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DOE Workshop on EBCs: Microturbines and Industrial Gas Turbines

DEVELOPMENT OF NONDESTRUCTIVE CHARACTERIZATION TECHNOLOGIES FOR EBC's: MONOLITHS AND CMC's

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Presented to DOE Workshop on
"New Developments in Silicon Nitride and Environmental Barrier Coatings for Microturbine and Industrial Gas Turbine Hot-Section Components"

Nashville, TN
November 6-7, 2002

Work support by U.S. DOE/Office of Distributed Energy and Electrical Reliability

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PRESENTATION OUTLINE

- Purpose
- Recent Results and NDE Approach for Tantalum Oxide EBC on AS800 Monolithic
  - –Rolls-Royce 501-KB Field-test
- Results and NDE Approach for BSAS EBC on MI SiC/SiC Composite
  - –Solar Turbine Field-test
- Concluding Remarks

Purpose

The purpose of this work is to develop non-contact, nondestructive technologies that can provide “status” (“health”) information for:

- Si_3N_4 components with an EBC
- SiC/SiC CMCs with an EBC
  - Delaminations: Size and Location
  - Thickness variations
  - Pre-spall conditions
  - Extent of FOD

Description of Si_3N_4 Vanes with EBC

- All were Honeywell AS800
- All coated with tantalum oxide EBC:plasma sprayed
- All either as-received or run in Rolls Royce/Allison 501-KB 4MWe natural gas fired gas turbine
  - 0, 542 and 1621 hours exposure

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Si_3N_4 Vanes with Tantalum Oxide EBC

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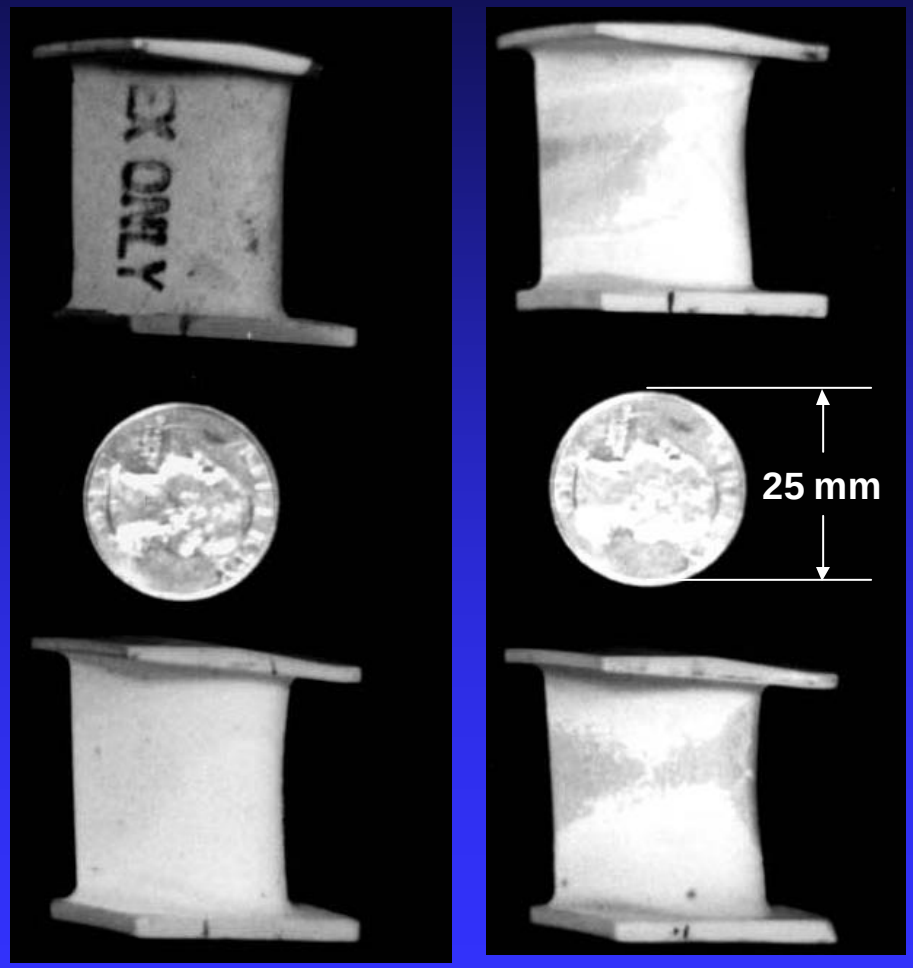
as received

1621 hrs.



542 hrs.

1621 hrs.

SCHEMATIC OF ELASTIC OPTICAL BACKSCATTER NDE EXPERIMENTAL TEST SETUP

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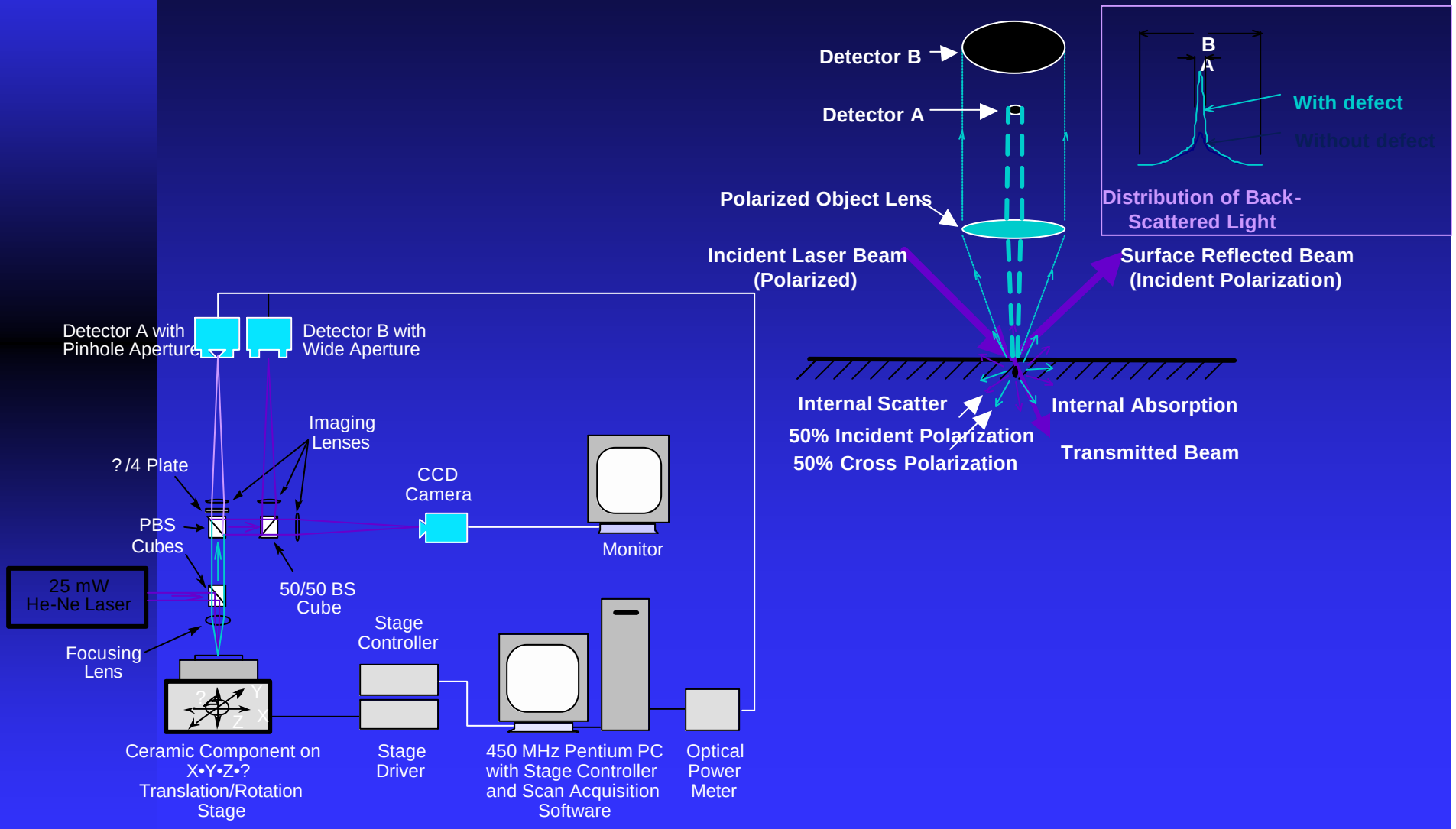

