INITIAL INVESTIGATION OF OPTICAL COHERENCE TOMOGRAPHY FOR NONDESTRUCTIVE EVALUATION OF CERAMIC COATINGS

R. J. Visher, M. D. Shields, W. A. Ellingson

ENERGY TECHNOLOGY DIVISION
ARGONNE NATIONAL LABORATORY

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Outline

- OBJECTIVE
- DESCRIPTION OF OPTICAL COHERENCE TOMOGRAPHY (OCT)
- OCT INVESTIGATION OF EBCS
- OCT INVESTIGATION OF TBCS
- CONCLUSIONS

Objective

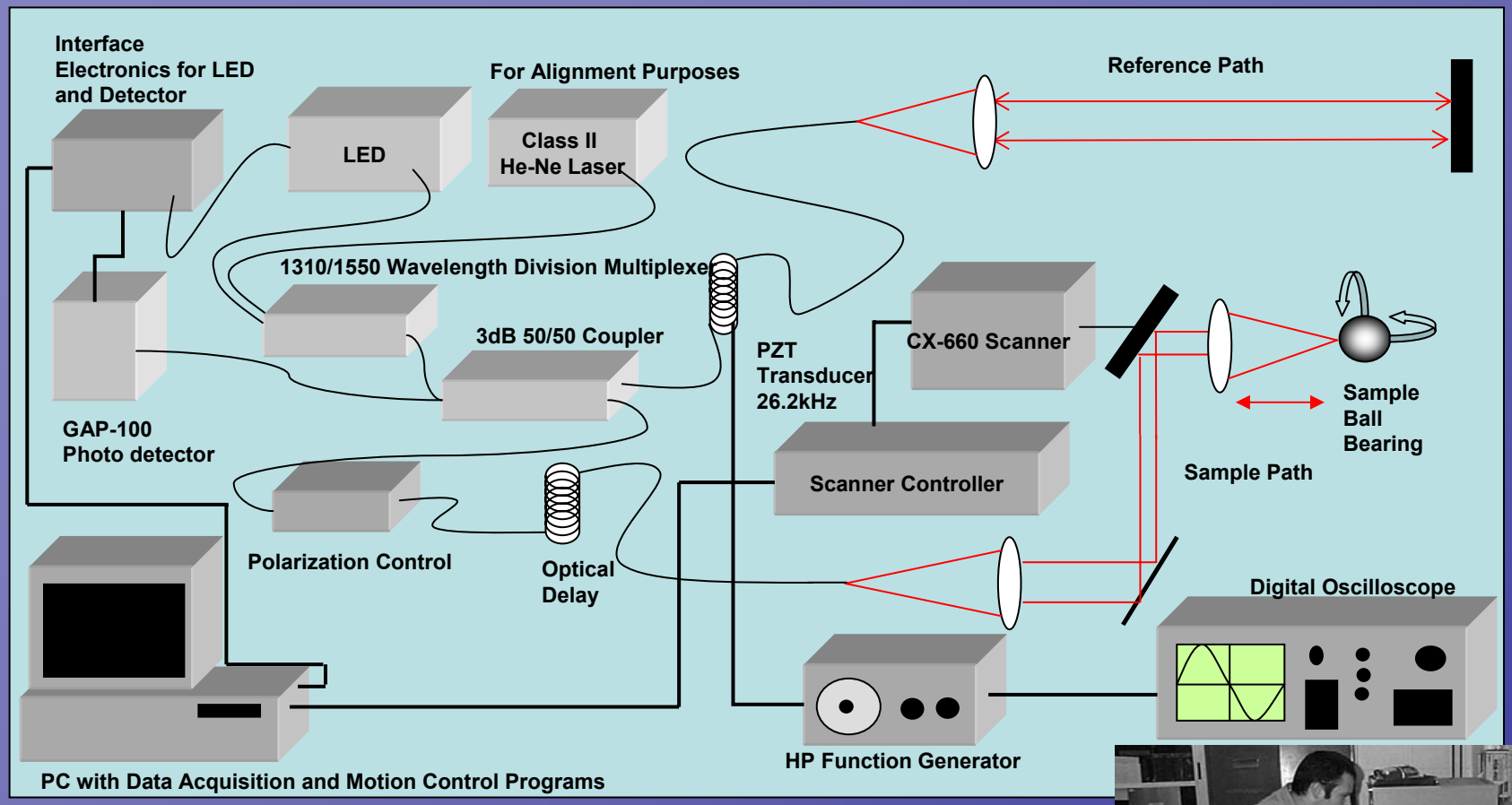
- DEVELOP NON-CONTACT, NON-INVASIVE METHODS TO MONITOR SURFACE AND SUBSURFACE DEFECTS IN ENVIRONMENTAL AND THERMAL BARRIER COATINGS THAT ARE CRITICAL TO THE HEALTH OF THE COMPONENT.

