Restoration of maximum gradient by laser re-melting a cavity pit

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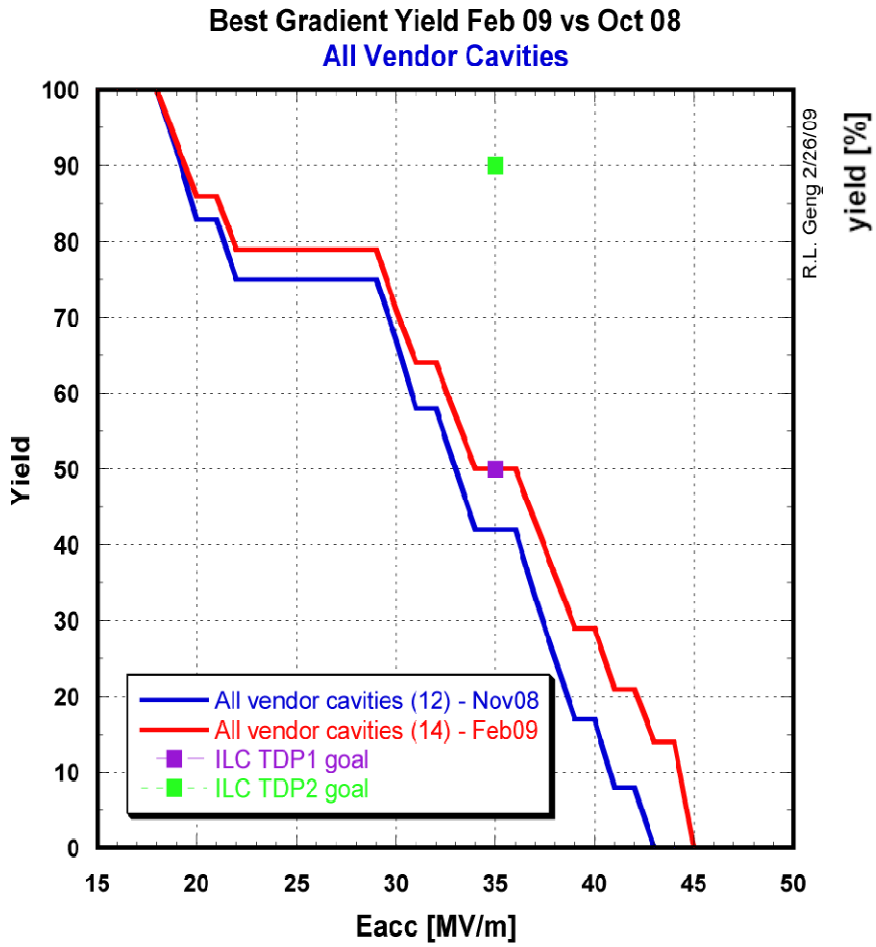
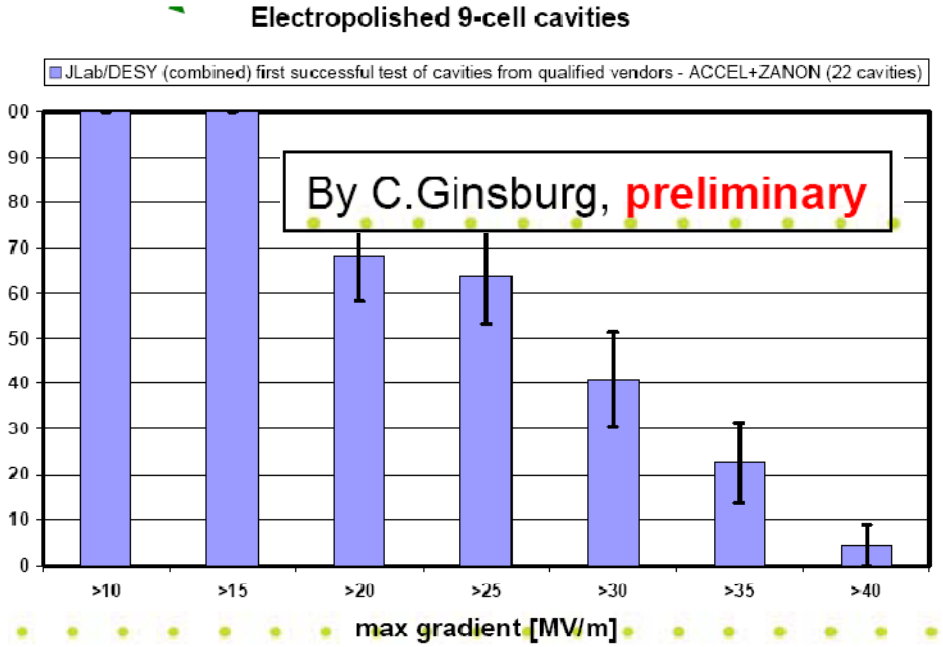
6th SRF Material Workshop
Feb 18th ~ 20th, 2010
Tallahassee, FL

outline

- Motivation
- Technical approaching
- Cavity test results

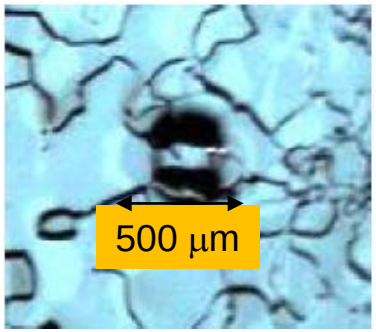
Cavity RF performance statistic

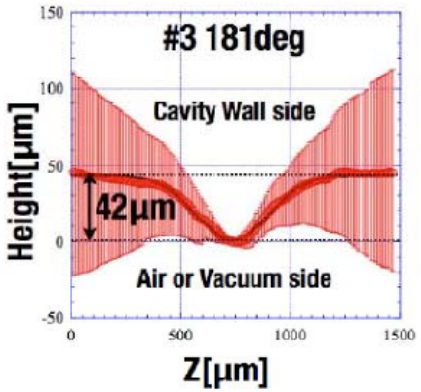




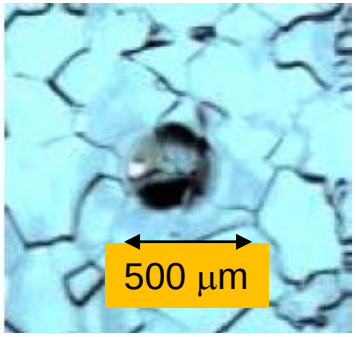
The data was from Jlab and DESY 9-cell cavity activity summarized by R.L. Geng and C.Ginsburg