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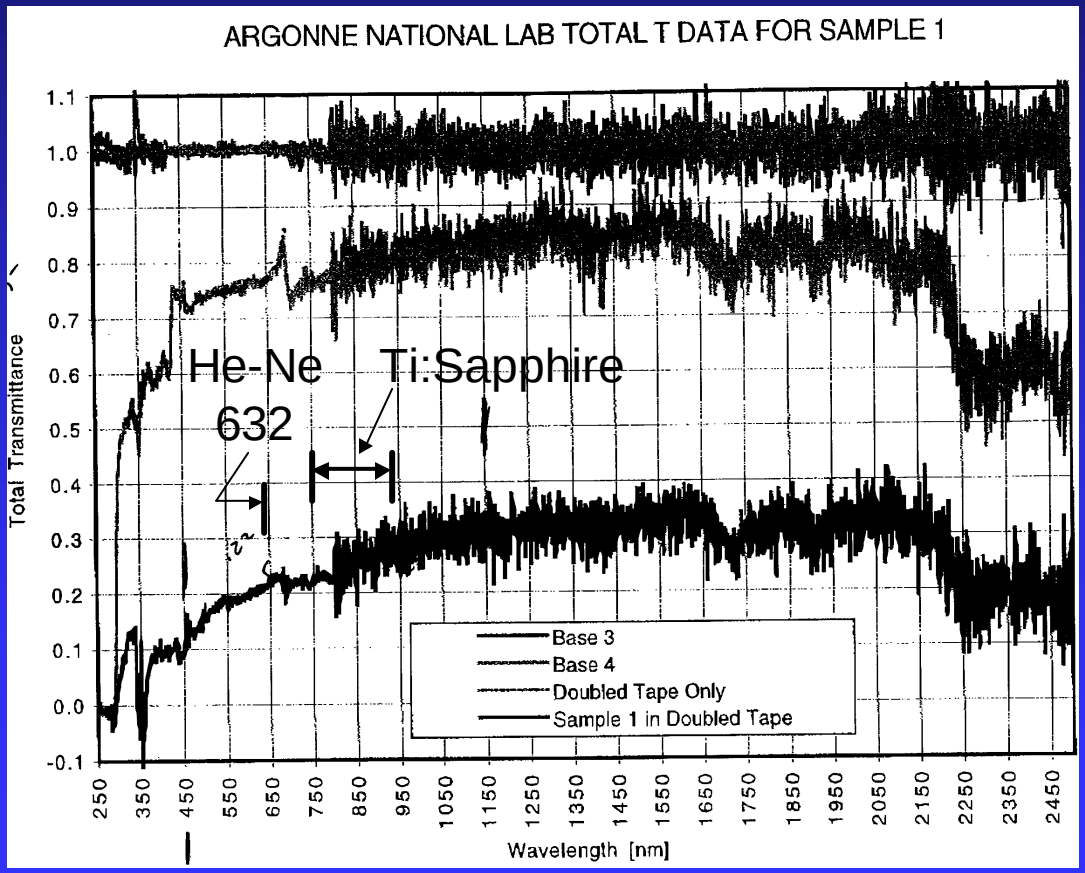
Optical Transmission of Tantalum Oxide

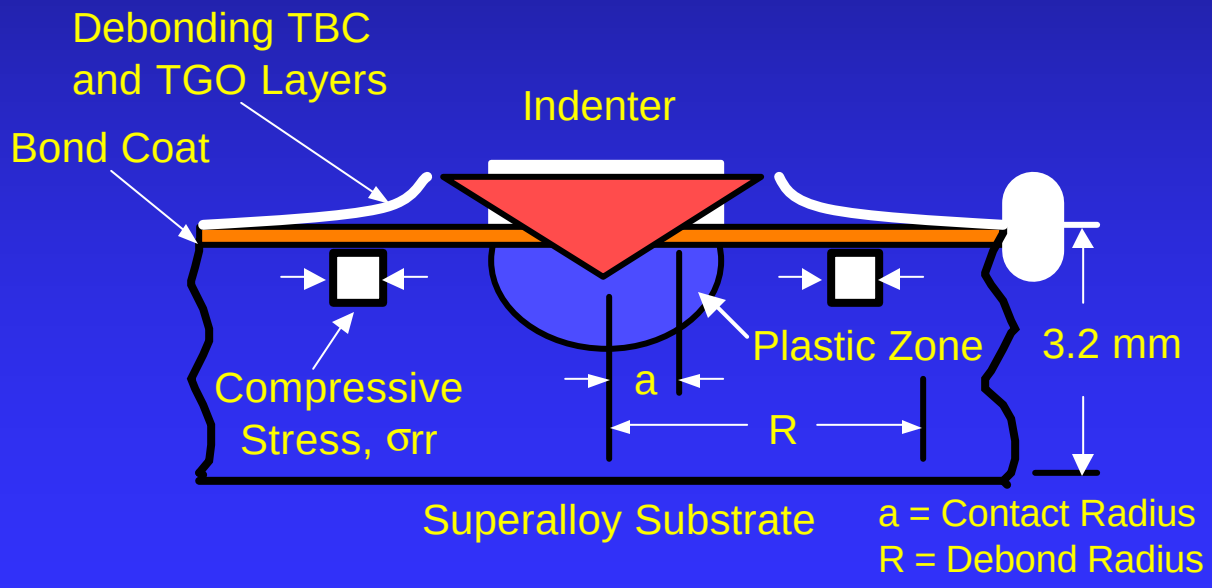
- Laser back-scatter method relies on the fact that the EBC has a reasonable optical transmittance



Recent Correlations Between Data from ANL's Laser Back-Scatter NDE method and Indentation Test

Note: Tests are on YSZ TBC

Indentation Test for Interfacial Toughness



From G. Meier, Univ. of Pittsburgh

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Correlation of NDE Data with Optical Data

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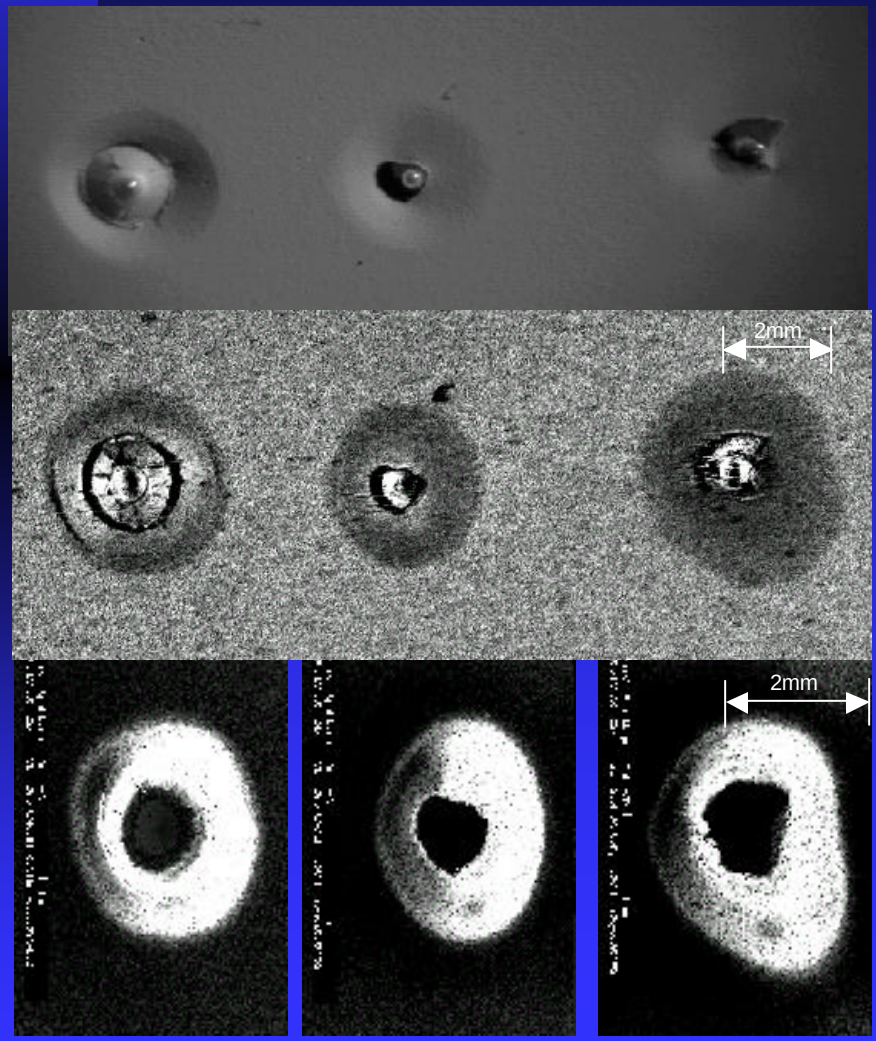
Note: These are for EB-PVD, YSZ, TBC

