Optical Inspection at JLab

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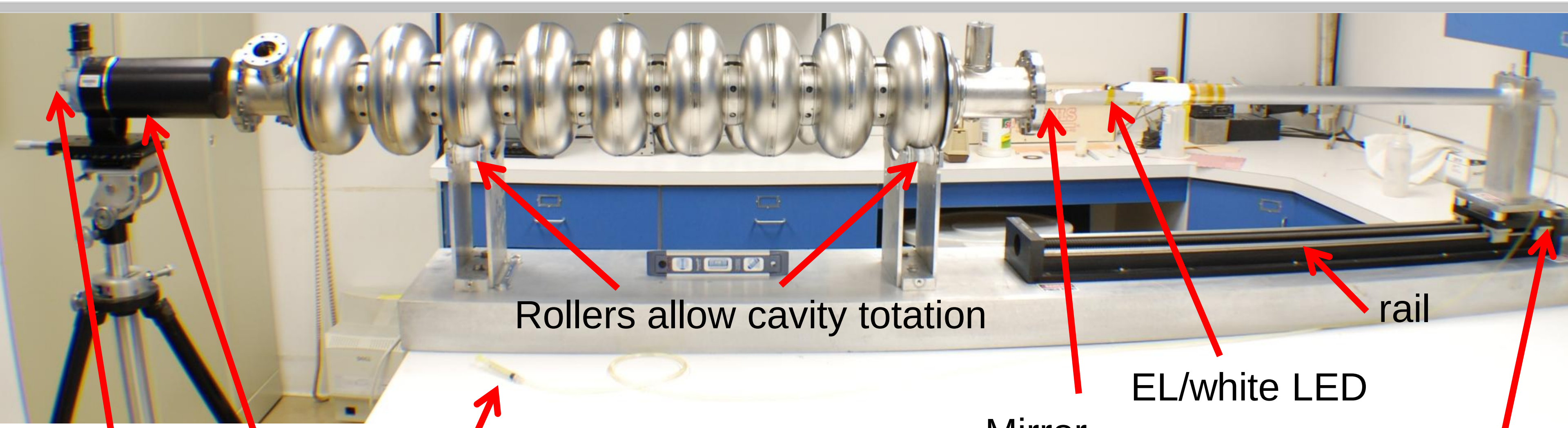
Jefferson Lab

ILC Cavity Group Meeting, September 16, 2008

JLab High Resolution Cavity Inspection Apparatus



Rollers allow cavity totation

rail

EL/white LED

Mirror

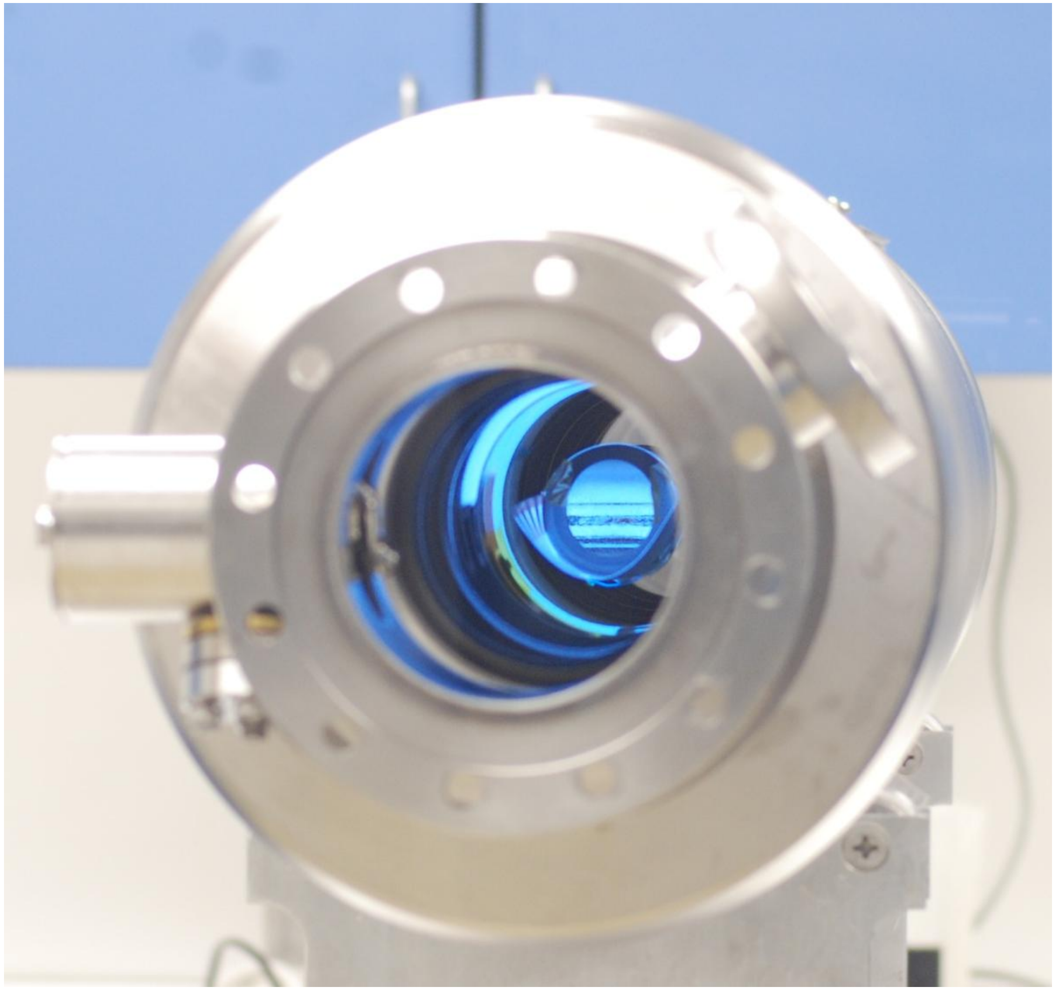
Mirror tilter

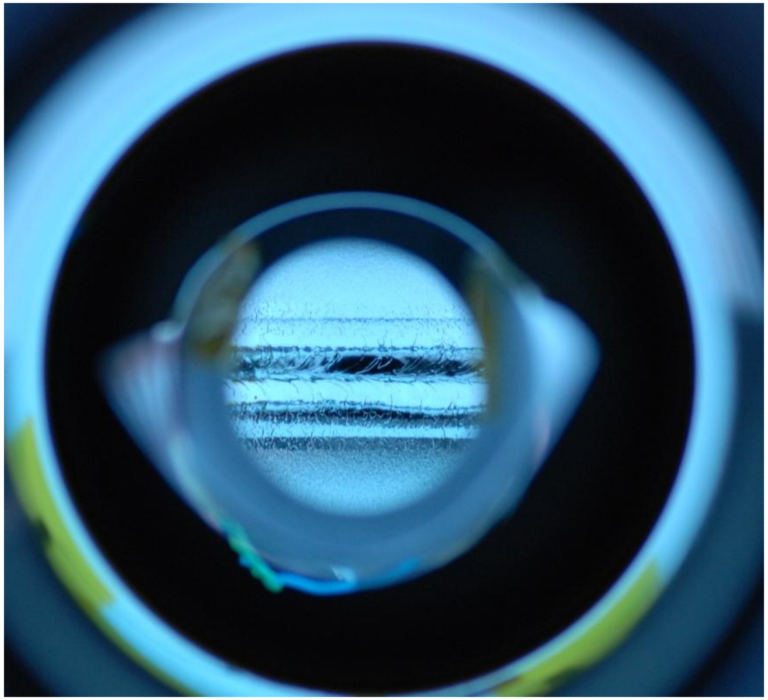
Questar QM1
- Working Range: 22 – 66 inchs
- Resolution: better than 3 microns at 22 inches

