Investigation of new EBW technique for SRF cavity fabrication
(EBW from inside a TESLA cavity)

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Preliminary

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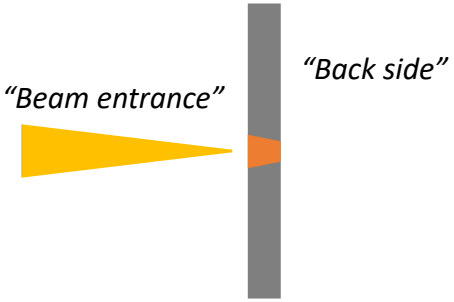
Nb welding in SRF cavity fabrication

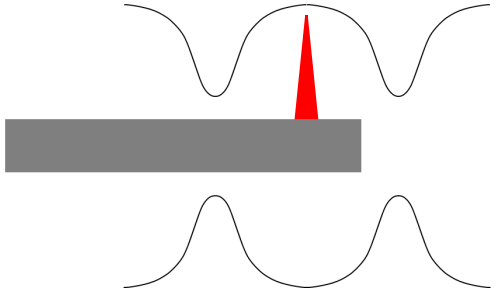
- Welding in cavity fabrication is one of the most importance process.
  →Bad welding can make defect
  →Welding directly affects to cavity performance
- In current 1.3GHz cavity fabrication, equators are at least welded from outside of cavity. (Iris is also in some manufacturers)
  →Making smooth surface inside of cavity is not easy
- Making smooth surface at “beam entrance” is much easier with defocused beam.
  →But penetration power will be reduced



Inside-welding

- Welding cavity from inside enables to make surface of welding bead at RF side smoother.
- Inside-welding tool (deflector nozzle) has possibility to reduce the cost for cavity fabrication.
  →Assembly all parts and weld them at once (with one step of a series of iris-equator-iris…, for multicell cavity)
- Deflector nozzle also enables to repair cavity (remove defect).
- Deflector nozzle has possibility to enable welding for more complex shape cavity.
- Deflector nozzle could weld higher thickness (cosmetic pass from inside and welding from out side)

CERN and TECHMETA (French welding expert) have investigated deflector nozzle which enables to weld 1.3GHz cavity from inside.



Procedure for inside-welding study of 1.3GHz Tesla cavity

- Fabricated three 1-cell cavity with exactly same procedure except welding.
  - ✓All cavity parts were prepared by KEK using same materials
  - ✓All parts were BCP'ed and assembled into welding jig (jig is designed and prepared by CERN and TECHMETA respectively)
  - ✓Parts set into jig were sent to CERN and TECHMETA, and welded from inside
  - ✓Last cavity was welded from outside (general procedure) at KEK as reference
- Welded cavities were sent back to KEK and same surface treatments were performed (ILC SRF standard recipe).
  - ✓100µm of EP1
  - ✓800deg x 3hrs annealing
  - ✓20µm of EP2
  - ✓120deg x 24hrs
- Finally, performance of these cavities were measured.

Material
Cell: Tokyo Denkai (FG), RRR = 273
Beam tube: ULVAC (FG), RRR > 300
Shape
TESLA Single cell (long-long)
Beam tube diameter: 78mm
Equator diameter: 207mm

CERN’s effort

Inside-welding tool at CERN

Machine and deflector manufacturer: SST
Nozzle diameter: 72mm
Current nozzle length: 600mm
Welding range: 400-1000mm depending on extension
Welding direction: manually rotatable 15° increments
Maximum voltage: 150kV
Maximum current tested: 100mA
Chamber size:11m^3

Welding procedure at CERN

Nozzle direction: horizontal
Beam direction: horizontal
Welding procedure: tack welding → final welding
Maximum welding power (iris): 2.6kW
Maximum welding power (equator): 3.2kW
Welding period: 2days (8 hours over 2days)
Chamber open: after every welds
Chamber vacuum (when EBW started): $< 3 \times 10^{-3}$Pa
Temperature when chamber was opened: < 40deg
*No cosmetic welding

TECHMETA's effort

Inside-welding tool at TECHMETA

Patented tool “TechBend”

Machine and deflector manufacturer: TECHMETA
Nozzle diameter: < 70mm
Nozzle length: 750mm
Welding direction: rotatable
Welding range : Enable to weld 9-cell cavity in two step
Maximum voltage: 60kV
Maximum current: 100mA
Chamber size: $2m^3$

Welding procedure at TECHMETA

Beam direction: tilted
Nozzle direction: horizontal
Welding procedure: tack welding → final welding
Maximum welding power (iris): 2.6kW
Maximum welding power (equator): 3.2kW
Welding period: 1day
Chamber open: one vacuum
Chamber vacuum (when EBW started): $< 3.5 \times 10^{-4}$Pa
Temperature when chamber was opened: Room temperature
*No cosmetic welding

KEK case (typical procedure)

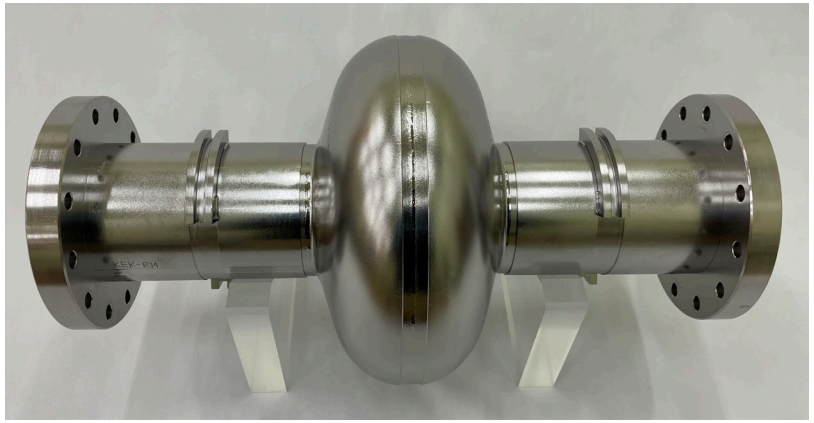
Welding procedure at KEK (reference)