Initially indented after 50 cycles

Initially indented in as-processed condition

Indented after 170cycles



Optical Macrograph

Laser Scatter Image(debonds appear dark)

SEM Charging Image(debonds appear light)

Cycles	R SEM (mm)	R Backscatter (mm)	% Diff
0	1.39	1.40	0.7
50	1.60	1.66	3.8
170	1.74	1.82	4.6

From G. Meier, Univ. of Pittsburgh

Correlation EBC thickness to elastic optical scatter intensity on AS 800 vane after 1621hrs. [Suction Side]

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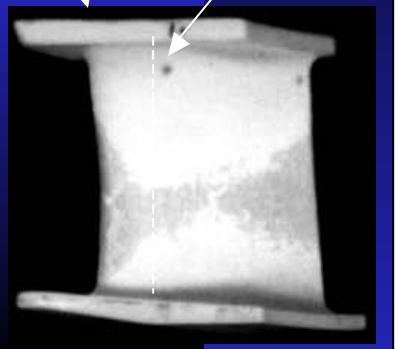
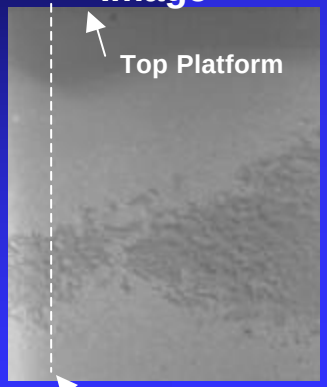
Top Platform

Optical Photo Micrograph



Photograph

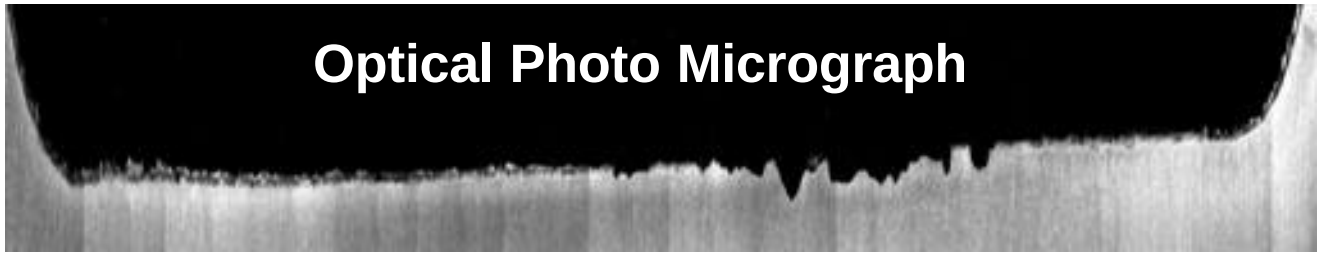
Optical Laser Scatter Image



Top Platform

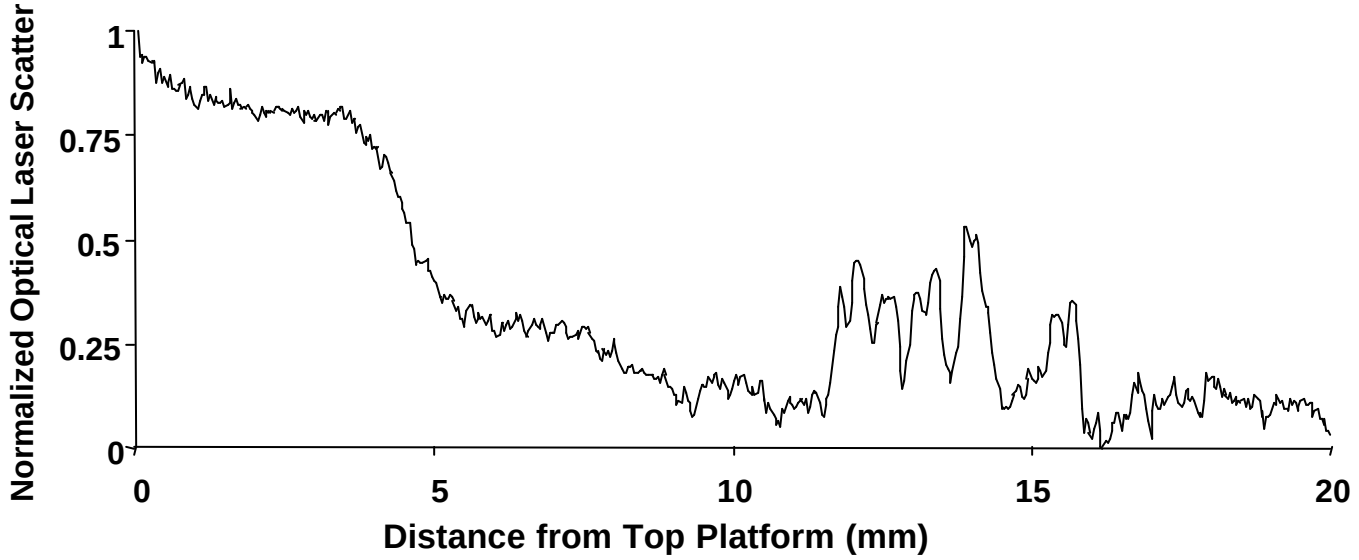
23 mm

876 mm



$$1 - \frac{\text{value}(x) - \min}{\max - \min}$$

Elastic Optical Scatter Line Scan



Detection of erosion of EBC on AS800 vane using elastic optical scatter - All data on suction side

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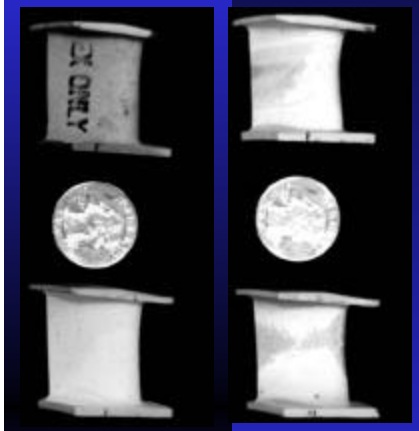
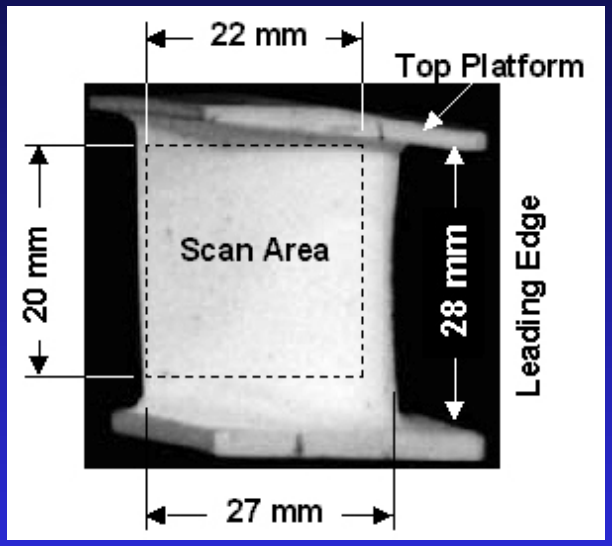
as received

1621 hrs.



542 hrs.