- EXAMPLES OF CRITICAL DEFECTS INVESTIGATED:
  - COATING THICKNESS
  - MACHINING DAMAGE
  - SUBSURFACE CRACKING

Approach

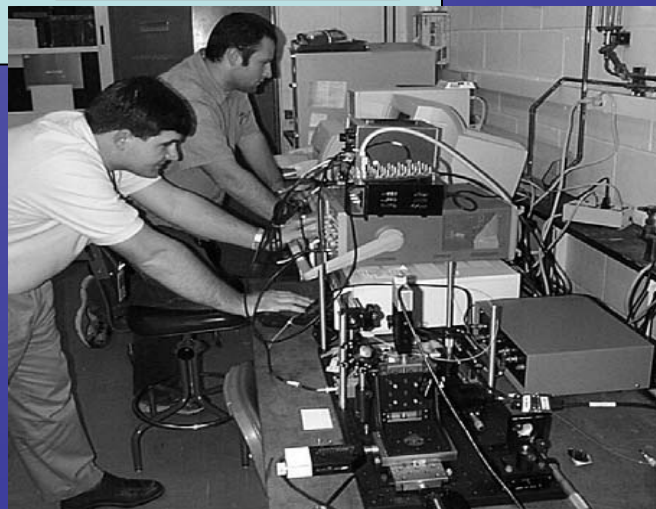
- NDE methods being developed for inspection of ceramic coatings at Argonne include:
  - Laser Backscatter
  - Thermal Imaging
  - OCT

WHAT IS OCT?



ARGONNE'S OPTICAL COHERENCE TOMOGRAPHY SYSTEM

Provided by Saint Gobain Ceramics and Plastics



OCT SYSTEM COMMENTS

- Material must be optically translucent.

- For a source such as a laser diode, depth resolution is a function of wavelength, λ, and coherence length, Δλ:

$$\Delta z = \frac{2 \ln 2}{\pi \Delta \lambda} \lambda^2$$

- Transverse resolution is the same as conventional optical microscopy and determined by the focal length of the lens, f, and the diameter of the spot size, d:

$$\Delta x = \frac{4\lambda}{\pi} \frac{f}{d}$$

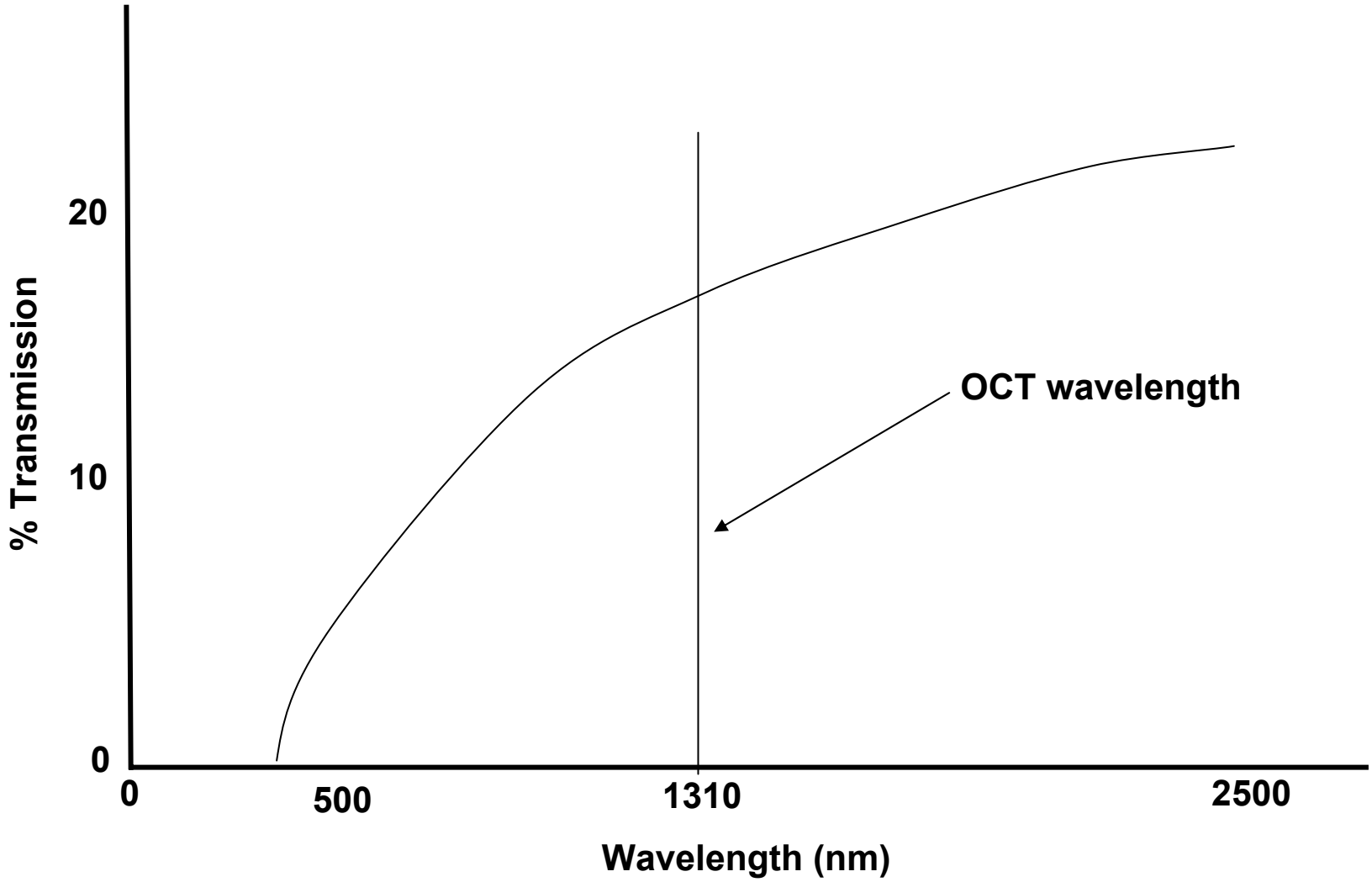
- The intensity of the measured signal is the correlation between the reference beam and sample beam:

$$I_O(t) \sim \frac{1}{4}|E_R|^2 + \frac{1}{4}|E_S|^2 + \frac{1}{2} E_S E_R \cos\left(2 \frac{2\pi}{\lambda}(l_R - l_S)\right)$$

- Data acquisition times are on the order of 4 sq. mm/s (approaching video rate times)