Beam direction: horizontal
Nozzle direction: -
Welding procedure: tack welding → final welding
Maximum welding power (iris): 1.9kW
Maximum welding power (equator): 2.2kW
Welding period: 1day
Chamber open: after every welds
Chamber vacuum (when EBW started): < 2.0 x 10^{-3}Pa
Temperature when chamber was opened: < 80deg
*No cosmetic welding

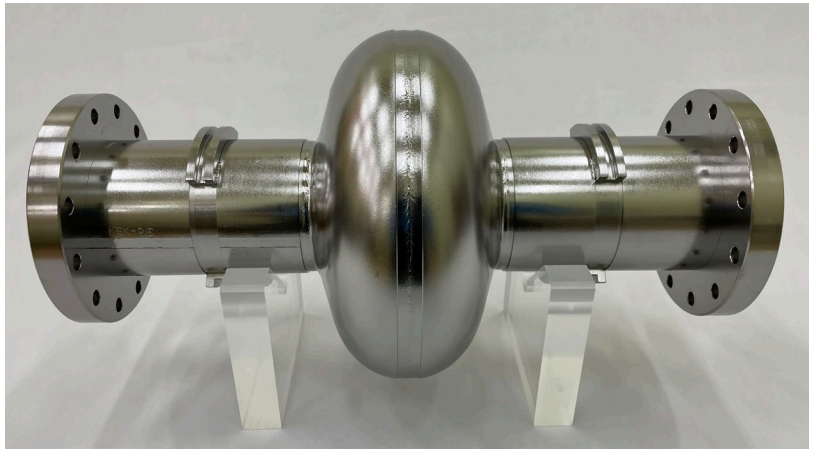
Fabricated cavities

Welded cavities

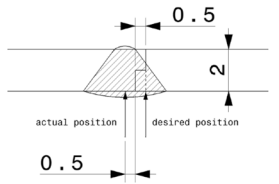
CERN



TECHMETA



Welding at Equator is penetrated.
But, joint can bee seen since welding position was shifted.



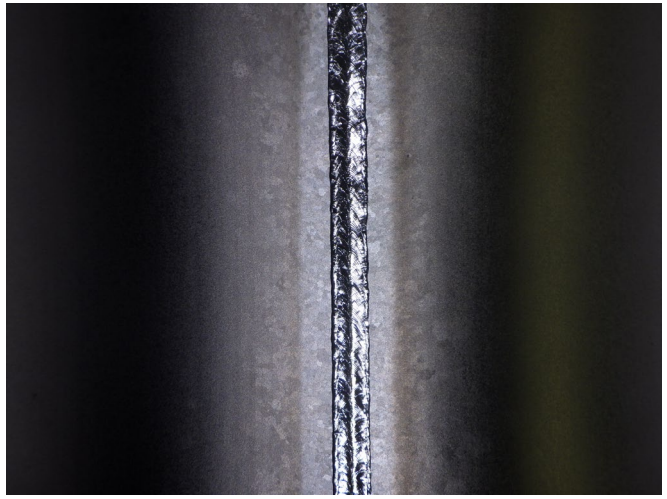
Welding at Equator is partially penetrated due to shift of beam focusing.

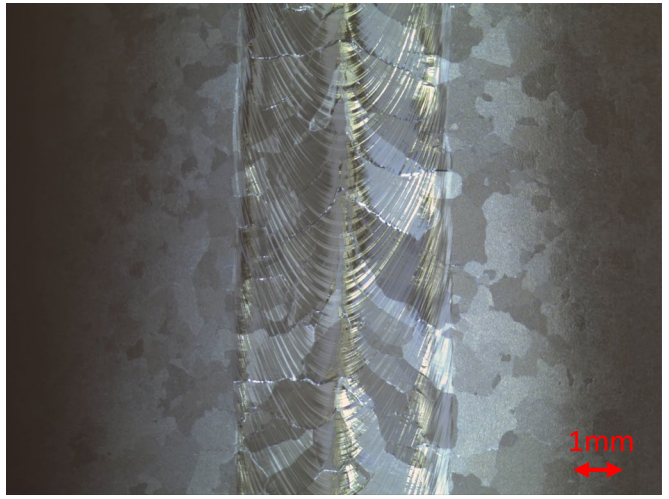
- Irises are well welded with both cavities. (completely penetrated)
- Inside of equators for both cavities are well welded. (good welding bead surface)

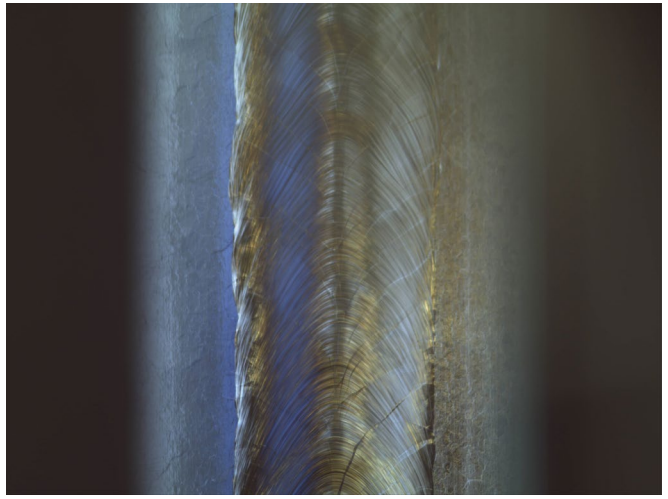
Photo from inside (as received, 0deg)

