Summary of the HOM workshop

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- **10 contributions – lots of discussion**

- **DISCUSSION SESSION ON "EXPERIMENTAL OBSERVATION**
By Sang-Ho Kim

- **DISCUSSION SESSION ON "DAMPERS TECHNICAL SOLUTIONS "**
By Wolfgang Weingarten

Participation

- 23 registred participants (10 CERNies)
- 10 Institution represented (SNS, FNAL, ESS, TRIUMF,CNRS,CEA,IPJ, DESY,SCK-CEN and CERN).

Workshop task

- We are organizing a mini-workshop on the subject of HOMs in a superconducting proton linac to be held at CERN June 25-26. The purpose of this workshop is to discuss more specifically the effects of HOMs on beam dynamics in the SPL and comparable accelerators and to provide guidelines for the specification of HOM dampers, if necessary.

LP and HP SPL

Low-Power SPL

kinetic energy	4 GeV
beam power (@ 4 GeV)	0.14 MW
repetition rate	0.6 - 2 Hz
pulse length	0.9 ms
average pulse current	20 mA
protons p. pulse	$1.1\ 10^{14}$
length (SC linac)	427 m

High-Power SPL

kinetic energy	5 GeV
beam power	3-8 MW
repetition rate	50 Hz
pulse length	up to 1.2 ms
average pulse current	0-40 mA
protons p. pulse	$1.5\ 10^{14}$
length (SC linac)	502 m

- Structures and klystrons dimensioned for 50 Hz
- Power supplies and electronics dimensioned for 2 Hz, 1.2 ms pulse.

LP vs HP (2 Hz vs. 50 Hz)

HOM are relevant only for the HP-SPL. Rep rate of 2 Hz is such that the HOM voltage induced decays between bunches and there is no build-up effects

$T_{decay} \div 2\ Q_{ext}\ /\omega_n$

(50 Hz , t=20 msec)

Effects of HOM – calculations tools

- 4 programs used on SPL
  - JT "5lines"
  - MS "500lines"
  - TALOBBU - SNS code used at TRIUMF
  - J-L B code

    - First 3 codes agree to the 5th decimal when using same input parameters
    - J-L B code agrees with JT for one case. Not extensively benchmarked against the other

There is no doubt about the calculation tool

HOM frequencies

- it is agreed that the most dangerous frequencies are the machine lines (multiples of 352 MHz).
- Calculations with field solvers were presented (HFSS/MAFIA). These programs show a fair agreement between each other and with measurements.
- In general HOMs can be excited at all frequencies provided there is a beam pattern that drives them (e.g. bunch charge fluctuations, transversely mis-steered beams, phase and energy jitter…)

Important parameters in the evaluation of HOM on beam dynamics

- Cavity geometry : Qext, frequency scatter (manufacturing errors).

- Beam : current, time structure , alignment errors, energy phase jitter.

Qext and R/Q i.e. the intensity of the induced voltage

- Q ext and measured value can differ by a factor 10. This effect could be explained by a different damping of the HOMs once the cavity is adjusted to have a flat field for the fundamental mode.
- Generally a safety factor of 10 has been taken for the current in the calculations, which has the same effect as taking a safety factor on Q_{ext}. In some of the simulation presented a r/Q independent of the particle velocity has been used.
- Agreement is that we need to use “effective r/Q” which includes the Transit Time Factor otherwise the effect of the induced voltage is overestimated.

Frequency scatter

- the frequency scatter is a very important parameter in the calculations. The smaller the frequency scatter, the easier it becomes to excite HOMs.
- In the simulations, values between 0.1 and 1 MHz have been used.
- Based on the experience of other projects (SNS, TESLA, JLAB), the consensus is that a value of 1-2 MHZ is more realistic, as a result of manufacturing errors

Beam current pulse-to-pulse variation

- a very critical parameter, as it is one of the drivers of HOM instabilities for frequencies outside of machine lines.

- Wide band measurements from the source are very difficult and values between 10 % and 1 % have been used in the simulations. Measurements from the ISIS source and measurements from the SNS source don’t seem to agree on a pulse-to-pulse stability value but possibly the interpretation is not clear.

- In any case there is a general agreement that 10% is excessive and that a value of 1-3% is more realistic.

Agreed parameters for further simulations

Beam Intensity	40 mA
Intensity pulse-to-pulse jitter	1-3%
r/Q	Take nominal and keep into account the effect of beam velocity
Frequency spread	1-2 MHz

- Other effects to be included as drivers of HOM are:
- Variable chopping pattern and partially deflected bunches
- Transverse alignment errors

Conservative approach :

- As there is potential for beam degradation/loss let’s take the dampers [SNS approach 2000]
  - Suitable technical solution
  - Complexity cost
  - Can the dampers actually be harmful, at least when the system is not fully commissioned and understood

Can the HOM dampers be harmful?

- Electron activities in the coupler
  - multipactoring
  - field emission

- Transverse field /kick generated by the coupler

Decisions, decisions….

- What can make us take a different decision than SNS-review?
  - Number of cavities (81 SNS, 234 SPL)
  - Chopping pattern
  - Be confident/test a coupler design
  - SPL as electron recirculator
- What can make us take the same decision as DESY?
  - convince ourselves that we have same strict bd requirements (unlikely)
  - Find out that transverse modes degrade significantly the beam dynamics

Conclusions

- It was agreed that new simulations of the SPL case with the parameters shown in Table 2 should be performed before taking any conclusion on the need of HOM dampers. Heat dissipation because of HOMs shall also be evaluated.
- The possibility to use a design similar to SNS, with the inter-cavity connections (bellows) providing sufficient HOM damping, shall be studied carefully. Should this not be sufficient in view of the results of the next simulations, a careful design (or possibly a test) of a sound technical solution for a damper shall be studied. Steps in this direction were presented during the discussion on "dampers technical solutions".
- It was also agreed that, because of the variety of potential future uses of the SPL, the superconducting cavities should be equipped with ports to allow both HOM monitoring as well as the possibility of adding dampers at a later stage. The design of these ports shall be part of the overall cavity design handled by the cavity working group.