1621 hrs.



as received

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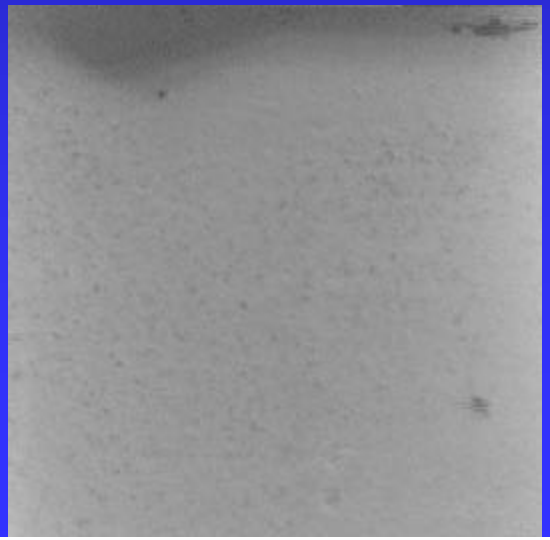
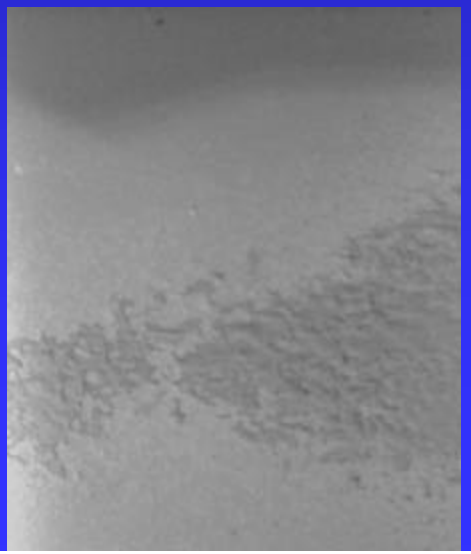
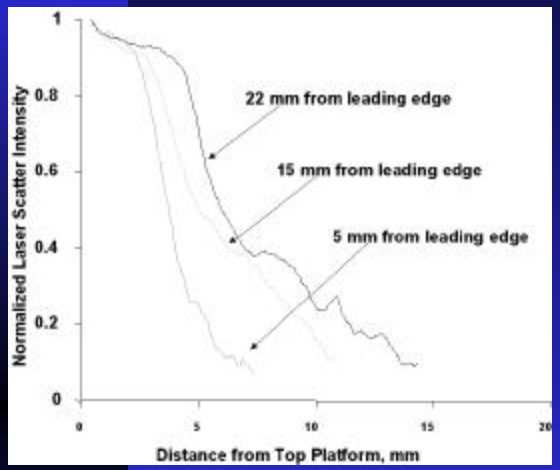




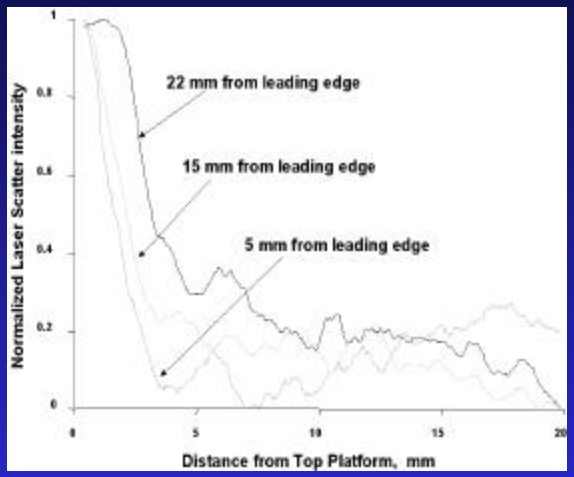
1621 hrs.

NDE measurement of recession of EBC on AS800 vane

Line Plots from Laser Scans



As received



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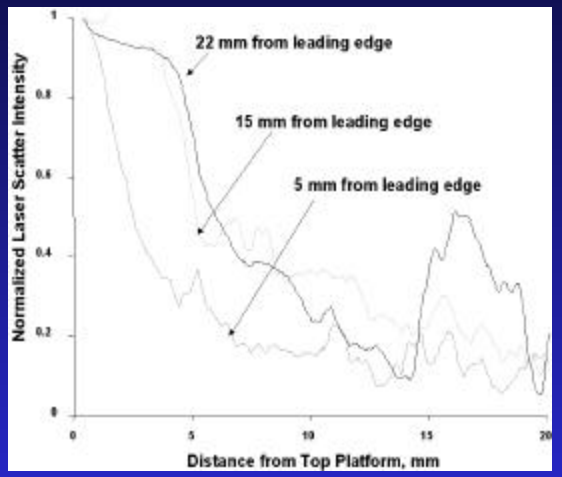
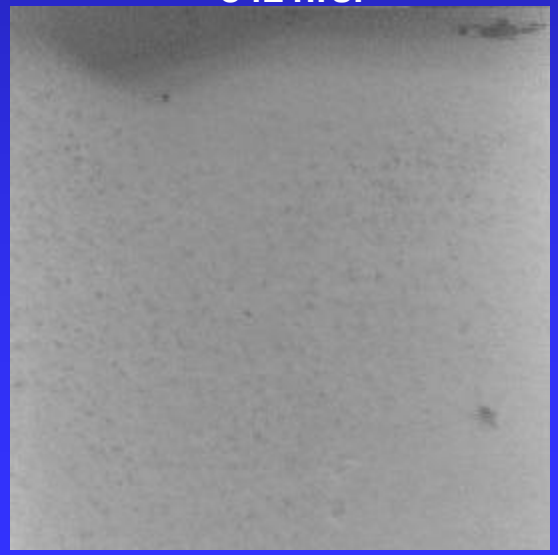


1621 hrs.

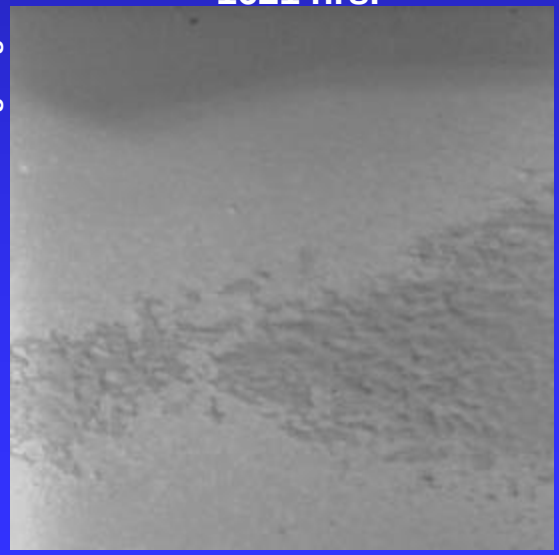
Top Platform

Leading Edge

Leading Edge



Leading Edge



Laser Scans

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Erosive wear measurements using normalized laser scatter intensity

