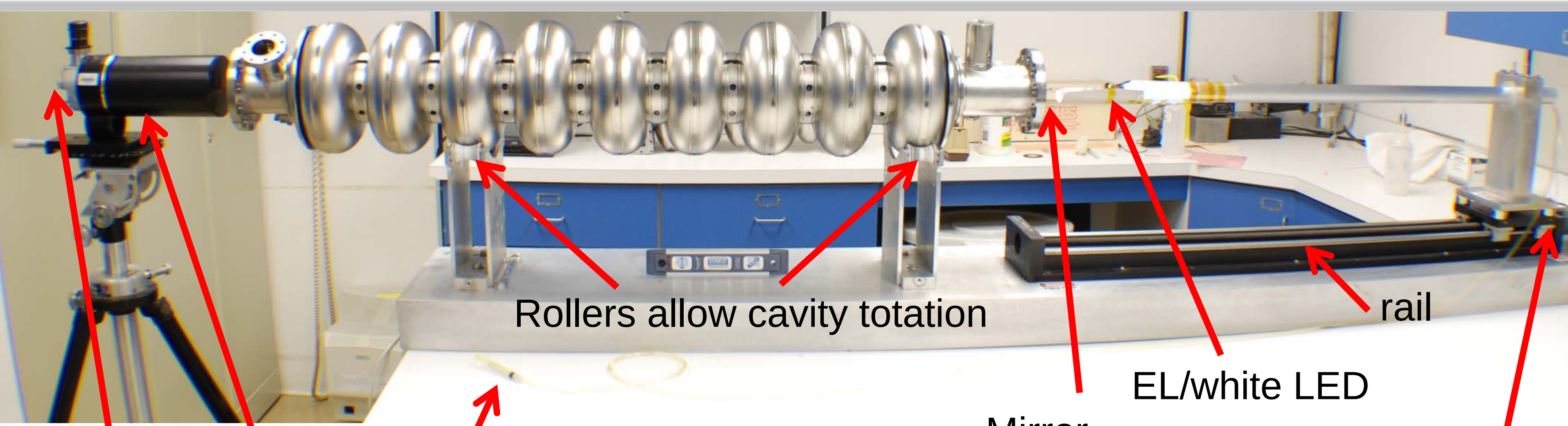
Experience with Optical Inspection

Bob Rimmer

For Jefferson Lab

TTC meeting, October 20-23, 2008

JLab High Resolution Cavity Inspection Apparatus



EL/white LED

Mirror

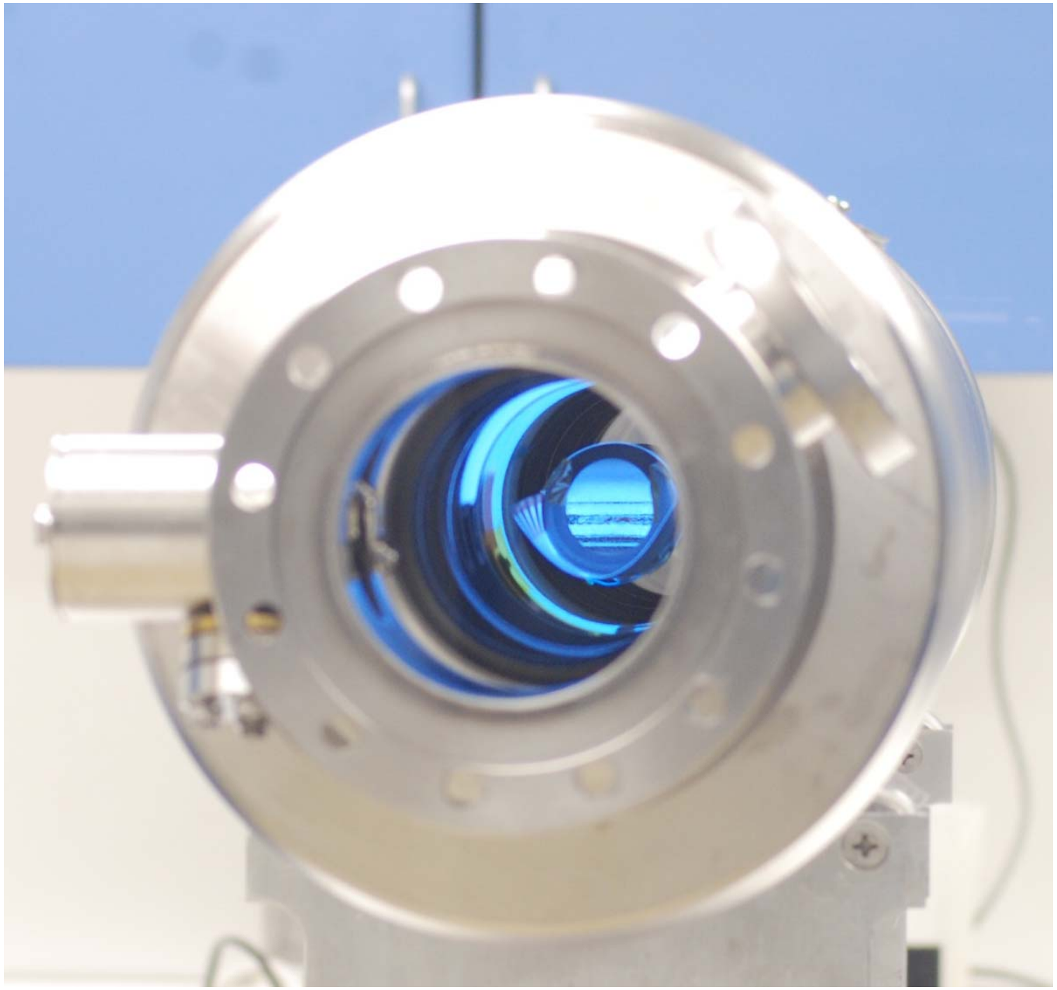
Mirror tilter

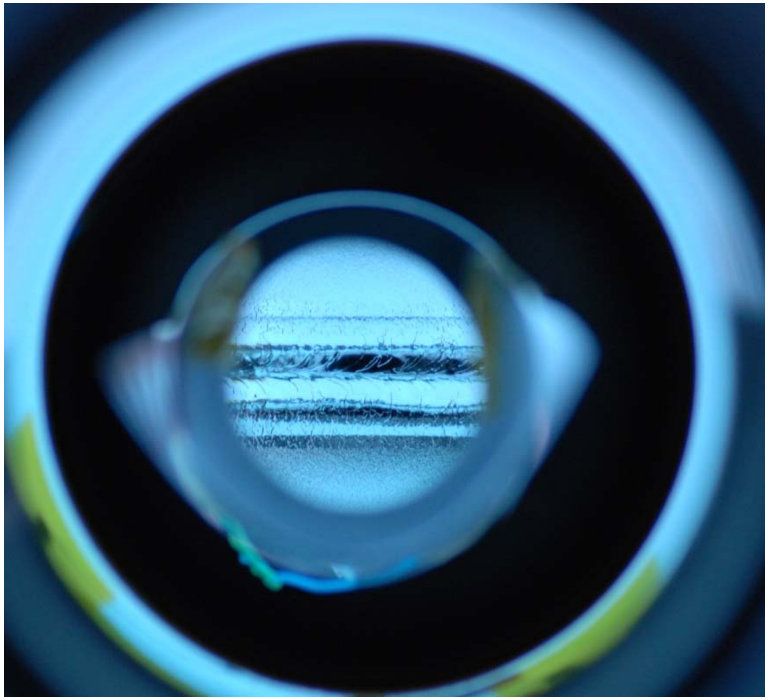
Questar QM1
• Working Range: 22 – 66 inchs
• Resolution: better than 3 microns at 22 inches

