Hot Topic #1
High-Field Q - Slope

SRF 2005
Wednesday, July 13, 2005
Summary of contributions from previous Day (P. Kneisel)

Observations at Saclay (B. Visentin) 5 min
Q - slope model (P. Bauer, FNAL) 5 min
Observations at DESY (D. Reschke) 5 min
Observations at KEK (K. Saito) 5 min
Discussion Items

- Is the high field Q-drop a magnetic or electric field effect?
- What is the impact of grain boundaries on Q-drop?
- Is there a frequency dependence of the onset value for the Q-drop? And if so, why?
- Are there other remedies than “in situ” baking to eliminate the Q-drop?
- Does surface smoothness play an important role in a successful “in situ” baking?
- Is there an optimum baking temperature and time for improving high field Q-values and maintaining the residual resistance?
- Is there a favorite model, which explains all the experimental observations?
- Does hydrogen play a role?
- What additional crucial experiments are necessary to fully understand the Q-drop?
**Q-drop: obstacle before the ultimate limit**

- Sharp drop of the quality factor at $B_p \cong 100$ mT without field emission
- Recovered by low temperature “in-situ” baking

![Diagram](https://example.com/diagram.png)
Statistic on Q-drop onset field

JLab data on 1.5 GHz single cells

No. of tests

Q-drop onset field range (mT)

- Before post-purification
- After post-purification
- Large grain
- Electropolished
BCP, EP, Fine grain, large grain

- Q-drop is common to BCP, EP and Single crystal cavities in high RRR niobium.
- The “onset” field increases with increased grain size (reduced # of grain boundaries?)
- The baking effect is different in “fine grain” niobium treated by BCP and EP; it is similar for increased grain size (e.g. after post purification @ T>1250°C)
- “Air baking” is less effective than “UHV” baking, but more/newer data available from B. Visentin
Q-drop onset freq. dependence

- No “Q-drop” observed in X-band cavities in the “old days”: f-dependence or mechanism (“global heating”? ) or material?

- No “Q-drop” observed in low frequency, low beta cavities, even though the peak magnetic fields are quite high: field distribution, different mechanism?
• The Q-drop similar in TM\(_{010}\) and TE\(_{011}\) mode
• T-maps show “hot spots” in high H-field region
  The Q-drop is due to high magnetic field
• Baking decreases I, RRR, R\(_{BCS}\), increases \(\Delta\)
• Surface studies, magneto-optics, susceptibility measurements point to oxygen diffusion = reduction of O concentration near surface as cause for reduction of Q-slope during baking
• Flux penetration might occur at grain boundaries
Schematic of the Nb surface

Before baking

After baking

Suboxides (NbO\textsubscript{2}, NbO)

Interstitial oxygen

Oxide cluster

\( \lambda \)
• Oxygen diffusion changes $\kappa$-value
• $B_{c1}$ reduced
• Surface barrier prevents flux penetration even above $B_{c1}$
• Surface barrier for flux penetration is reduced for rough surfaces (BCP, fine grain), but is larger for smooth surfaces (EP, larger grains)
• Therefore increase in onset-field
New Models

Q-drop explained on the basis of

- Non-linearity of BCS surface resistance + hot spots in surface (A. Gurevich)

- Overlayer of poor superconductor on good superconductor (E. Palmieri)
Newer Experiments

• Anodizing of nearly “Q-drop-free” surface re-introduces Q-slope (G. Eremeev)

• Fast “in air” baking reduces/ eliminates Q-drop (B. Visentin)
Open issues

• Is there enough experimental evidence to exclude H from playing a role in the Q-drop?
• How can we test the hypothesis of flux penetration during Q-drop?
• Interpretation of experimental data against O hypothesis:
  - Saclay data: Q-drop is not restored after HF rinsing of baked cavity (O conc. near surface restored as before baking- is that true?)