Crab cavity and Beam halo monitor activities at KEK

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CERN-KEK collaboration on the crab cavity development

Research title: R&D of high field SRF crab cavities for HL-LHC
Research expenditure: 100,000 CHF
Research term: from 2015/7/1 to 2017/3/31

Objectives:
Based on research and development on crab cavities for the LHC luminosity upgrade progressed, as a cooperative work between KEK and CERN, this agreement, Appendix 16, aims to develop state of the art surface treatment techniques for high field superconducting crab cavities that deflect beam bunches in order to realize the crab crossing for the LHC accelerator luminosity upgrade.

KEK responsibilities for:
Development of a vertical electro-polishing (VEP) system,
Application of VEP to crab cavities,
Fundamental studies on vertical electro-polishing conditions.

Extended to 2019/3/31
Vertical EP successfully applied to the LHC Crab cavity

VEP conditions
Average current: 120 A
Average current density: 17.6 mA/cm²
Applied voltage: 16~17 V
Electrolyte flow rate: 15L/min
Electrolyte temperature: 28 degC
Cavity cell temperatures < 40 degC
Total integrated current: 293 Ah

VEP results
Average removal thickness: 35 μm
1. Top plate: 44 μm
2. Bottom plate: 22 μm
3. Upper wall: 30 μm
4. Lower wall: 80 μm

Sufficient surface removal obtained

LHC crab cavity and power amp from CERN

Large removal. Need to improve. Turnover during polishing is an option.
Setting up EP apparatus
Vertical EP at KEK

EP electrolyte filled in the cavity

Tilt the cavity to remove air

Hydrogen bubbles clearly separate from the electrolyte

EP electrolyte filled in the cavity
After VEP

Taking off the central electrode

Taking off Teflon boxes

Low pressure shower rinsing with Teflon boxes for 10 minutes

Inspection of the inner surface
Rinsing procedure

Ozonized water rinsing for 10 minutes with overflowing ozonized water

Ultra sonic rinsing for an hour in a 50 C hot water bath

Cavity in our clean room
Almost all port flanges leaked several times before we used annealed gaskets from CERN. Micro-particles may contaminate the cavity during the gasket exchange.
Our cold test stand modified from the KEKB system successfully cooled the cavity to 2K. Newly developed 400 MHz RF measurement system worked well to measure the cavity performance before and after the VEP.

Results of cold tests
1. Q factors are almost the same at low fields. Significant improvement was not observed for this cavity.
2. Heating at beam pipe flanges limited its fields.
3. Field emission was observed at relatively low fields (2.6MV), suggesting particle contamination during leakage repairing.
Future plans

- **Cold test of the VE-polished cavity at CERN**
  - The cavity will be high-pressure rinsed and cold-tested at CERN to examine the effect of vertical EP in detail.

- **VEP application to another cavity**
  - BNL-type double quarter wave cavities for the SPS beam test.
  - Examine the possibility to improve the field emission at high fields by VEP.

- **Development of high pressure rinsing system at KEK**
  - Dedicated system for LHC-crab cavities needed after VEP.

- **Additional budget**
  - Almost run-out the originally assigned budget.
  - Additional budget needed to continue VEP treatment at KEK.
Collaboration for HL LHC

First Observation of the LHC Beam Halo using Synchrotron Radiation Coronagraph and Design for phase 2 coronagraph.
Halo observation with horizontal beam blow up at 450GeV

Before blowup

Subtraction

after blowup

Beam core (1/1000 shorter exposure) without opaque disk
Halo observation with vertical beam blow up at 450GeV

Before blowup

Subtraction

after blowup
Summary for phase 1 coronagraph testing at 450GeV

The Phase 1 coronagraph is installed and tested at 450GeV

With artificial-made beam halo with beam exitor, we have observed beam halo in the range of $10^{-3}$ to $10^{-4}$ of peak intensity of the beam core.

Design for phase 2 coronagraph

The 6m focal length objective mirror system based on the telephoto lens has been designed
Design for Coronagraph objective for phase 2 coronagraph

Telephoto type with reflectors (off axis design)

First mirror concave
Second mirror convex
Focus of first mirror
Synthesized focus of two mirrors

On axis design is better for the convenience of alignment

R1=4000mm
R2=-2100mm
F=6000mm
Optical performance

Through focus spot diagram

Spherical aberration

Point spread function
Optical performance

Almost no geometrical aberration due to off axis arrangement

Spherical aberration on axis is very small

Diffraction limited performance
Thank you for your attention.