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HOM Measurements for Cornell's ERL Main Linac Cryomodule

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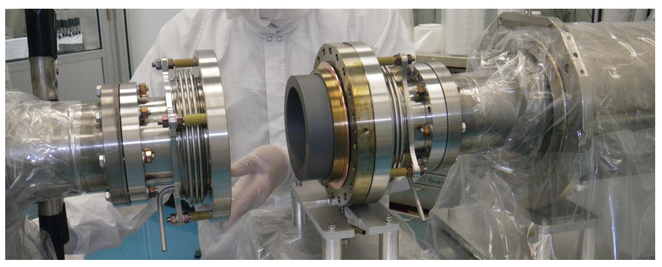
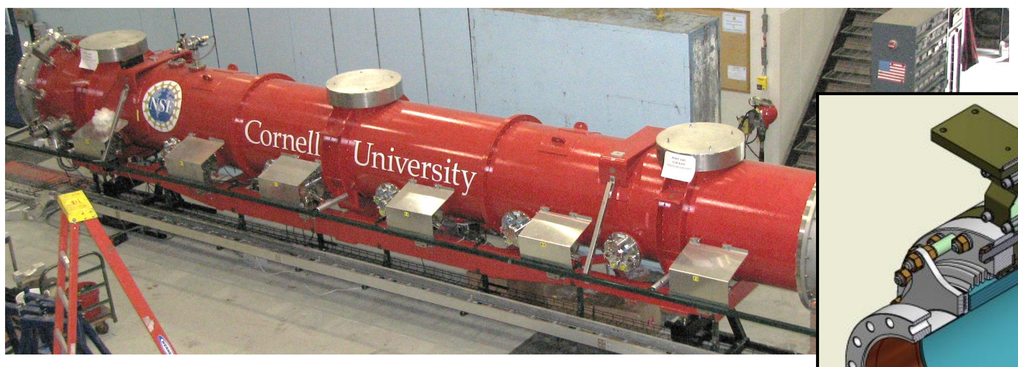
Introduction

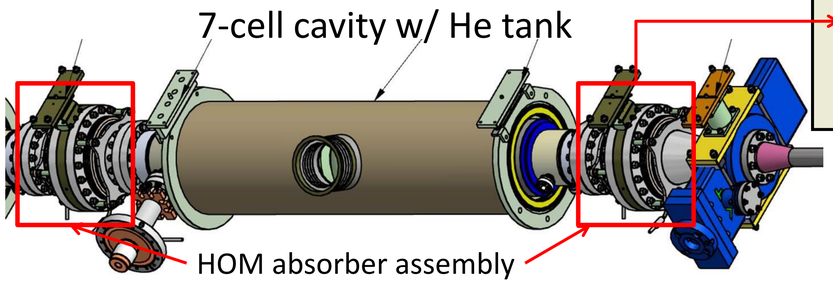
The main linac cryomodule (MLC) for a future energy-recovery linac (ERL) based X-ray source at Cornell has been designed, fabricated, and tested. It houses six 7-cell SRF cavities with individual higher order-modes (HOMs) absorbers, cavity frequency tuners, and one magnet/BPM section. All HOMs in MLC have been scanned in 1.8K. The results show effective damping of HOMs, and also agree well with simulation results and the previous HOM scan results on one 7-cell cavity prototype test cryomodule. Here we present detailed results from these HOM studies.

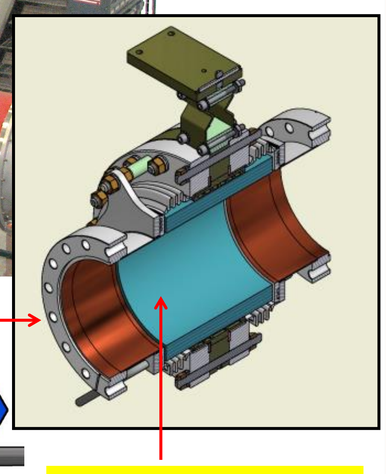


MLC and HOM absorber

The Cornell ERL main linac cryomodule (MLC) is 9.8 m long and houses six 1.3GHz 7-cell superconducting cavities with Individual HOM absorbers. Due to the high beam current combined with the short bunch operation, a careful control and efficient damping of higher order modes (HOMs) is essential. Therefore, HOM beamline absorbers are installed at the beam pipe ends of each cavity.