Step motor

Nikon digital camera
Pixelink CCD camera

The Mirror



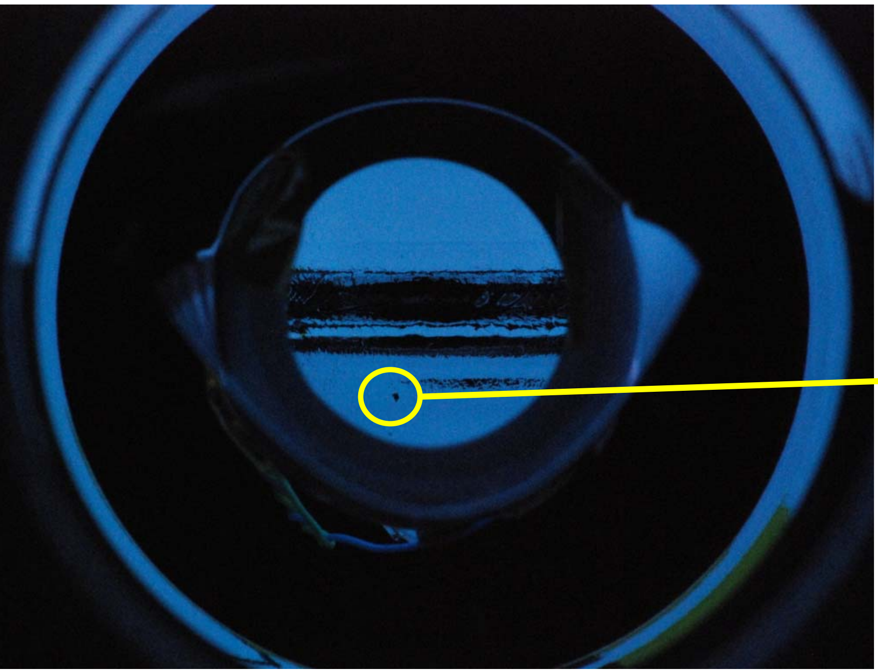


Inspection of previously processed and tested cavities

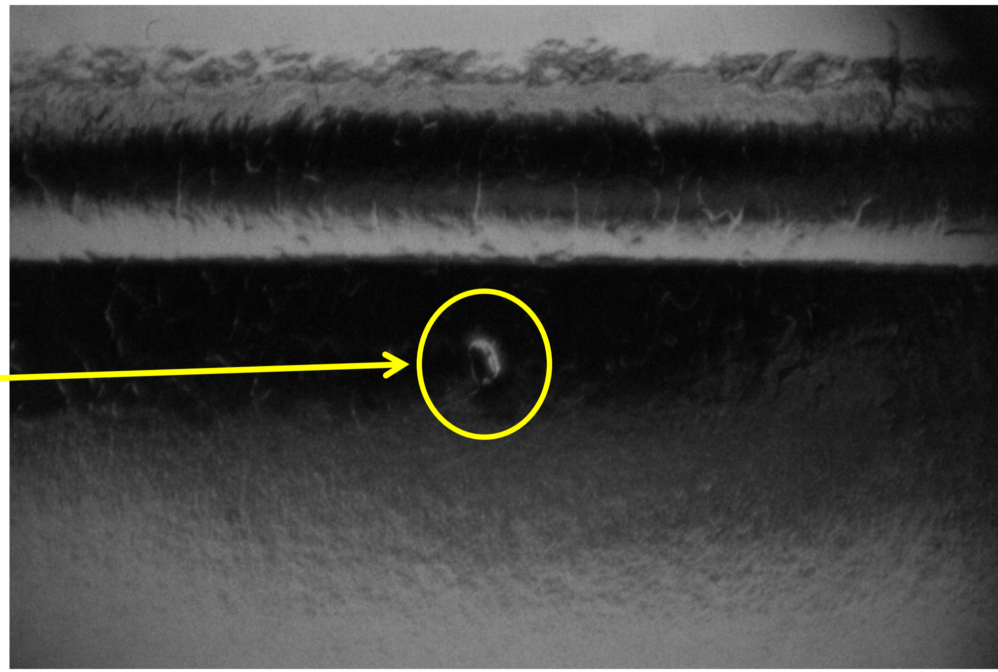
In some cases, cavity behaviors are correlated to observed defects