Step motor

Nikon digital camera
Pixelink CCD camera

The Mirror



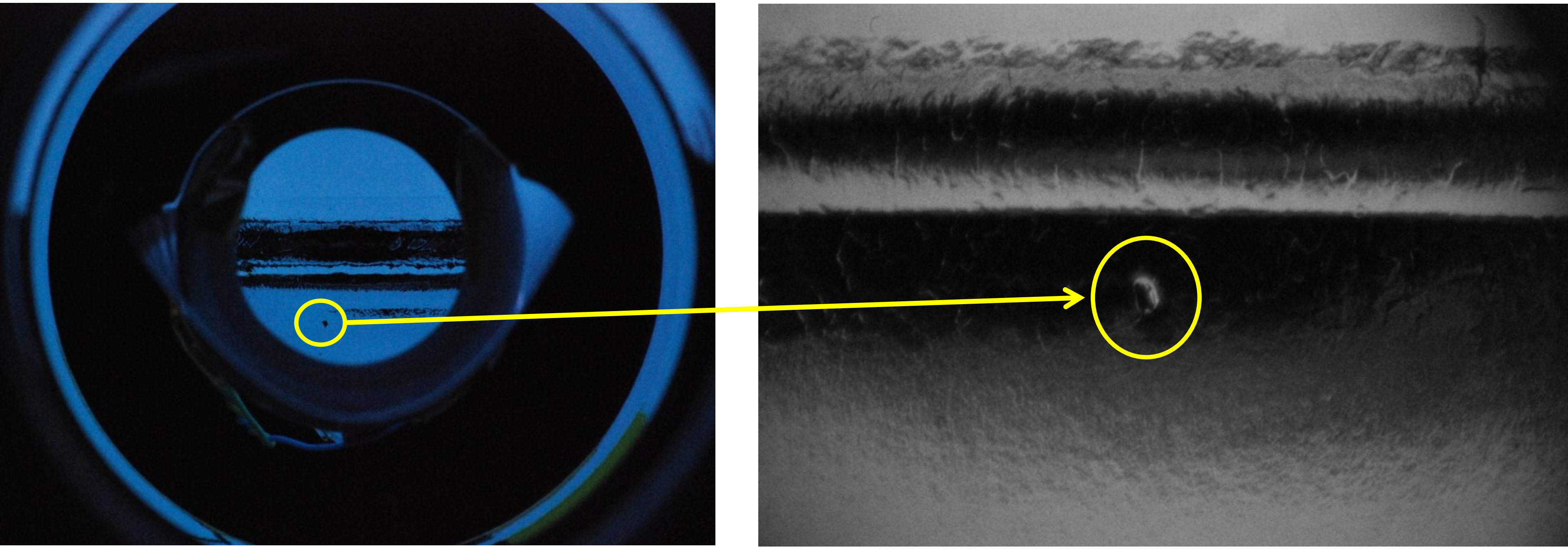


Inspection of previously processed and tested cavities

In some cases, cavity behaviors are correlated to observed defects

1st Example of Finding Defect in Equator Region

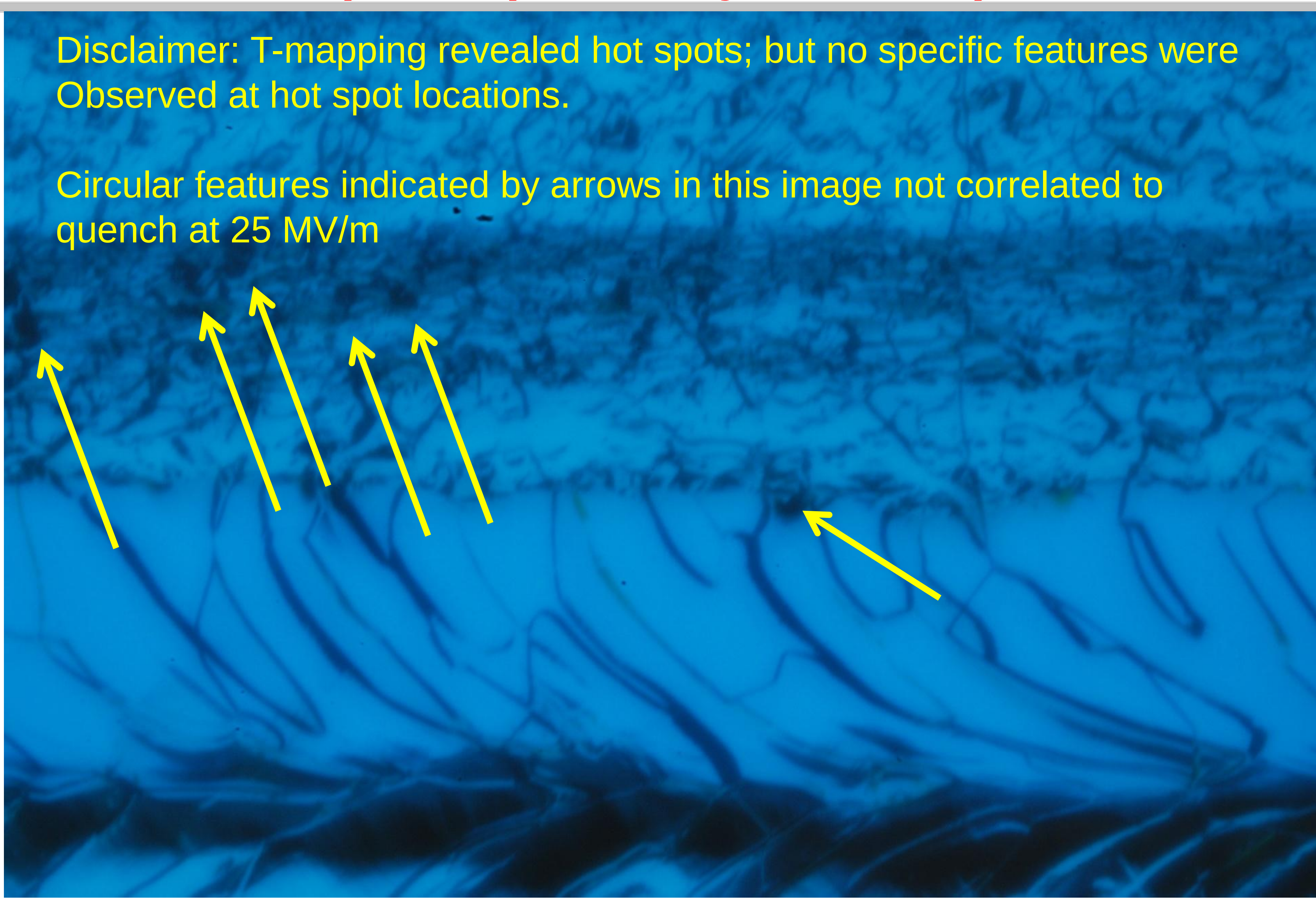
- A15 hard quench limit 17-19 MV/m
- Pass-band measurements pointed to cell #3/7
- T-mapping found hot spots correlated to quench
- Optical inspection found defect near hot spot



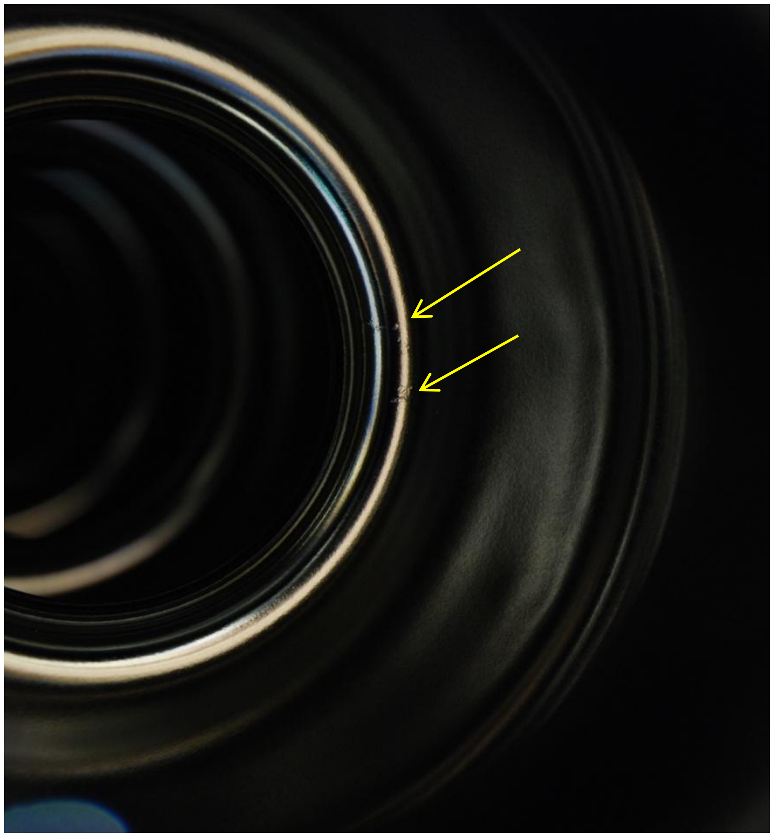
Direct Nikon digital camera

Questar QM-1

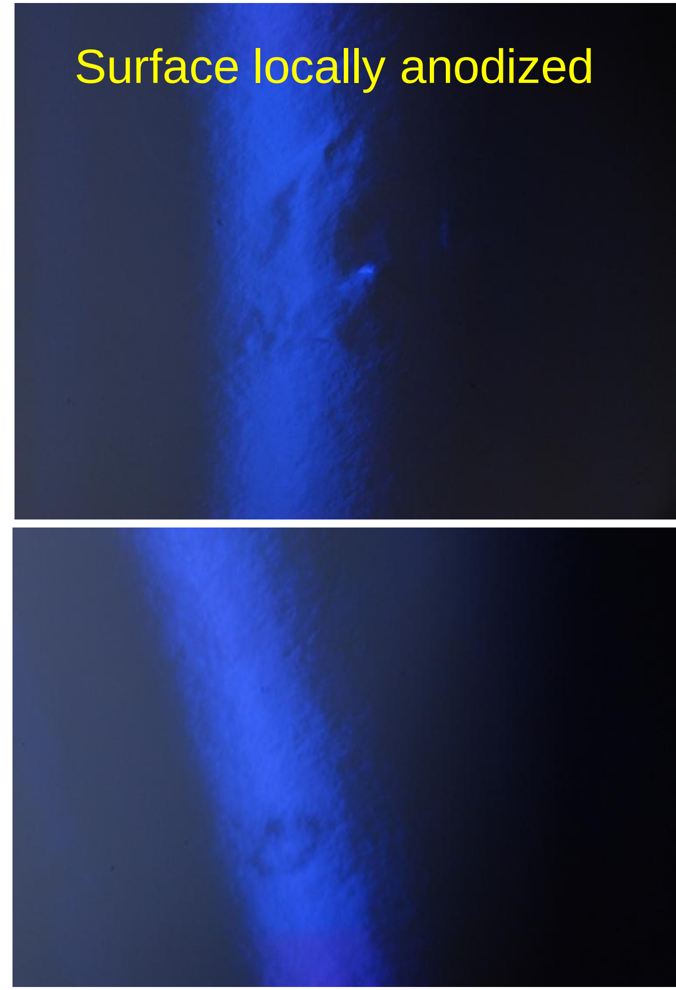
JL001 (25 MV/m)
Equator (BCP only + 1250C)