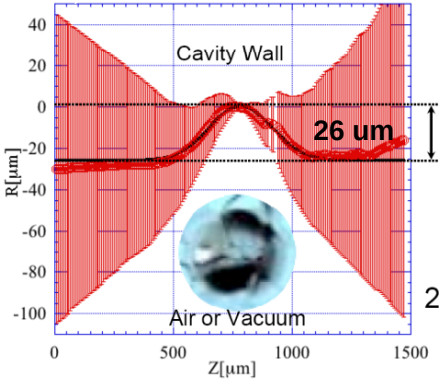
Surface defects (Pits and Bumps) caused quench Identified by Thermometry and Optical Inspection



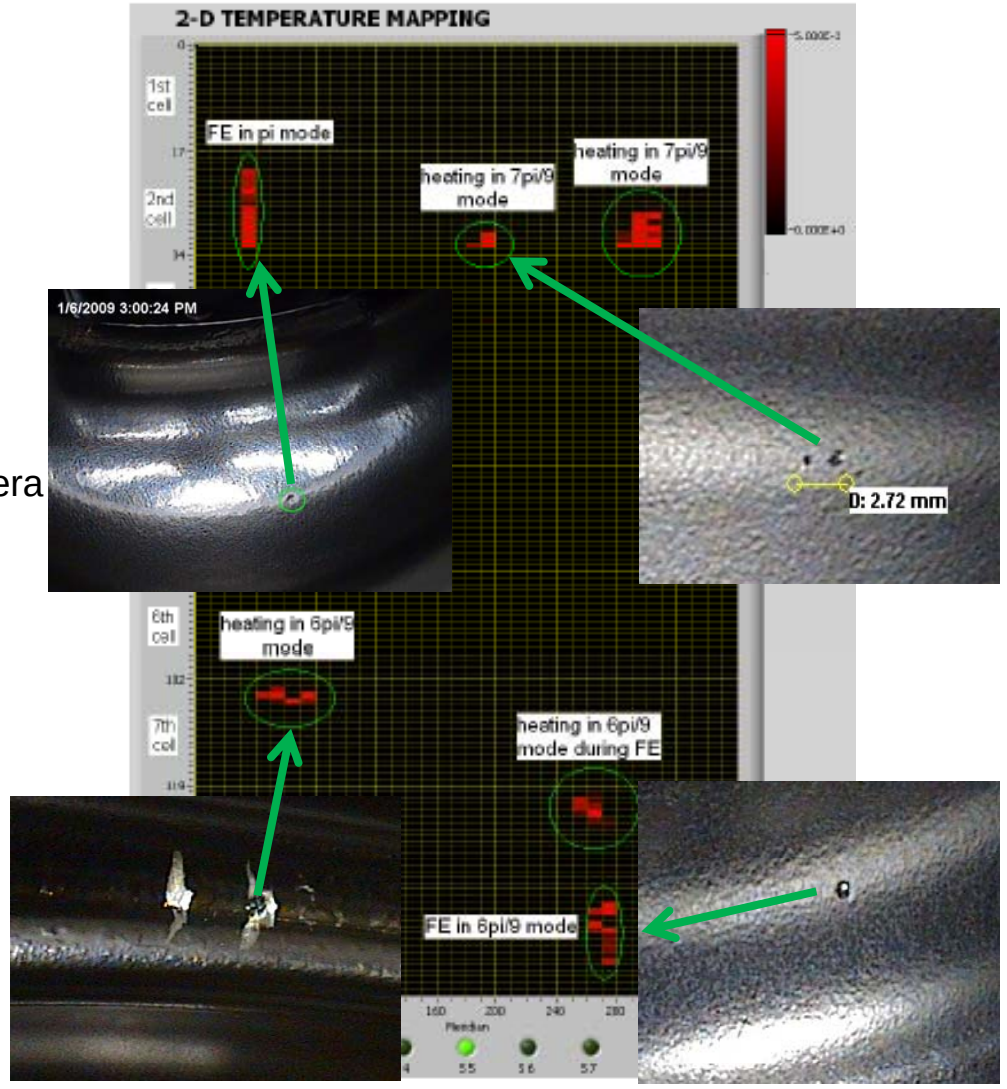


Bump found by KEK Optical Inspection with CCD camera in AES 9-cell cavity with thermometry (Jlab and FNAL) Quench at 18 MV/m



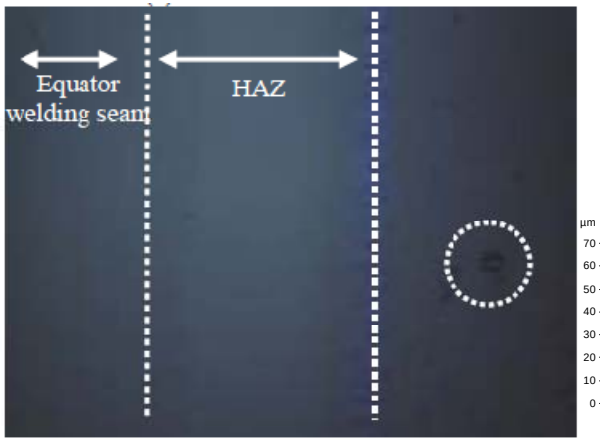


Pit found by KEK optical inspection with CCD camera in AES #1cavity Quench at ~ 18 MV/m

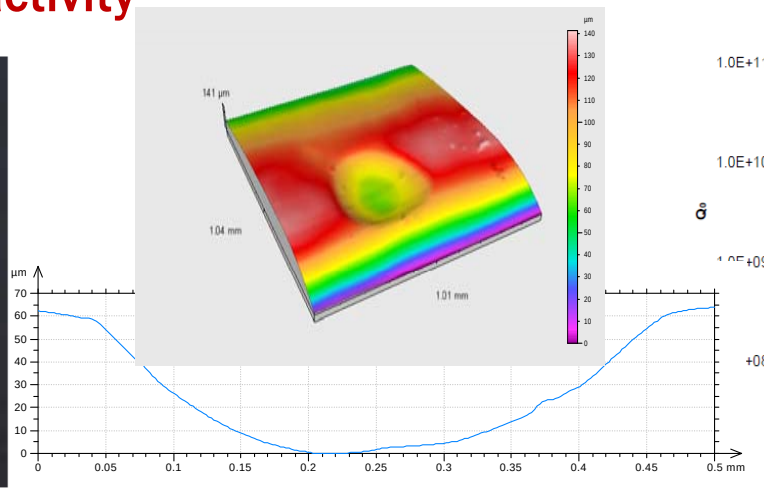


Defects in cavity AES003 correlated to heating detected by T-mapping

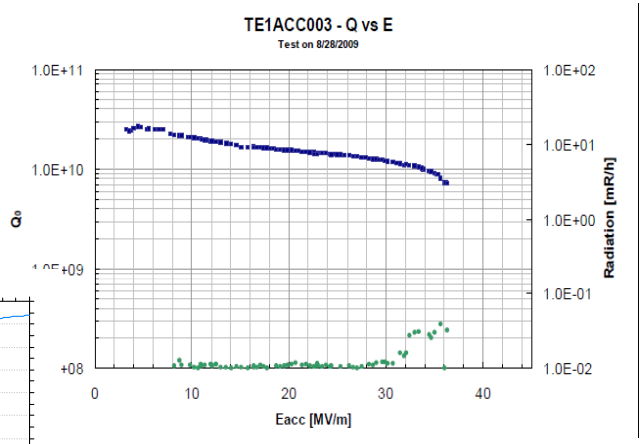
Experience from Fermilab 1.3GHz single-cell cavity activity



