Automation and R&D in SRF cavity optical inspection at Fermilab

20 March, 2011

Evgeny Toropov, Fermilab, TD/SRF

Acknowledgements:

Dmitri Sergatskov, Fermilab, TD/SRF

Peter Lee, Florida State University

Goals of activities:

EQUIPMENT

- Using KEK / Kyoto inspection system

PRODUCTION :

- Inspection of cavities before and after processing
  - Maintain a visual record of cavity features, equator & iris
  - Automate image acquisition
- Computer-aided close inspection of particular regions

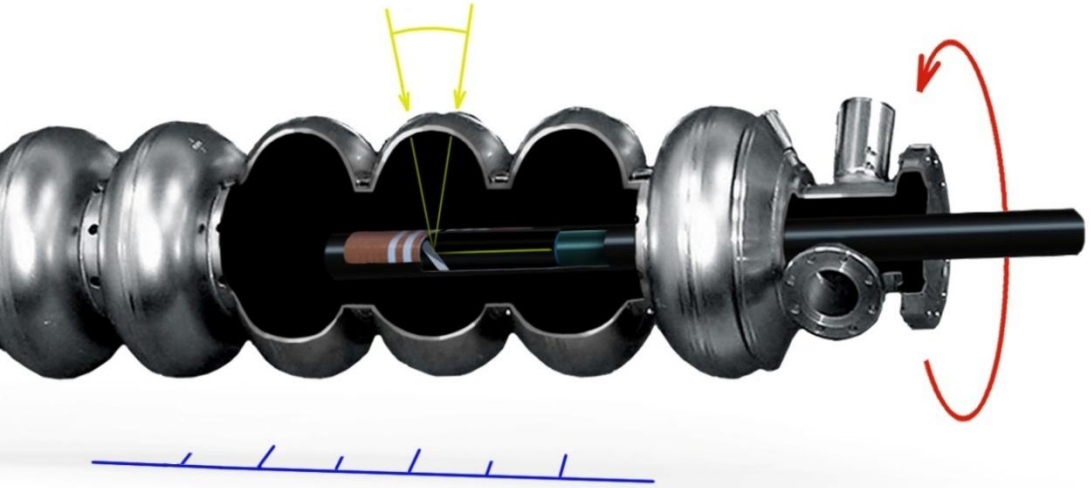
R&D

- Develop ability to inspect 650 MHz cavities
- Inspection between equator and iris
- Computer analysis of images
  - Can grain-boundary structure be used to assess roughness?
  - Can a computer algorithm identify pits?