ICHIRO5 Surface Damage in Iris Region



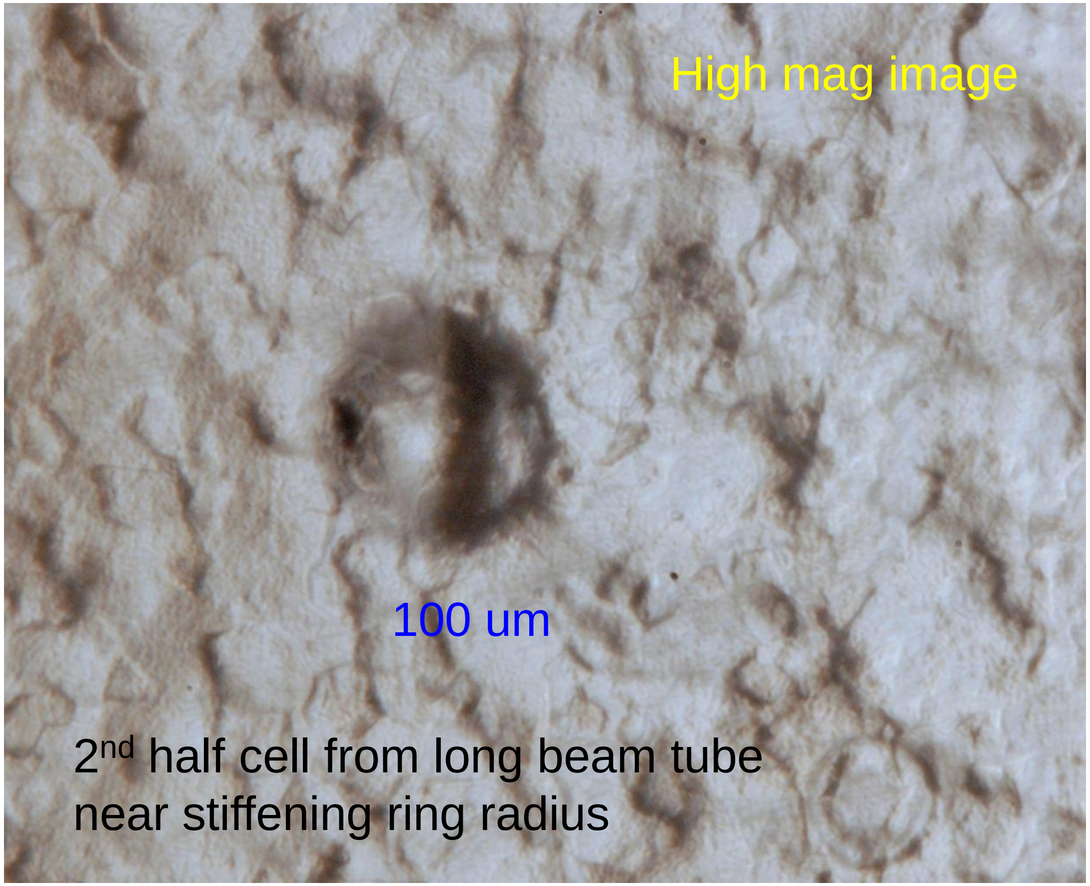
As received (digital camera image)



After EP + RF test w/ FE limit

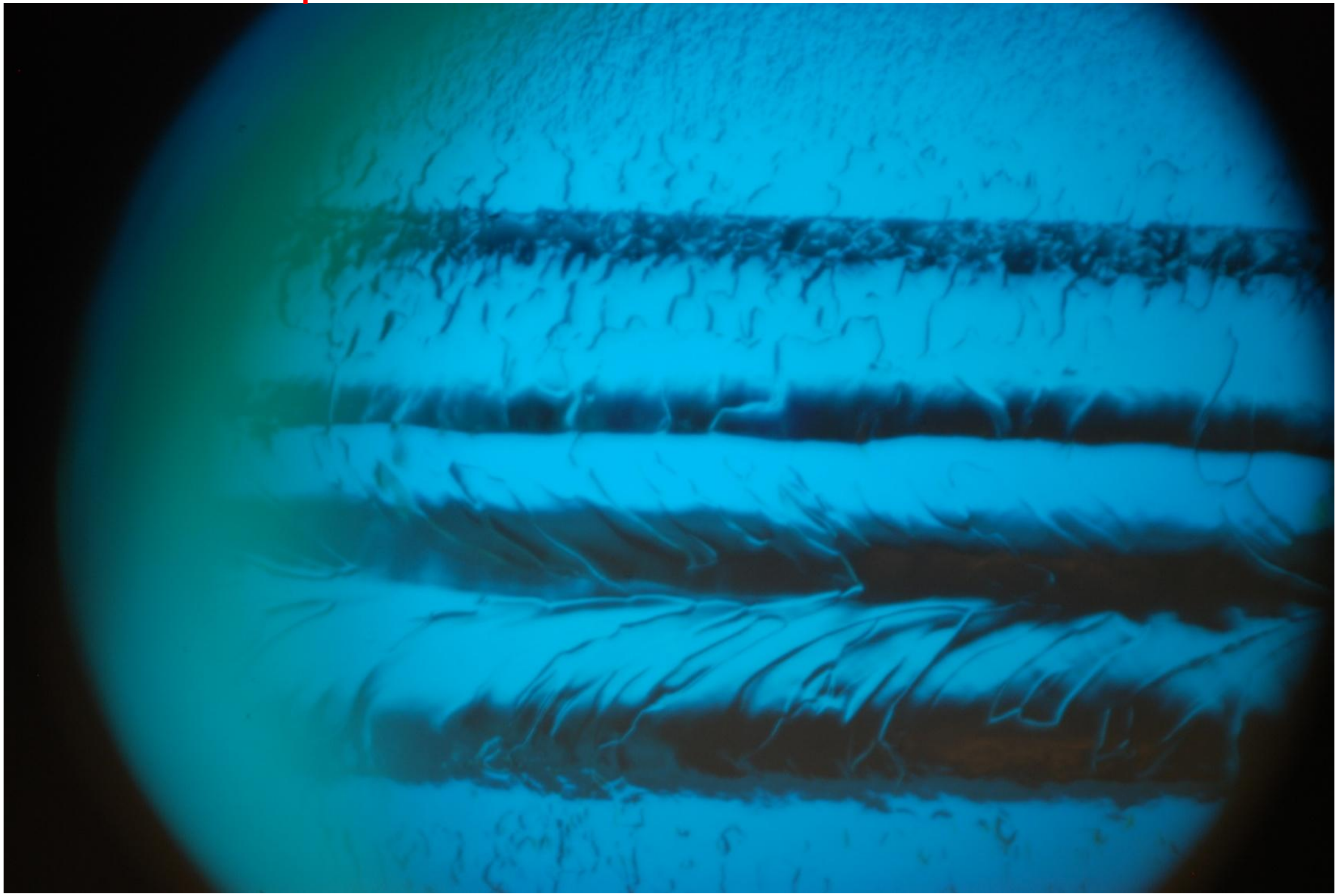
AES4 High E Field Region

Cavity FE limited even after repeated EP
pass-band measurements suggest field emitters in end cells



A8 – 32 MV/m Surface

Typical Appearance of Equator Weld, w/ exception of one observed irregularity,
Which corresponds to an observable dent from exterior surface