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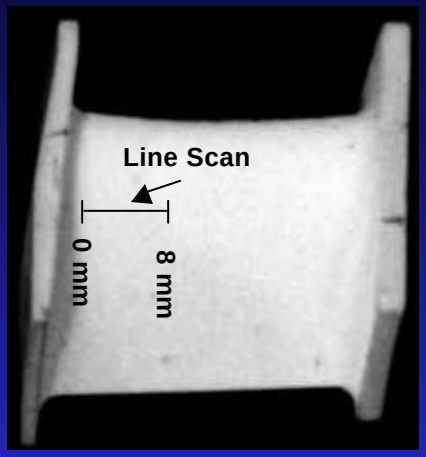
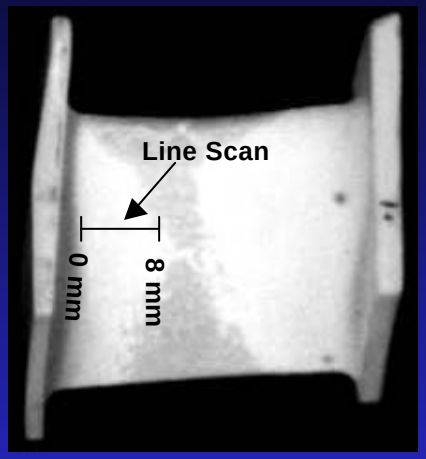
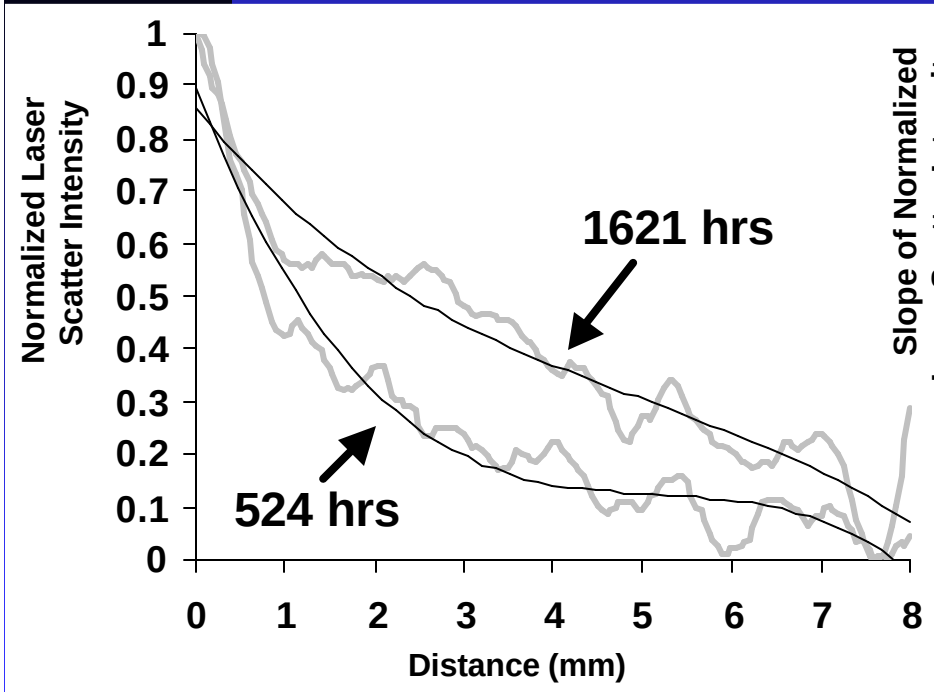
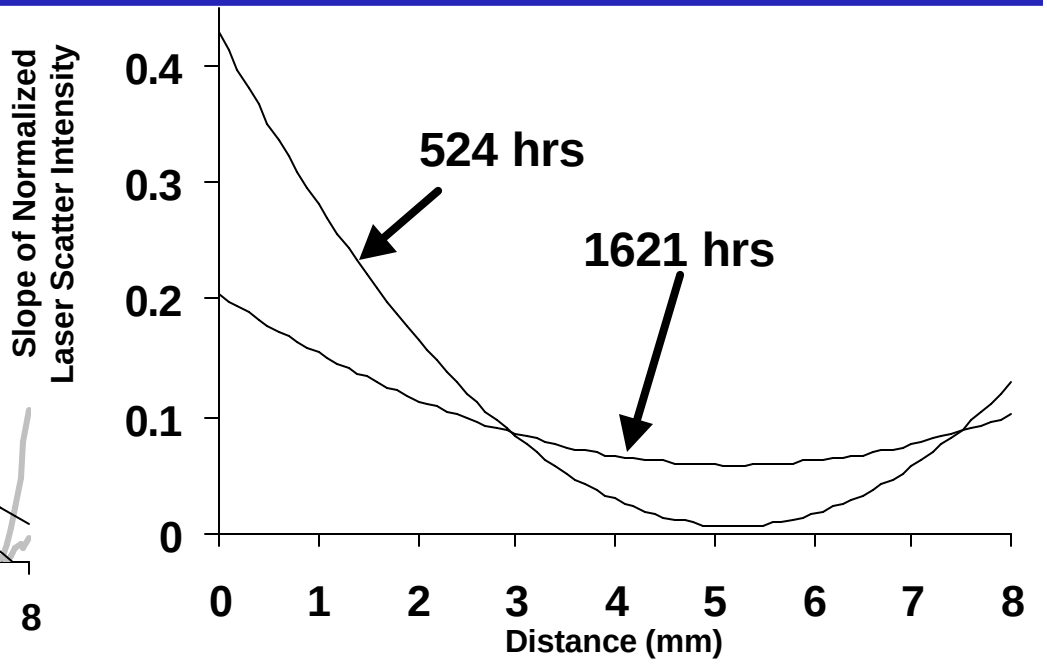
524 hrs.





1621 hrs.





EBC FOR SiC/SiC

DELAMINATION COUPONS FOR NDE

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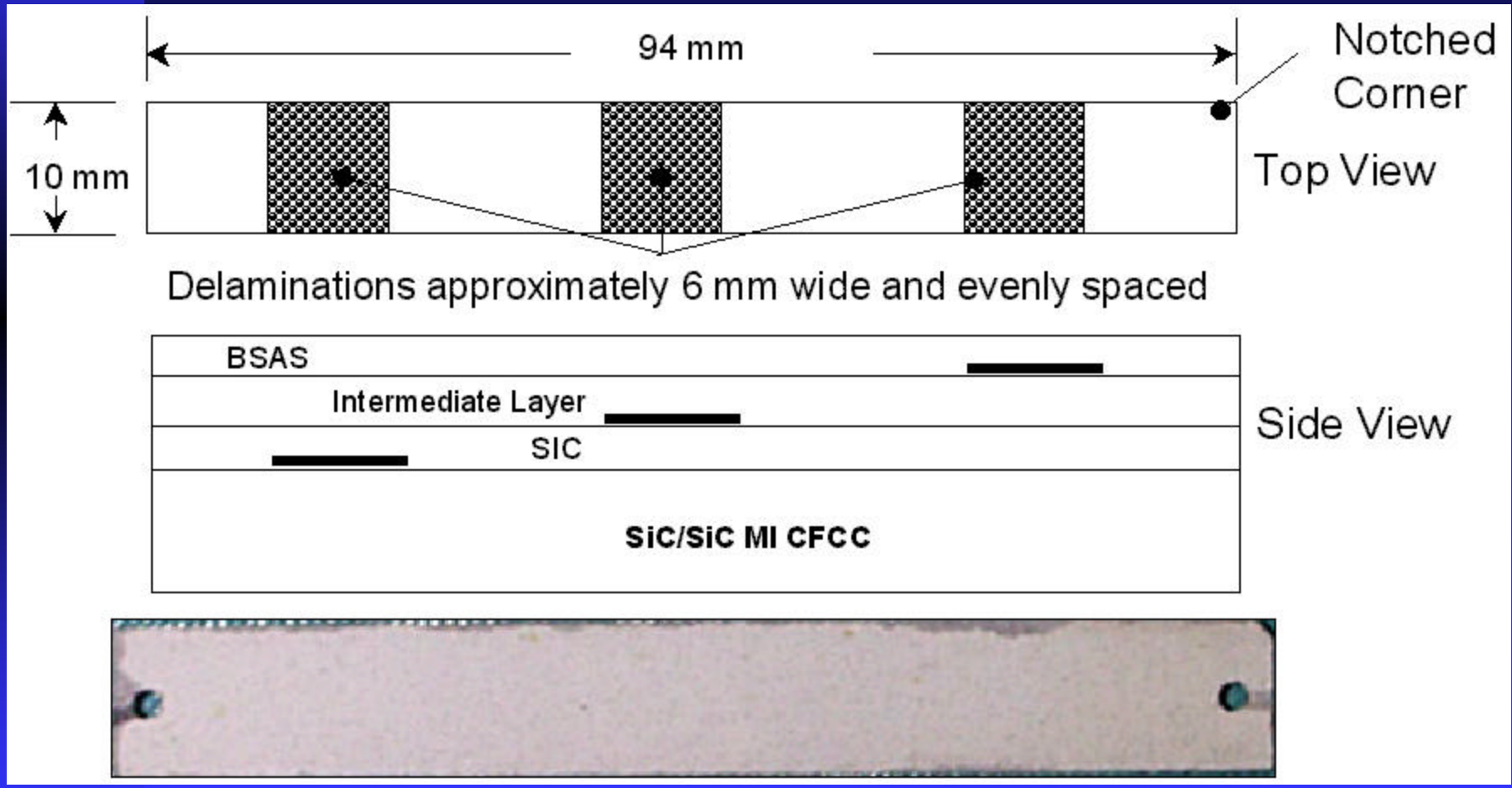
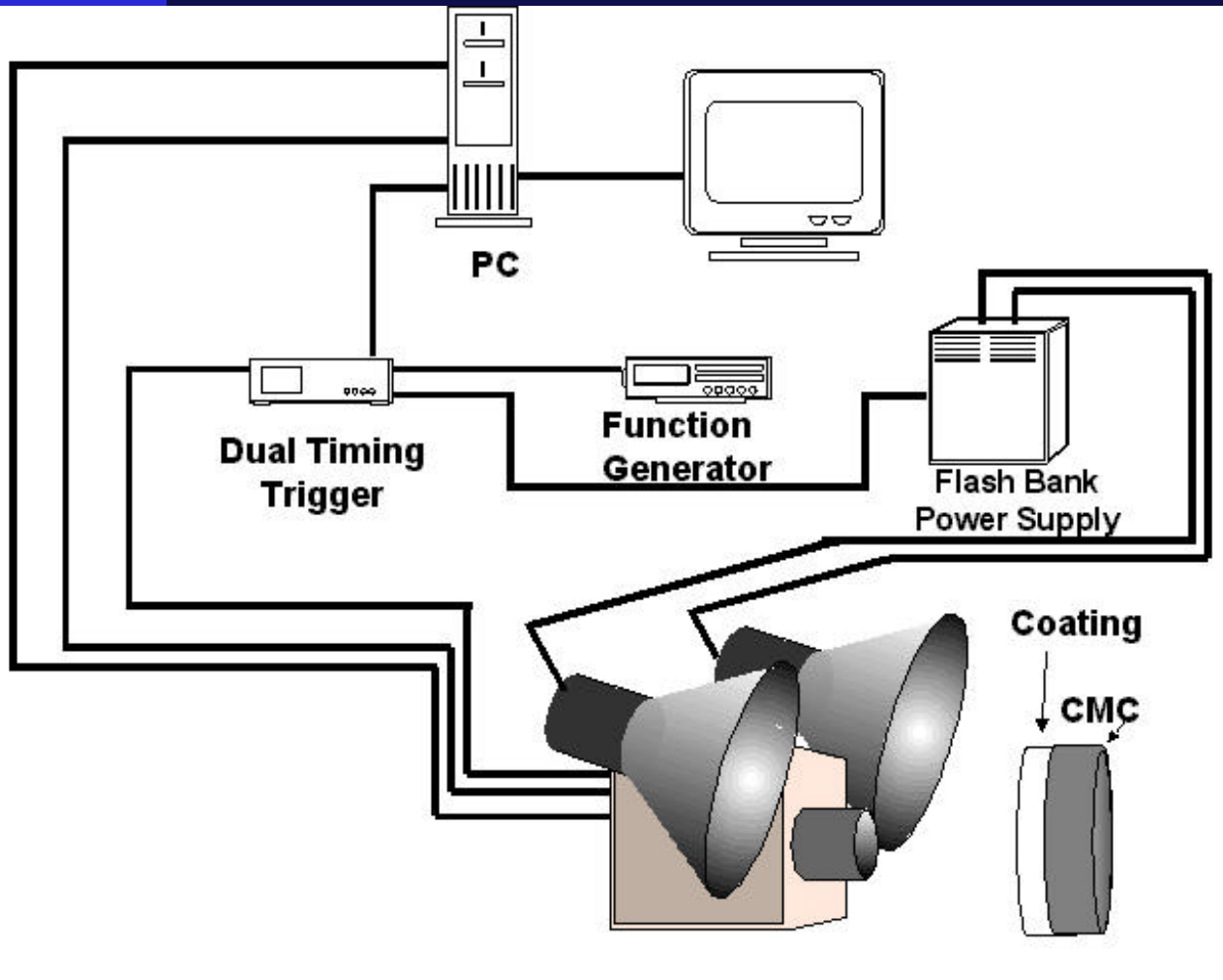