Equator | Equator | Iris

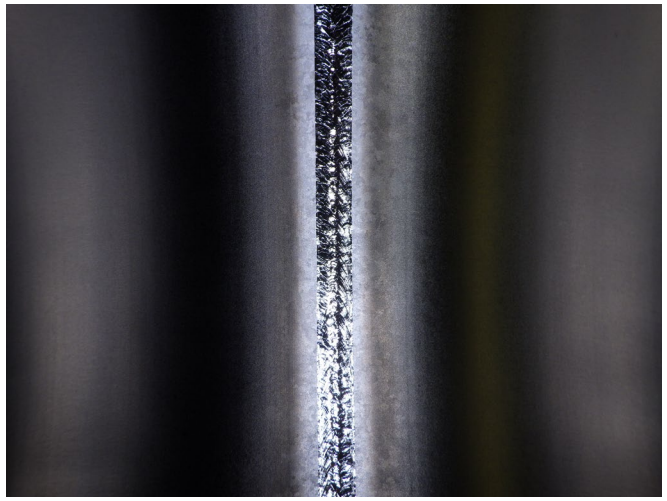
CERN







TECHMETA



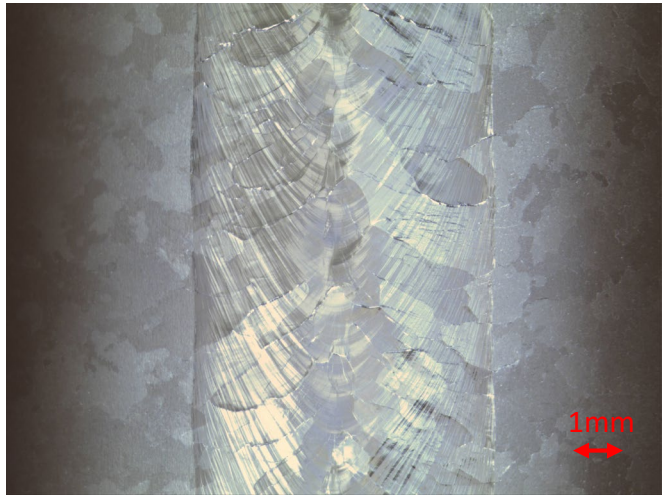


Photo from inside (as received, 180deg)