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

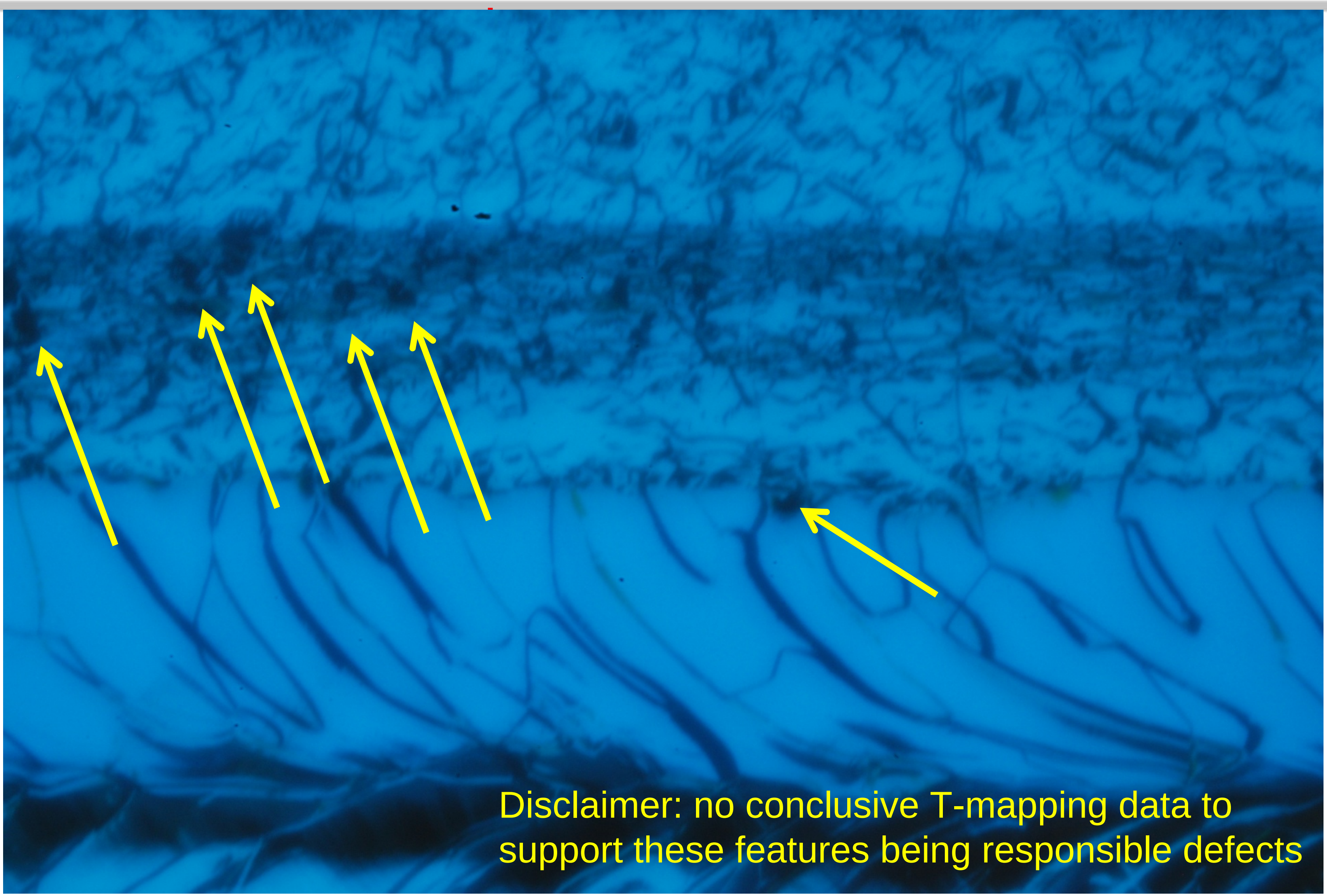


Direct Nikon digital camera

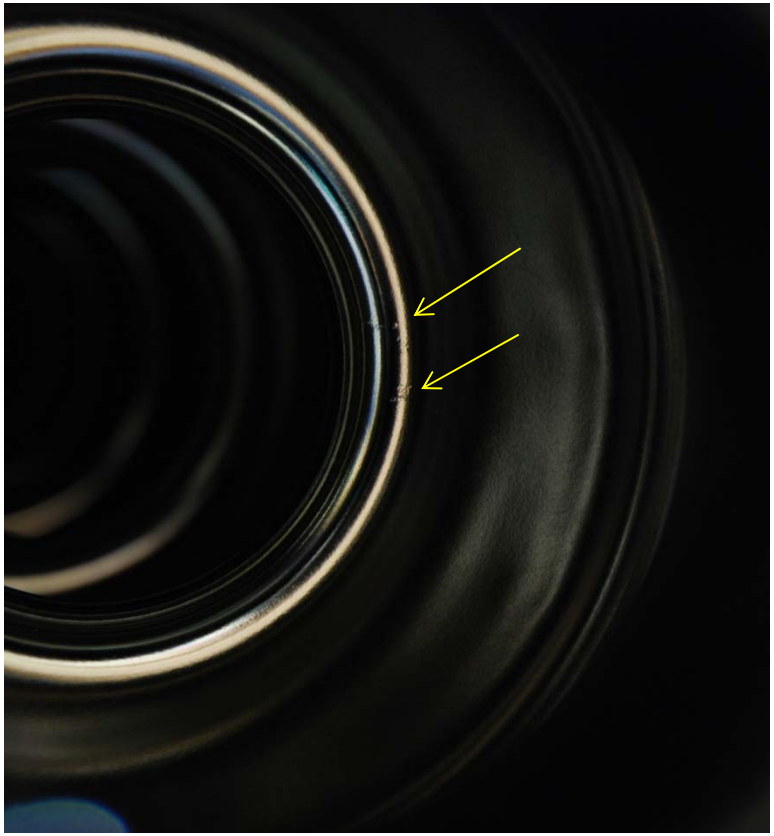


Questar QM-1

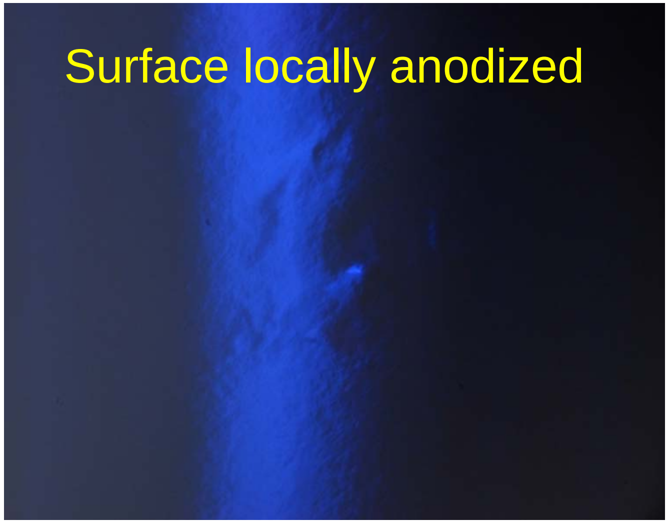
JL001 (25 MV/m)
Equator (BCP only + 1250C)

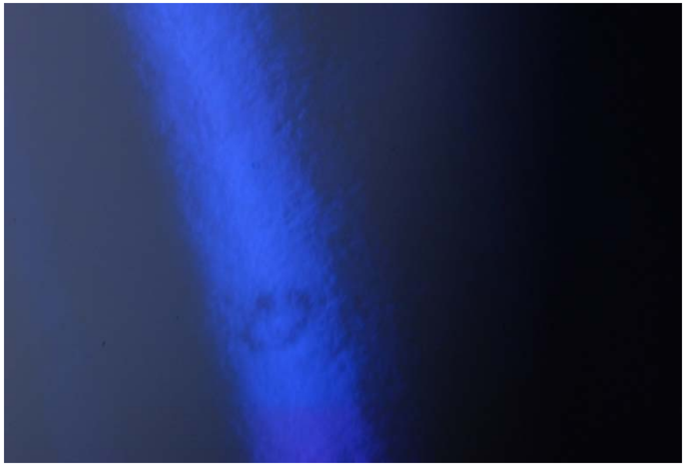


ICHIRO5 Surface Damage in Iris Region



As received (digital camera image)

