The HOMSC2018 Workshop in Cornell

A Brief Summary

Nicoleta Baboi, DESY
DESY-TEMF Meeting
DESY, Hamburg, 15 Nov. 2018
ICFA Mini Workshop on Higher Order Modes in Superconducting Cavities (HOMSC2018)

1-3 October 2018
Physical Science building (PSB)
America/New_York timezone

The objective of this workshop is to bring together researchers studying high order mode (HOM) suppression in superconducting RF cavities for applications ranging from energy recovery linacs and light sources to linear colliders. HOMs excited by a beam in superconducting cavities can create excessive heat load on the cryogenic system and dilute beam quality, giving rise to a beam break up instability in the worst case. This workshop will discuss the current status of both experimental and theoretical work in this area. Issues in electron and proton linacs, Tesla style cavities, 3rd harmonic cavities, TEM crabbing and other cavity designs will be considered.

Starts Oct 1, 2018 08:00
Ends Oct 3, 2018 20:55
America/New_York

Physical Science building (PSB)
401
Cornell University
Ithaca, NY 14853
United States

Prof. Liepe, Matthias

http://indico.classe.cornell.edu/event/185/overview
Scientific Program

- 4 working groups
  - WG 1: High-current accelerators and HOM damping requirements
  - WG 2: Numerical simulation – modelling approaches and tools
  - WG 3: Design of SRF cavities and HOM damping schemes
  - WG 4: HOM measurements, beam effects, and diagnostics
High-current accelerators and HOM damping requirements

- HOM damping requirements for high-current option of FCCee, Ivan KARPOV (CERN)
  - Low-energy Z machine

  - highest current ($\approx 1.4$ A)
  - most challenging for high-order mode (HOM) power extraction (max power 1 kW per HOM coupler)
  - 13 cryomodules with four 400 MHz single-cell LHC-like cavities

- 1 mode below cutoff has high R/Q
- Critical filling schemes identified
WG1: High-current accelerators/requirements

SRF Developments for BESSY VSR, Adolfo VELEZ (HZB G-ISRF)

• Challenges:
  • CW, 20MV/m, 300mA
  • Very strong HOM damping etc.
• Optimization of damping techniques, wakefields, absorbers etc.

• Testing prototypes
WG1: High-current accelerators/requirements

Overview of CBETA and the role of HOMs, **HOFFSTAETTER, Georg (Cornell)**

The test ERL in Cornell’s hall LOE

- Cornell DC gun
- 100mA, 6MeV SRF injector (ICM)
- 600kW beam dump
- 100mA, 6-cavity SRF CW Linac (MLC)

Existing components at Cornell
- Investment value: $32M
- Return loop closed with
- NYS funding: $25

Then available for High-power R&D

Electron Current up to 320mA in the linac
Bunch charge Q of up to 2nC
Bunch repetition rate 1.3GHz/N
Beams of 100mA for 1 turn and 40mA for 4 turns

**Cornell-BNL ERL Test Accelerator**

42, 78 1st beam through all essential components:

_Electron Current up to 320mA in the linac_
_Bunch charge Q of up to 2nC_
_Bunch repetition rate 1.3GHz/N_
_Beams of 100mA for 1 turn and 40mA for 4 turns_

**Cornell-BNL ERL Test Accelerator**

42, 78 1st beam through all essential components:
WG2: Numerical simulation

Propagating Eigenmode Simulations in SRF Multi-Cavity Cryomodules Using ACE3P, Liling XIAO (SLAC)
WG2: Numerical simulation

Update on HOM studies for PIPII SC linac, Alexander SUKHANOV (Fermilab)

**PIP-II Project**

- PIP-II Linac

<table>
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<tr>
<th>IS</th>
<th>LEBT</th>
<th>RFQ</th>
<th>MEBT</th>
<th>β</th>
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<tr>
<td>HWR</td>
<td>SSR1</td>
<td>SSR2</td>
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- Elliptical 5-cell
  - LB650
  - HB650

- DC
  - 0.03 MeV

- 162.5 MHz
  - 0.03 - 10.3 MeV

- 325 MHz
  - 10.3 - 185 MeV

- 650 MHz
  - 185 - 800 MeV

- Complex beam current spectrum
- No HOM couplers and dumpers (QL up to 1e7)
**WG3: Design of cavities and HOM damping**

**SRF cavity design and HOM damping for eRHIC e- storage ring,**
*Wencan XU (bnl)*

- *eRHIC requires a 563 MHz fundamental SRF system for energy compensation, and a 3rd harmonic cavity for beam instability.*
WG3: Design of cavities and HOM damping

HL-LHC DWQ HOM coupler design and SPS measurements,
James MITCHELL (CERN)

DQW Crab Cavity

Worst case power:

The coupler should be altered to:
1. Reduce transverse impedance below threshold.
2. Reduce maximum foreseeable HOM power to below 1 kW.

13 times larger than 1 kW limit.
Due to mode at 960 MHz – coupler needs to be altered.