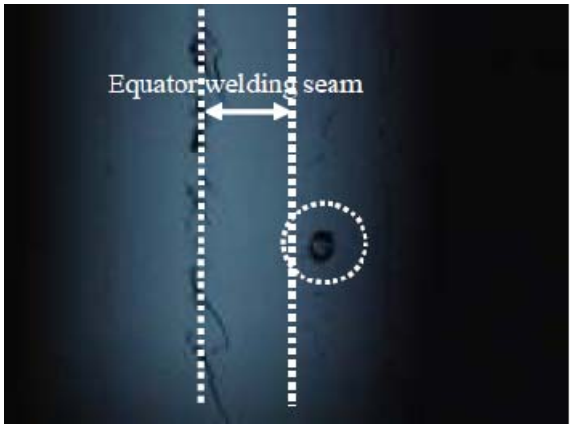
TE1ACC003



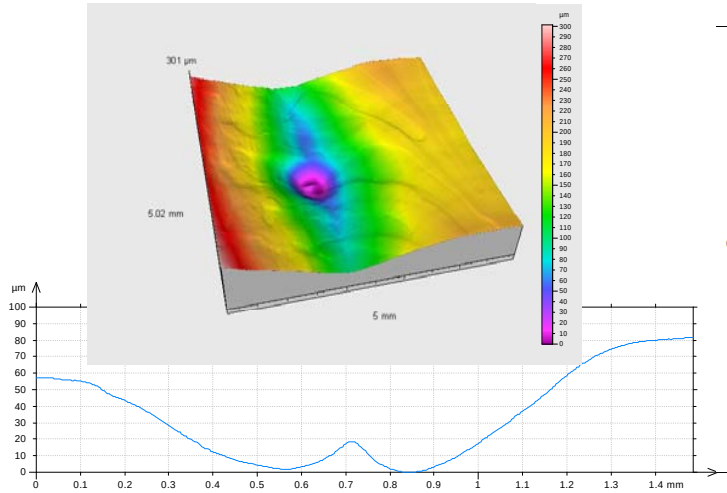
Diameter: 400µm,Depth: 60µm



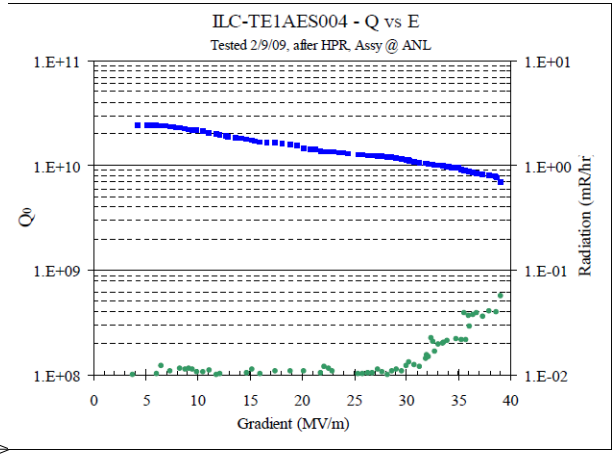
36MV/m quenched at pit region



TE1AES004



Diameter: 1300µm, Depth: 60µm
A 15µm tiny bump in the center.