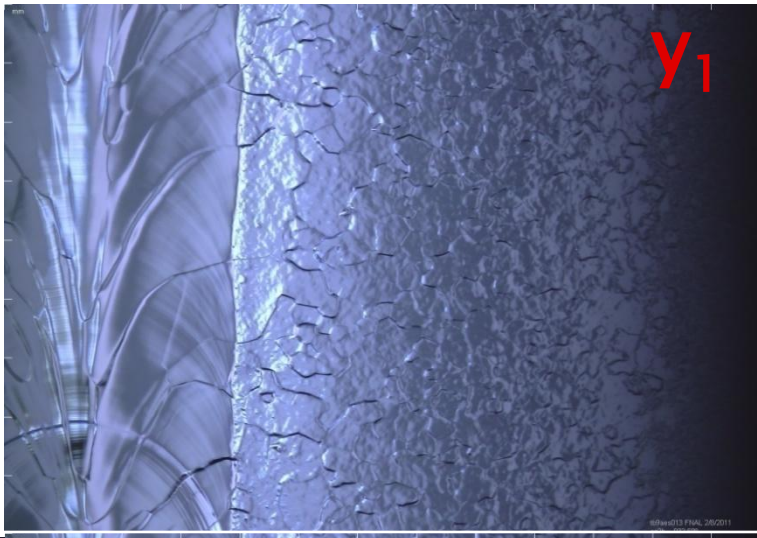
Image acquisition sequence

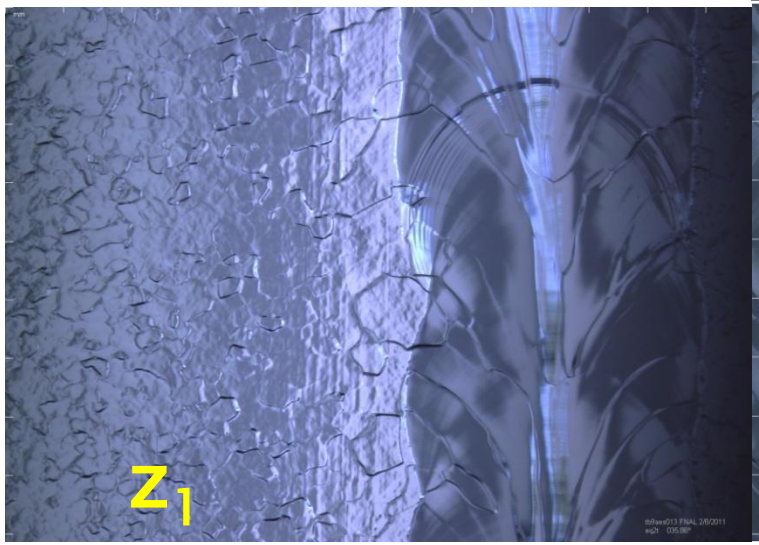
3. Slight tilt z to select side of weld

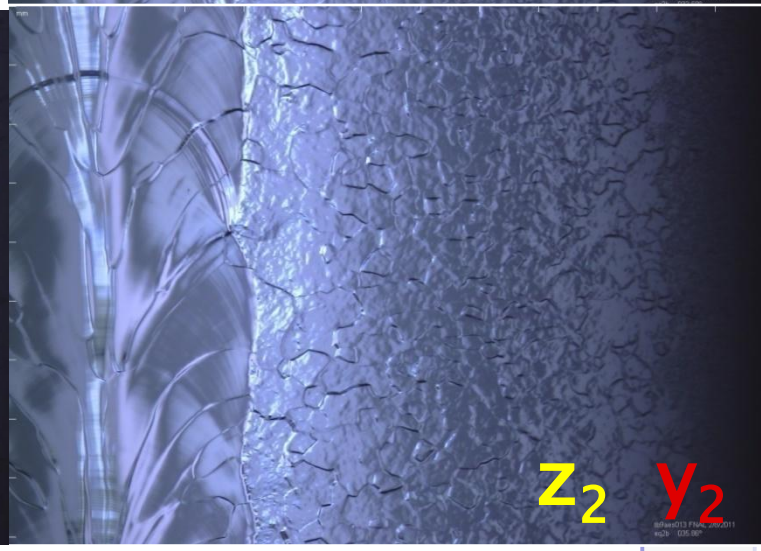
2. Map angles y to cover circumference



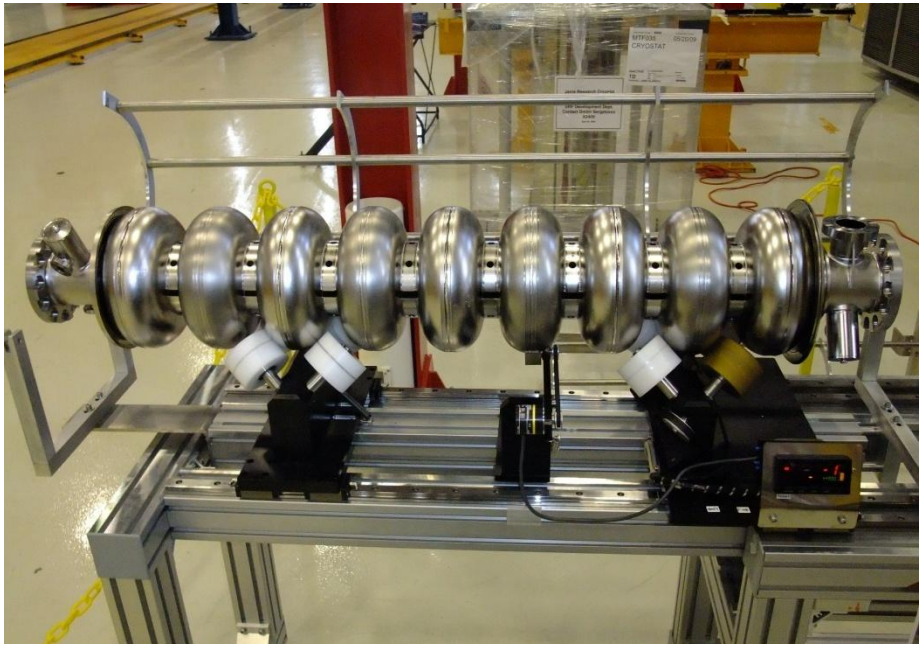
1. Align camera with equator or iris

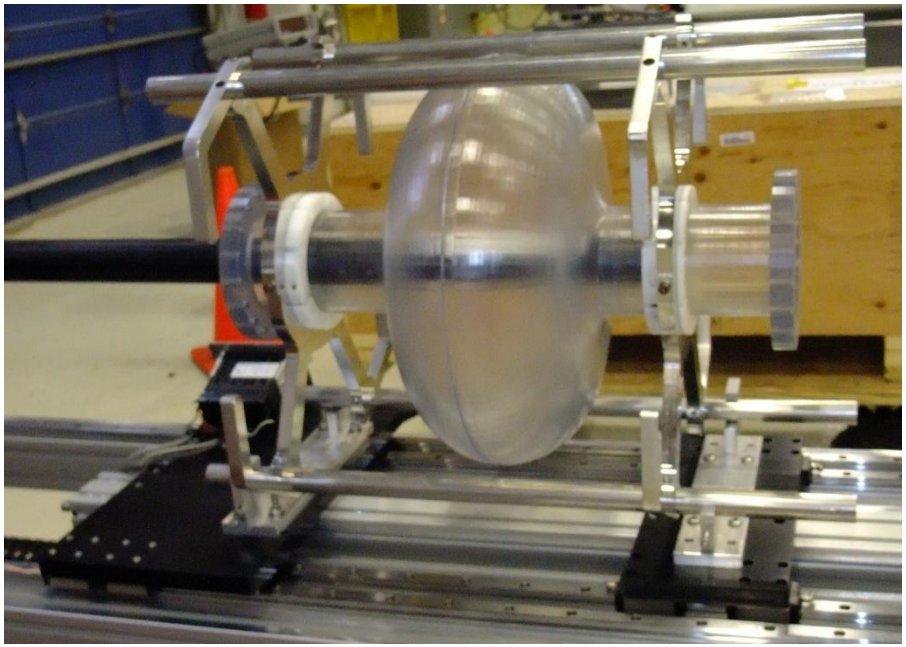






There are two inspection systems at Fermilab





Production system	R&D system
bare 1.3 GHz	dressed 1.3 GHz, 650 MHz
Cavity rotates around camera – stable	Camera rotates inside cavity – adaptability

Time required to complete automated image acquisition from all welds

	Production bare 1.3 GHz	R&D system dressed 1.3 GHz	R&D system 650 MHz
Camera resolution	20 um / pixel	8 um / pixel	15 um / pixel
Total number of images	~2500	~5500	~2000 *
Time for automated acquisition	**2 hours**	**8 hours**	**6 hours ***

