The Injector Cryomodule for e-Linac at TRIUMF


PAC11, WEOCS6, March 30, 2011
E-Linac Cryomodules

- TRIUMF is building an electron linac (50MeV/10mA) as a second driver for radioactive ion beam production for the ISAC facility
  - see Shane Koscielniak talk Thursday afternoon for overview
- E-Linac requires one nine-cell in the injector section and four nine-cell cavities in the accelerator section – choose 1+2+2 cavities/cryomodule
  - Injector Cryomodule (ICM) to be used as a working prototype for Accelerator Cryomodule (ACM)
  - Two ICM’s will be built and tested with beam - one for TRIUMF and one for VECC (Kolkata)
  - Two cavity ACM fits staging scenarios and is conveniently sized
- 1.3GHz Cavities require operation at 2K, two cw 50kW power couplers per cavity required to supply beam loading of 100kW/cavity
VECC/TRIUMF Collaboration

ISAC-II Vault

- VECC/TRIUMF Collaboration
- Cryoline
- 12m
- 30kW IOT System
- 2K pumps
- Equipment Racks
- Power coupler test station

Will use an existing lab space in ISAC-II for a beam test with 30kW rf source

will test the front end of e-Linac by 2012

E-Gun

• 100kV gun available for initial LEBT commissioning

• 300kV gun in design (TUP017)

LEBT design finalized – in procurement phase

ICM design in progress
Injector Test Layout - 2012

- E-Gun
- Buncher
- Solenoids
- Diagnostic Box
- Injector Cryomodule
Injector Test Layout - 2012

E-Gun

LEBT

ICM

MEBT

Solenoids

Diagnostic Box

Injector

Cryomodule
Cryomodule Concepts (end load)

- Typically elliptical cavities housed in pipe like vacuum chambers with cold-mass loaded from one end.
- 2K production from custom cold box or local JT expansion valve box.

**XFEL/ILC Style**

- 2 K return
- 80 K return
- 4.5 K return
- 40 K forward
- 2.2 K forward
- 4.5 K forward
- Cool down/warmup
- Cavity
- Coupler
- Support

**Daresbury HI Module (Stanford)**

**Cornell (after Tesla)**
Low beta cryomodules – top load

- Low beta cryomodules tend to utilize the top loading box concept
  - Large transverse cavity dimensions
  - Cavities loaded on strongback
  - 4K helium reservoir/phase separator on board
  - Common or separated vacuum solutions available
Cryomodule design philosophy

• ICM and ACM’s will be installed in stages- ICM will be tested in ISAC-II (4K plant) then delivered to e-Hall
  • Convenient to make each cryomodule self sufficient as far as 2K production – each equipped with heat exchanger and JT valve
• Decide to take advantage of experience with ISAC-II as far as practical to reduce design time and take advantage of existing infrastructure
E-Linac cryogenic system borrows significantly from ISAC-II
- Cold box delivers 4K liquid to a central supply dewar
- 4K liquid at ~1.3Bar is delivered to a trunk line and distributed in parallel to each of the cryomodules
- Phase separator in each cryomodule collects 4K liquid with cold vapour returned to the cold box

Expansion to 2K within each module
- LHe is expanded in JT valve to produce 2K liquid
- Sub-atmospheric pumps maintain 30mBar operating pressure
e-Linac cryogenic system

Compr. MAIN

He

4K – 1.4Bara

CB
E-Linac cryomodule borrows significantly from ISAC-II

- Top loading box concept
- Strongback mounted from struts
- LN2 thermal shield
- 4K phase separator on board

Key differences

- Cold mass operates at 2K
- Elliptical cavities vs quarter wave cavities
- MLI ok – separated vacuum
**e-Linac Cryomodule features**

- **Top loading box concept**
- **Cryogenic insert with 4K phase separator JT valve and heat exchanger on board to produce 2K liquid; insert is removable with cryomodule in situ**
- **Cold mass supported by strong-back**
- **LN2 cooled thermal shield; 4K circuit for intercepts**
- **Warm and cold mu-metal**
- **Pair of alignment pick-ups upstream and downstream of each cavity**
Vacuum chamber

- Stainless steel ribbed enclosure
- Window openings for power coupler installation
- End ports for beam pipe, WPM ports and warm isolation valve
- Top opening for cryo insert; side window for cryo-connections
- Top ports for vacuum pumps, WPM cables, tuner actuator, rf pick-ups, diagnostics (temp sensors, heaters, level probes)
**Cavity parameters**

- Baseline cavity is the 1.3GHz Tesla 9-cell bulk niobium cavity.
- Two power couplers (50kW cw each) limit $P_{rf} \leq 100\text{ kW}$ per cavity; means $\Delta E \leq 10\text{ MeV}$ for $I=10\text{ mA}$ – corresponds to $E_a=10\text{ MV/m}$ design specification – 10W at $Q_0=1\text{ e10}$.
- End cells are modified to accommodate the large power couplers and mitigate higher order modes driven by high beam current.
• Cavity sub-assemblies are formed into a hermetically sealed unit (cavity string) bounded by isolation valves and containing cold power coupler, two phase pipe and WPM supports.

• The cavity string is then outfitted with magnetic shielding and tuners and then mounted to the strong back for alignment.
A pair of alignment brackets are placed upstream and downstream of each cavity fixed to the beam tube and indexed to the beam center.

The brackets can host optical or WPM targets.

Variable mounting supports from cavity to strongback are used to align the targets.
Power coupler gymbal and mock-up

- Need to maintain support for power coupler while allowing it to move under cooldown and maintain low stress on window
  - Design gimbaled support system
  - Making a mock-up tank-flange and power coupler cavity flange to test range of motion of coupler
  - Useful for working out installation of warm coupler end to installed cold part
Cavity tuner and end flange

• End flange
  • Utilize angled end flange and warm isolation valve
  • ie ATLAS Energy upgrade cryomodule

• Cavity tuner
  • Utilize JLab scissor tuner with long actuator and warm motor on top of cryomodule
Cryo-insert design

- Design enables prototyping and testing of cryo-insert in existing test cryostat (141MHz cavity cryostat)

Diagram:
- JT& Control valves
- 4K GHe return
- 4K LHe supply
- Mounting flange
- 4K reservoir
- Heat exchanger
- 4K reservoir
Cryogenic-insert Design

4K/2K cryo-insert

Accelerating Cryomodule

141MHz Test Cryostat
Injector Cryomodule

- Scissor Tuner (Warm Part)
- Cryo-Insert
- Support & Alignment Post
- Support Strut
- Vacuum Chamber
- Cold to warm transition
- Scissor Tuner (Cold Part)
- Isolation Valve
- 9 cell module & LHe jacket
Summary

- **E-Linac cryomodule concept**
  - ISAC-II design features incorporated where possible to save engineering time and profit from available infrastructure
  - Cryomodule – top loading box with 4K to 2K production on board
  - 4K cold box delivers 4K liquid at 1.3 Bar in parallel to each cryomodule phase separator

- **Status**
  - Cavity being prototyped in copper at PAVAC
    - Soon to start fabrication in niobium
  - 4K/2K insert in procurement phase
  - ICM detailed design on-going
  - Plan for a beam test in 2012
Thank You!

Merci!