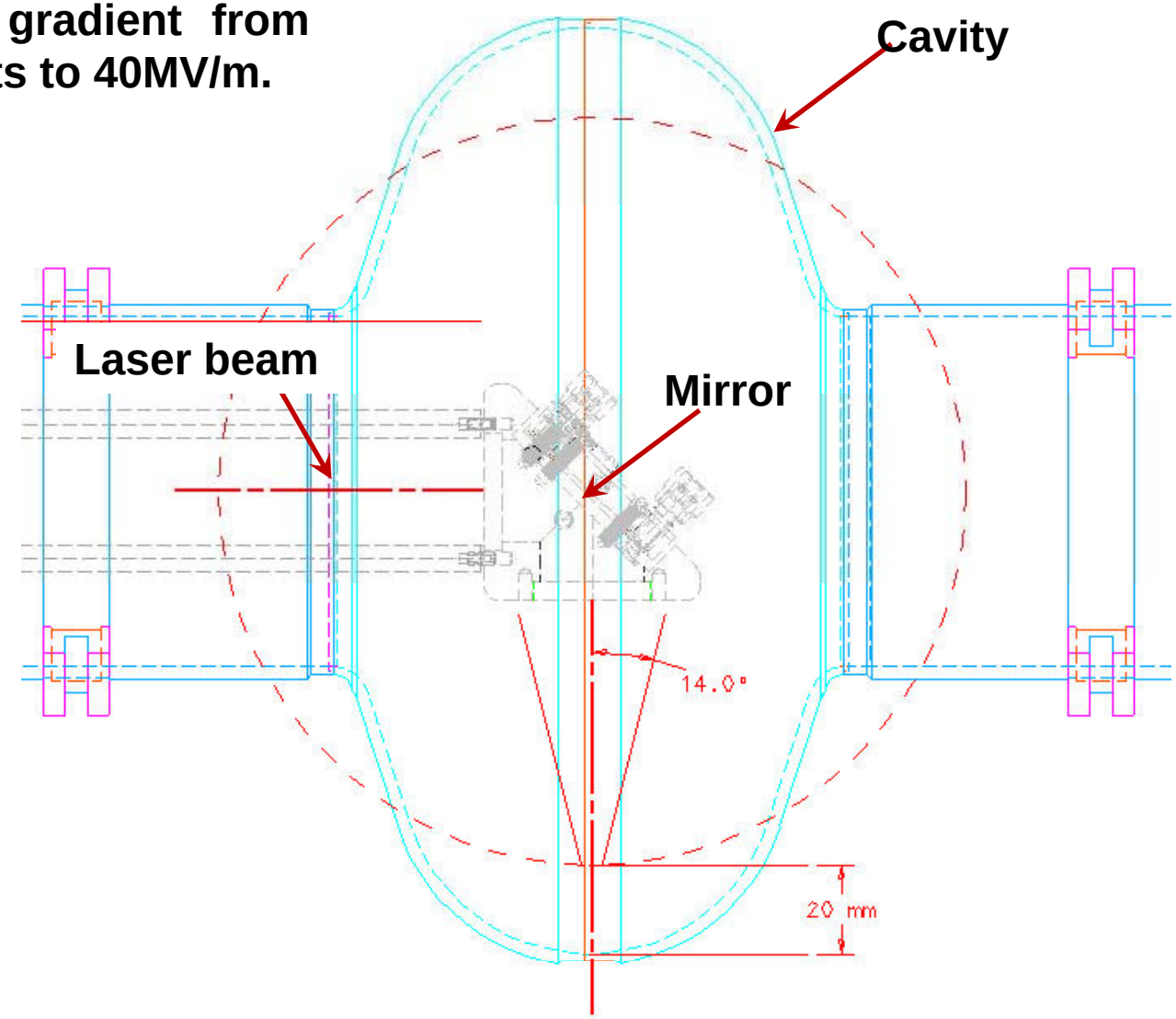
39MV/m quenched at pit region

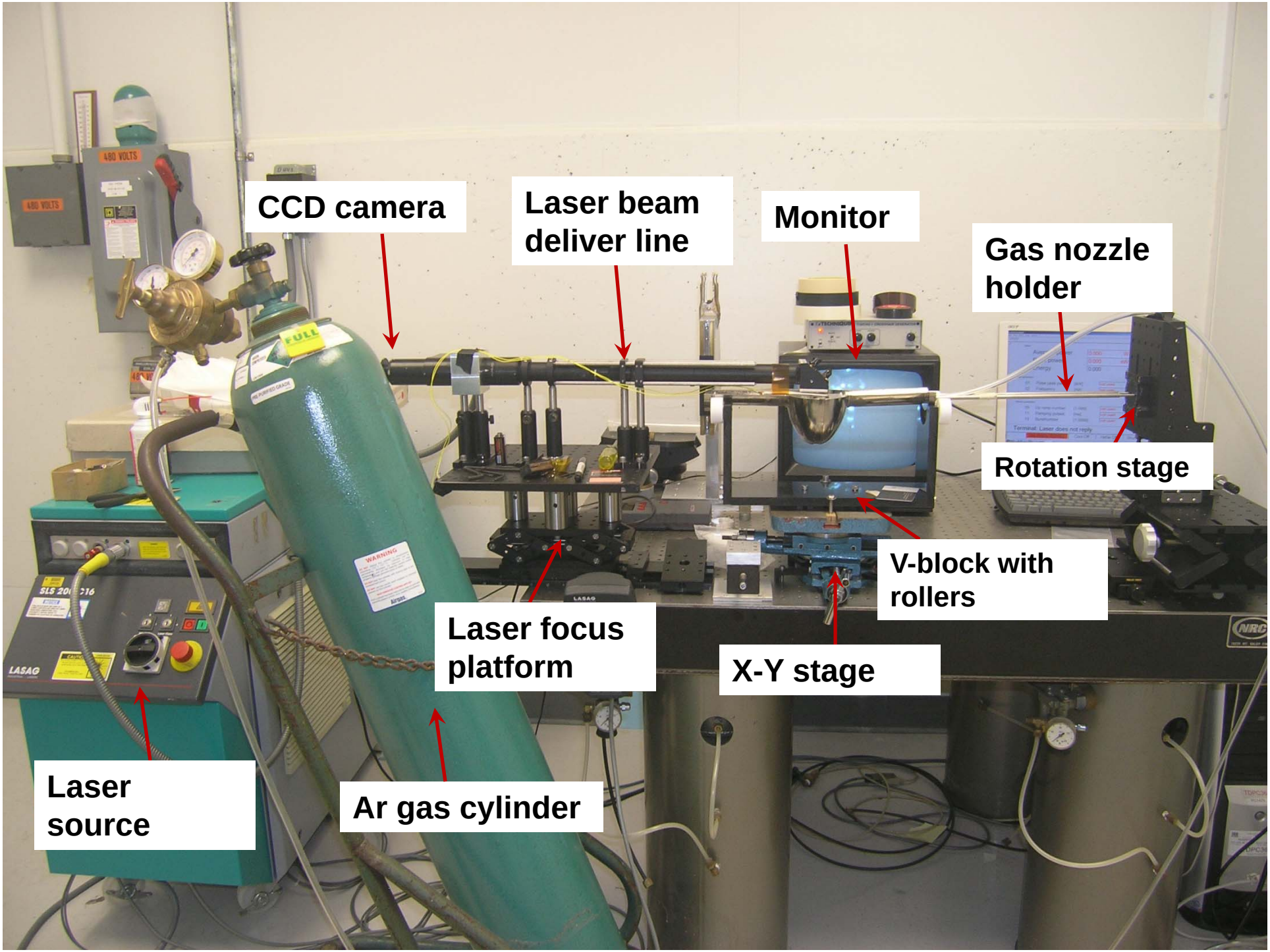
Laser repair tool

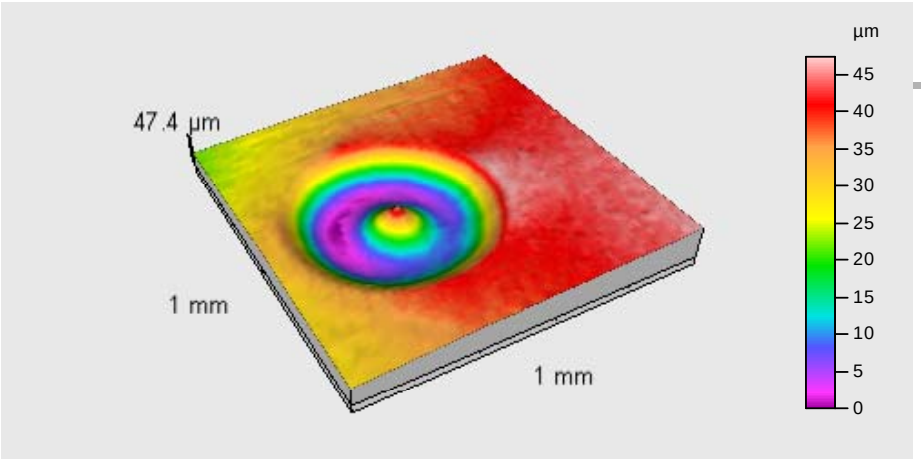
Fermilab

Goals:

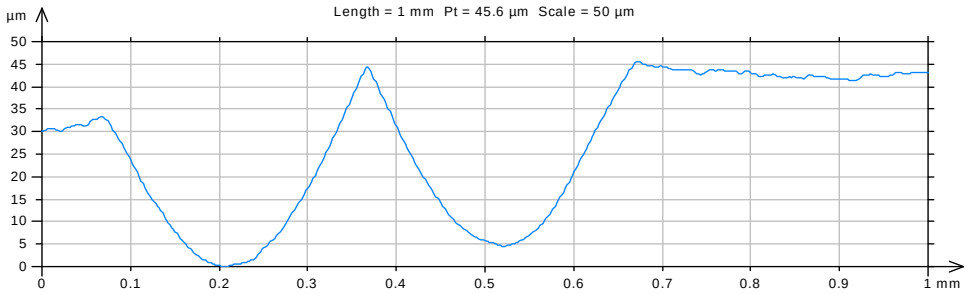
Try to push cavity gradient from 20MV/m limited by pits to 40MV/m.