Student price!
Design of the BESSY VSR waveguide damped cavities and ancillary components for the cold string, Andranik TSAKANIAN (HZB)
WG3: Design of cavities and HOM damping

HOM loads development at JLAB: BESSY VSR and bERLinpro,
Jiquan GUO (JLAB)

bERLinpro

BESSY VSR (Variable pulse length Storage Ring)
WG3: Design of cavities and HOM damping

SRF above 1.3 GHz: Motivation and Implications for Higher Order Modes,
James MANISCALCO (Cornell)

Abstract

Recent research into impurity-doped niobium and Nb$_3$Sn have pushed towards unprecedentedly high quality factors and low cryogenic power consumption for SRF accelerators. These open the way to high frequency cavities (above the 1.3 GHz standard in contemporary SRF projects such as EXFEL and LCLS-II) which could significantly decrease costs for new accelerator facilities. In this talk we provide some background on these novel surface treatments, give motivation for the move to higher frequency, and raise some points of discussion for the impacts on higher order mode consideration.
WG3: Design of cavities and HOM damping

HOM damping schemes for the FCC-ee cavities,
GORGI ZADEH, Shahnam (Universität Rostock)
WG3: Design of cavities and HOM damping

JLEIC HOM damping study, Jiquan GUO (JLAB)
Parallel-bar travelling wave accelerating cavities

Equivalent Circuit Modelling
WG3: Design of cavities and HOM damping

Higher Order Mode and Cavity Studies at the University of Rostock since HOMSC16, Ursula VAN RIENEN (University of Rostock)

State-Space Concatenations (SSC)
- Application to FLASH
- Application for BESSY VSR
- Computation of External Quality Factors

Mode resonating at 2.797 GHz

Uncertainty Quantification Techniques and Stochastic Models for SRF Cavities

Resonant HOM excitation $V_{L,max}$ due to horizontal HOM

Transverse deflecting cavity
WG4: HOM measurements

Observations of Sub-Macropulse Electron-Beam Dynamics Correlated with Higher-Order Modes in TESLA-Type Cavities, Alex LUMPKIN (Fermilab)

- FAST facility, TESLA cavities

- Observed transverse oscillations on multi-bunch beam (3MHz)
  - Vertical: 100kHz
  - Fits to calculations with mode at 1.87GHz
  - Horizontal: 380kHz
WG4: HOM measurements

Measuring HOM parameters with beam for Cornell’s ERL cavities,
Adam BARTNIK (Cornell)

- Idea: excite single HOM by modulating bunch charge

- Plan to repeat with finer step

Found lots of peaks!
WG4: HOM measurements

HOM Beam Based Diagnostics at FAST, Olivier NAPOLY (FNAL)

- Proposal to investigate the HOM full potential in beam diagnostics and beam based tuning
  - achieving minimal transverse wake kicks
  - transverse beam size measurement, based on quadrupole modes
- HOMs in FAST

![Graphs showing HOMs in FAST](image.png)

77° ± 8°

e.g.: measurement at TTF (now FLASH)
WG4: HOM measurements

HOM Based Beam Diagnostics in TESLA Superconducting Cavities at FLASH, Junhao Wei (DESY)

- HOM based beam position measurement
- HOM based long-term beam phase measurement
- HOM based cavity tilt measurement

• Following talk
WG4: HOM measurements

BBU Simulation, William LOU (Cornell)

- Simulations for CBETA
  - Studied threshold current for various options
  - With various cavity shape errors

Potential ways to improve $I_{th}$:

1) Change bunch frequency
2) Introduce additional phase advance
3) Introduce x-y coupling
WG4: HOM measurements

HOM absorbers, HOM heating, and current limits, including measurements for CBETA, Nilanjan BANERJEE (Cornell University)

- Chose beamline absorbers for the ERL project
- Injector absorbers
  - ferrite tiles fixed to copper plates
- Main Linac Cryomodule absorbers
  - six 7-cell cavities
  - Silicon Carbide (CoorsTek SC3)
- CBETA current limits

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<tr>
<th>High Current</th>
<th>eRHIC</th>
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<tr>
<td>Injection Rate (MHz)</td>
<td>325</td>
</tr>
<tr>
<td>Max Bunch Charge (pC)</td>
<td>123</td>
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<tr>
<td>Max Current (mA)</td>
<td>40</td>
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WG4: HOM measurements

Status of HOM Spectra Measurements in 1.3 GHz Cavities for LCLS-II,
Andrei LUNIN (FNAL)
Discussion

Hot Topic

• Which directions should future HOM R&D focus on, i.e. where is rapid progress needed?

Outcome of the discussion

• How about SRF structures at frequencies $\gg 1.3$ GHz – possibility of multi-cell structures with large number of cells? On-cell coupling? Superstructure?

• For many of absorber materials, there are issues with thermal conductivity/power density. How about completely new materials?

• HOM coupling techniques: on-cell coupling, hook/antenna coupling, absorbing tiles in beam tube, waveguide coupling.

• HOM-free cavities – need large beam pipes

• Need funding for “true R&D”, high-potential/high risk studies. This should be easier if we work together between labs/Universities → set up an interest group?

• Power levels at HOM couplers ($\approx 1$ kW) reach similar levels as at FPC’s; similar technologies should be used/applied. Issue: ageing/cleanliness/particulates.

• HOM-based diagnostics – use the wealth of available information – also here: more money/manpower needed to deepen R&D
HOMSC2018, Cornell

27 participants
Thank you