Status of the CESR Superconducting RF System

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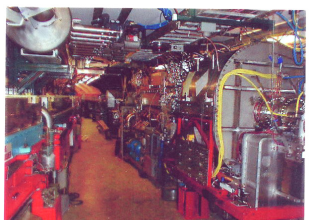
Abstract

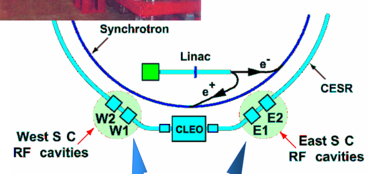
Electron-positron storage ring CESR operates with four superconducting single-cell cavity cryomodules. CESR runs in two distinct regimes: i) as CESR-c collider at 1.55 to 2.5 GeV and ii) as CESR-CHESS synchrotron light source at 5.3 GeV. RF system is configured with one klystron per two cavities for both regimes of operation. In CESR-CHESS mode SRF cryomodules have to support maximum beam current of 500 mA by delivering up to 160 kW of RF power per cryomodule. CESR-c operation is radically different for RF system as the emphasis is not on delivering very high RF power to beams, but on providing very high RF voltage to produce short bunches and high synchrotron tune. Superconducting cavities perform well in both regimes.

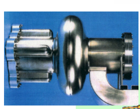
Superconducting RF system

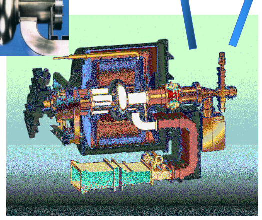
4 superconducting B-cell cavity cryomodules

Resonant frequency	499.765 MHz
R/Q	89 Ohm
Q_0	10^9
Q_{ext}	2×10^5
Operating temperature	4.5 K
Accelerating voltage	up to 3 MV per cavity
Static heat leak	30 W





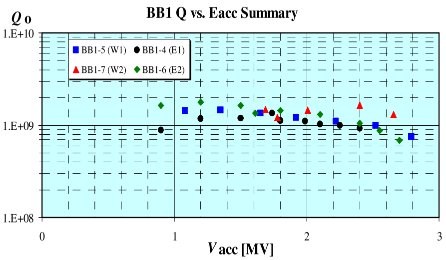




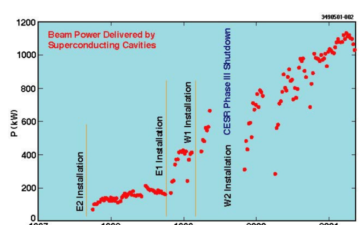
Highlights

- **1994:** **Beam test, first demonstration of high current operation**
- **1997:** **First SRF cavity installed in CESR for routine operation**
- **1999:** **First storage ring to run entirely on SRF cavities**

As a high luminosity, electron-positron collider CESR gained important advantages from superconducting cavities. Ampere size beam currents are stored in a large number of bunches, spaced very closely together. The high current and the tight bunch spacing make control of multi-bunch instabilities an important issue. Superconducting cavities allow very efficient damping of all higher-order modes, which can drive multi-bunch instabilities. Since superconducting cavities economically provide higher CW gradients than copper cavities, the needed voltage and beam power is provided by 4 superconducting cells which replaced the original CESR RF system of 20 copper cells. CESR has been operating with SRF cavities since October 1997.



Cryomodule test results.



RF power delivered to CESR beams by SRF cavities.

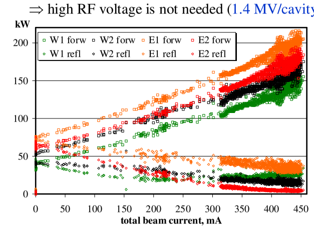
Status

Presently CESR operates in two distinct modes: charm/tau factory CESR-c (beam energy 1.55…2.5 GeV) and light source CESR-CHESS (beam energy 5.3 GeV). RF system is configured with one klystron per two cavities.

CESR-CHESS light source (E=5.3 GeV, Ibeam=500 mA)

- relatively high RF power per cavity (160 kW per cavity)
- emphasis on long beam lifetime, short bunches are not required

$\Rightarrow$ high RF voltage is not needed (1.4 MV/cavity)



Typical plot of RF power (forward and reflected) dependence on total beam current for four superconducting cavities in CESR (CESR-CHESS).

CESR-c tau/charm factory (E=1.55…2.5 GeV)

- ❑ high luminosity means strong IR focusing and short bunch length (1 cm)

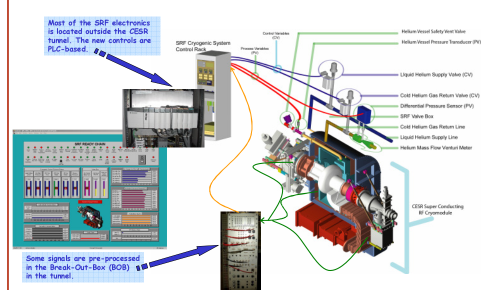
$\Rightarrow$ high RF voltage (1.85…3 MV/cavity)

- ❑ low beam energy loss per turn & lower beam current

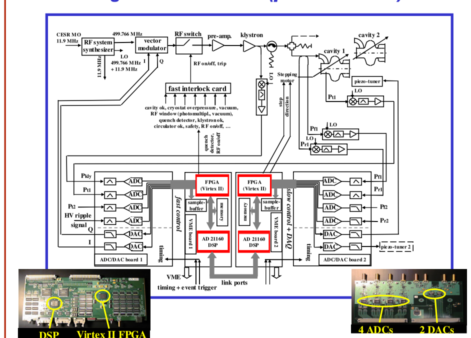
$\Rightarrow$ low RF power (10…40 kW per cavity)

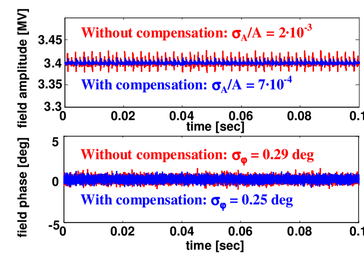
To reduce RF power consumption it was proposed operating some of CESR superconducting cavities in a passive mode. Experiments were performed to prove the validity of this approach. First proof-of-principle experiments were successful, but an attempt to raise Q_{ext} of a passive cavity to $>10^7$ lead to instability of RF control loop. While we are investigating possible cures of this instability, more recently three-stub waveguide transformers were used to raise external quality factors of active cavities from nominal values of 2×10^5 to 4×10^5. Operating active cavities at higher Q did not have any adverse effects on amplitude and phase stability of cavity fields.

PLC-based cryomodule electronics



Digital RF controls (poster ThP67)





Vector sum amplitude and phase stability without/with HV ripple compensation.

Summary

- Superconducting cavities operate in CESR since 1997. They perform well running at various accelerating voltages and delivering to beams as much as 300 kW of RF power per cavity.
- CESR-type cryomodules are now available from industry (ACCEL) on a turn-key basis. Three third generation light sources (Taiwan Light Source, Canadian Light Source, DIAMOND) had chosen CESR B-cell cryomodules for their RF systems.
- Recently we have experimented with using superconducting cavities in passive mode and in active mode with raised external quality factor.
- New FPGA/DSP-based digital RF control electronics has been recently developed and now is used in routine operation. It stabilizes vector sum of fields in two cavities connected to a single klystron. Similar electronics will be used for Cornell ERL superconducting cavities.
- The first set of new PLC-based cryogenic controls has been commissioned and will serve as a base for developing cryogenic controls for Cornell ERL injector cryomodule.