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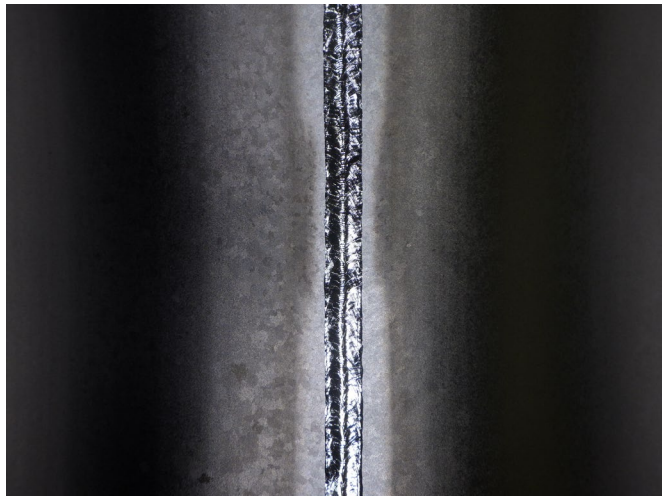
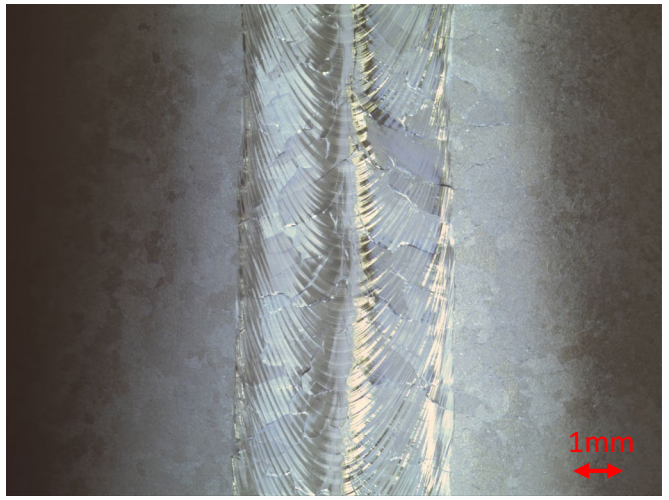
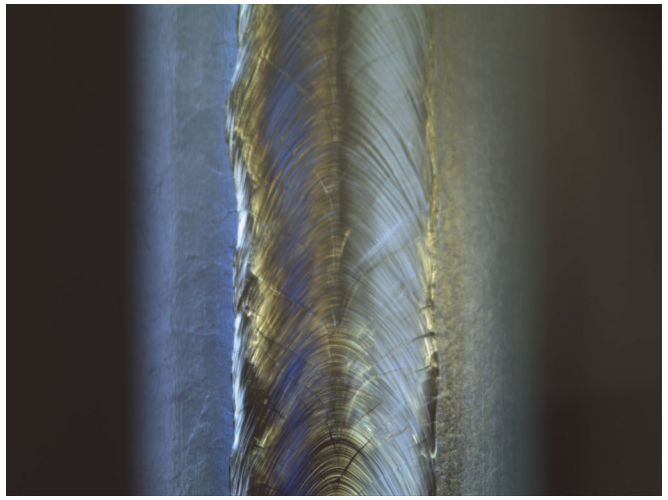
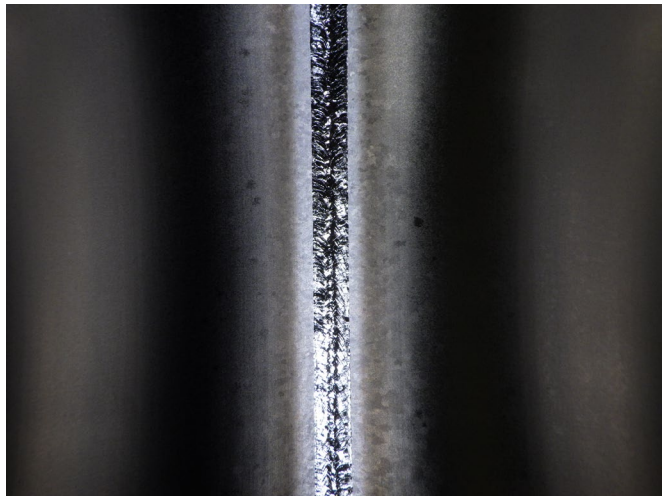
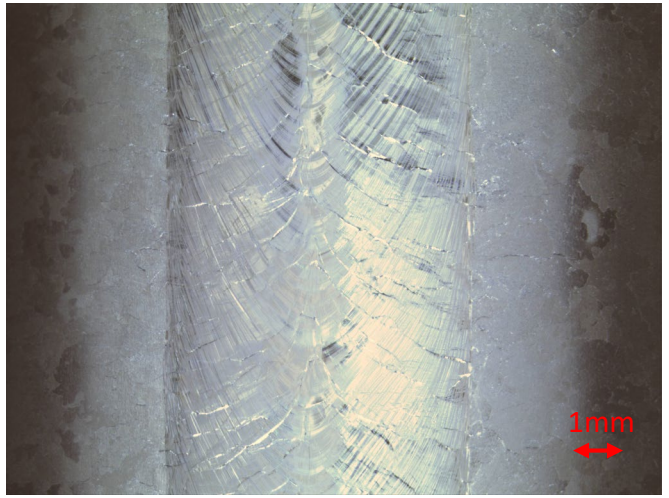
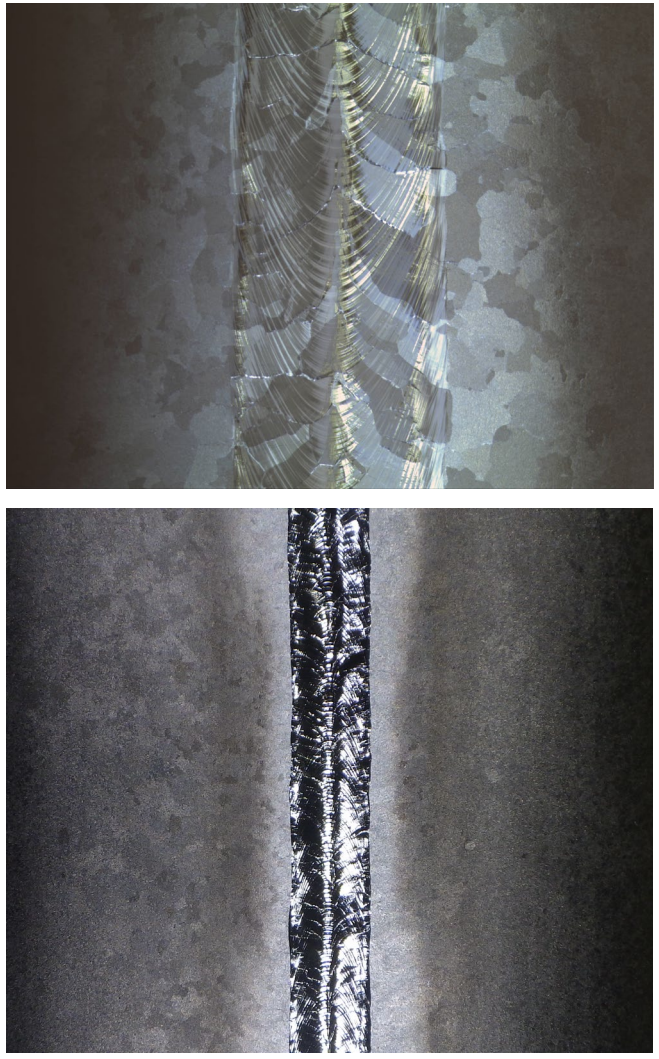
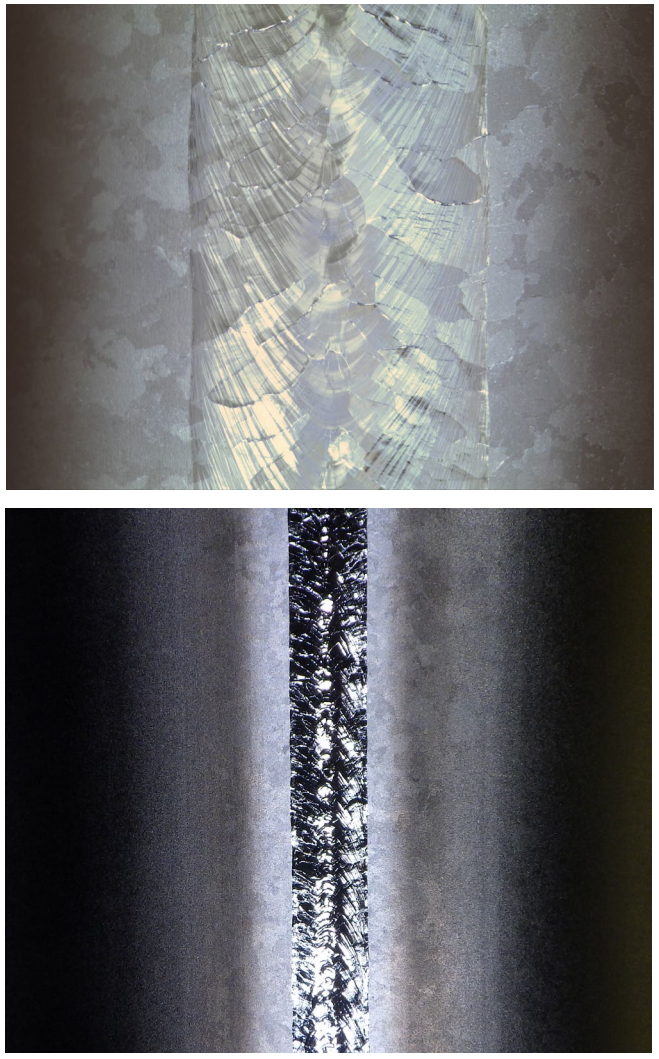
	Equator	Equator	Iris
CERN			
TECHMETA			