Test Samples Provided by UTRC

NDE APPROACHES FOR EBCs FOR NON-OXIDE CMCs

- Spectrally tuned flash infrared imaging
  - through transmission
  - one-sided
- Air-coupled ultrasonics
  - through transmission
  - one-sided

THERMAL IMAGING NDE EXPERIMENTAL APPARATUS



Detector

- 256x256, InSb, 200 mm
- 12-bit dynamic range
- Full window frame rate to 120 Hz
- 64x64 window frame rate to 1900 Hz.
- Typical flash pulse width approx. 6.0 ms

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OPTICAL SPECTRAL ENERGY DISTRIBUTIONS OF ARGON FLASH LAMPS

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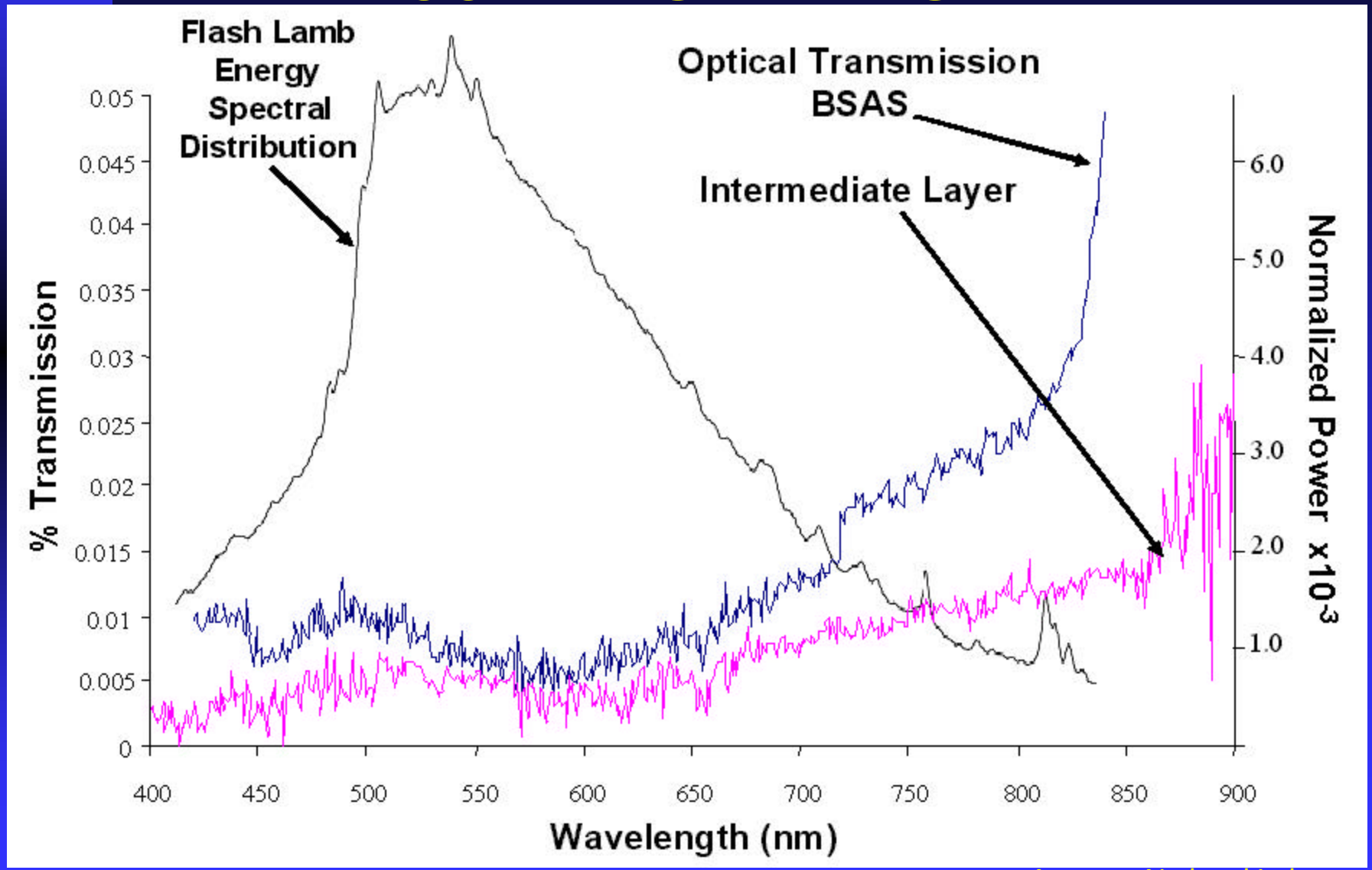