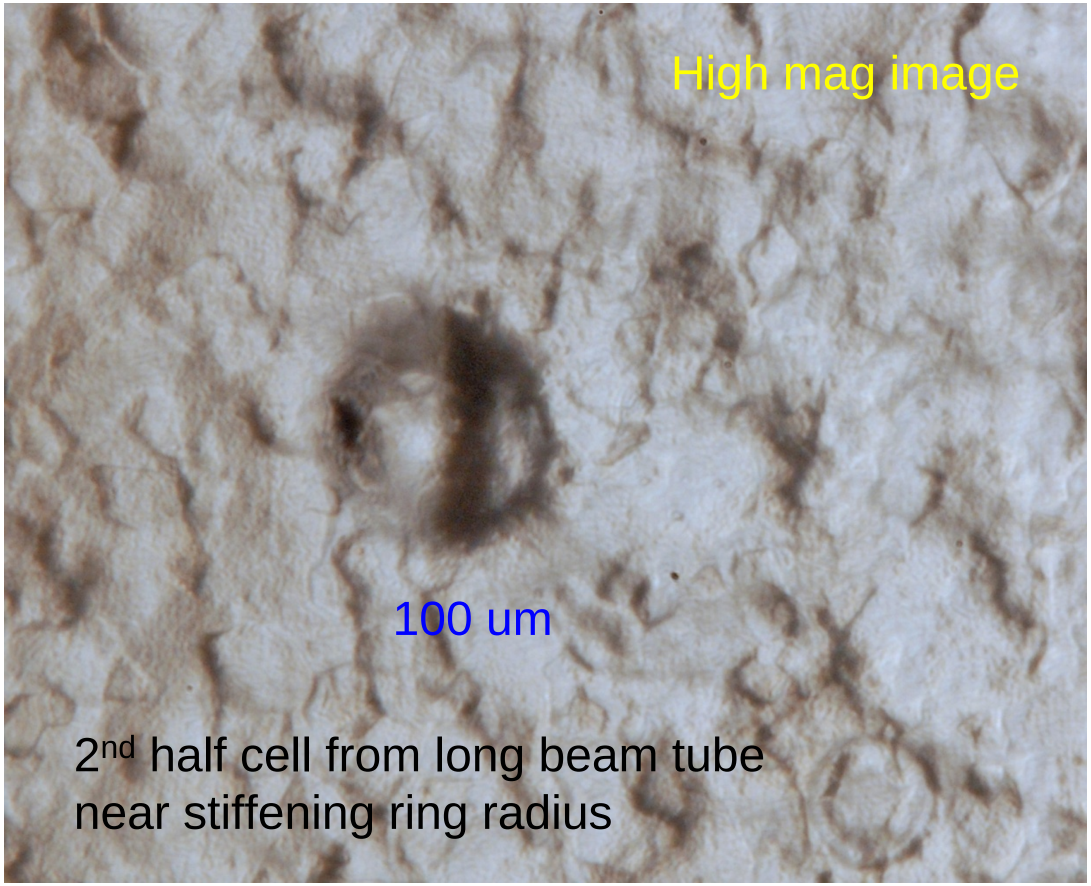




After EP + RF test w/ FE limit

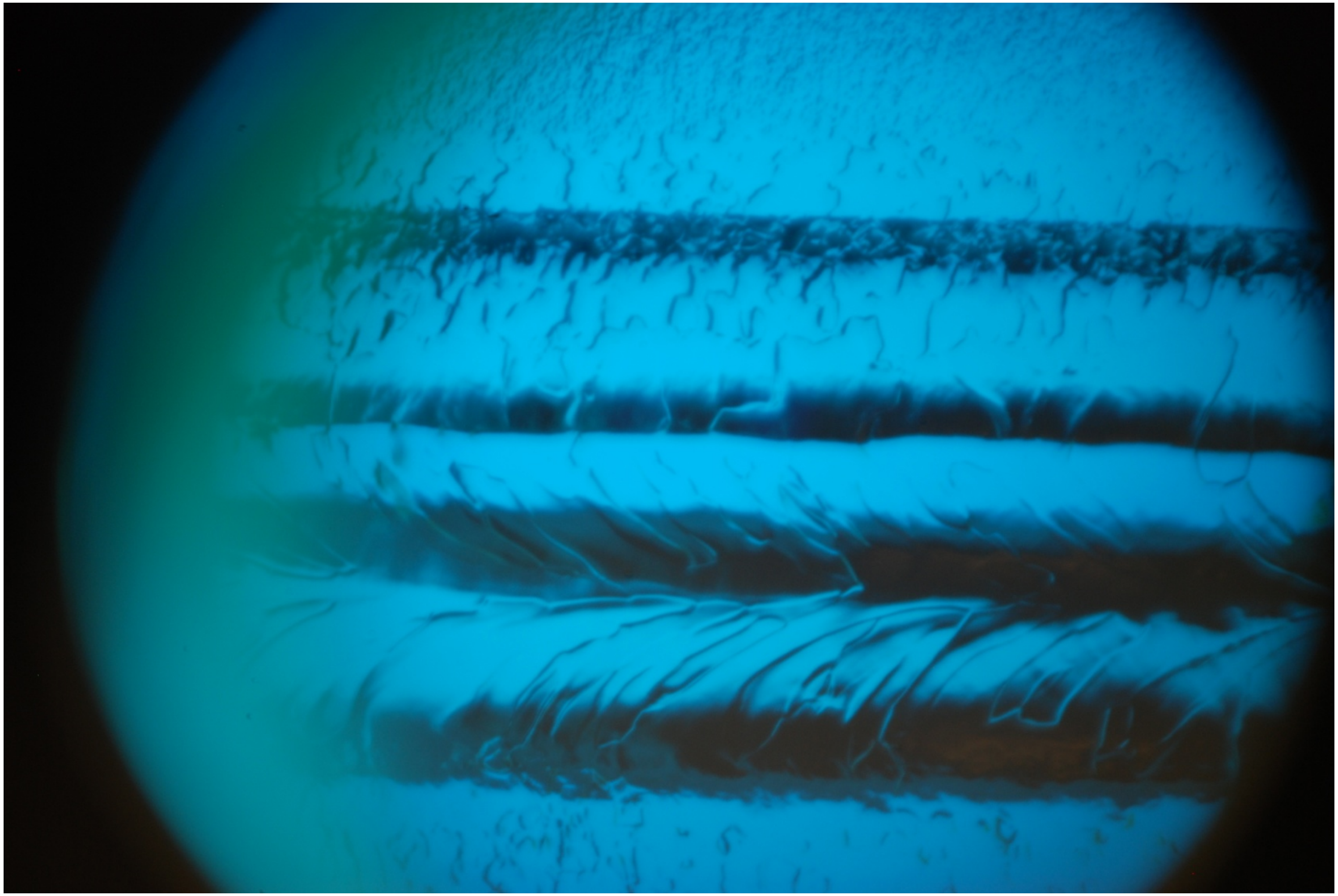
AES4 High E Field Region

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



AES4 High E Field Region

A8 – 32 MV/m Surface
Typical Appearance of Equator Weld

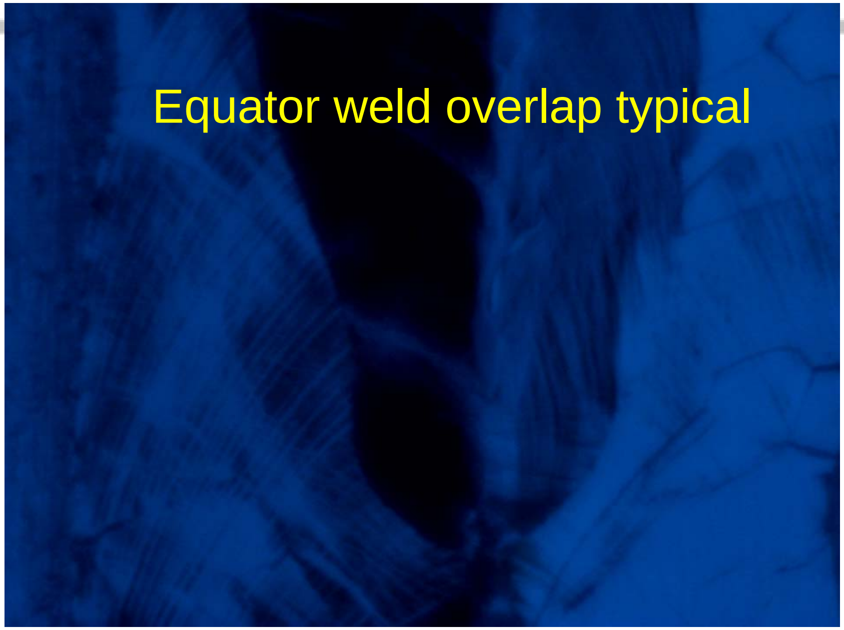


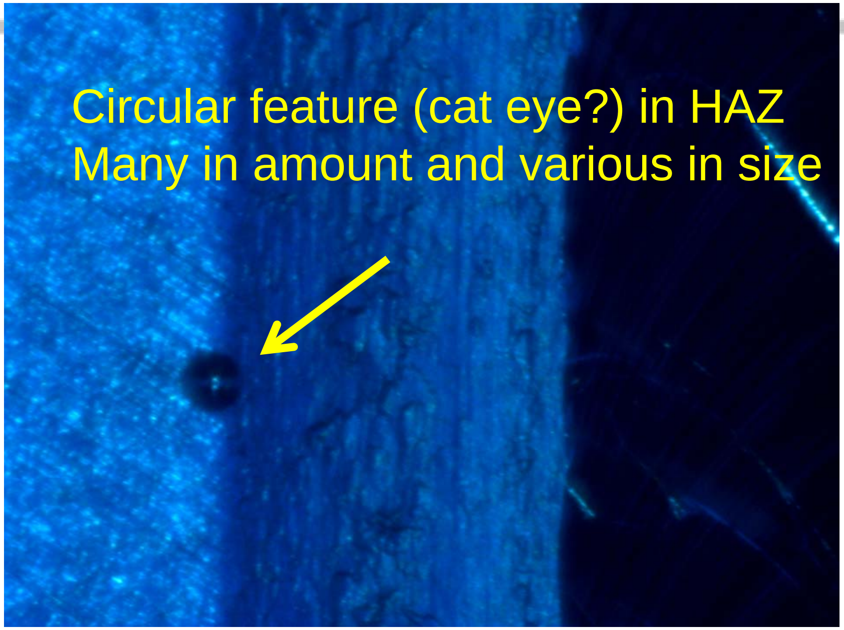
Inspection of an as-built 9-cell cavity

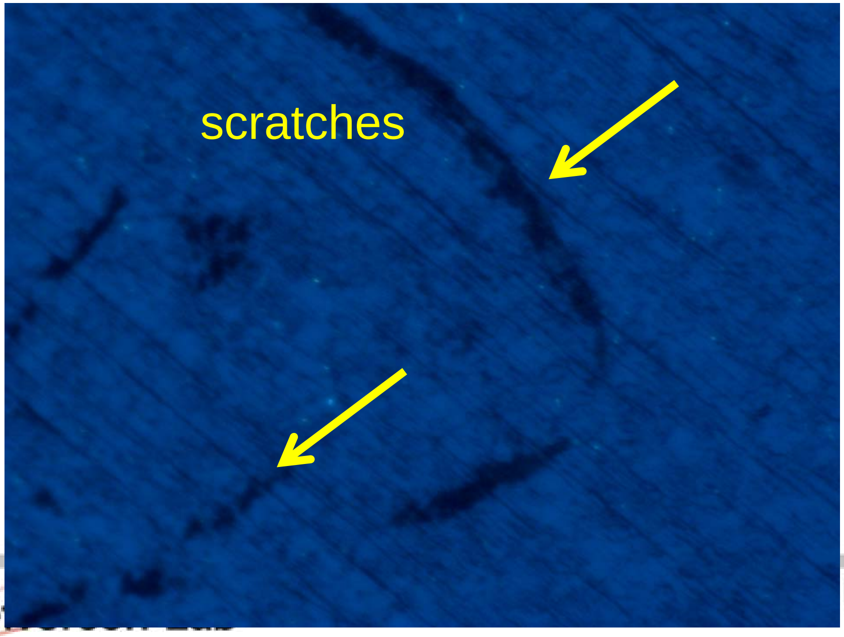
No correlation with cavity behavior is established yet

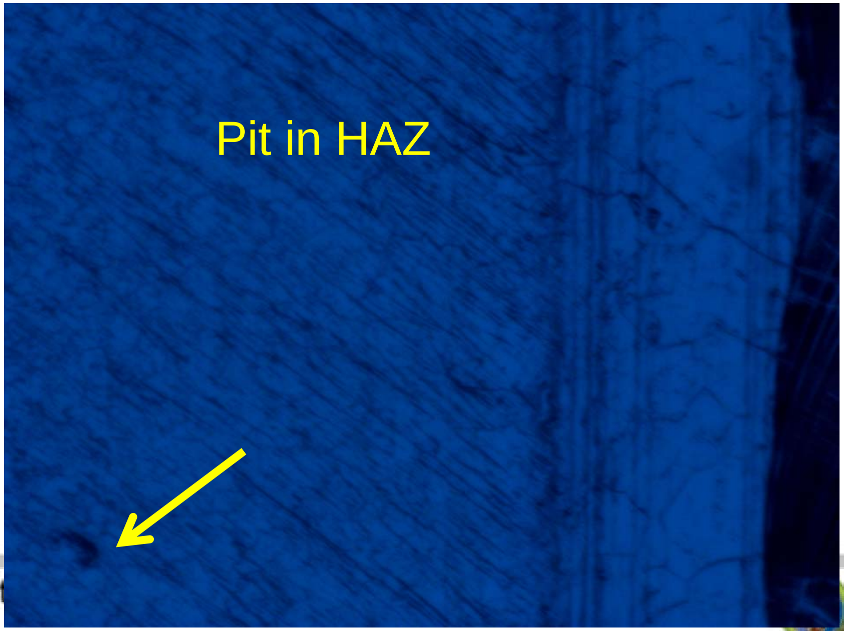
Goal is to understand initial surface conditions