Compare to normal cavity (Equator)

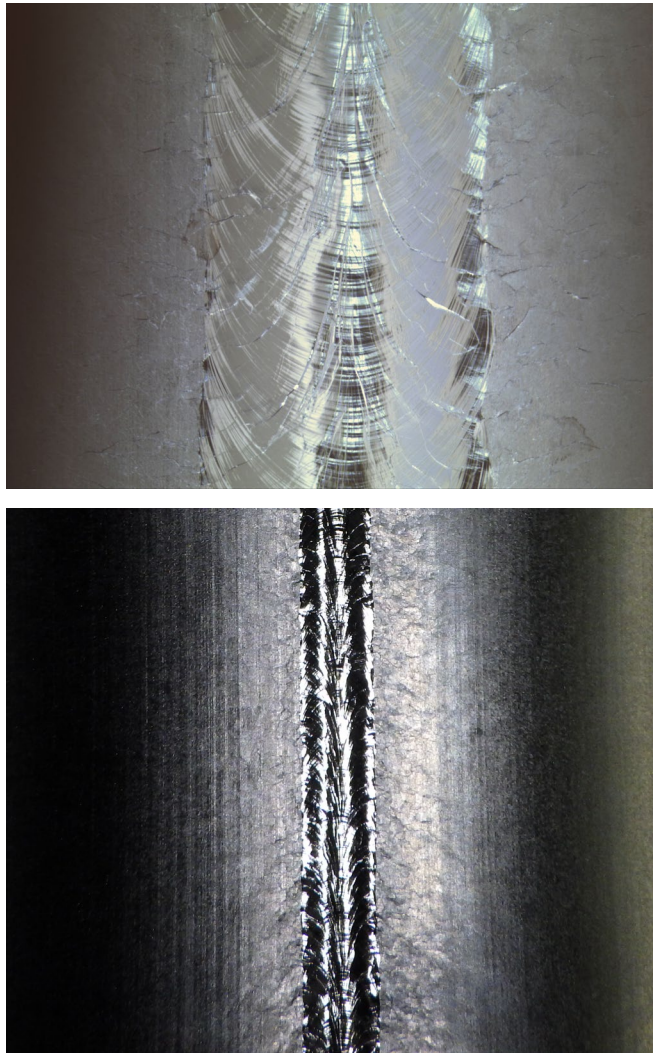
CERN



TECHMETA



KEK (Outside welding)