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ONE SIDED THERMAL IMAGING OF SEEDED COUPON

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closest to surface

.1 sec

.2 sec

.3 sec

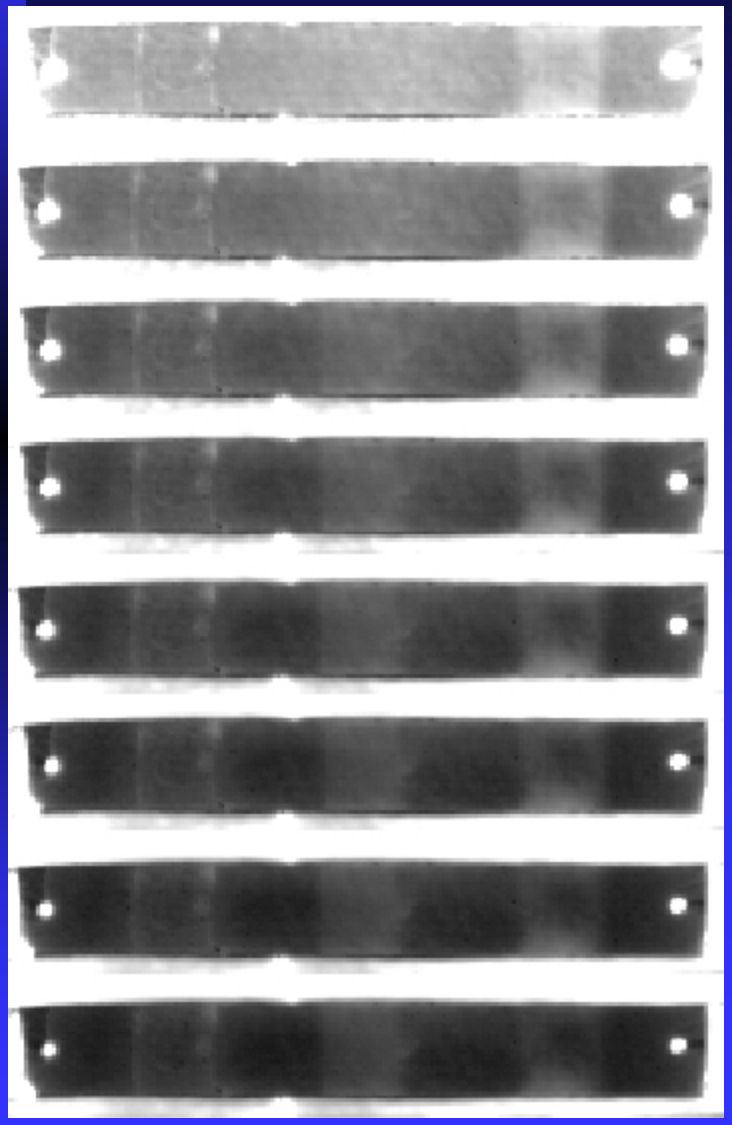
.4 sec

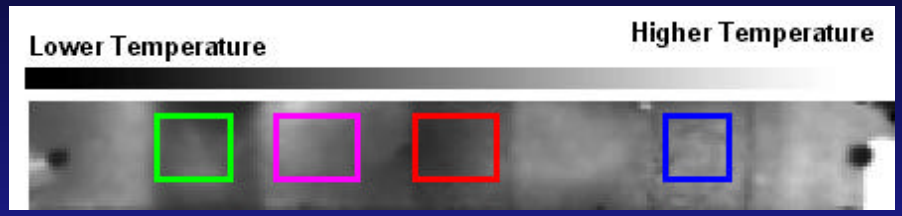
.5 sec

.6 sec

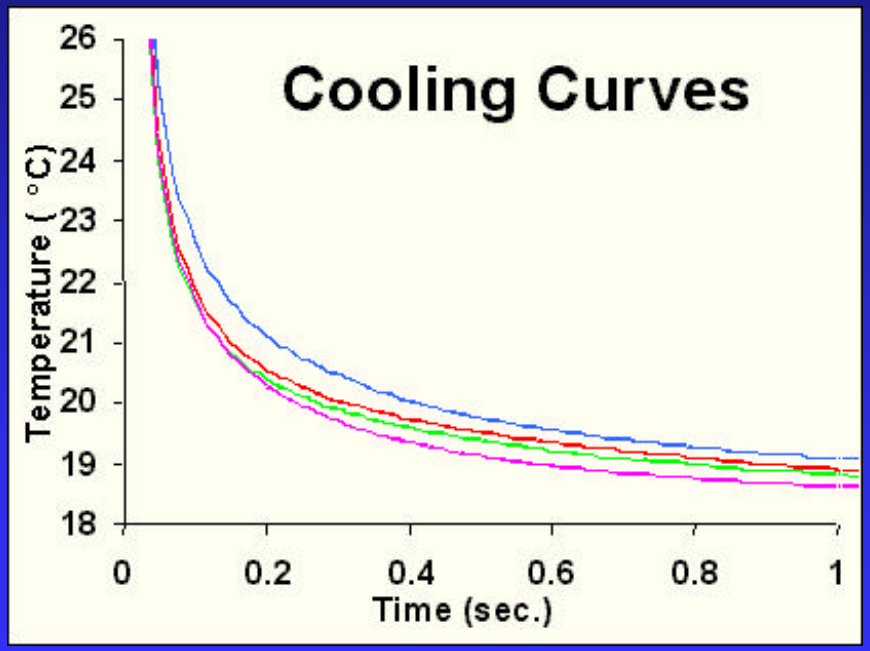
.7 sec

.8 sec





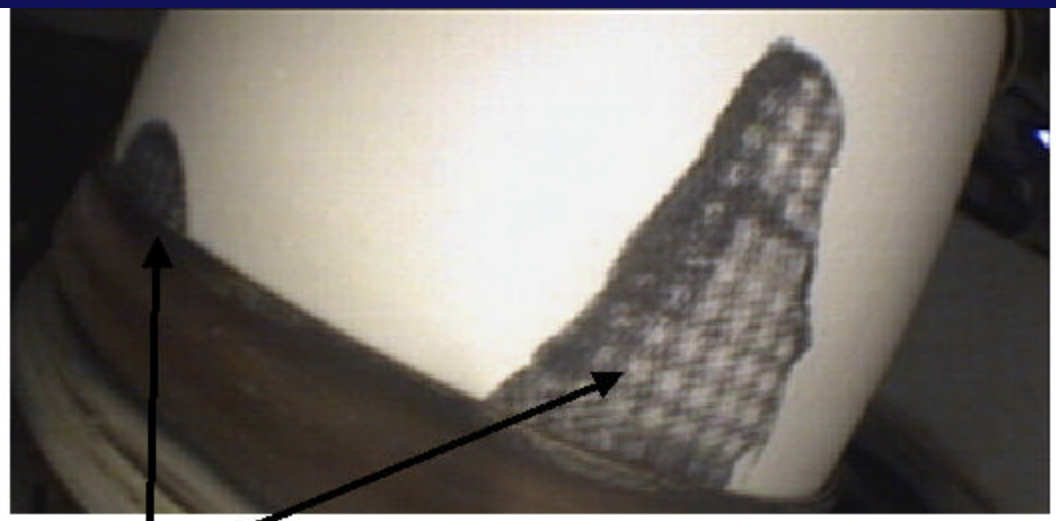
Diffusivity Map



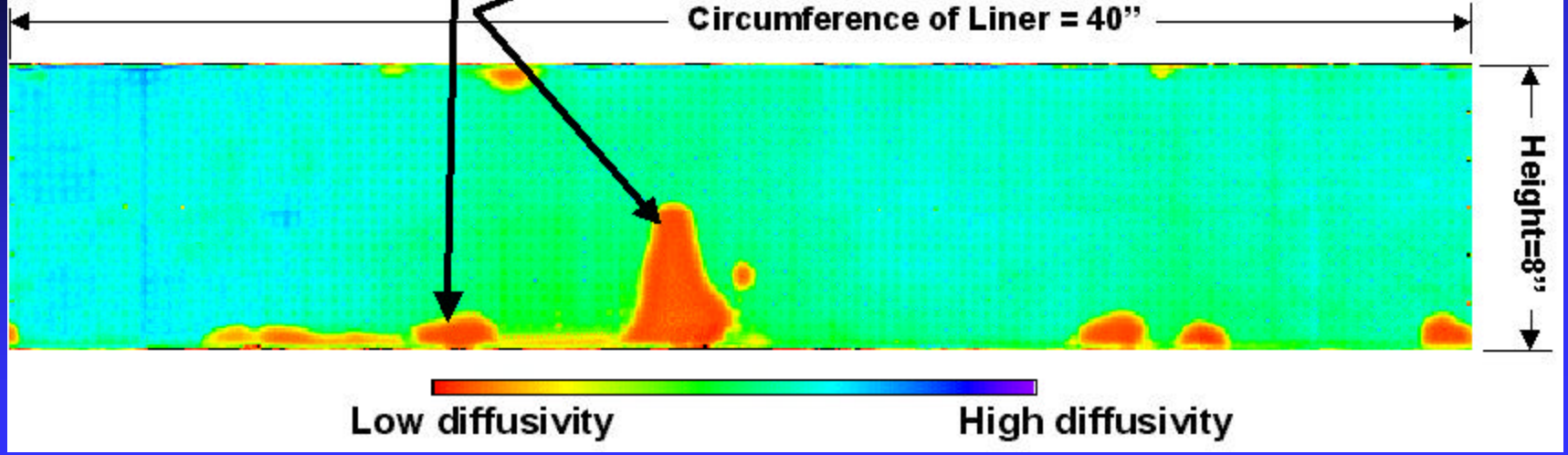
If volumetric heating was significant, seeded delamination would be indistinguishable from non-flawed regions

