Minutes of the Meeting on the WP2 RF Collaboration
held on 27 September (09:00-12:00) via ZOOM

Participants:

- ESRF: Jörn Jacob (JJ), Vincent Serriere (VS), Alessandro D'Elia (AD), Simon White (SW), Lee Carver (LC)
- KEK: Shogo Sakanaka (SS), Naoto Yamamoto (NY)
- PSI: Lukas Stingelin (LS)
- SOLEIL: Patrick Marchand (PM), Alexis Gamelin (AG), Massamba Diop (MD), Fernand Ribeiro (FR), Ryutaro Nagaoka (RN)

Compiled by: PM and RN

The main goal of the meeting of this day was to see together the results of simulation studies made at KEK and SOLEIL on the performance of bunch lengthening cavities for the SOLEIL upgrade. In both cases, four EU-type HOM-free cavities, as developed by the ESRF for the ESRF-EBS, was assumed for the main RF system (MC). NY presented active schemes using the normal conducting (NC) harmonic (h=4) cavities (HC), which are also being developed at the ESRF, while AG reported on passive schemes using superconducting harmonic (h=3 and 4) cavities, along with an updated broadband impedance model developed for the SOLEIL upgrade. These two presentations were followed by status reports from the ESRF, one by the RF group (JJ et al.) on the NC-HC development, and another by the Machine Physics group (LC et al.) on the simulation code development. The programme of the meeting is attached at the end of this minutes. All the slides presented in the meeting should be found at: https://gitlab.synchrotron-soleil.fr/PA/workshop/rf-collaboration/...

The feasibility studies of the active NC-HCs made by NY took the same approach as that of AG on the passive SC-HCs, which first evaluates the stability of beam analytically using a known threshold formula as a function of the HC detuning to identify approximately the possible stable working range, followed by tracking using MBTRACK to pursue more realistic stability limits. Three different configurations were considered for HCs and their respective performance compared: 1) one HC alone (one 2_cell cavity). 2) two HCs. 3) two HCs in the bunch lengthening (BL) mode and one HC in the bunch shortening (BS) mode. It was shown that 1) manages to achieve more than a factor of 3.5 bunch lengthening (BL) in all three beam filling modes envisaged for SOLEIL-II, however it associates a HC wall power dissipation of ~40 kW, which was considered to be close to the feasibility limit. The case 2) eases the power dissipation issue, but the BL factor was significantly reduced especially in multibunch as the onset of instability appears earlier. The case 3) was indeed introduced to mitigate the instability and the BL factor improved as expected, but not as much as 1).
In the simulation code, three types of RF related controls were implemented: a) Coupled-bunch mode damper, b) Direct RF feedback and c) Feedforward Transient Beam Loading (TBL) compensation.
The simulations show that in case 1, the introduction of a direct RF feedback allows to reach the flat potential condition without instability occurrence, which leads to bunch lengthening factors > 4.5 for all the operating modes. Such feedback becomes ineffective when using more than one cavity.

The presentation by AG on the passive SC-HC (h = 3 and 4) reported on additional findings since the last meeting as the basic lengthening performance studied was already presented earlier. It was shown that the broadband impedance model has evolved significantly as the vacuum chamber system of the SOLEIL-II ring has evolved in the TDR phase. While the thickness of NEG assumed previously to be 1

μm was decreased to 0.5 μm, reducing in consequence their inductive contributions, the geometric impedance increased notably especially due to integration of a large number of taper transitions in the arc sections, compensating the former and increasing the high frequency resistive impedance, enhancing the microwave instability for high current bunches. It was shown that with the new broadband impedance model, the previously existing difference in the bunch lengthening performance in multibunch at 500 mA between the h = 3 and h = 4 systems diminished and the h = 4 system which was inferior in this operation mode obtains a sufficient margin (BL factor of ~5), enhancing the interest of choosing this system as opposed to h = 3. The performance results were updated for the remaining two operation modes (100 mA in 8 bunches and 20 mA in single bunch) as well, where in the 8-bunch mode, an instability which seems like exhibiting a dipole-quadrupole mode coupling was also identified.