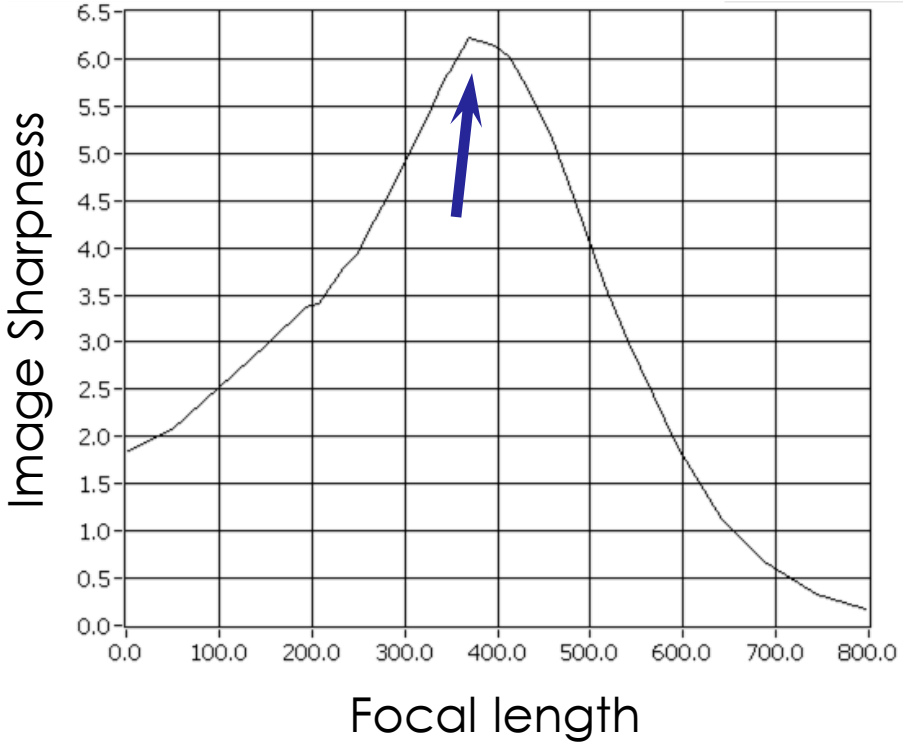
* - estimate

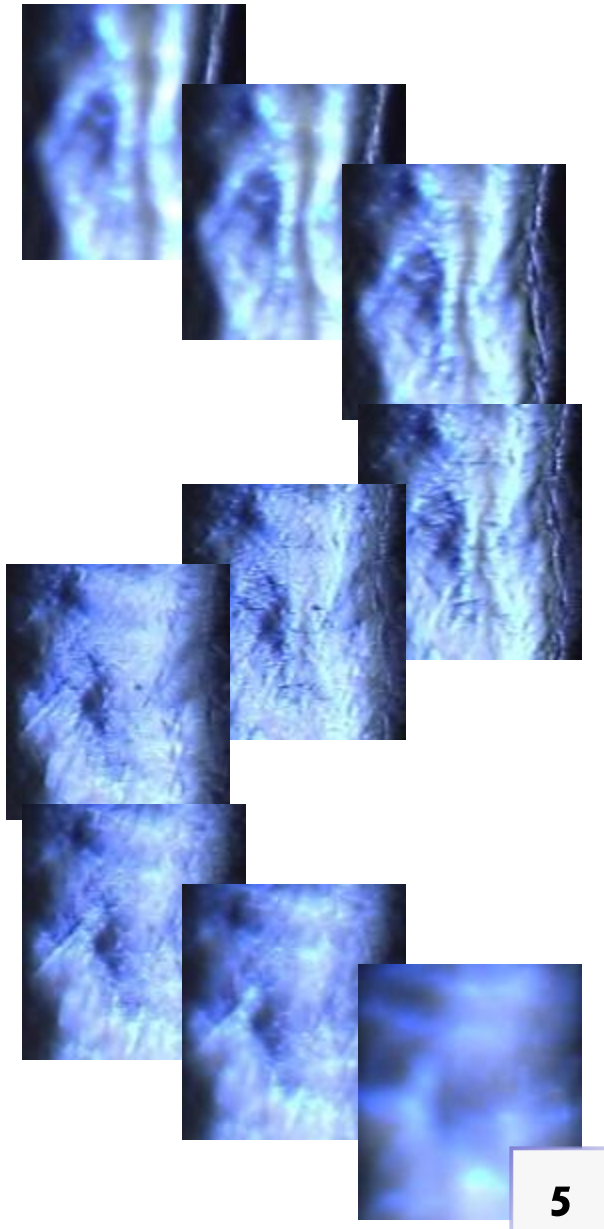
Inspection time depends on:

- Camera stability (if rotating camera)
- Cavity stability (if rotating cavity)
- Hardware (e.g. buffering, transfer rate)
- Operator choice of quality vs. speed
- Illumination

How does auto-focusing work?

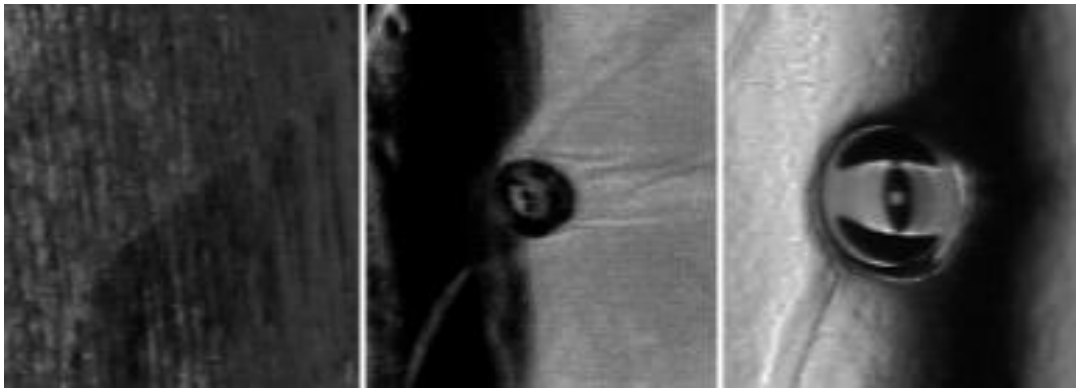
1. Images are sampled vs. focal length
2. A textbook algorithm is applied to each sample, giving a number as an index of sharpness
3. Focus is defined as the local extremum of the sharpness index vs. focal length