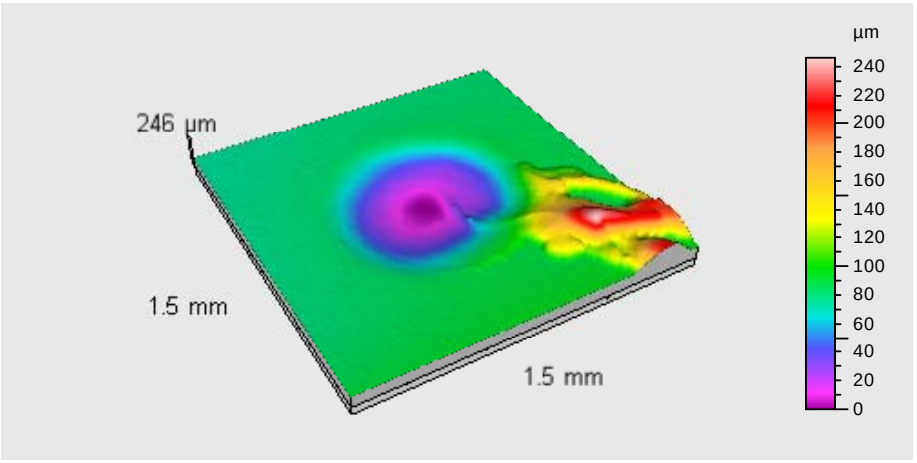


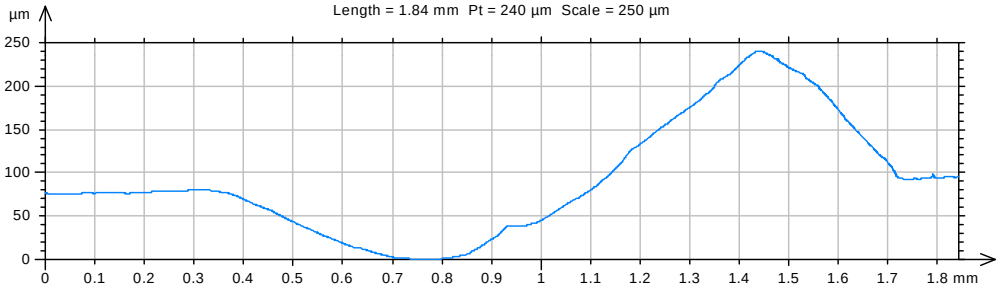

CCD camera
Laser beam deliver line
Monitor
Gas nozzle holder
Rotation stage
V-block with rollers
Laser focus platform
X-Y stage
Laser source
Ar gas cylinder

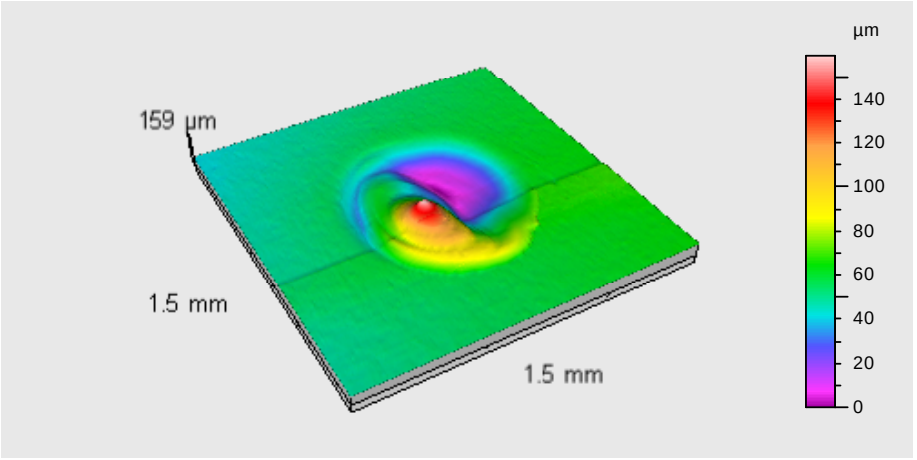

47.4 µm
1 mm
1 mm
µm
45
40
35
30
25
20
15
10
5
0

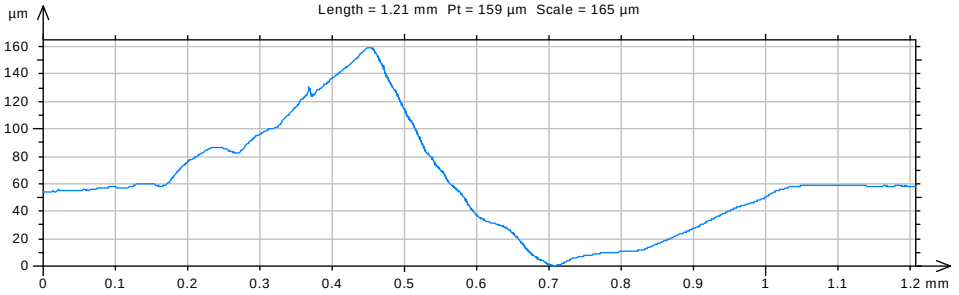
Fermilab


Length = 1 mm Pt = 45.6 µm Scale = 50 µm
µm
50
45
40
35
30
25
20
15
10
5
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 mm