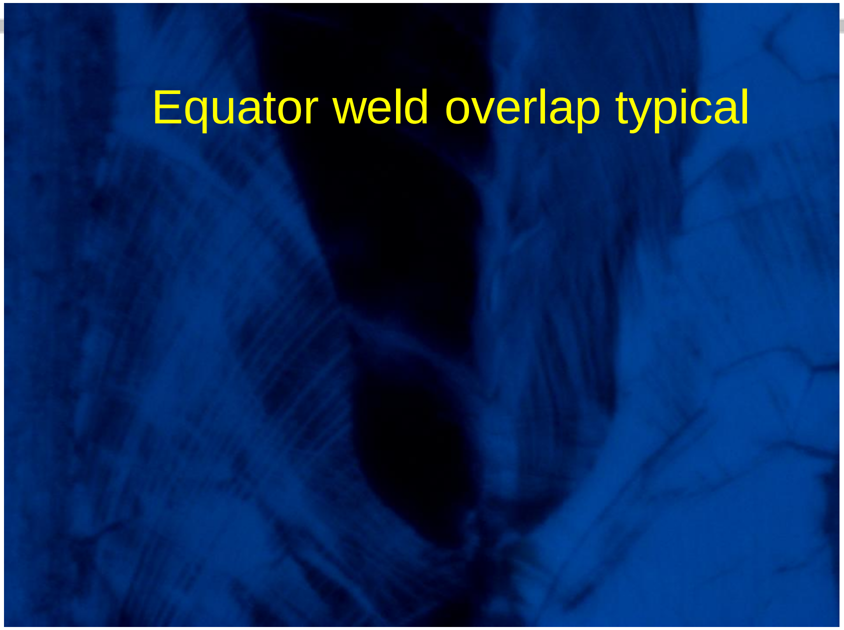


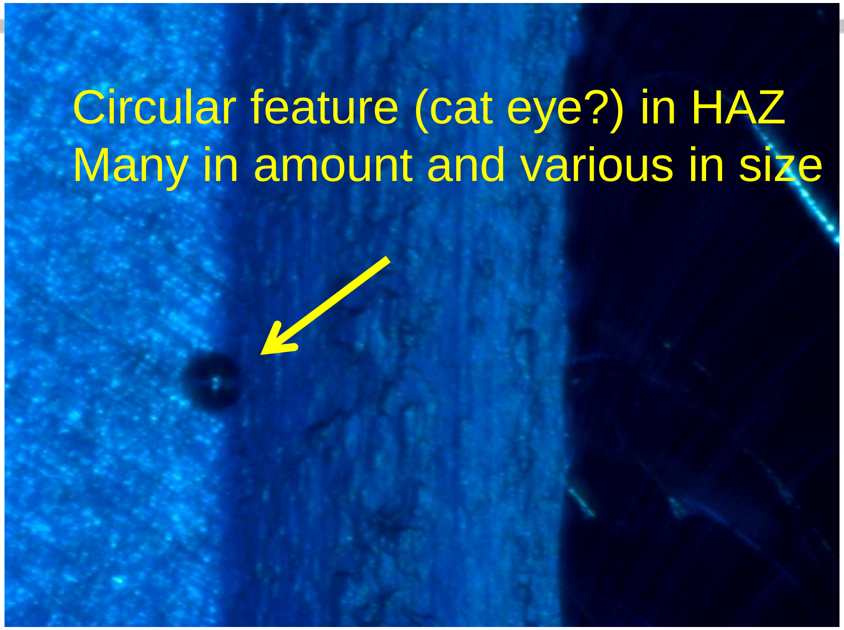
Inspection of an as-built 9-cell cavity

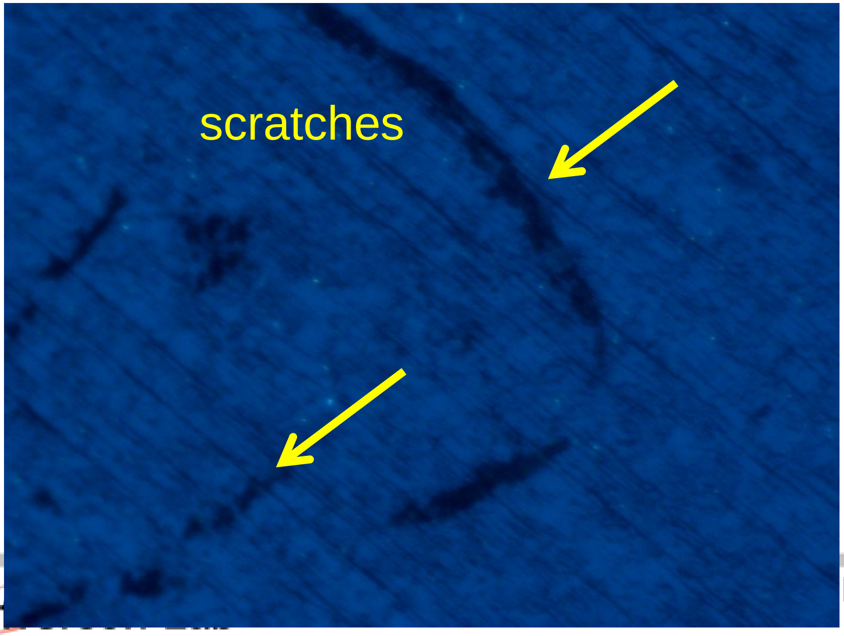
No correlation with cavity behavior is established yet

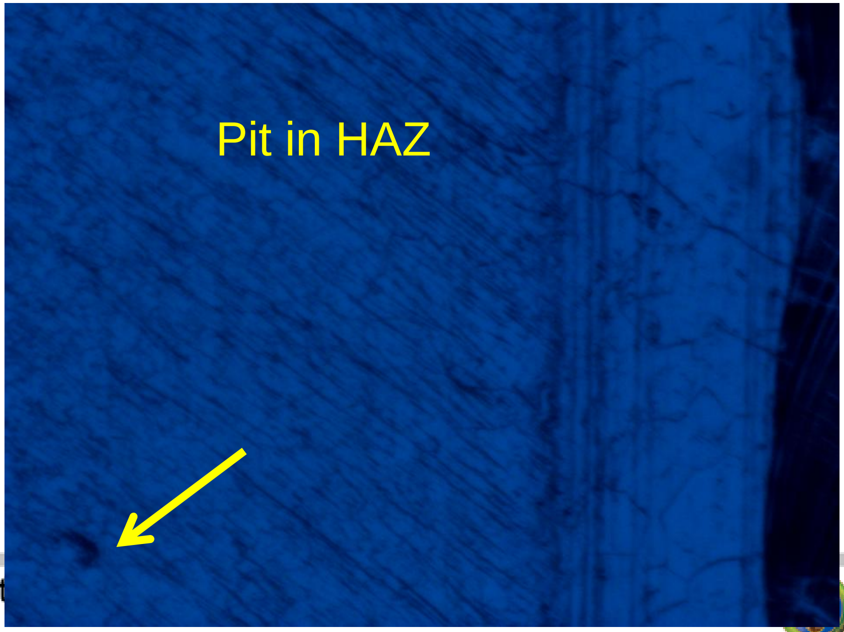
Goal is to understand initial surface conditions