CORRELATION OF NDE PREDICTED EBC DAMAGE WITH BOROSCOPE OBSERVATION FOR SOLAR TURBINE LINER

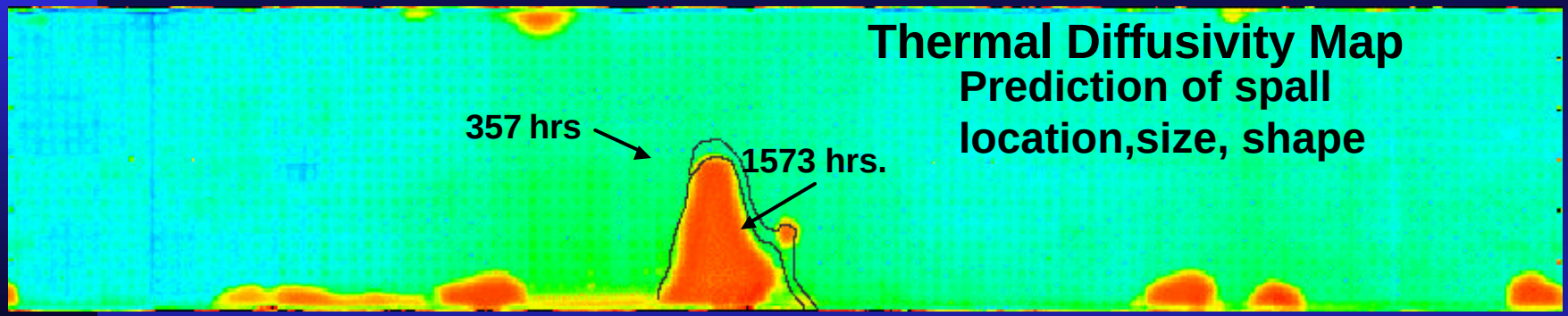
- 13” Diam. MI SiC/SiC Inner Liner



Thermal diffusivity map taken prior to service



NDE PREDICTED SPALL

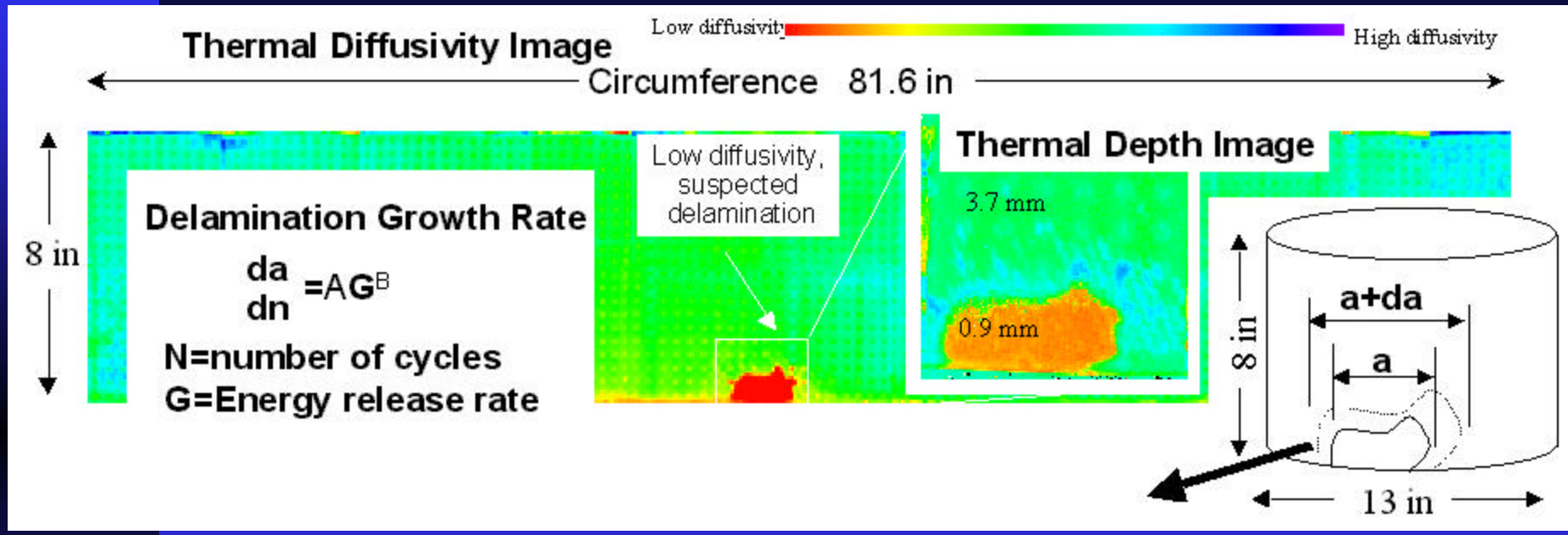


357 hrs.

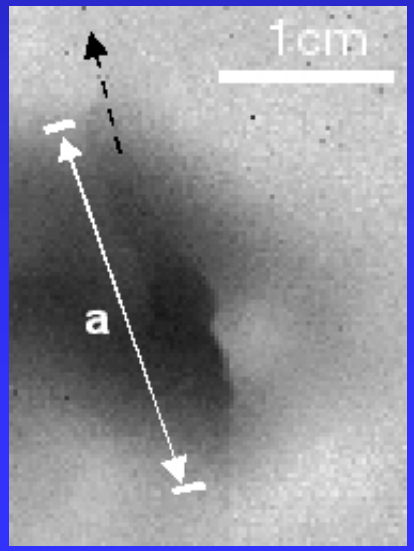
Boroscope Images

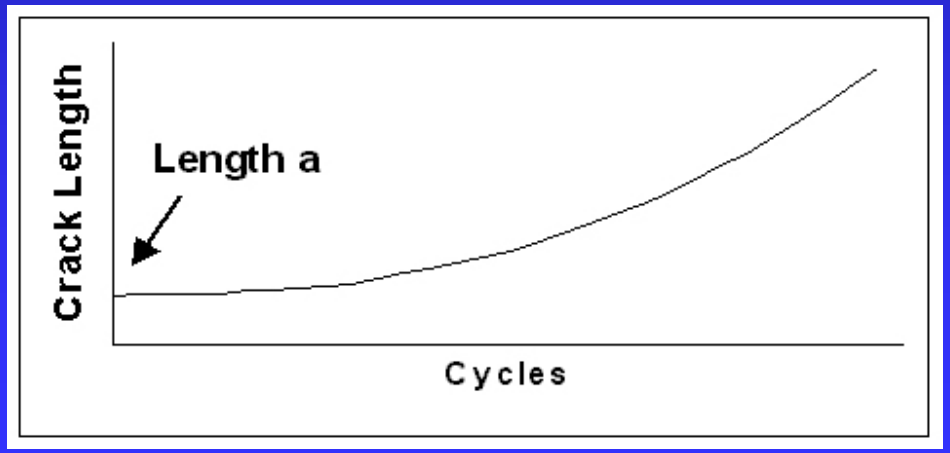
1573 hrs.

Large Flaw Characterization



Predicted Crack Growth Rate





Summary/Conclusions

- EBC's on monolithics
  - Elastic optical laser scattering is under development to characterize EBC coatings for determining uniformity of thickness, detecting and sizing delaminated regions, estimating size and extent of FOD
  - Results to date suggest sensitivity to thickness variations e.g. erosive wear
- EBCs on non-oxide CMCs
  - One-sided, spectrally-tuned, flash, thermal imaging is under development to characterize EBCs for delamination (size and depth location), size and depth of effect of FOD, and estimating growth of delaminated regions