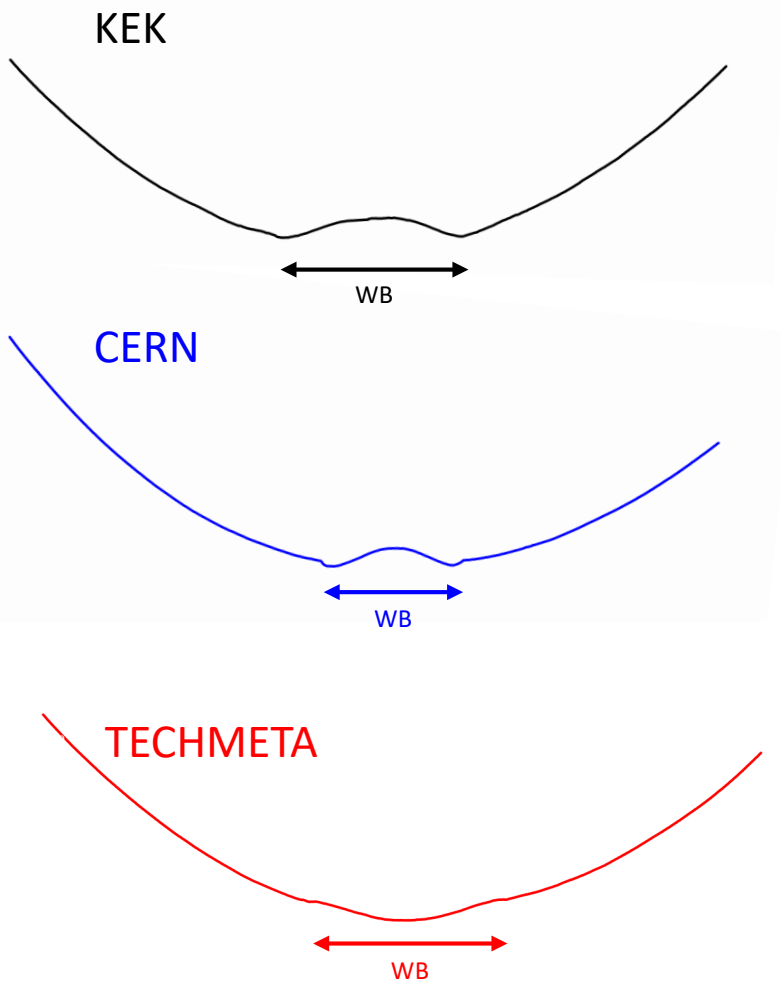


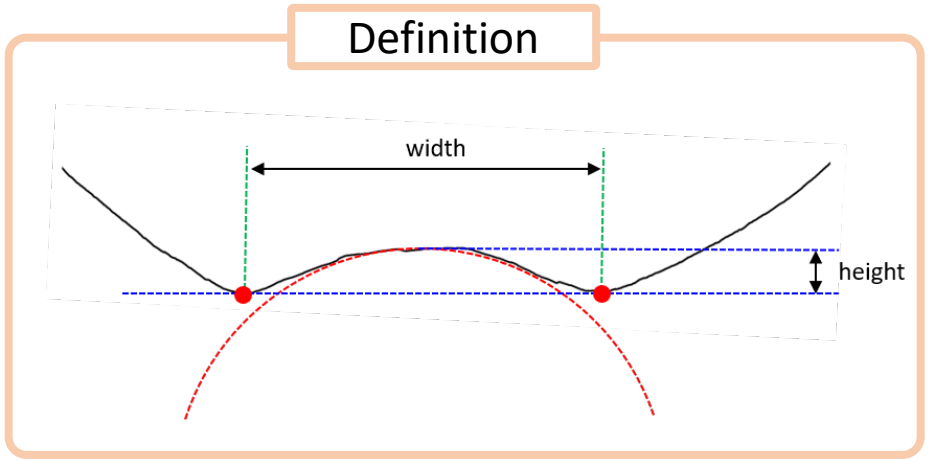
Welding bead analysis

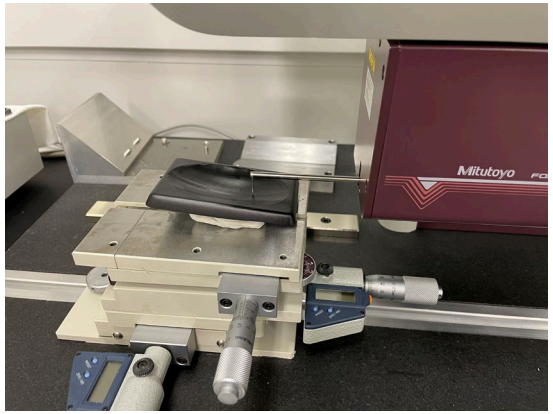
Casts (replicas) were made from inside of equator.
Shape of welding beads were measured.

		Bead Ra [μm]	Height [mm]	Width [mm]
KEK	0deg	0.6	0.12	5.01
	180deg	0.47	0.08	4.62
CERN	0deg	0.57	0.07	2.99
	180deg	0.51	0.1	3.43
TECHMETA	0deg	0.53	-0.12	5.21
	180deg	0.54	-0.1	5.23

Cross section shape of welding bead







WB=welding bead

Performance test results

CERN

TECHMETA

- CERN cavity was quenched at 37.8MV/m, TECHMETA cavity was quenched at 37.3MV/m.
- Q_0 value of CERN cavity was 1.9×10^{10}, TECHMETA cavity was 1.7×10^{10}@ 35MV/m.
- No defects or strange structure was found around quench position.
- E_{acc} and Q_0 for both cavity satisfied ILC specification.

Summary

- New deflector nozzles for EBW machines which enables to weld 1.3GHz from inside were newly investigated at CERN and TECHMETA.
- Three TESLA-type 1-cell cavity were welded at CERN, TECHMETA and KEK.
  - ✓ CERN and TECHMETA welded from inside, KEK welded from outside as a reference.
  - ✓ Same materials were used.
  - ✓ All parts were machined with same procedure by KEK.
  - ✓ Same surface treatments were performed.
- Performance of two cavities by CERN and TECHMETA has been already measured.
  →Both of them have achieved 37MV/m which satisfy ILC requirement.

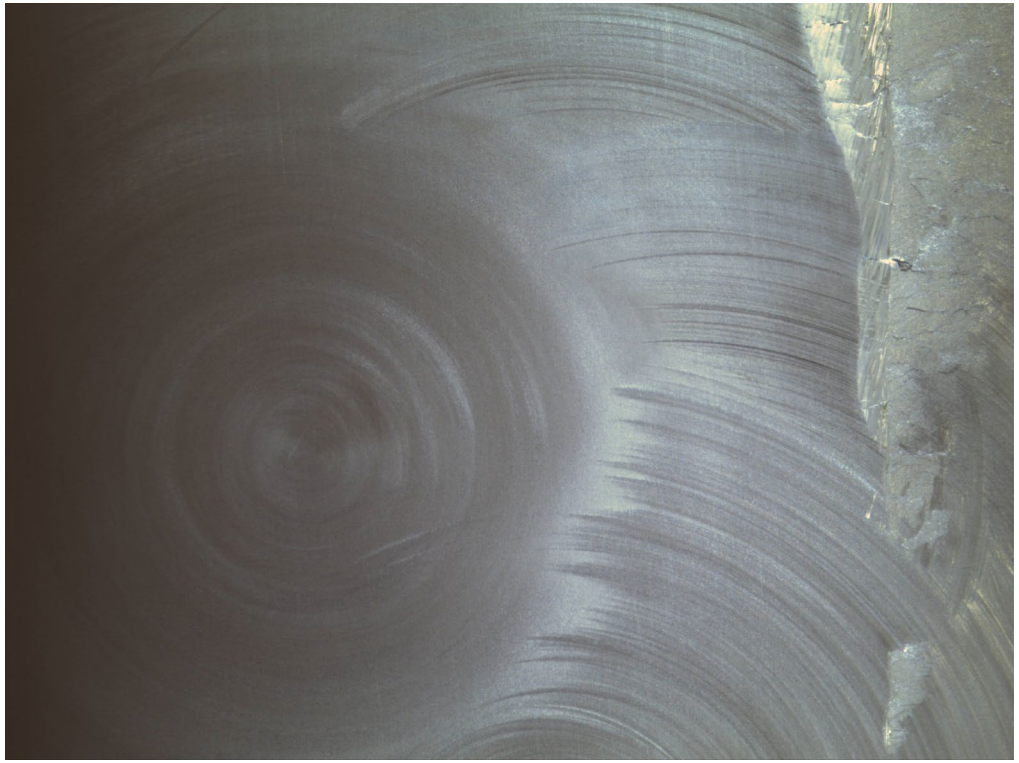
Outlook

- Reference cavity by KEK is now under preparation for performance test.
- Further detailed analysis around welded region will be performed (CERN)
- Planning to use this tool for cavity repair (TECHMETA)
- Planning to weld 3-cell cavity in one inside-welding process (in one vacuum) (TECHMETA)
- Further technical details will be reported individually by CERN and TECHMETA.