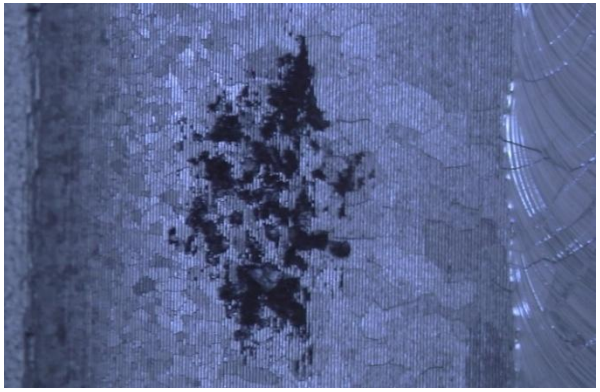


Production and R&D examples

Tracking production steps: This defect was uncovered during sequential processing



Production: pre-screening for contamination



R&D: An image from between equator and iris gave feedback to vendor

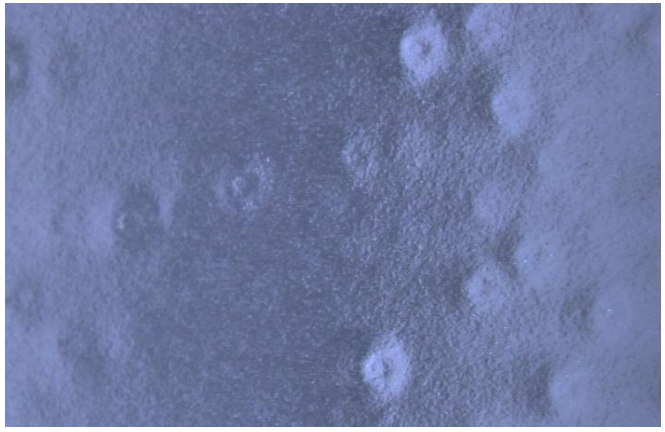
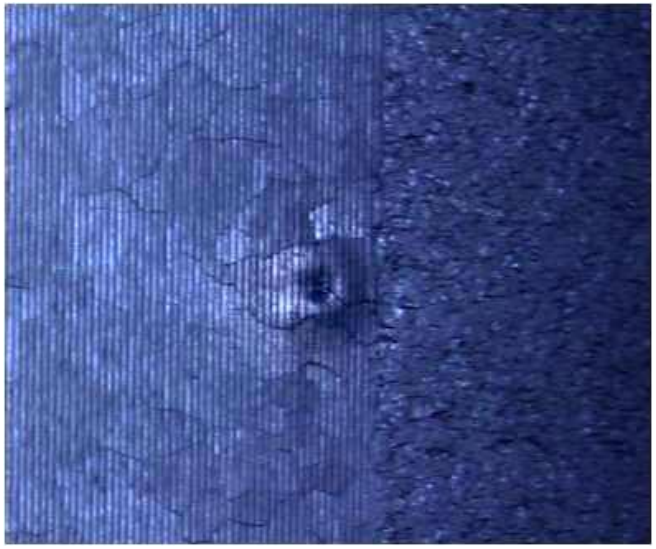


