Testing Superconducting RF Cavities of the Highest Field Gradients for the International Linear Collider

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ILC and SRF

- ILC = International Linear Collider
- The ILC is a proposed electron-positron collider that uses superconducting radio-frequency (SRF) cavities for acceleration
  - ~16,000 SRF niobium cavities are needed
  - All cavities must reach accelerating gradients of $E_{\text{acc}} = 35 \text{ MV/m}$ during tests
• $Q_0 =$ cavity’s intrinsic quality factor
  – High $Q_0$ is desired $\Rightarrow$ indicates efficient performance
  – Great: $Q_0 \approx 10^{10}$ or $10^{11}$

• **Quench** = the transition from super- to normal conducting, often caused by unwanted heating
  – It becomes prohibitively harder to excite normal conducting cavities to high $E_{\text{acc}}$

• Good cavity preparation is essential for high quality factors *and* for getting to high $E_{\text{acc}}$
Improving Cavity Performance

• **Defects and impurities** on the cavity surface can lower $Q_0$ and cause quenching
  – Increases the surface resistance of niobium
  – Causes high RF losses that generate heat
  – With enough heat, the cavity quenches

• **Common procedures to get rid of defects**
  – Chemical treatments
  – Clean assembly
  – High pressure rising
  – Baking
• **Chemical treatments** use acid solutions to etch away the outer layers of niobium
  – **Buffer chemical polish (BCP)** is a rough etch
  – **Electropolish (EP)** is a finer, smoother etch

• There exists a proposal that only BCPs are needed for large grain cavities

• BCPs and EPs use Hydrofluoric Acid → undergraduates must stay away!
Clean Room Procedures

• **Cavity assembly**
  – Always done in the clean room to minimize the number of particulates that enter the cavity

• **High pressure rinsing (HPR)**
  – Performed in clean room
  – Spray interior of cavity with jets of ultrapure water at 1000 psi
  – This dislodges loose particulates in the cavity
Cavities Bakes

- Bakes are performed for freshly electropolished cavities
  - Baking reduces the surface resistance of niobium
  - All bakes performed for this project were at 110°C, but higher-temperature bakes at ~800°C are also common
• Cavities are tested in a liquid helium bath

• Measurements are made through input and output power couplers
  – The output power probe is coupled to the cavity very weakly
  – We want the input power probe to be unity coupled to the cavity for tests
  – Probe length is semi-adjustable during tests

• $Q_0$ values are obtained at various $E_{\text{acc}}$ values to create a $Q$-curve
• Three single-cell cavities were tested
  – AES-2
  – NR1-2
  – LR1-5

• All tests suggested high Q’s, but the only Q-curve obtained was from AES-2

• Difficulties with coupling prevented us from obtaining Q-curves for NR1-2 and LR1-5
Notes on the Tests

• NR1-2 Cavity Test:
  – Input coupler’s probe length was too long ⇒ cavity was always overcoupled
  – Estimated a low-field Q of over $8 \times 10^{10}$

• LR1-5 Cavity Test:
  – Could not unity couple to the cavity
  – Measured Q-value were: $2.4 \times 10^{10}$ and $8.9 \times 10^{9}$
  – This was a large-grain reentrant cavity that had only received a BCP
Notes on the Tests

• AES-2 Cavity Test:
  – Q curve looked good: Q-values around $10^{10}$
  – We were able to get above $E_{\text{acc}} = 42 \text{ MV/m}$
  – Not enough liquid helium to finish the Q slope
AES-2 Q-Curve

AES_2 12June09

\[ E_{acc} \text{ (MV/M)} \]

- $1.00 \times 10^{11}$
- $1.00 \times 10^{10}$
- $1.00 \times 10^{9}$

- 0.00 10.00 20.00 30.00 40.00