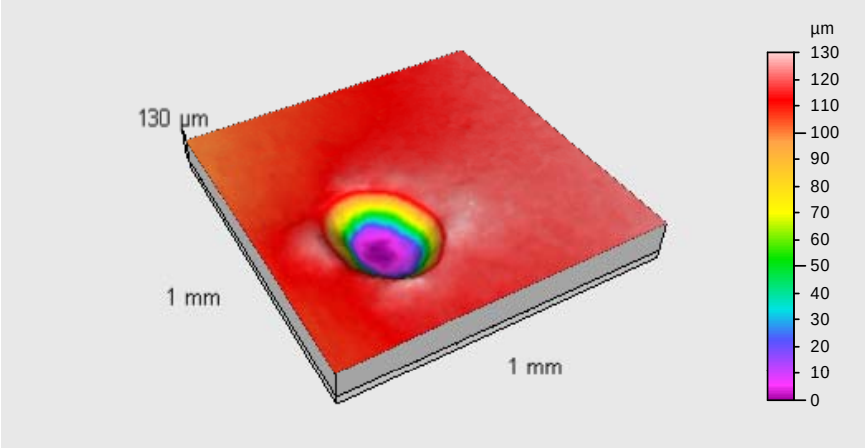

246 µm
1.5 mm
1.5 mm
µm
240
220
200
180
160
140
120
100
80
60
40
20
0

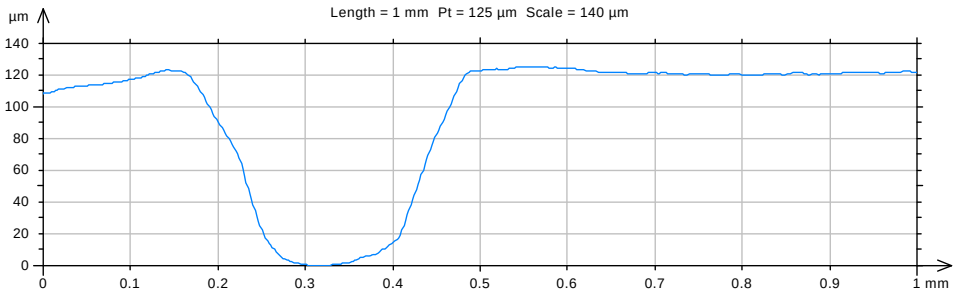

Length = 1.84 mm Pt = 240 µm Scale = 250 µm
µm
250
200
150
100
50
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 mm


159 µm
1.5 mm
1.5 mm
µm
140
120
100
80
60
40
20
0

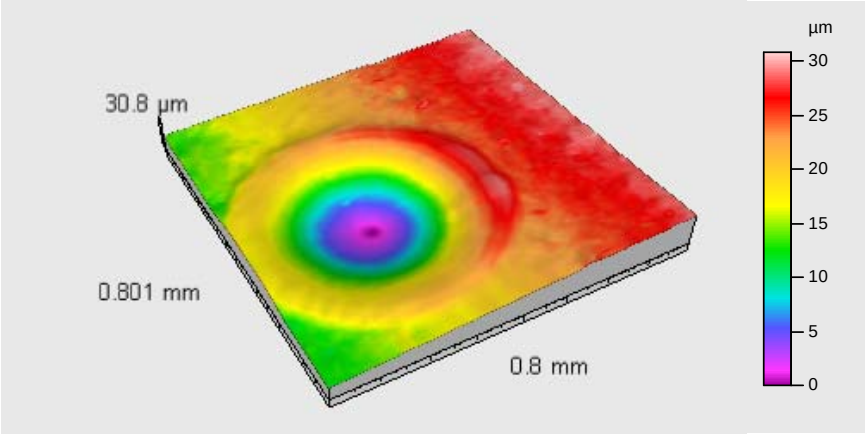

Length = 1.21 mm Pt = 159 µm Scale = 165 µm
µm
160
140
120
100
80
60
40
20
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 mm

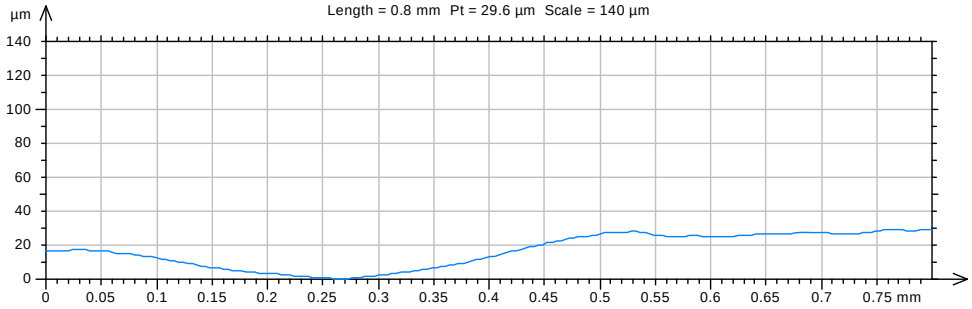
Profile Comparison before and after laser re-melting





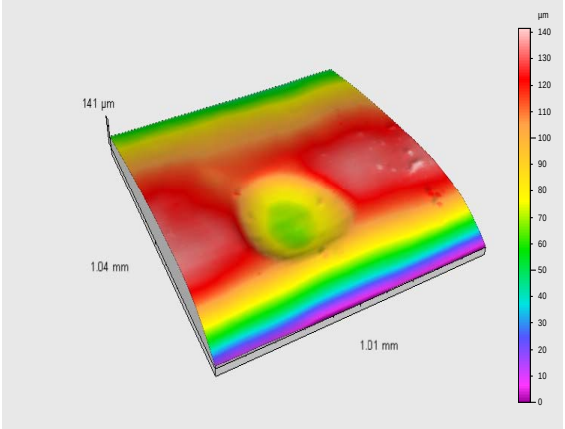
Manmade pit

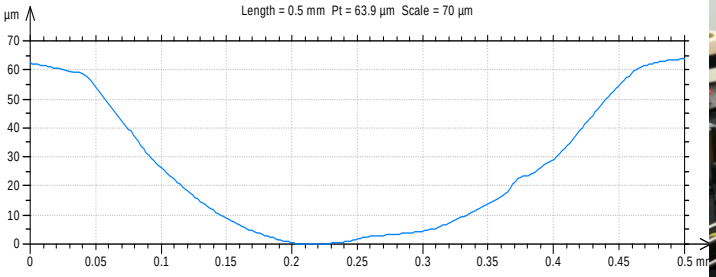




After re-melting the pit profile changed from 120um deep to 30um flat

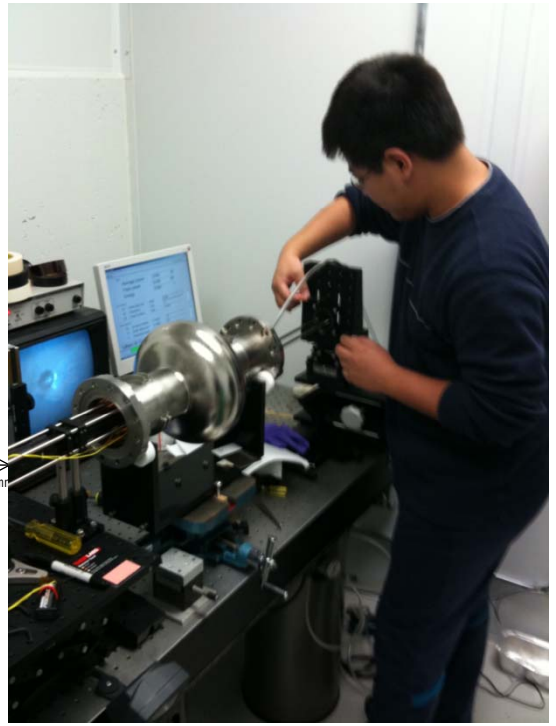
Laser processing of 1.3GHz single-cell cavity TE1ACC003