The ongoing development of the h = 4 active NC-HCs at the ESRF was reported by JJ. He explained that the coupling slots of the 2-cell cavity creates an asymmetry in the fundamental field which increases its power dissipation inside the ferrite. They are investigating how they can reduce this field leakage and what is the dissipation limit of the ferrite. Nonetheless, they hope to arrive at a point to make calls for tender by the beginning of next year.
On the other hand, they consider that their quite sophisticated cavity cooling system with several water channels is well able to evacuate a wall dissipation up to 50 kW.
The main uncertainty for the use of such a cavity in SOLEIL II is its HOM damping capability, which is largely sufficient for the ESRF case but likely not for the much more demanding SOLEIL II case. It remains also to investigate how one can control such a double RF system, with active MC and HC, which are strongly coupled.
The above information and the project status were recently communicated by JJ to Amor Nadji (SOLEIL-II Project Leader) and PM. Otherwise, JJ explained that the primary reason for having chosen a h = 4 system was simply because at the time of the start of development, high power transistors at 1.056 GHz corresponding to h = 3 frequency were not available, while they are today. The recent suggestion made by PM to have a look at the h = 3 solution in view of relaxing the power dissipation issue appears indeed to be interesting.

LC reported that they have made good progress in the last months on the development of PyAT (the Python version of Accelerator Toolbox), regarding the part related to multibunch tracking for collective effects studies, in particular, the simulation of coupled-bunch instabilities involving multiturn (long-range) wakes. The code is now capable of simulating transverse resistive-wall instabilities and RF cavities driven instabilities. A question was raised by AG if the chosen treatment of storing wake potentials over a large number of past turns would be adequate in simulating instabilities whose growth time could be as long as a second.

The contributions of the present collaboration on RF in the forthcoming HarmonLIP workshop (10-12 October at MAXIV: https://indico.maxiv.lu.se/event/5098/) were reviewed together by following the programme. JJ pointed out that since he cannot handle as many as three talks requested, he shall contact the organizers to reduce his contributions, especially on the review between passive and active HC systems. It was also discussed how the works carried out within the frame of this collaboration should be shown. PM and RN responded that they shall think of a way and diffuse it around (→ it was suggested to include a text "*This work (or Part of this work) has been performed within the frame of the WP2 collaboration among ESRF, HZB, KEK, PSI and SOLEIL*")

Lastly, future directions of the subsequent activities of the collaboration were discussed. It was commonly agreed that cross-checks of the simulation codes in course of development and/or available today, specifically mbtrack2, pyAT, elegant (Pelegant) and pyHEADTAIL …, would be of primary importance. We could take the same settings (machine, the beam and the HC parameters) to compare the outputs, as well as carry out benchmarking against available and feasible beam-based measurement. As to the latter, LS mentioned that he could think of reorganizing experiments on the SLS machine as the general situation against the pandemic has much improved since. He could also recontact the colleagues at BESSY to seek for such opportunities at BESSY-II, where we hear that testing of the 1.5 GHz NC-HCs developed at ALBA has begun.

[ANNEX]

Programme of the Meeting on the Collaboration on RF WP2 held on 27 September 2022

9:00-9h30: Active NC HC applied to the SOLEIL II case (Naoto Yamamoto)
+ 10' for questions/discussion

9:40-9:55: Passive SC HC with collective effects in SOLEIL II (Alexis Gamelin)
+ 5' for questions/discussion

10:00-10:15: ESRF 4th HC R&D status (Jorn Jacob, Vincent Serrière, Alessandro d'Elia)
+ 5' for questions/discussion

10:20-10:35: Pyat developments at ESRF (Lee Carver)
+ 5' for questions/discussion

10:40-11:00: Discussion
- Presentations at the HarmonLIP workshop
- Further activities of the collaboration
- Miscellaneous