ABSTRACT

22 Linac Coherent Light Source II (LCLS-II) cryomodules were successfully tested at the Cryomodule Test Facility (CTMF) at Fermilab. Following the completion of the LCLS-II testing program, CTMF has shifted to testing cryomodules for the LCLS-II High Energy upgrade (LCLS-II-HE). The first LCLS-II-HE cryomodule, the verification cryomodule (vCM), was successfully tested and verified the readiness of LCLS-II-HE cryomodule testing at CTMF, and production cryomodule (CM) testing has begun. Presented here are the production CM test acceptance criteria, testing plan, and CM test results so far.

LCLS-II HIGH ENERGY UPGRADE

Having concluded the LCLS-II test program, Cryomodule Test Stand 1 at CTMF is now fully dedicated to LCLS-II-HE CM testing. The infrastructure of the test stand remains largely unchanged. Eight, 7 kW solid state amplifiers have replaced the 4 kW amplifiers used during the LCLS-II test program, which were installed and commissioned during the final LCLS-II CM test. An EPICS-based controls system has also been implemented to conform with a model like what is used for the accelerator controls at SLAC. CTMF houses a state-of-the-art cryo-genic facility with a cryogenic capacity of 500 W at 2 K. Cavities use 2/0 doping recipe and nominal gradient increased to 21 MV/m.

KEY PARAMETER DIFFERENCES: LCLS-II & LCLS-II-HE

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LCLS-II</th>
<th>LCLS-II-HE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalized Cavity Gradient [MV/m]</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td>Max. Cavity Gradient [MV/m]</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>Min. CM Voltage [MV]</td>
<td>132</td>
<td>173</td>
</tr>
<tr>
<td>Multipacting Processing [Days]</td>
<td>1-2</td>
<td>4-5</td>
</tr>
</tbody>
</table>

MULTIPACTING PROCESSING

Operating gradient for LCLS-II-HE cavities, 21 MV/m, lies within multipacting (MP) band, necessitating processing of cavities. MP typically presents as: sporadic quenching, radiation spikes, combination of the two. MP seen in both vertical cavity test as well as CM test.

Procedure:
- Increase gradient until quench.
- Return power to cavity until stable.
- Repeat process until quench field or admin. limit, whichever comes first.
- Long runs (2-4 hr) at 21 MV/m before Unit Test.

CM TEST RESULTS

Two CM have been fully tested and qualified. Third production CM set to be tested Aug. 2022.

Verification Cryomodule (vCM)
- First LCLS-II-HE CM (prototype)
- Tested April – October 2021, fully qualified
- Record performance for CW machine: 211 MV max. voltage

4 cavities plasma processed:
- No cavity degradation
- No MP observed for processed cavities

First Article CM: F1.3-21 (F21)
- First LCLS-II-HE production CM
- Fully qualified, but some nonconformance observed:
  - 2 K dynamic heat load over spec – contribution seems to lower Q0 from LCLS-II cavities (not 2/0 recipe)
- Three cavities with microphontics > 10 Hz

- No MP observed at 21 MV/m after processing

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