J1 9-cell cavity as-built RF surface

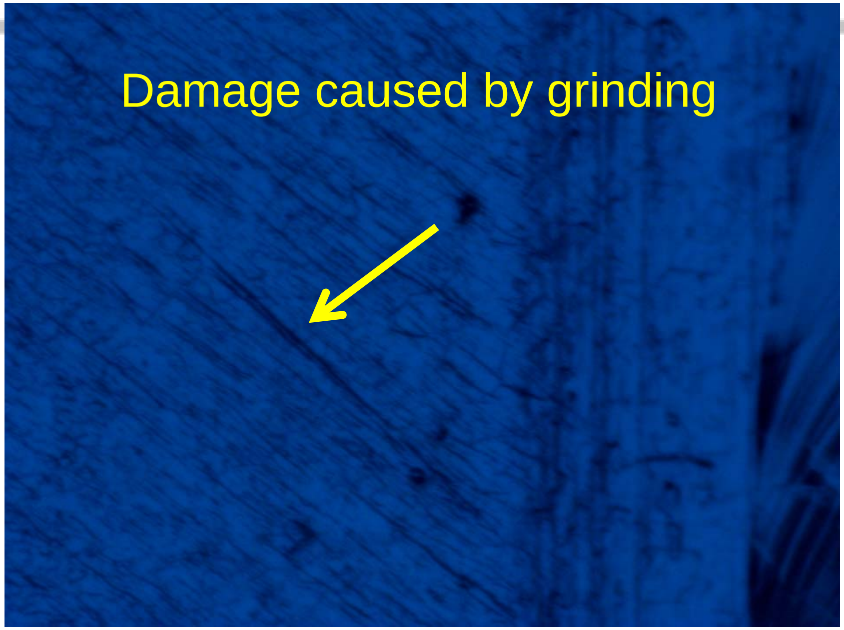


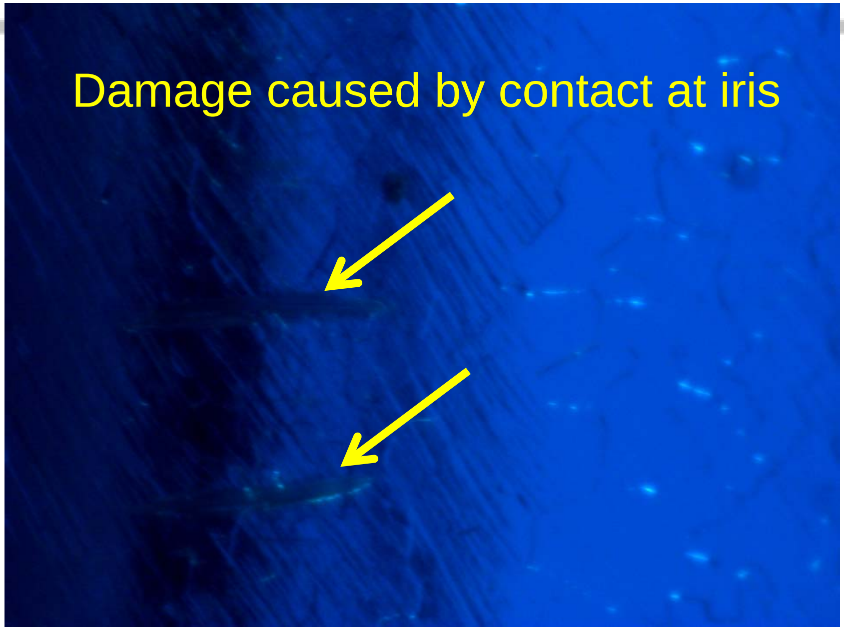




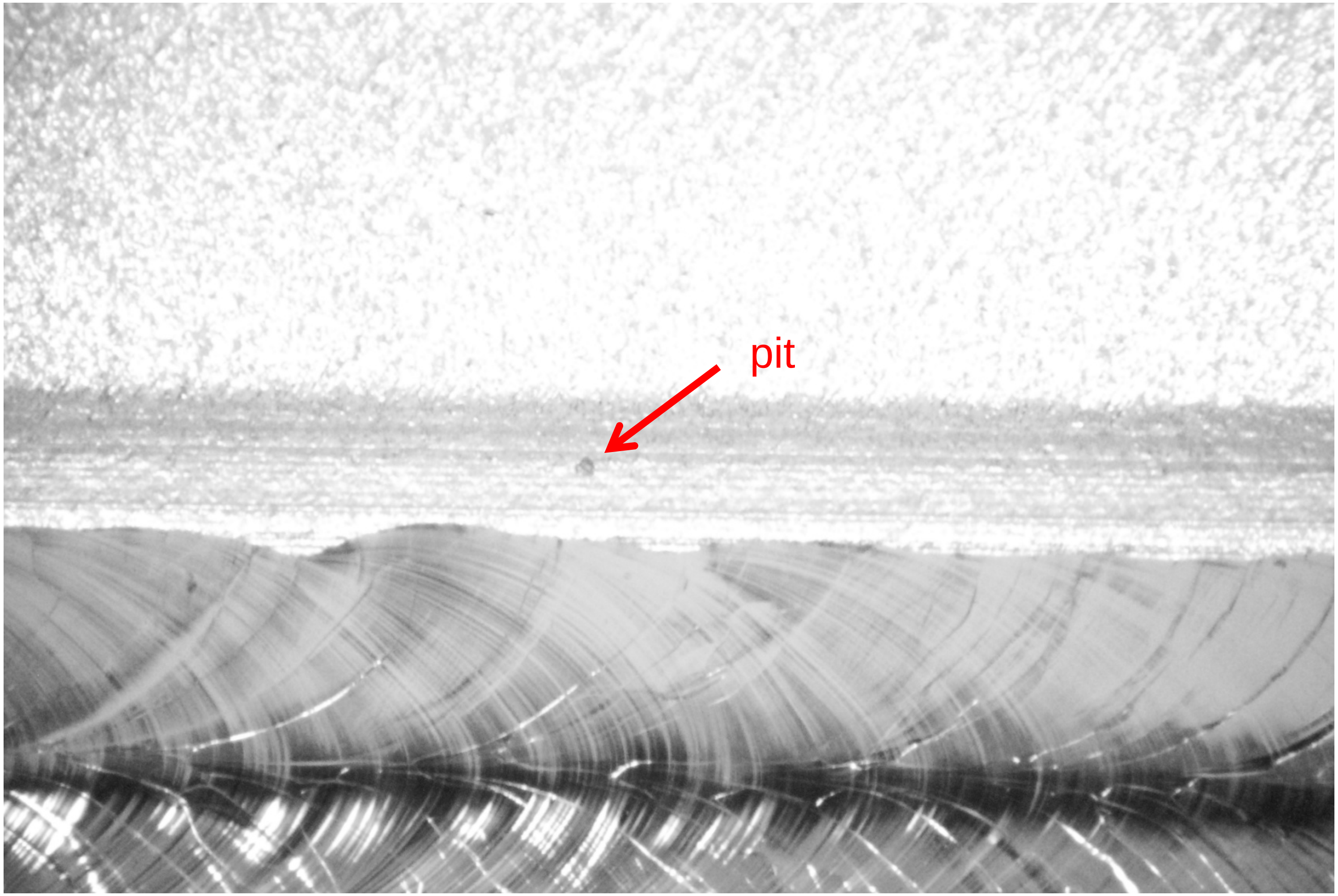


J1 9-cell cavity as-built RF surface

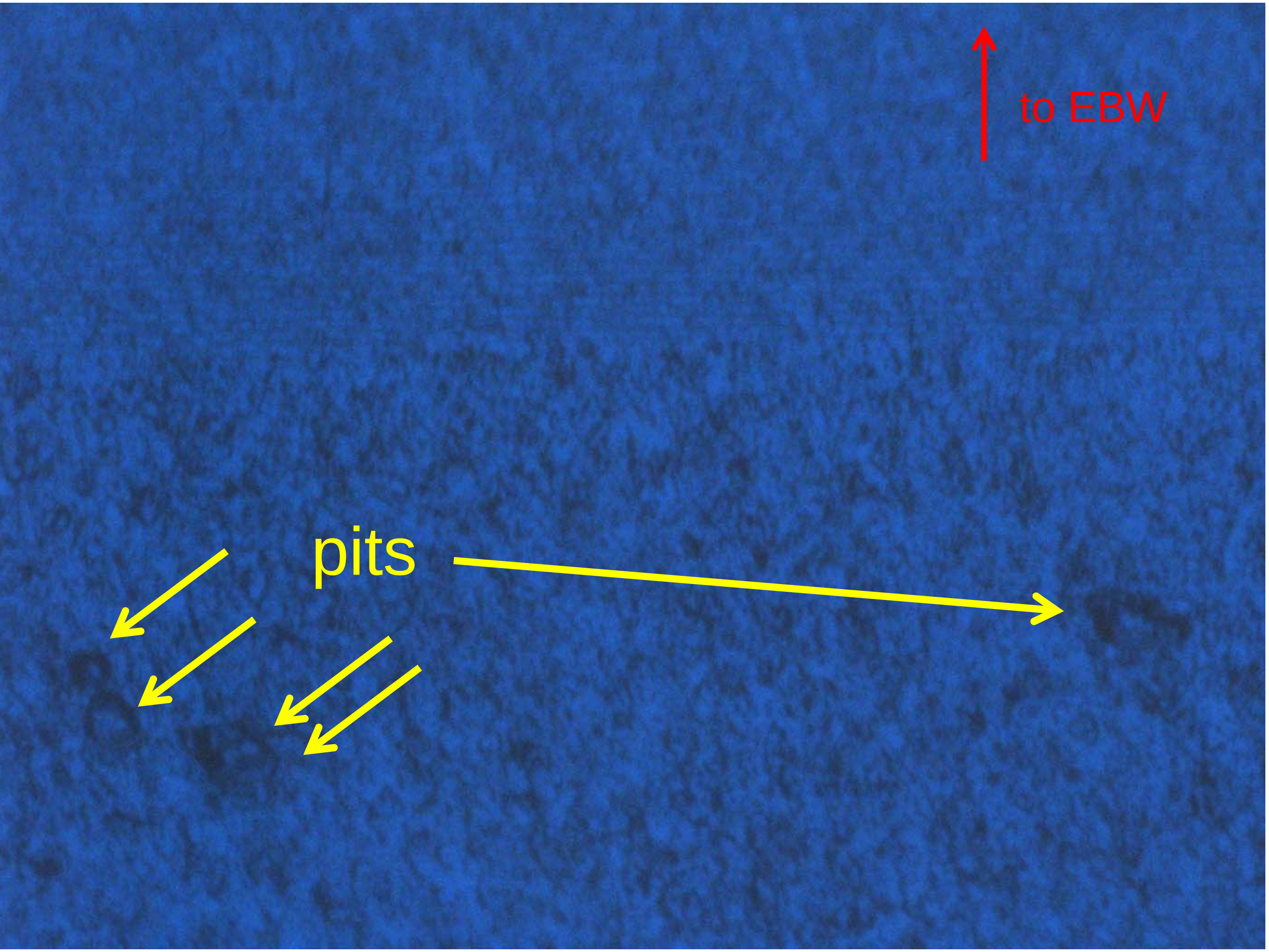


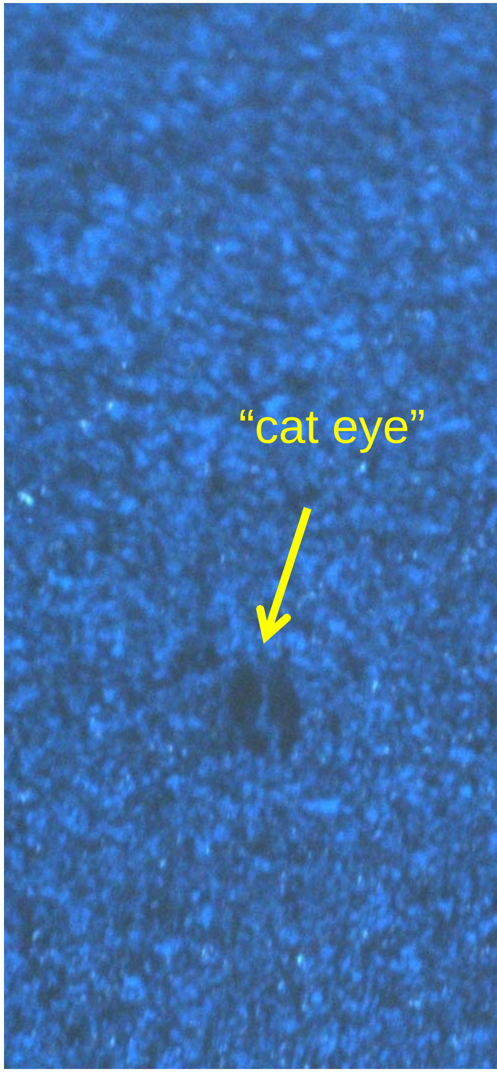