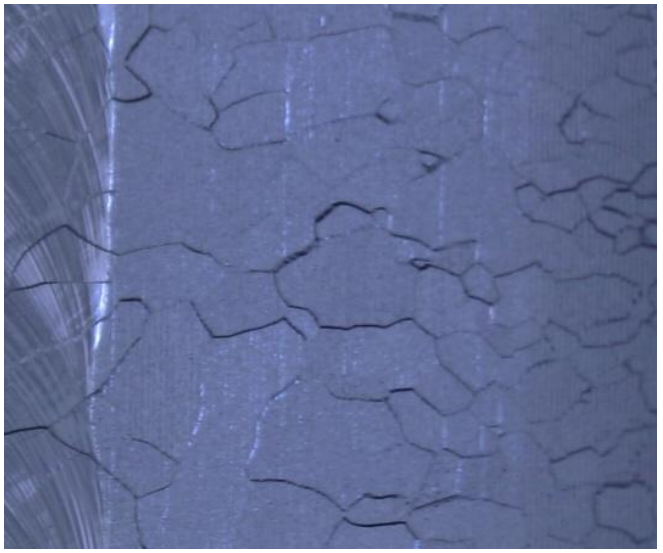
Image processing R&D

At present, all images must be reviewed by an operator.

Computer-assisted defect recognition: Automatically flag images with particular features



Grain-boundary recognition: Verify if recognition of grain boundaries gives an assessment of roughness



Stereoscopic imaging found NOT to be practical with present hardware and illumination (Collaboration with Florida State)

Concluding Remarks

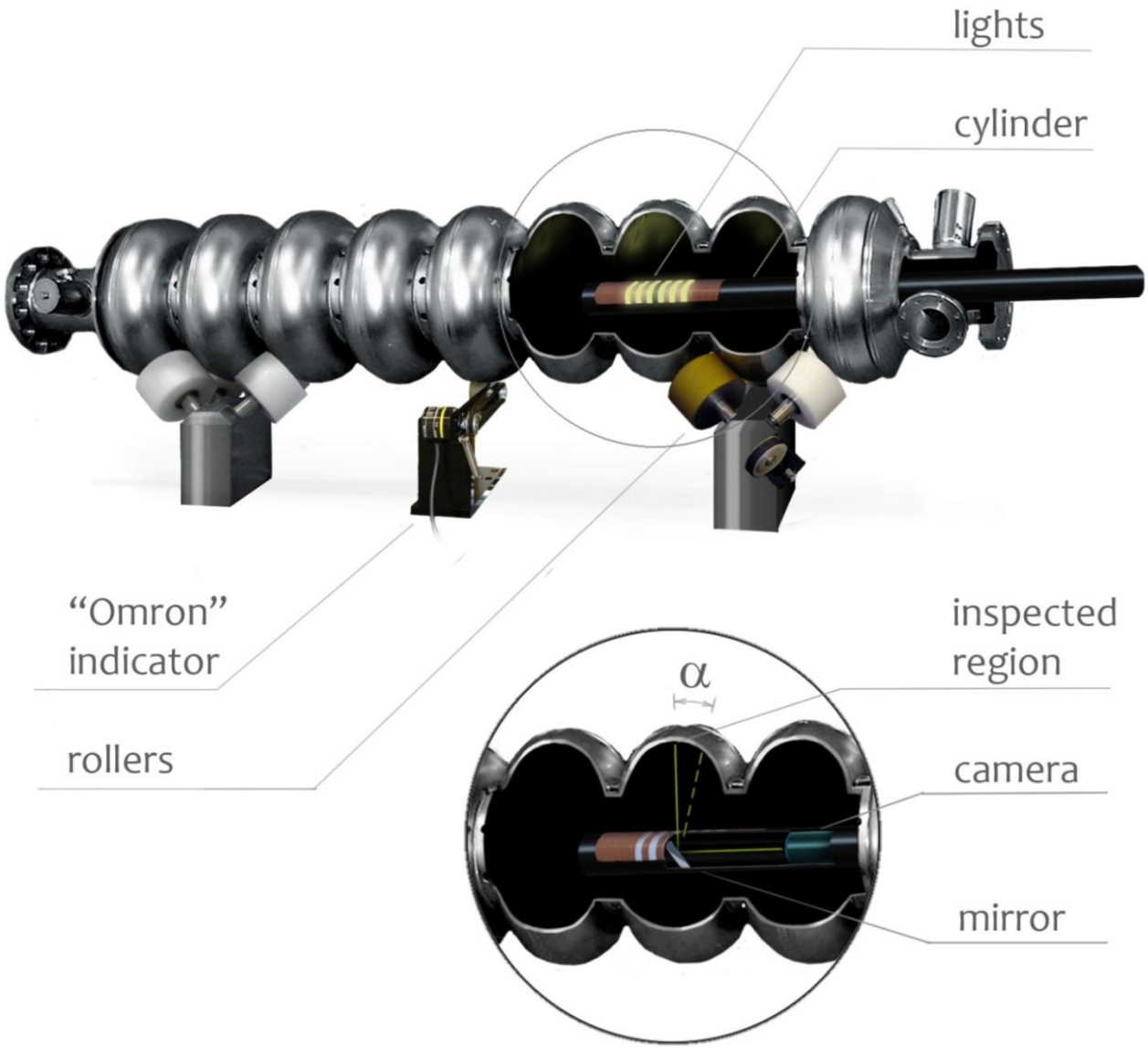
- The optical inspection systems provide important information for process feedback.
- The lower stability of the rotating camera significantly increased inspection time, even though inspection could be adapted to 650 MHz and dressed 1.3 GHz cavities.