Backup

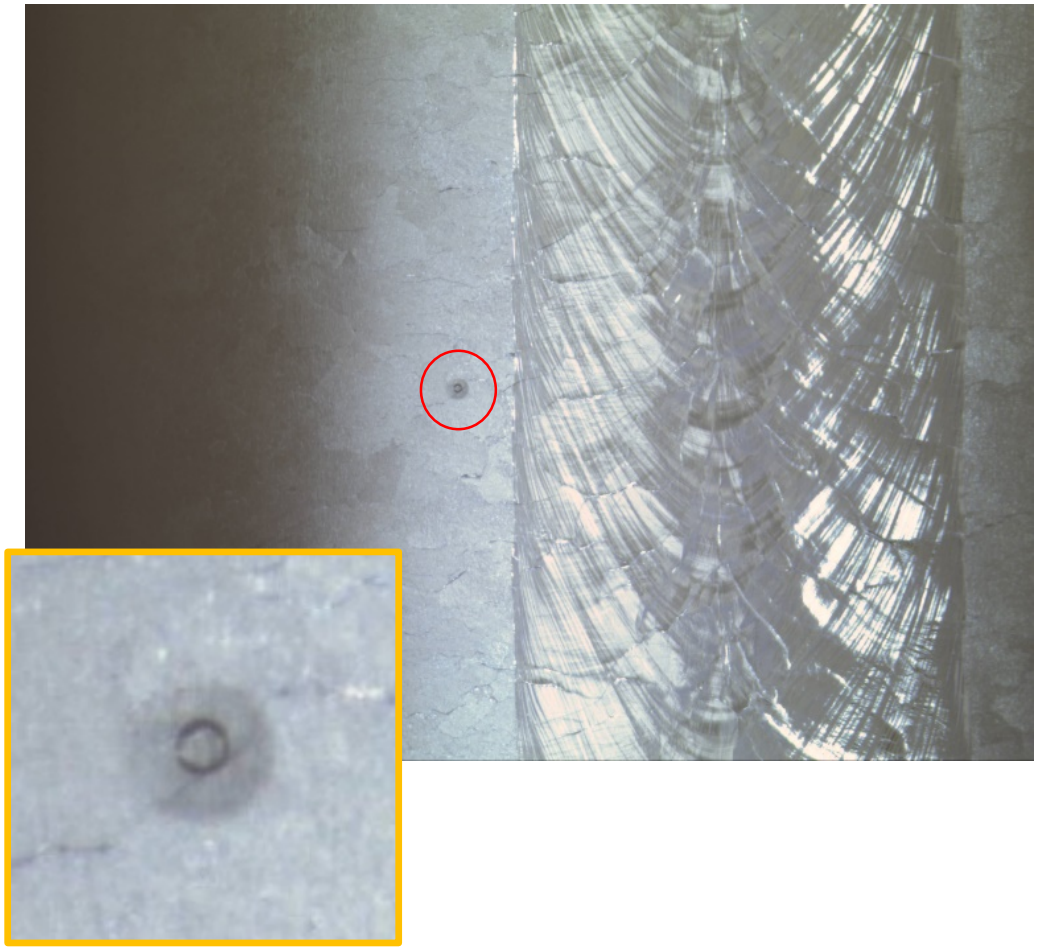
Local grinding of CERN cavity

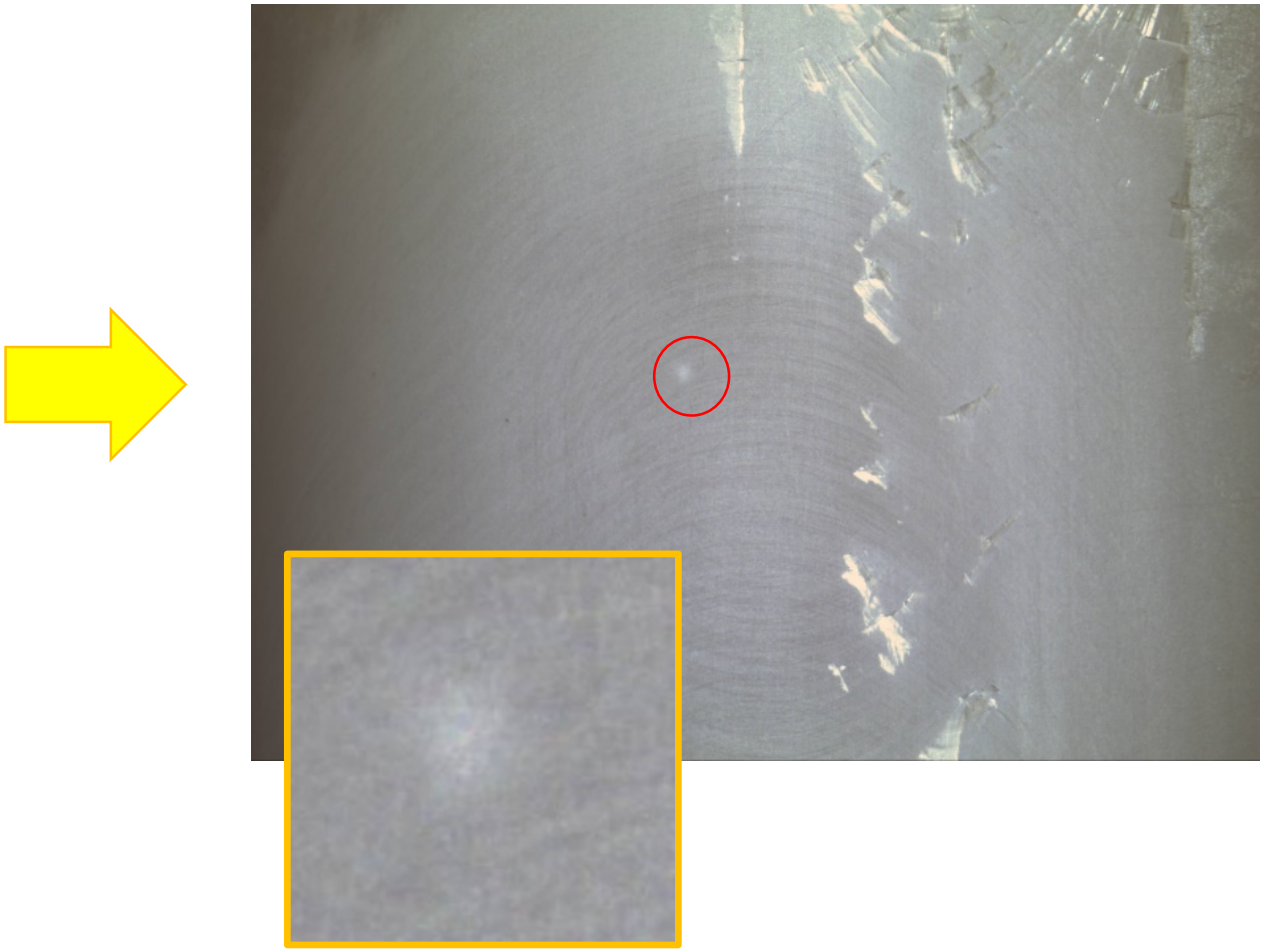
Around 319deg



Local grinding of TECHMETA cavity

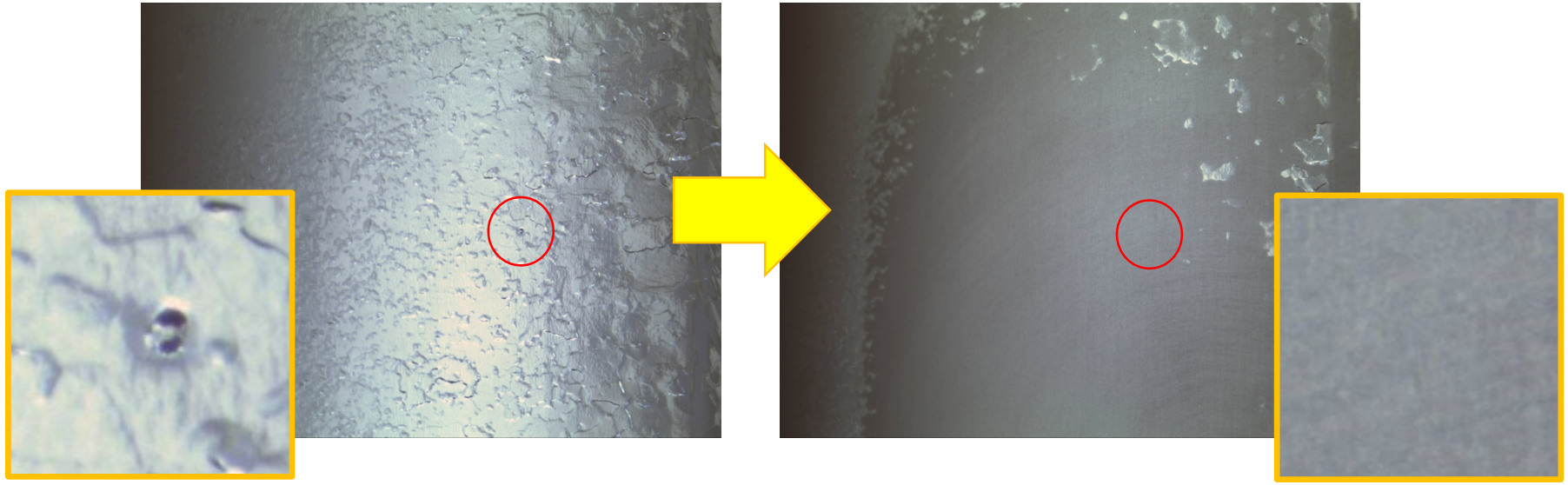