J2 9-cell cavity as-built RF surface



A13 HAZ equator weld as build



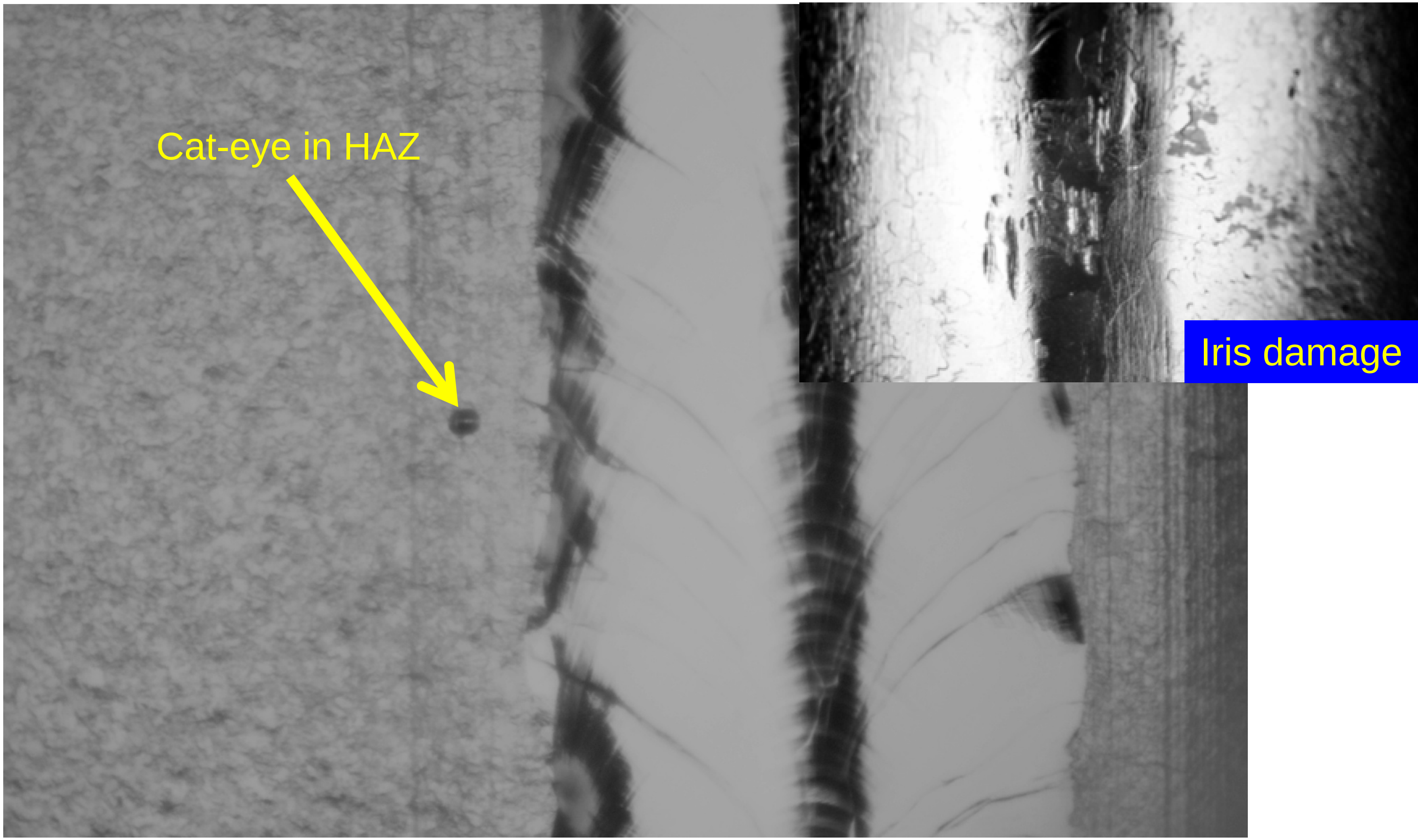


Bulk EP and 600 C furnace heat treatment done, re-inspection next

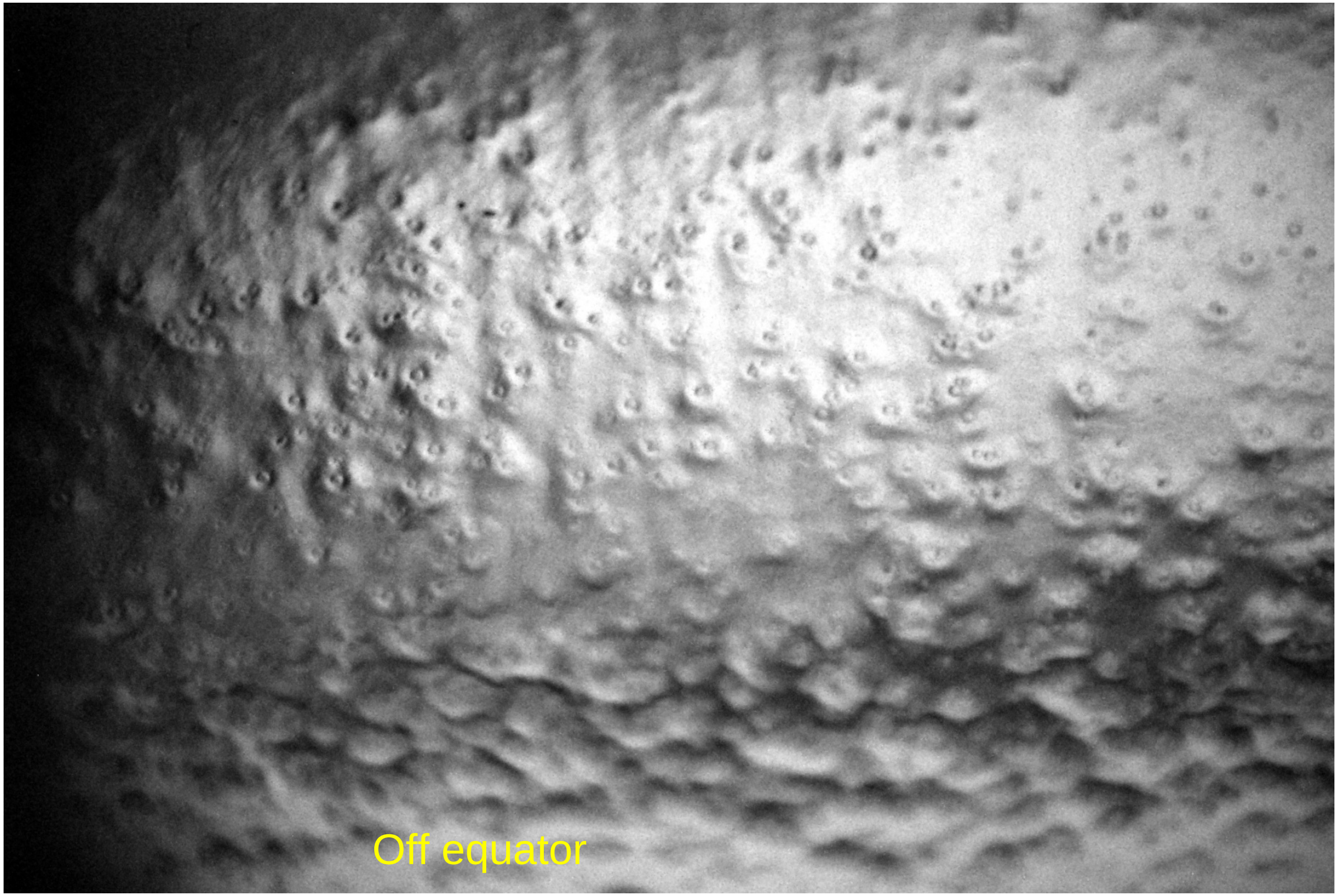
Additional Inspection of Cavities of Various Sources/Histories