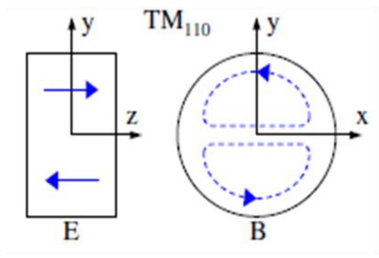


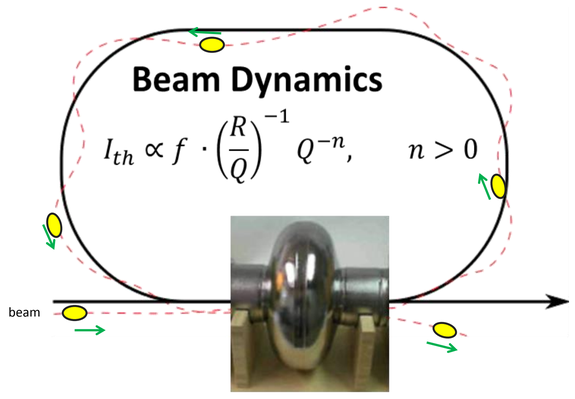


Silicon Carbide SC35 Absorbing cylinder

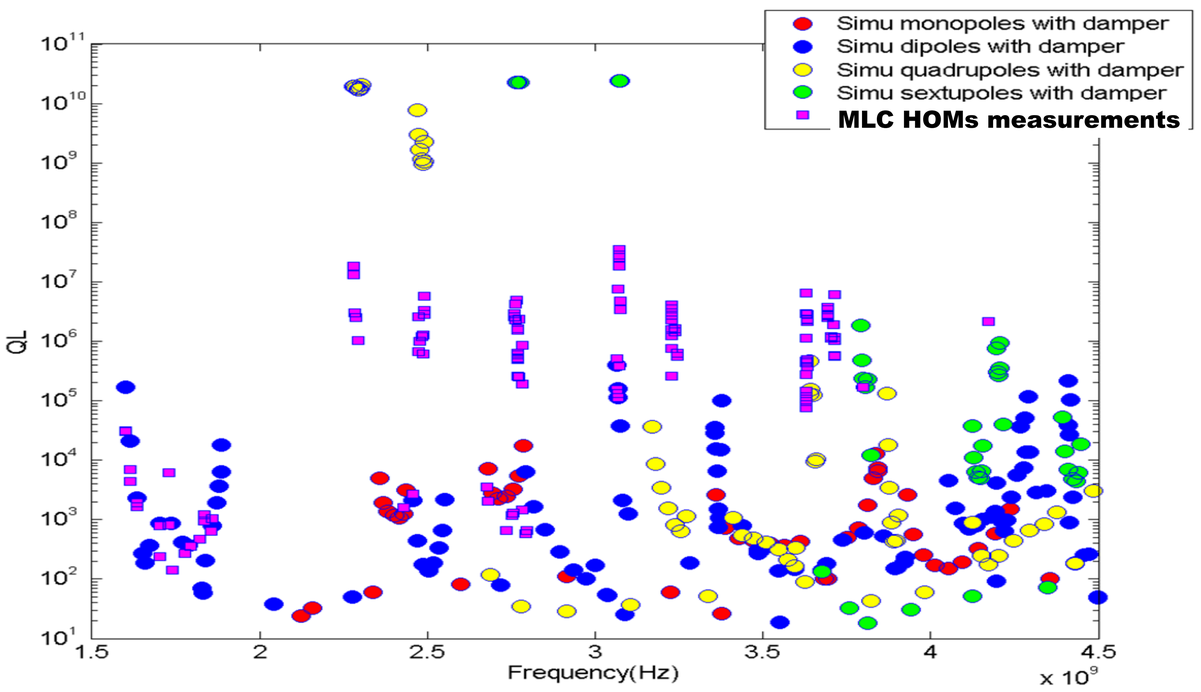
Beam Break Up instability for ERL

High Order Modes (HOMs) excited by the beam in the SRF cavities could lead a deflection of the beam. Especially, the dipole modes, which can make a transverse kick on the beam bunch and start bunch oscillation around the design orbit, need to be damped strongly to avoid resulting beam break up (BBU).





