eight cavities with alternating coupler positions and a package of a quadrupole magnet with a BPM.

2. Quadrupole magnet position

The beam steering through the 1.3 GHz injector module and the 3.9 GHz module (XACC39) become independent from each other inserting a beam steering section in between. Cold quadrupole magnets contain steering magnets. A beam steering section between the 1.3 GHz cavity string and the 3.9 GHz cavity string can be constitute putting the quadrupole magnet of the 3.9 GHz to the beginning rather than to the end.

> The package of the quadrupole magnet and BPM will be placed at the beginning of XACC39.

Beam optics requires also a quadrupole magnet at the end or after XACC39.

Action:

> YK investigates whether a warm quadrupole after the cryogenic end cap succeeding XACC39 will be sufficient or whether an additional cold quadrupole has to be added to XACC39 at the end of the cavity string.

3. Beam pipe and vacuum diameter

As we deal with a single module, the position of the transition form the 1.3 GHz beam pipe diameter of 78 mm to the 3.9 GHz beam pope diameter of 40 mm can be shifted inside XACC39. Placing the taper at the end of the package of a quadrouple magnet and BPM the standard 1.3 GHz version can be used without modifications like an inner beam tube (previous design).

> XACC39 consists of a standard 1.3 GHz gate valve at the beginning, followed by a standard package of BPM and quadrupole magnet.
>
> The taper, reducing the beam pipe diameter from 78 mm to 40 mm, is located after the quadrupole magnet, just before the cavity string.

The warm section following XACC39 and the cryogenic end box has a beam pipe diameter of 40.5 mm. As a consequence:

> The gate valve at the end of XACC39 needs to be a 40 mm version preventing the built up of an unfavourable and unwanted cavity like structure.
>
> If we need to add a cold quadrupole magnet after the cavity string in XACC39 an inner beam tube has to be inserted keeping the beam pipe diameter at 40 mm.

4. Trapped HOMs and beam pipe HOM absorber

Higher order modes with frequencies above 10 GHz may be trapped in the 3.9 GHz cavity string. A part of these modes will leave the string, both, at the up- and downstream end. Modes leaving at the downstream end are expected to be well absorbed by the subsequent warm beam pipe which has a length of 70 m before the next 1.3 GHz accelerating structure of the injector linac start.

> Actually, we do not plan to design a beam pipe HOM absorber for beam pipes with 40 mm diameter, e.g. a special version for 3.9 GHz sections.

Modes leaving the 3.9 GHz cavity string at the upstream end will be absorbed by the beam pipe HOM absorber located at the end of the 1.3 GHz injector module (between the two quadrupoles magnets). The 78 mm beam pipe HOM absorbers have been designed for damping 1.3 GHz HOMs at high energy where the bunches are short. This type of absorber is expected to be fully suitable for damping 3.9 GHz HOMs in the low energy section of the injector where the bunches are still long and the generated HOMs have lower frequencies.

> A ‘standard’ 78 mm beam pipe HOM absorber will be located between the 1.3 GHz injector module and XACC39.

Modes (1.3 GHz HOMs and somewhere reflected 3.9 GHz HOMs) passing the absorber downstream without hitting the absorbing surface are expected being reflected by the taper 78 mm to 40 mm in front of the 3.9 GHz string. This should improve the HOM absorber efficiency as these modes may be absorbed at a second passage. For the same reason, HOMs generated by 1.3 GHz cavities are not expected being trapped in the 3.9 GHz cavities.

Nevertheless, in the case ACC39 in FLASH show high frequency HOMs and trapped HOM affecting the beam and the accelerator operation seriously, we may have to consider inserting pipe HOM absorber for beam pipes with 40 mm diameter between all 1.3 GHz cavities. This would seriously complicate the module design and delay the completion of XACC39.

> If the operation of ACC39 in FLASH shows a serious negative influence of high frequency HOMs and trapped HOM on the beam and the accelerator operation, XACC39 may require beam pipe HOM absorbers between all 3.9 GHz cavities. This would increasing the module length by approximately 1.2 m. The space given by the injector building and subsequent accelerator tunnel will not restrict such a design change. The space available for beam diagnostics will be reduced.

Supplementary remarks from EV from February 11th

At February 11th, EV performed two visits to the scene, one to the cold magnet test stand together with H. Brück followed by one to the module assembly area with K. Jensch.

> The order gate valve, BPM, quadrupole magnet, reducer, bellow, first cavity is in principle possible.

Action:

> According to the meeting with K. Jensch, we have to check the work and cost required for switching the magnet wiring box at the magnet, so that the wires and connections of the warm cold transition direct upstream and consequently out of the module. Otherwise they may interfere with the thermal shield.

Supplementary remark from February 12th – Action: Second magnet needed? No!

According to the most recent beam optics investigations no second quadrupole magnet is required in XACC39. Hence, the basic module contents remains unchanged. The order of the BPM, quadrupole magnet and the cavity string should be like the one given in the ~~subsequent~~ table **'XFEL 3.9 GHz Module'**.

Summary from February 12th

See in the ~~subsequent~~ table **'XFEL 3.9 GHz Module'** the proposed new version of the inner XACC39 module design. It is basically the old one turned back to the front. The cryogenic pipes of the module and the connections building blocks like the magnet are not back-to-front symmetric. ~~Hence, the technical consequences and the feasibility remain to be checked and discussed.~~