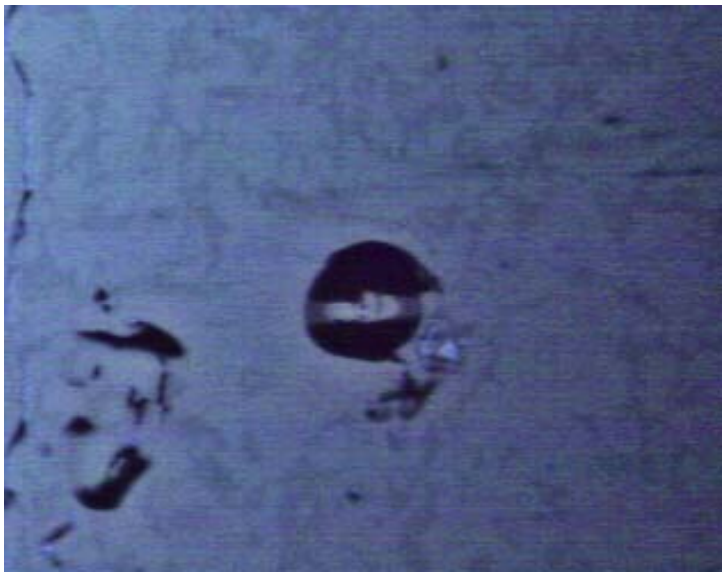




400 micron in Diameter

60 Micron in depth

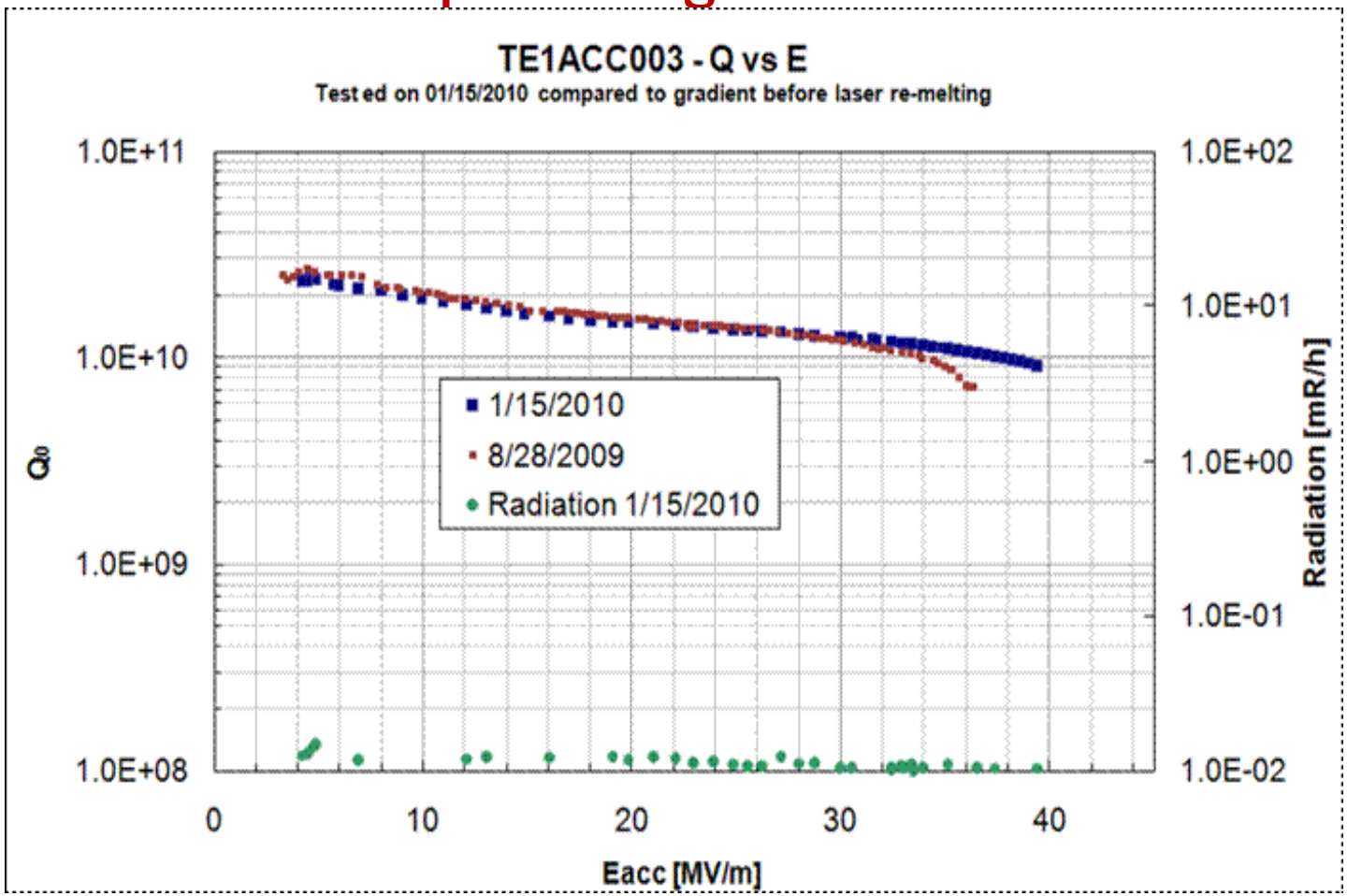




The Pit before re-melting **After re-melting**

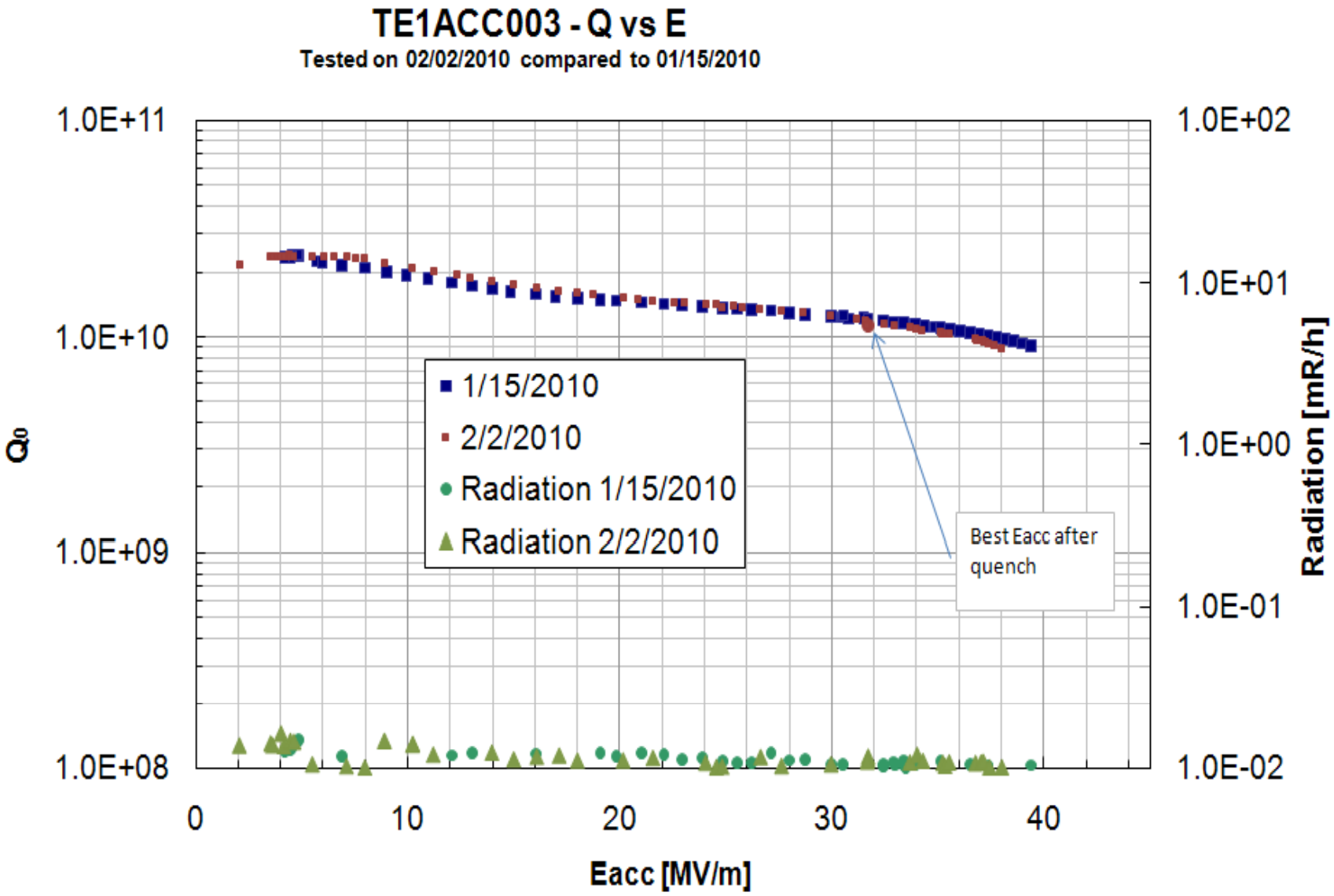
Images was taken from Kyoto Optical Inspection machine

TE1ACC003 vertical test results before and after laser processing



After Laser processing: EP 30um+HPR+120C baking;
Gradient achieved 39.4MV/m, quenched at molten region, no pre-heating was detected;
After flux trapped into cavity, cavity quenched at 32MV/m.

To confirm flux trapping



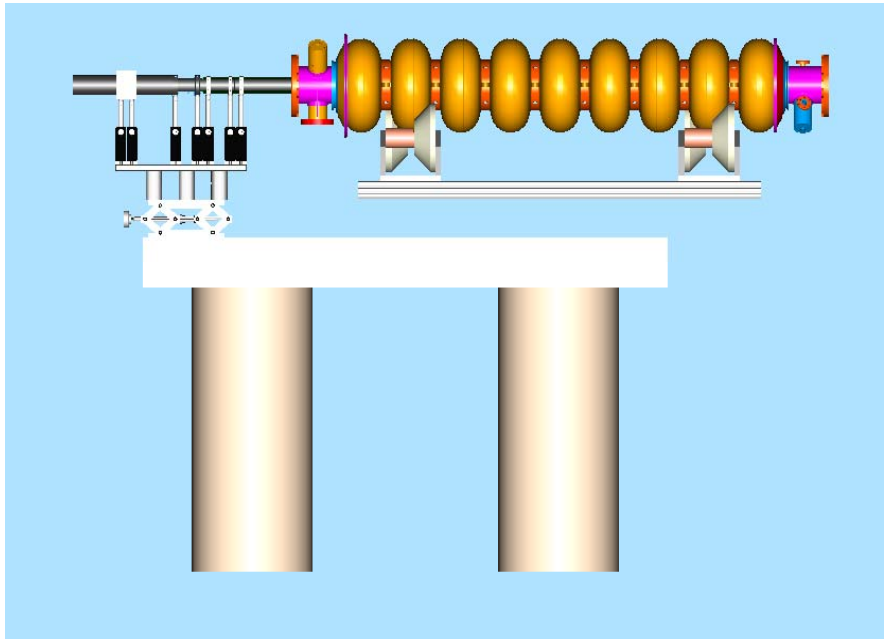