J1 9-cell cavity as-built RF surface

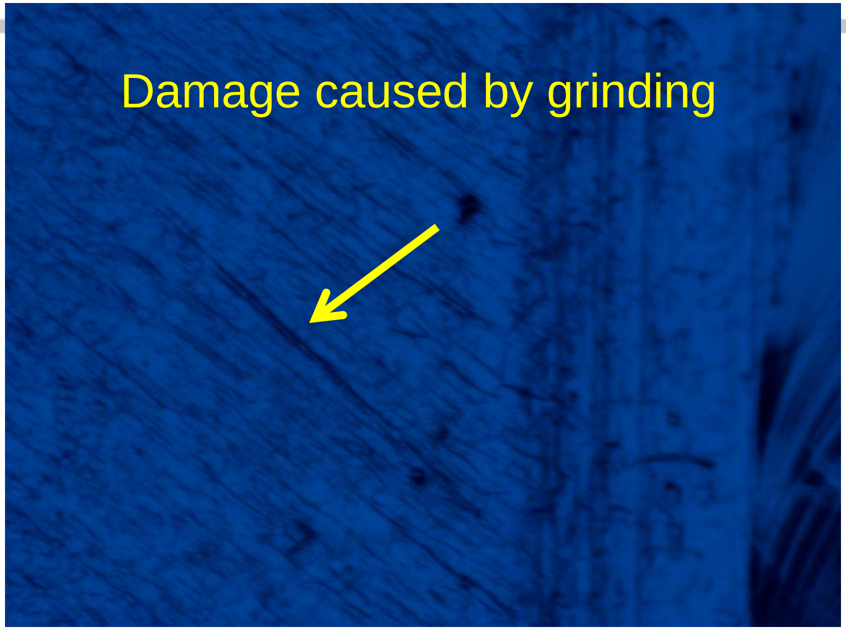


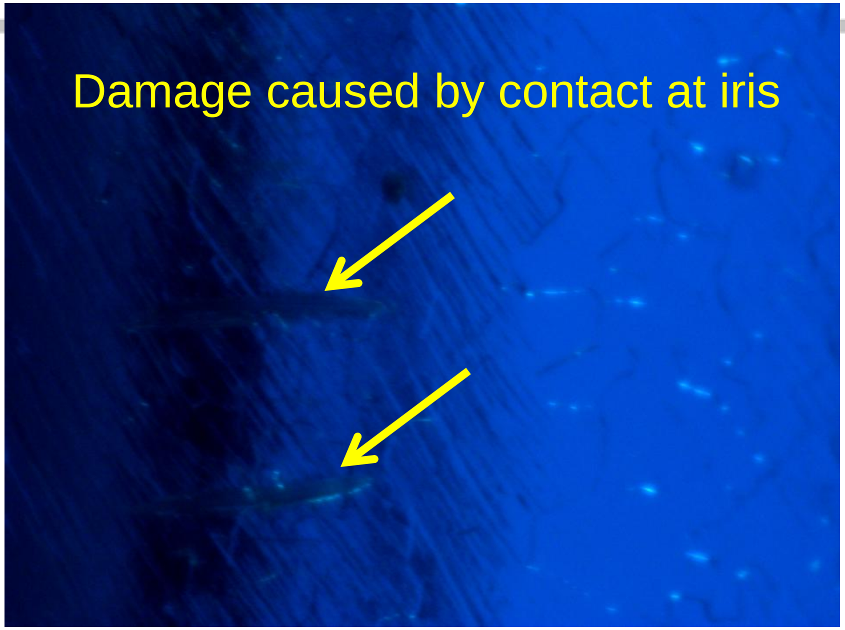




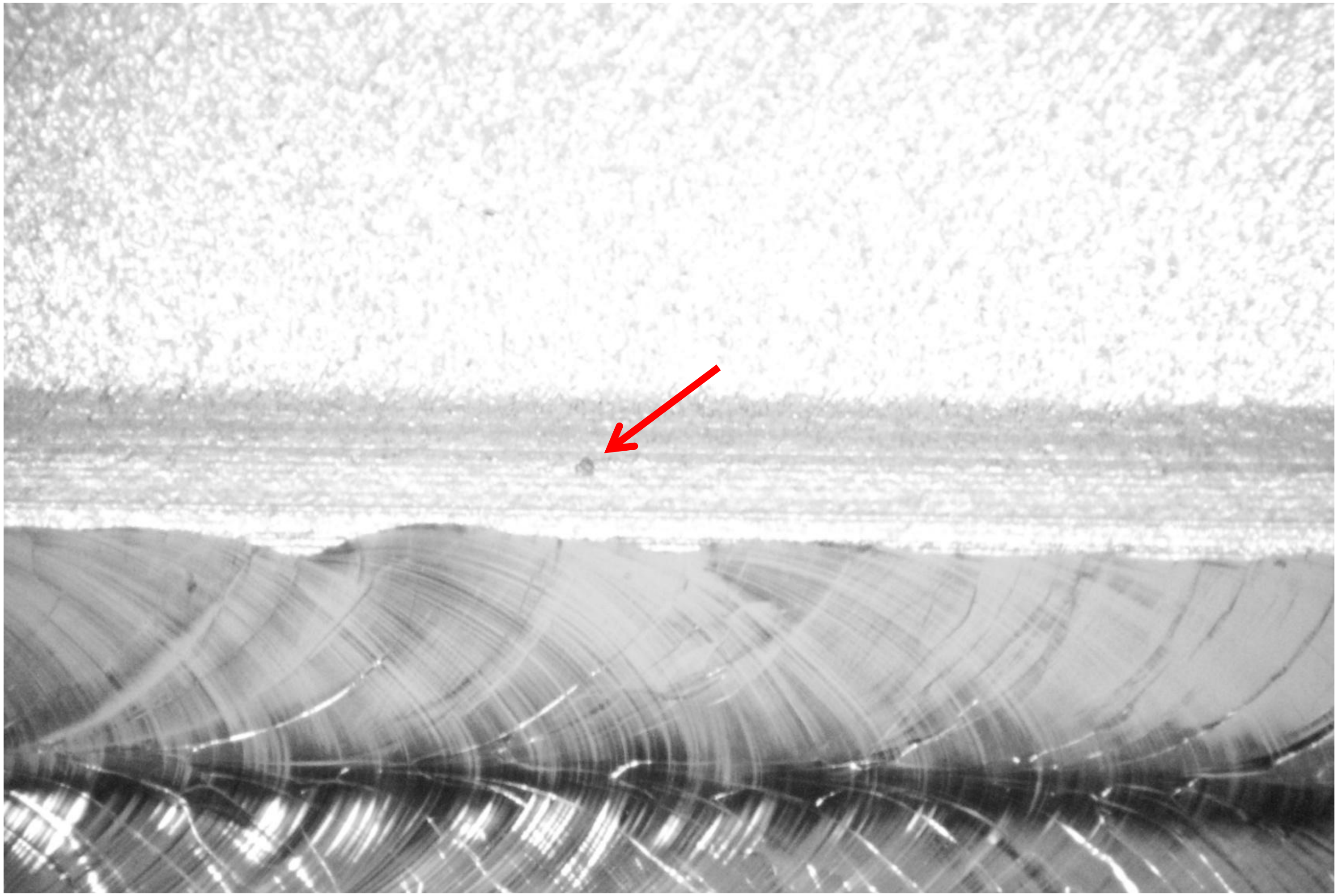


J1 9-cell cavity as-built RF surface





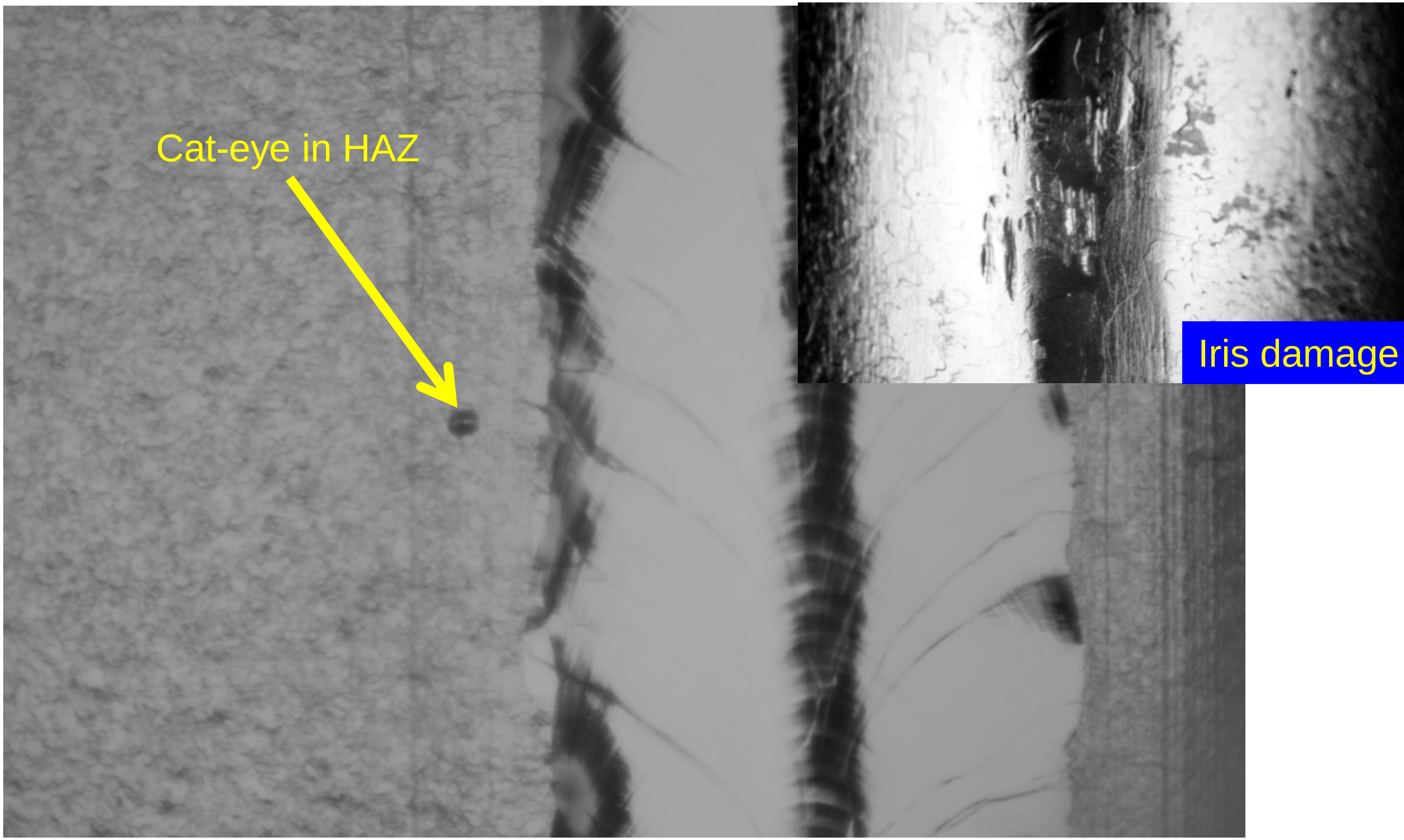
J2 9-cell cavity as-built RF surface



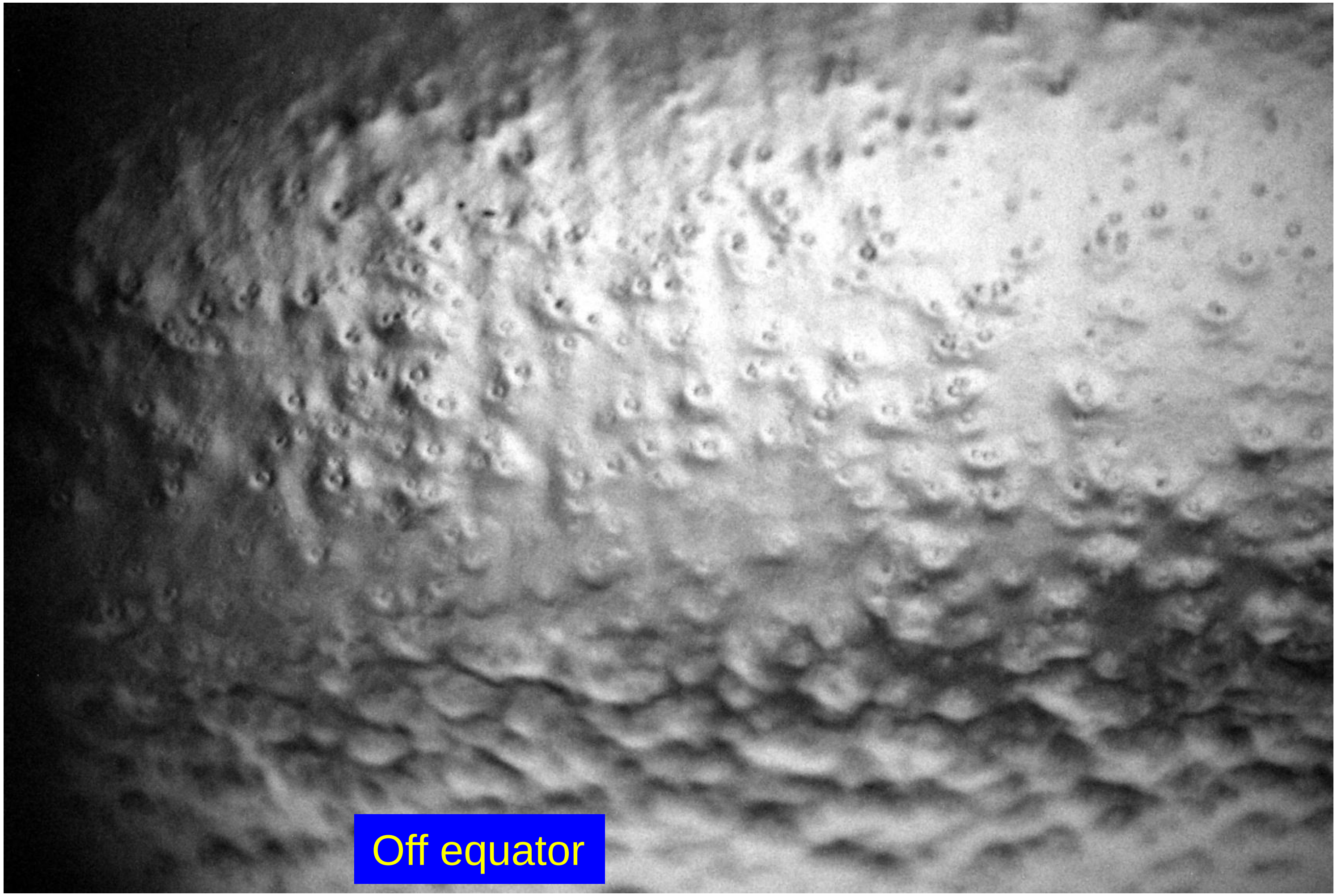
Additional Inspection of Cavities of Various Sources/Histories

Some results are from LG cavity or BCP etched cavities – they are shown for reference purposes

