High power CW tests of cERL main-linac cryomodule

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Compact ERL(cERL) at KEK



Compact ERL main linac cryomodule configuration



(Compact) ERL target Frequency : 1.3 GHz Input power : 20kW CW (SW) Gradient: 15MV/m Q0: >1*10^10 Beam current : max 100mA (against HOM-BBU instability)

2-cavity cryomodule was developed for compact ERL main linac to demonstrate the high current ERL operation at cERL. We have done the high power test by using this cryomodule.



Results of vertical test of cERL Main linac two cavities



Module Assembly after V.T



After Ar gas purging into cavities, He jacket, were welded on cavities. Diameter of jacket is <u>300</u> <u>mm</u> to make He level inside the jacket to fulfill CW operation,



After fixing alignment, warm window were set and vacuum vessel were mounted. Gate valves were set on both sides

Cavities, HOM absorbers and cold window of input couplers were assembled in class 4 clean room supported by backbone through 5K frame support



Assemble He line, magnetic shield, thermal Insulator, sensor and so on

Setup of high power test at cERL beam line





Cryomodule Cooling to 2K

Strategy of cooling

•HOM damper should be cooled down slowly, to avoid cracking of ferrite.3K/h was required for 80K line, which cool the HOM dampers.

•Relatively large temperature difference was avoided within each 2K, 5K(He) and $80K(N_2)$ lines.



History of 2k cooling



Performance test of cERL cryomodule







Radiation pattern also changed after X-ray burst

during assembly work and high power test.



Measured error is assumed end point of bremsstrulung effect





• We can keep the following voltages of Upper cavity : 14.2MV Lower cavity : 13.5MV

for more than 1 hour. (40-45W heat @2K) •We cannot keep more than 14.5MV field because of the lack of the cryogenic power (>50m^3/h ~50W)

We note that He gas return, He level and He pressure were also stable. Especially He pressure was kept stable within 10Pa (measured)



2K microphonics measurements

Pk-pk

=7Hz

•Example of#3 cavity, QL = 1.15*10^7



Pk-pk = 7Hz by oscilloscope. It allow us to increase the QL higher than several *10^7 → lower power
 Main peak was observed at 49.5Hz (not 50Hz of electrical noise) by FFT analyzer ,which was not come from cavity resonance frequency.

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We need to continue measuring michrophinics on next cERL operation

Summary

- After V.T, we prepared the main linac cryomodule with two 9cell ERL cavities and installed it into cERL beam line on 2012/Oct.
- Main linac cryomodule was able to cooled down to 2K by controlling the cooling condition including 3K/h speed at HOM absorber.
- Both cavities reached 16MV by feeding CW power. But we met the <u>severe field emission</u> by newly produced emitter which came from the cryomodule assembly work and during high power test.
- We can keep <u>13.5-14MV</u> of accelerating voltage for more than 1 hour.
- Cavity movement was 0.4mm under 2K cooling
- Michrophinics was measured to 7Hz of Pk-Pk. We need to measure more.
- In 2013, beam operation of injector was started. During summer shutdown we will install round loop of cERL. After that we will start the beam operation with energy recovery on cERL.
- Main linac stable operation of cERL is next issues for our module by Digital LLRF for beam operation.
- •To improve the gradient , we also try the He processing to our cryomodule.



Backup

Detailed design of Cryomodule of cERL main linac

Magnetic shield equipped just outside 5K frame with 1.5t thickness



Temperature rise around cavity on high power feeding & SBP HOM heater test



Cavity alignment setting under cooling

4 outside targets on R.T to make base lines of telescope



Precise measurement of cavity movement by laser position monitor

To confirm the measurement accuracy of target, we also measure the movement by newly developed laser position monitor with 10um level accuracy by setting one target.



Laser monitor roughly agree with target measurement by telescope with ±0.1mm
While keeping 2K , target movement was stable within 10um → cavity was stable within 10um
Temperature of 5K frame is sensitive for 5K frame movements by laser position monitor.



This monitor based on interference of ASE light between target and reference position. By measuring reference position movement we know the target position movement





Radiation calculation (EGS5)

electron



photon