Cavity was warmed up to room temperature and cooled down to 2K

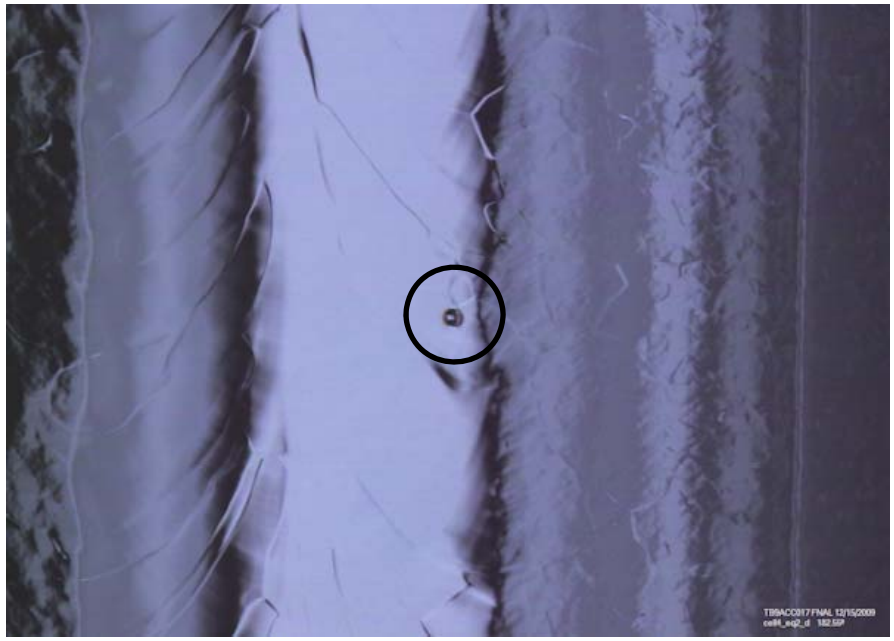
Summary

- Successfully re-melted pit inside 1.3GHz single-cell cavity.
- Cavity gradient achieved nearly 40MV/m.
- No pre-heating was observed during the quenching.
- Flux trapping degraded gradient from 39MV/m to 32MV/m.

The next step

- Surface analysis via Nb coupons and samples cut off from single-cell cavity.
- Produce manmade pit in cavity and recover by laser
- Extend system to 1.3GHz 9-cell cavity.





Pit in 1.3GHz 9-cell cavity TB9ACC017
Quenched at 12MV/m.

Thank you