  A fixed-camera, rotating cavity system would speed image acquisition for 650 MHz cavities
- Automated image acquisition should now be coordinated with computer-assisted image processing

  Operators likely cannot review ~5000 images with complete objectivity.

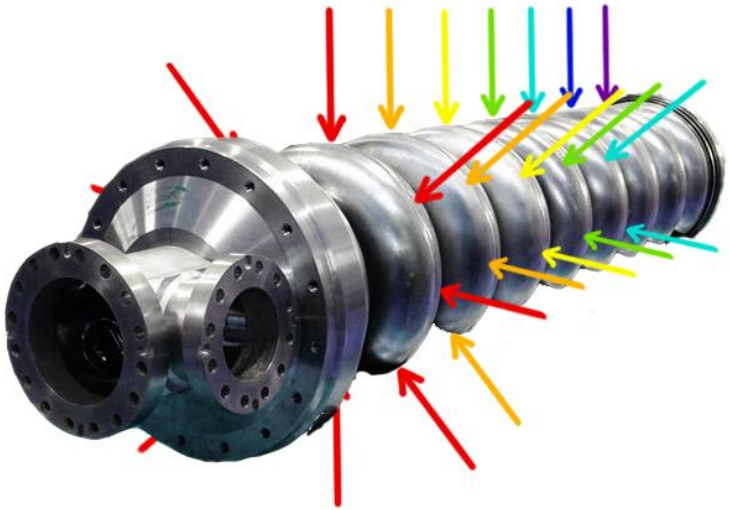
Q & A

Appendix 1 (system design)

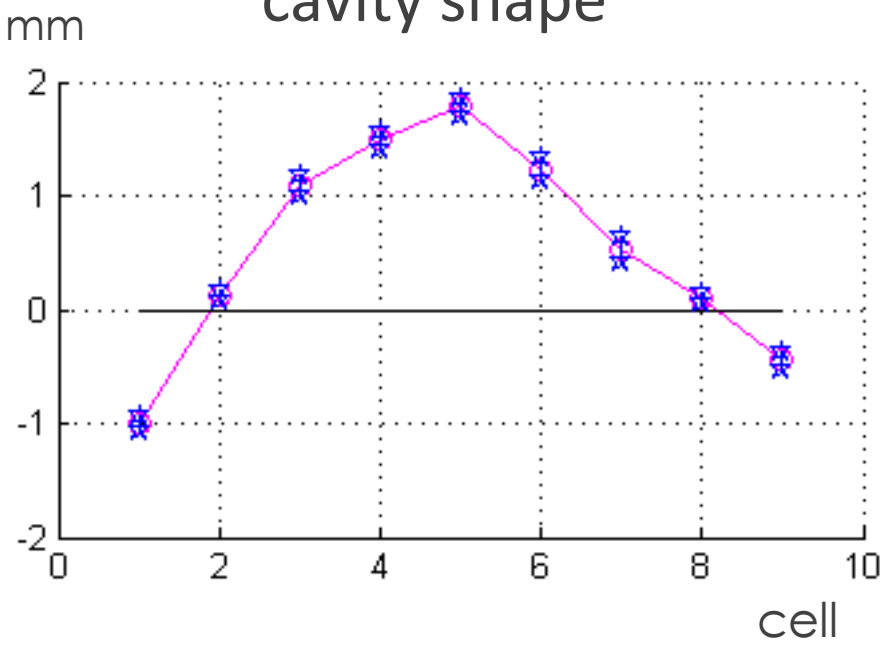


Appendix 2 (cavity shape from auto-focusing)

autofocus data



cavity shape



The auto-focus results agree with tuning machine measurements