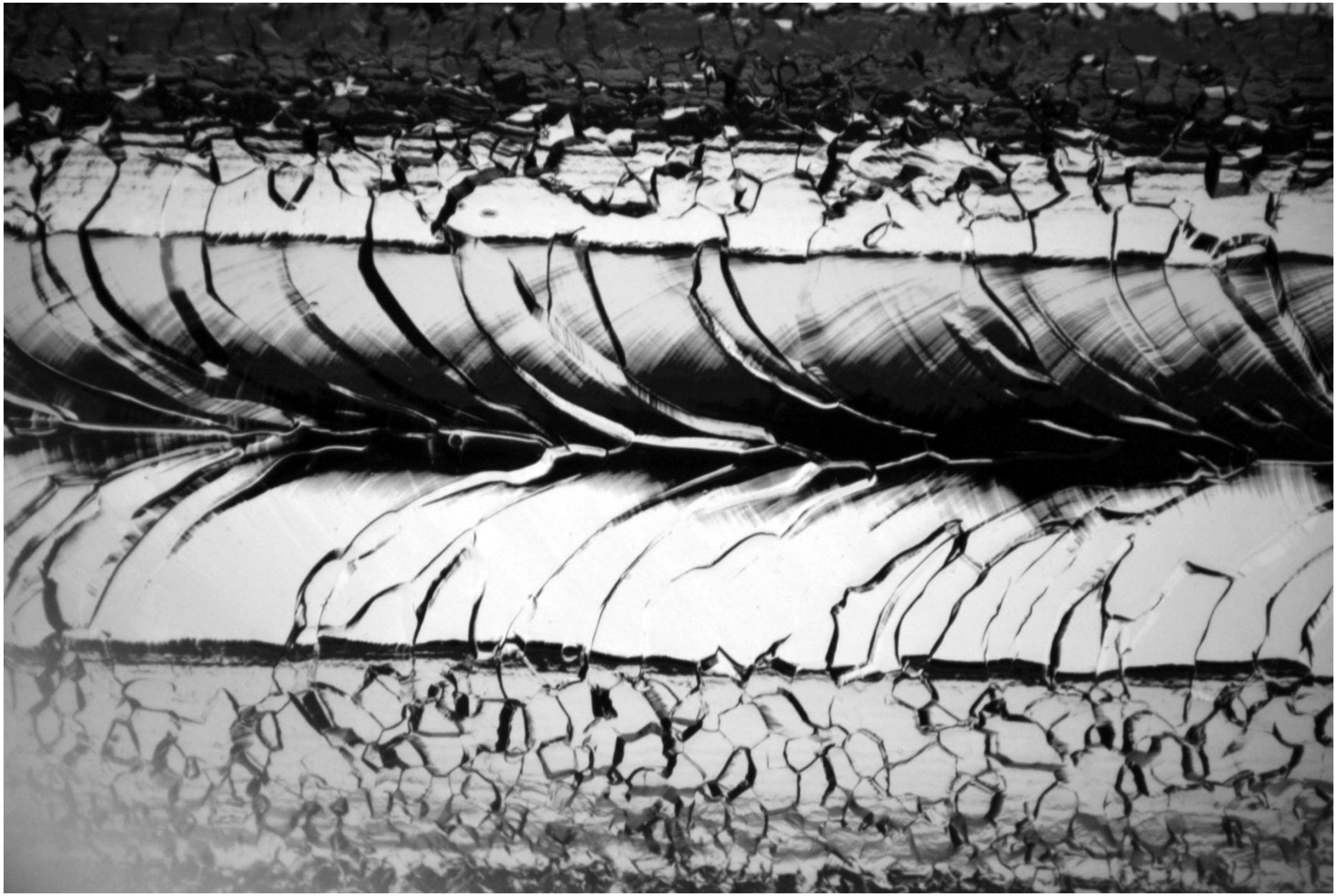
PKU 9-Cell – As Built



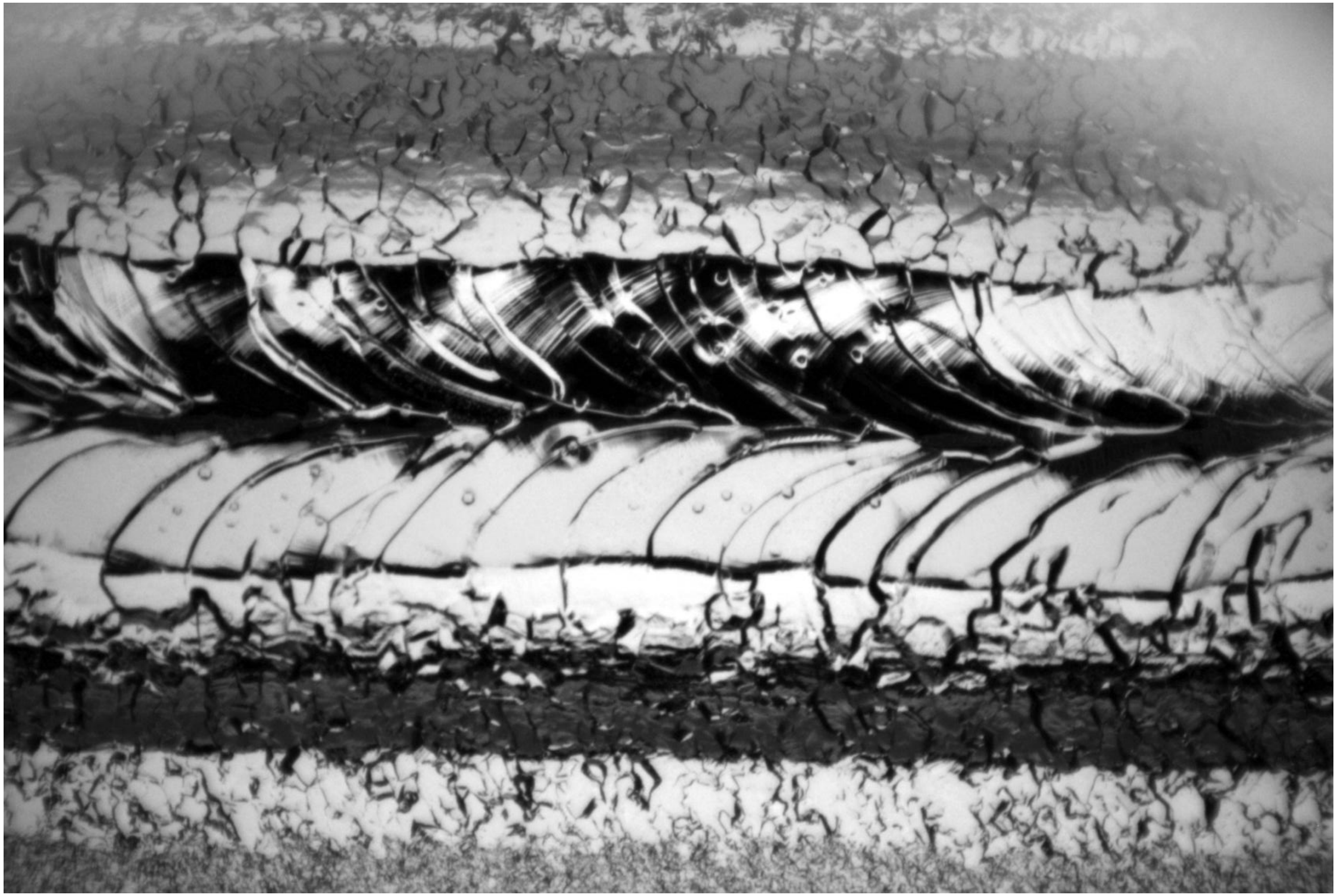
JLab LG1 – BCP surface



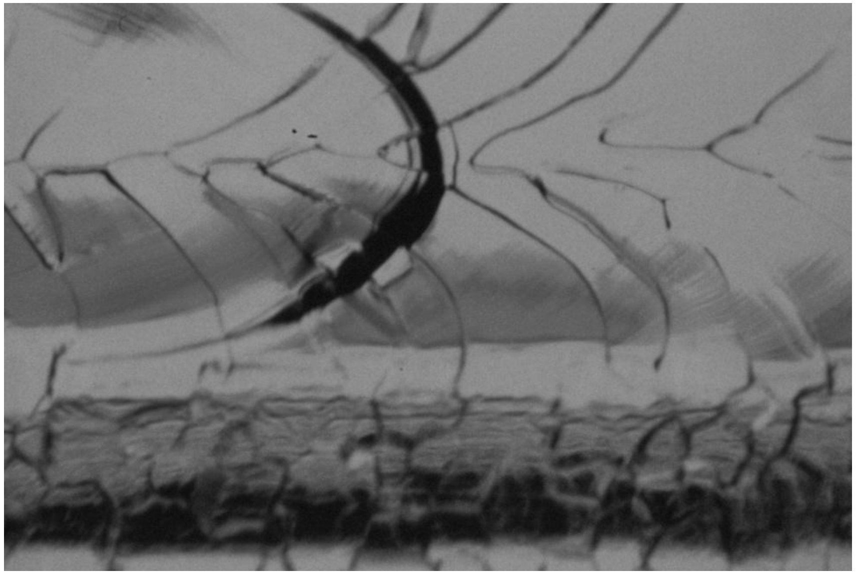
HC1 Equator Weld (1) – BCP Etched only

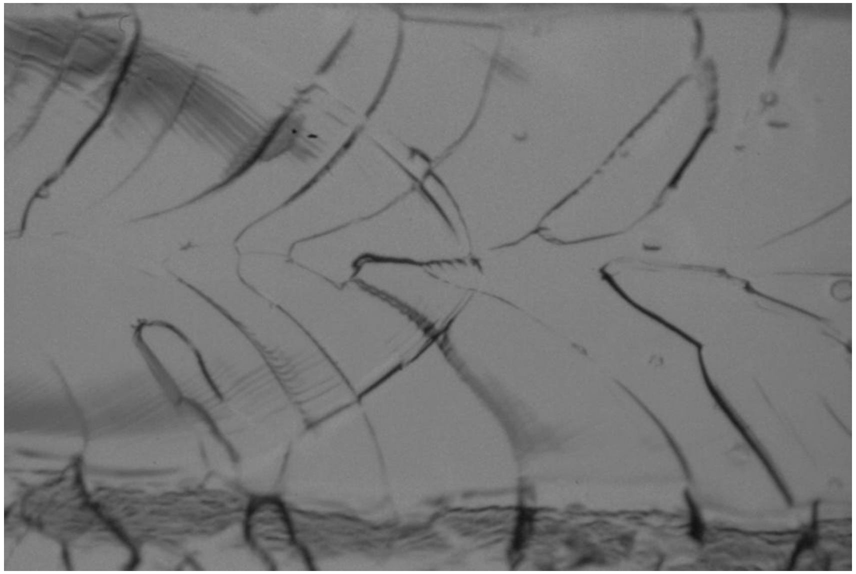


HC1 Equator Weld (2) – BCP Etched only



HG006 (1) – after 340 um BCP

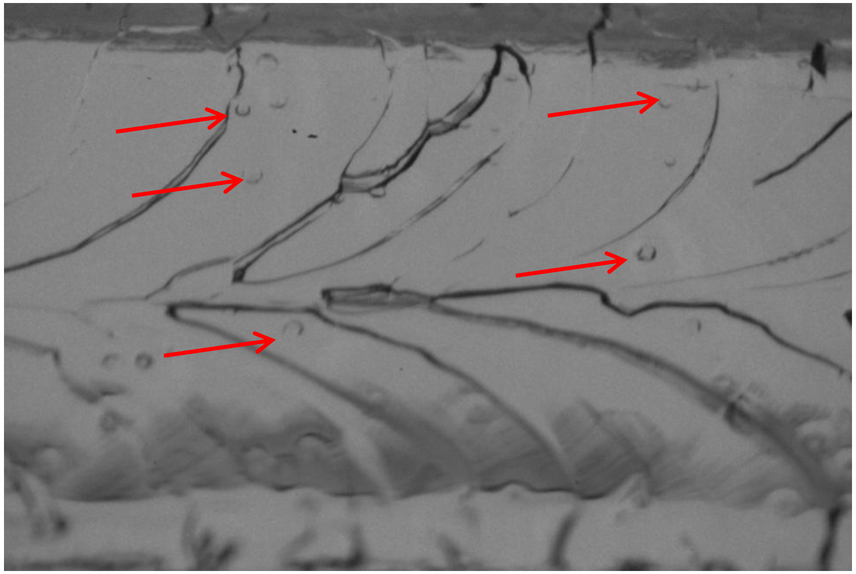




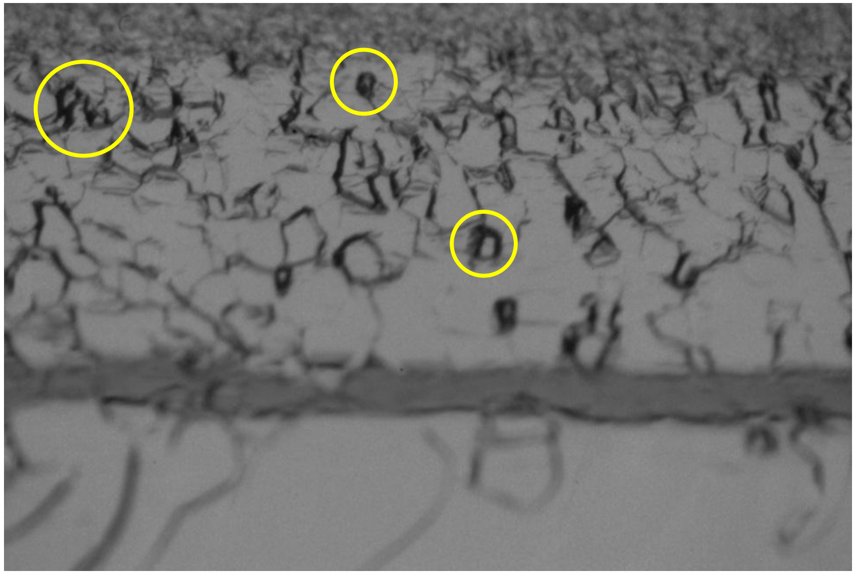
Outstanding irregularity (step) near equator
EBW overlap of cell#7 from WG

Two other cells less pronounced feature
Four other cells no recognizable feqture

HG006 (2) – after 340 um BCP

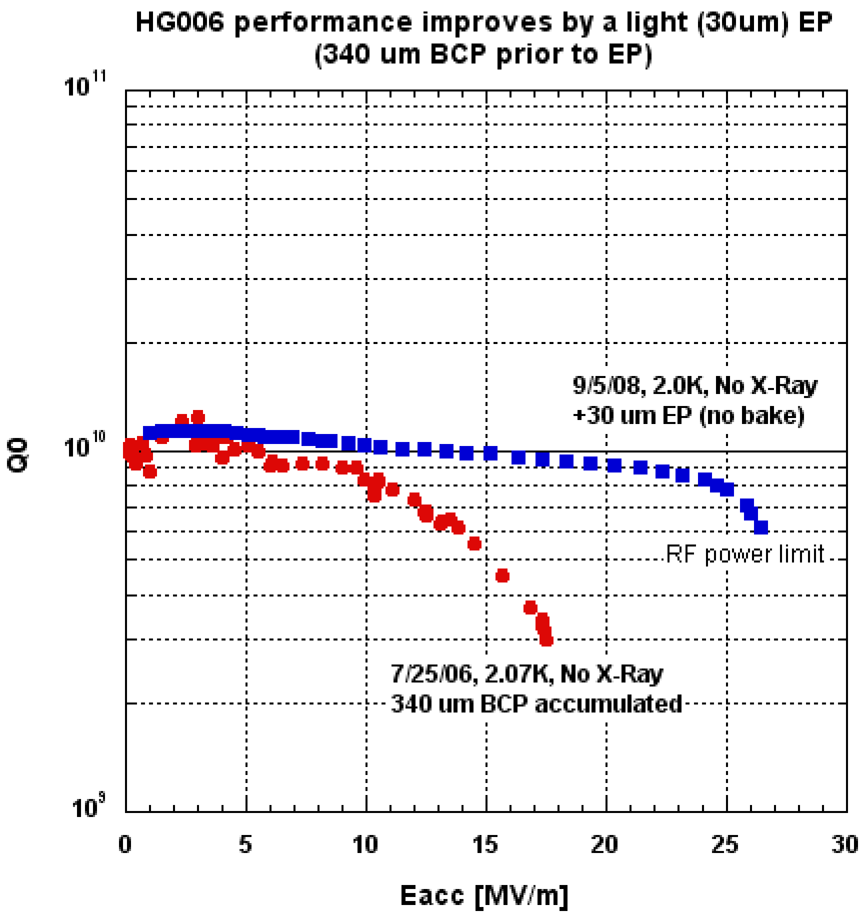


Many “blisters” inside weld
somehow no “blister” in some area



Many apparent “deep pits”
in heat affected zone

HG006 + 30 um EP – Performance Improves

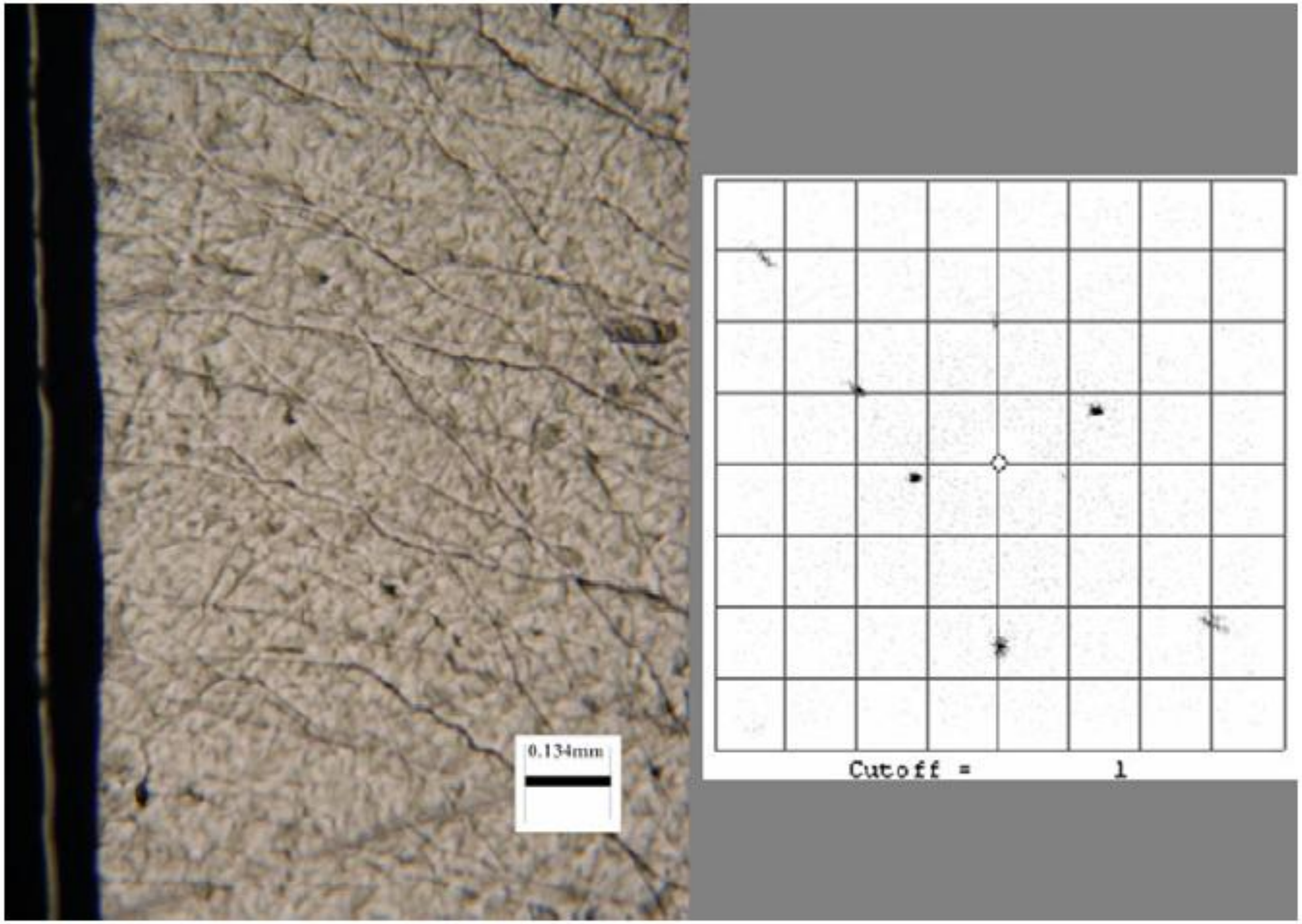


Next: low temperature bake + test + re-inspection

Personal Observations (1)

- Defects of a few hundred micron in diameter in high magnetic field (equator) have been observed and correlated with quench <= 20 MV/m.
  - A15, JLab, T-mapping + LDM, 200 um pit.
  - AES1, FNAL/KEK/Kyoto, 400-600 um pit/bump/"cat-eye". (ASC09)
  - Re-entrant 9-cell, Cornell, 100um pit. (TTC report)
  - AES3 (Thermometry done, no inspection yet)
- Similar defects have been observed in high electric field region and coincide with strong field emission cells.
  - AES4, JLab,100um "cat-eye".
- Similar defects found in as-built cavities before any chemistry (and possibly in BCP etch cavities as well as in large-grain cavity)
  - J1, J2, PKU 9-cell (HC1, HG006, LG1)
- These defect are all close to the EBW
  - HAZ of equator EBW: A15, AES1, AES3, RE 9-cell, J1, PKU 9-cell, HG006, LG1
  - Inside surface of the stiffening ring EBW: AES4
- Origin of these defect not clear. It seems they are observable at random depth into the bulk. They are observable independent the manufacturer. Fine grain or large grain niobium (next slide for one example). It is possible they have to do with some intrinsic behaviors of electron beam weld of niobium.