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

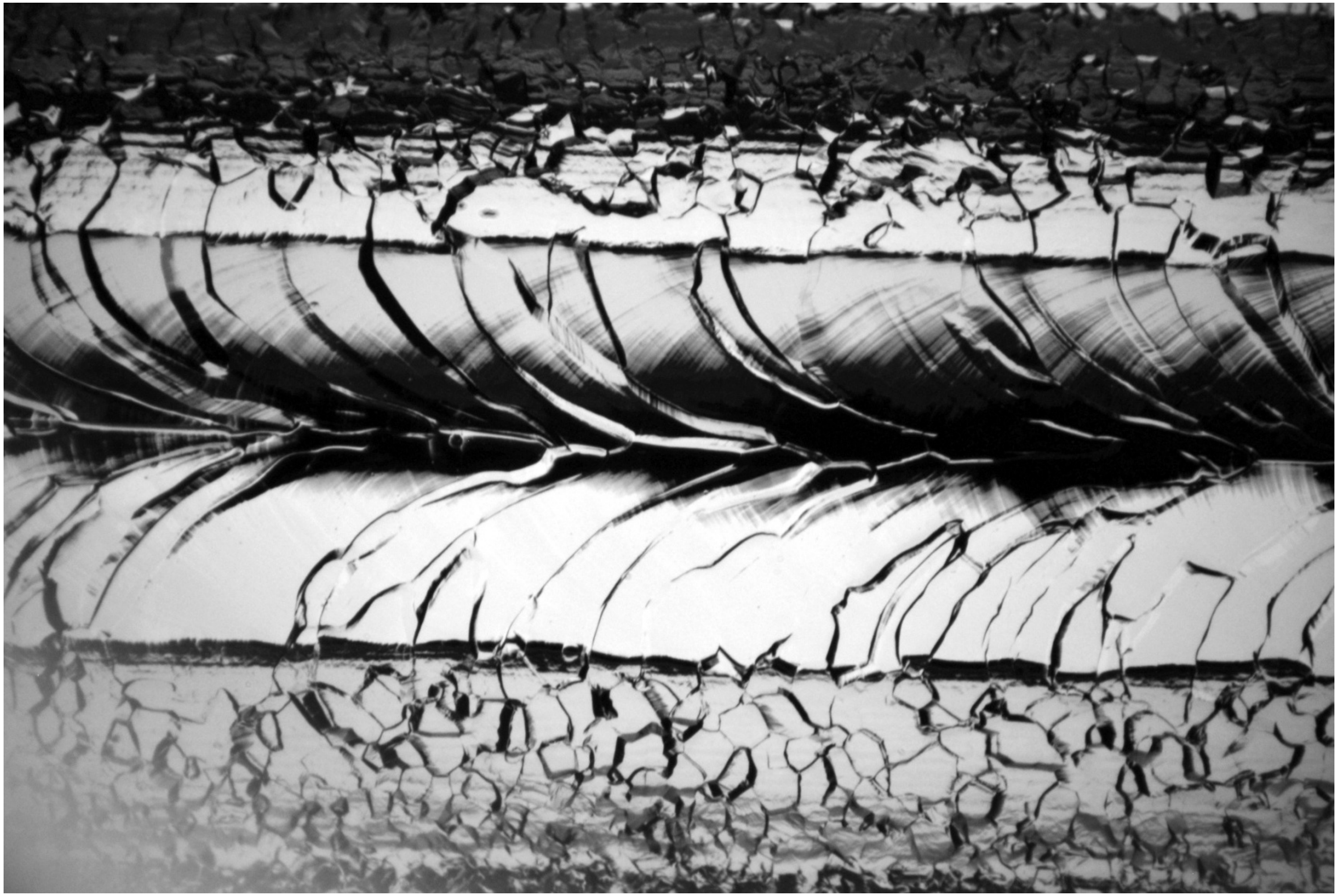
PKU 9-Cell – As Built



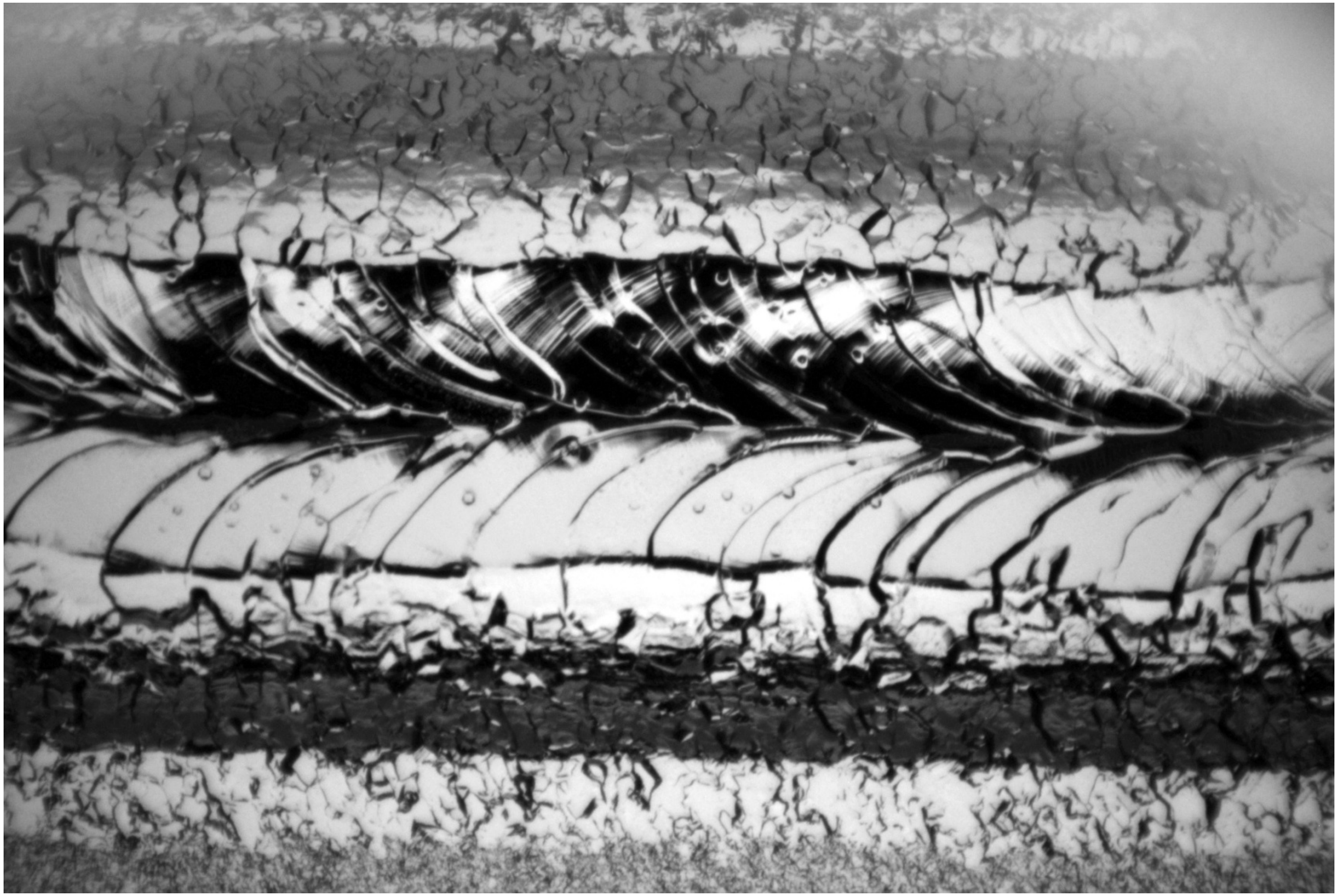
JLab LG1 – BCP surface



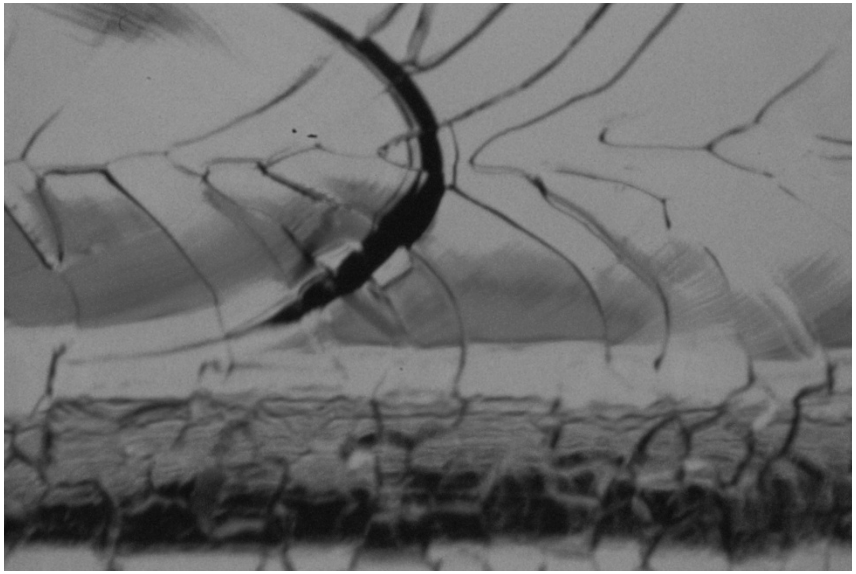
HC1 Equator Weld (1) – BCP Etched only

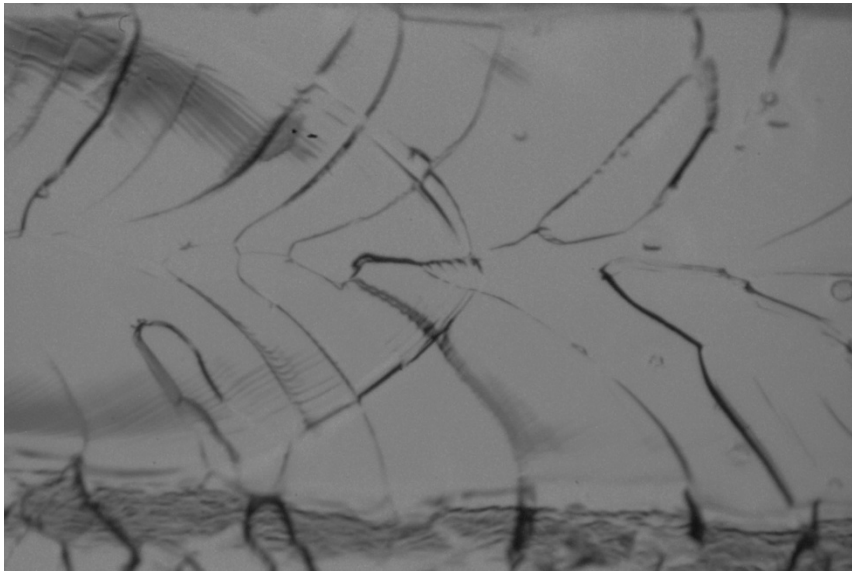


HC1 Equator Weld (2) – BCP Etched only



HG006 (1) – after 340 um BCP

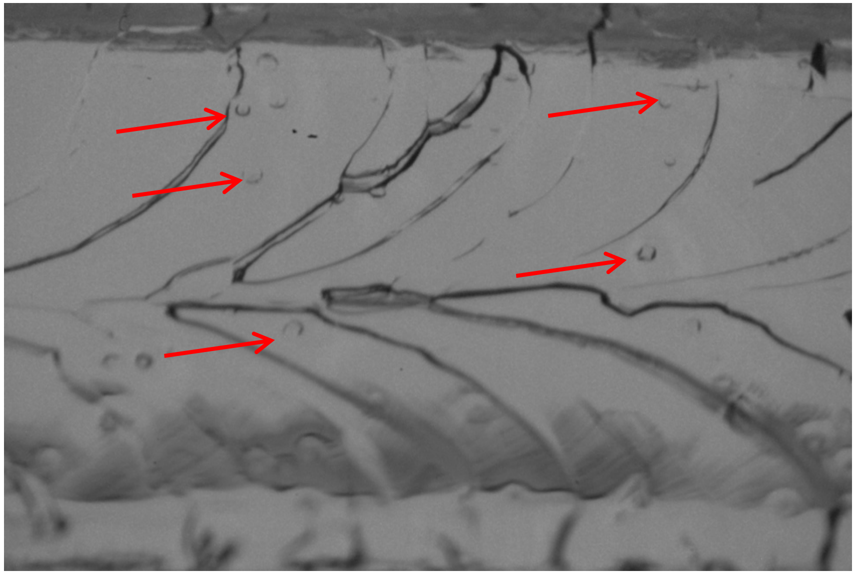


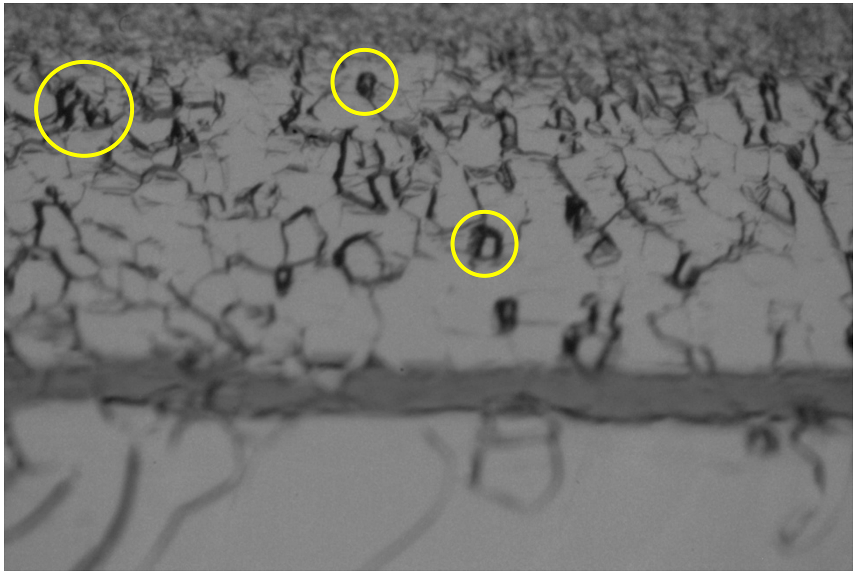


Outstanding irregularity (step) near equator
EBW overlap of cell#7 from WG

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

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, T-mapping + LDM, 200 um pit.
    - Also AES1, KEK/Kyoto/FNAL/JLab, 400-600 um pit/bump/”cat-eye”.
- Similar defects have been observed in high electric field region and coincide with strong field emission cells.
    - AES4,100-200um “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, 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.

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.
    - 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.