MLC HOM summary, Q_L comparison between simulation and analysis



Simulation notes:

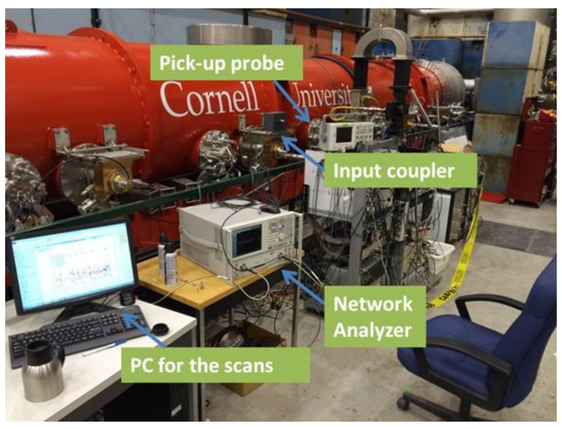
- Used a full cavity model without ports, which is axially symmetric.
- 2D electromagnetic solvers CLANS for simulation of monopole modes.
- CLANS2 for simulation of multipole modes.
- Parameters of absorbers were Re{ε} = 60, Im{ε} = 20, Re{μ} = 1, Im{μ} = 0

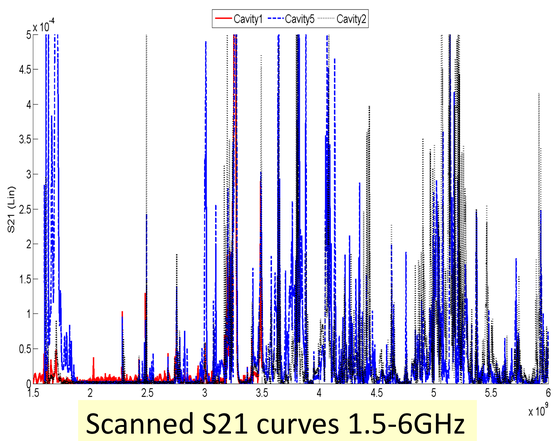
Summary

- **Dipole HOMs on MLC were strongly damped below Q_L~10^4.**
- **Consistent with HTC and simulation results.**

HOM scan on MLC

HOMs in the MLC were scanned via S21 Network analyzer measurements at 1.8K. High power RF input couplers were used as input port and field pick up probes were used as output. The scanned frequency range was 1.5GHz to 6GHz with the frequency step (df) of 125Hz.





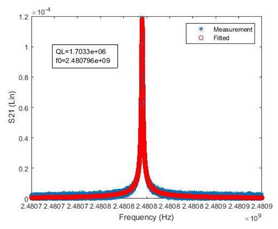
Scanned S21 curves 1.5-6GHz

Q_L analysis on HOM

Measured S21 curves showed resonant modes in the cavities. Those modes can be divided into two groups.

1) monopole mode which has a single peak for each mode. Q_L could be extracted by using the 3dB method from fitting its S21 curve, shown in Eq. (1)

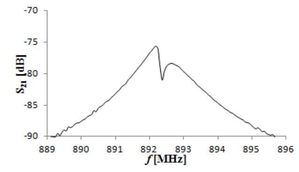
$$|S_{21}|(f; a, b, f_0) = \frac{10^{-a}}{\sqrt{10^{-2b} + \left(\frac{f}{f_0} - \frac{f_0}{f}\right)^2}}$$



2) non-monopole mode such as dipole, quadrupole, etc., having more than one peak for a mode. These mode have a mode mixing issue, e.g. the dipole has two peaks mixed together which distorts their S21 curve. Eq. (2) was used for fitting Q_L for these modes.

$$S_{21} = \sqrt{\frac{D_1^2}{1+\Delta_1^2} + \frac{D_2^2}{1+\Delta_2^2} - \frac{2D_1D_2Cos(\pi-\theta)}{\sqrt{1+\Delta_1^2}\sqrt{1+\Delta_2^2}}}, \qquad \Delta = Q_L\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right),$$

*Fitting parameters: QL1, QL2, D1, D2, theta.



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