Point & Line Defects in HAZ of Large-Grain Niobium EBW Sample



R.A. Cates, SRF060811-06, Cornell University

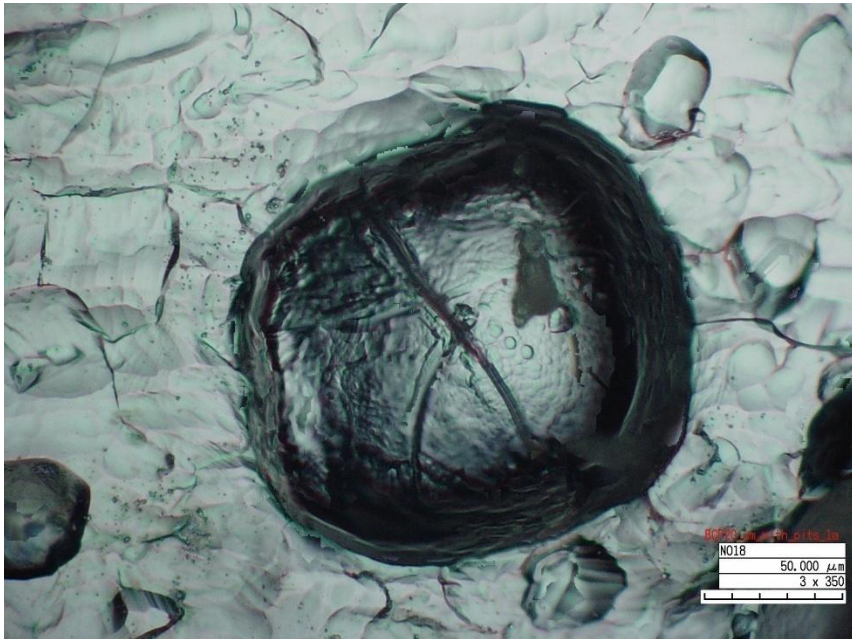
Personal Observations (2)

- If indeed this is an intrinsic problem
  - Is it possible to avoid them in the first place by optimized EBW parameters?
  - Is it possible to remove them by chemistry (BCP or EP)?
    - One JLab experiment showed BCP is unable to remove sub-mm pit (next slides).
    - Similar JLab samples with controlled pits are sent to KEK to explore the effect of EP.
  - Is it possible to remove them by local repair (guided repair, local barrel polishing, local re-melting)?
- JLab has started to work on niobium re-melting technique, aiming for repair of the known bad 9-cell cavities (such as A15, AES3).
- Proof of principle established with Nb samples.

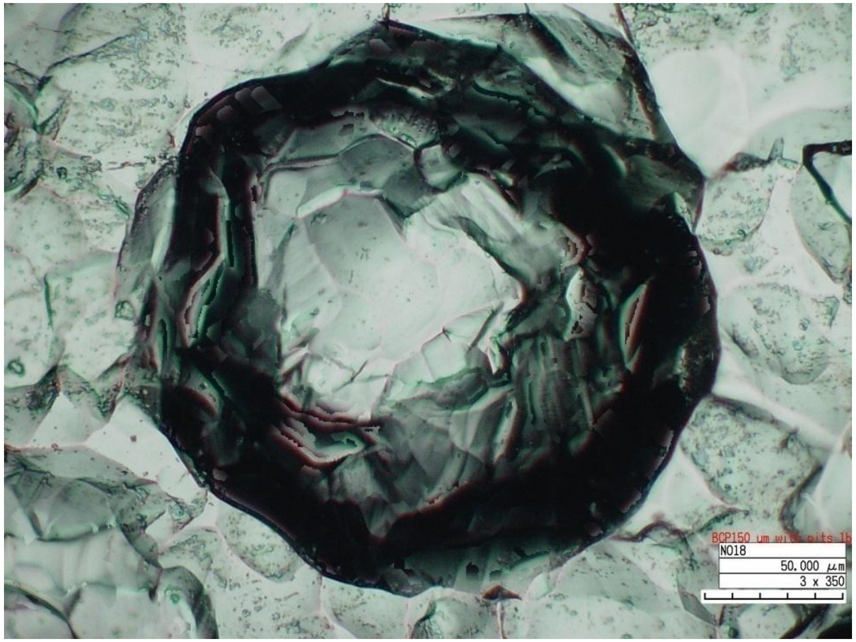
Inability of BCP to Remove Pit

Controlled mechanical defect (~100 µm) for re-melting test

A pit becomes a bigger pit after more BCP



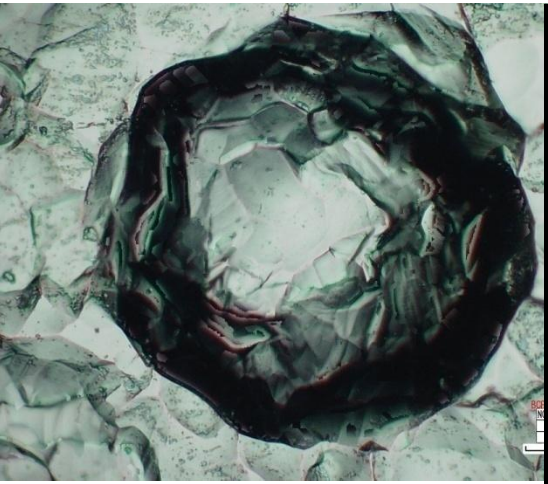
BCP 20 µm

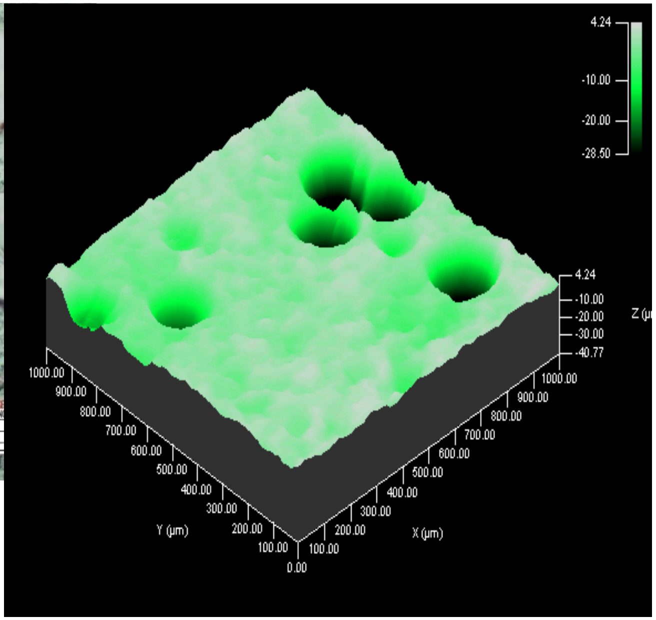


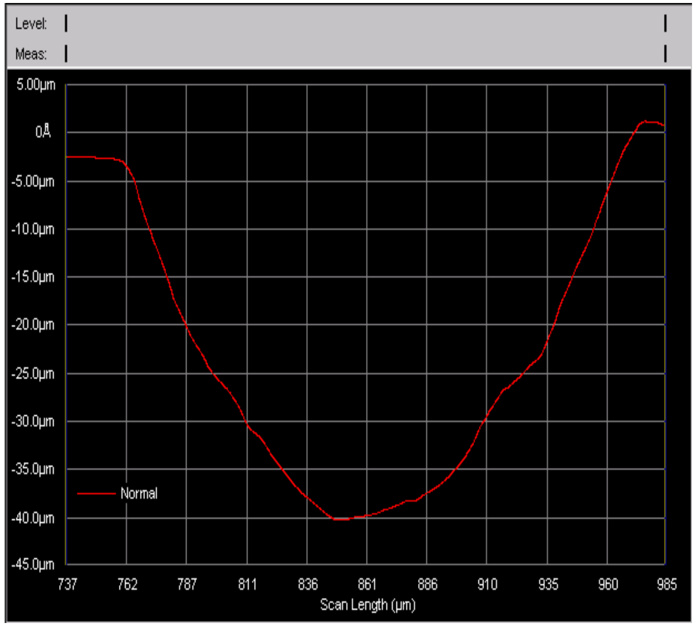
BCP 150 µm

Inability of BCP to Remove Pit

An example of depth profiling of controlled defect







Slope angle 26°-47°

Magnetic Field Enhancement Effect

$$h \sim r^n$$

n=-1/3, C. Reece, SRF-840302, Cornell University, 1984

h upto 3, J. Knobloch, SRF Workshop, 1999

h upto 5, V. Shemelin, TTC-Report-2008-07, 2008

Personal Observations (3)

- Clear advantage of local re-melting
  - True local repair, other good surface not touched.
  - Outside re-melt (can be done with JLab EBW facility).
  - Local heat treatment – improve local thermal conductivity so as to stabilize the defect (mini-postpurification).
  - Inside re-melt – need to upgrade JLab EBW facility with internal gun.

•Barrel polishing remove local defect at cost of spoiling good surface outside defect; post-polishing chemistry needed; may in the end disclose new defects.

- Guided repair used in the past with larger cavity at lower gradient. But again defect removal at cost of spoiling good surface outside defect – with the added problem of creating new damage due to tools touching good surface.