Around 229deg



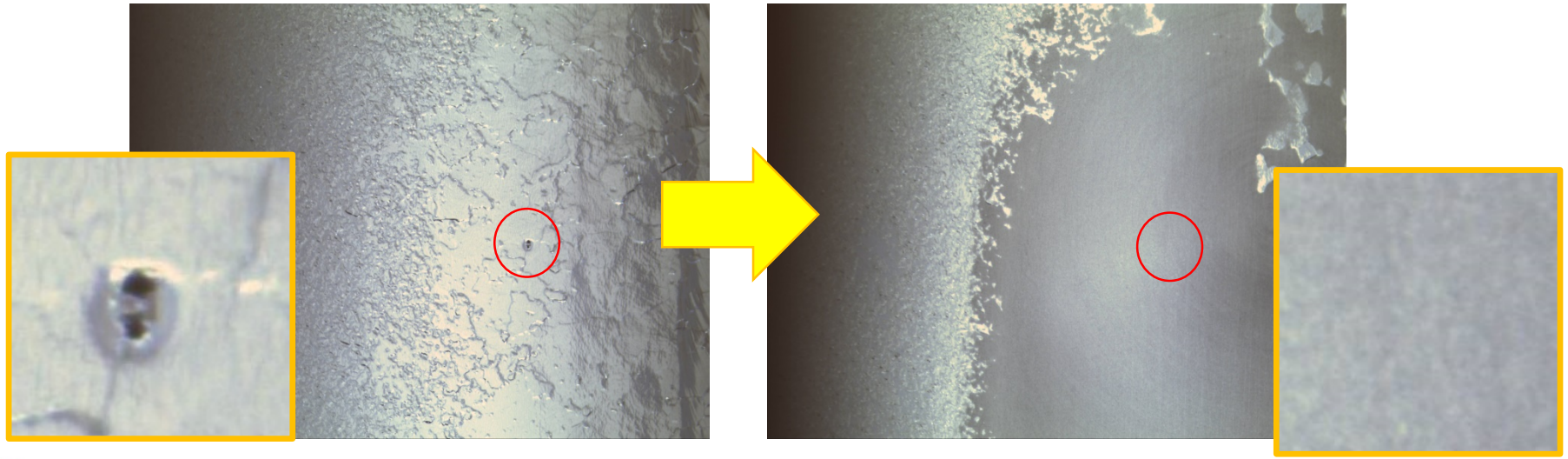


Local grinding of TECHMETA cavity

1-cell equator downstream, θ = 234 deg.



1-cell equator downstream, θ = 337 deg.



R_{res} and R_{BCS}