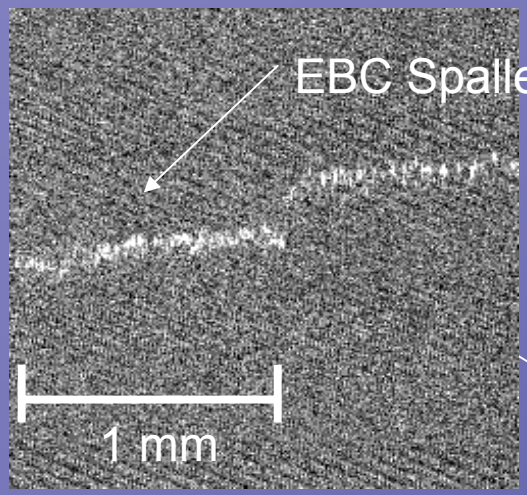
*Bouma, B.E., and Tearney, G.J., ed. *Handbook of Optical Coherence Tomography.* Marcel Dekker, Inc. New York: 2002.

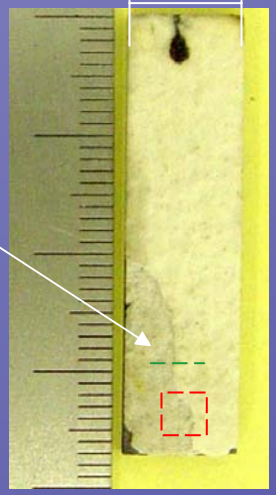
TYPCIAL OPTICAL TRANSMISSION CHARACTERISTICS FOR CERAMIC COATINGS



Application of OCT to Thermally Cycled BSAS EBC on SiC/SiC Substrate

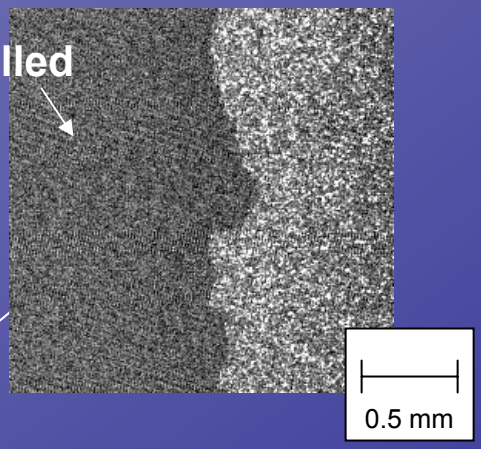
Vertical Cross-Section of EBC Spall BSAS on SiC/SiC

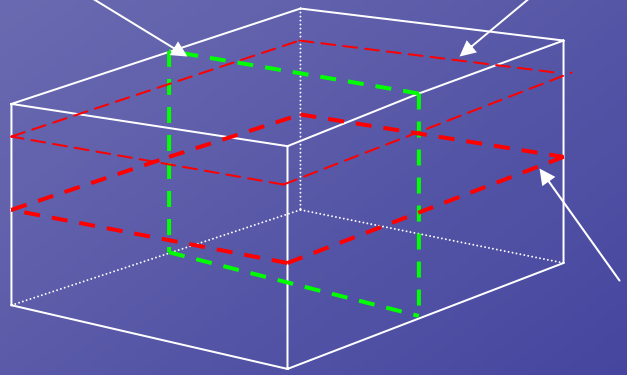




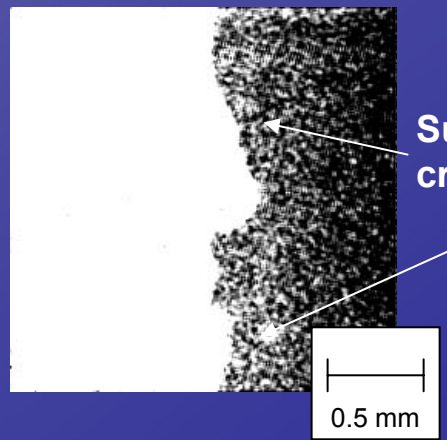
Horizontal Cross-Section of EBC Spall BSAS on SiC/SiC

~20 µm below EBC surface





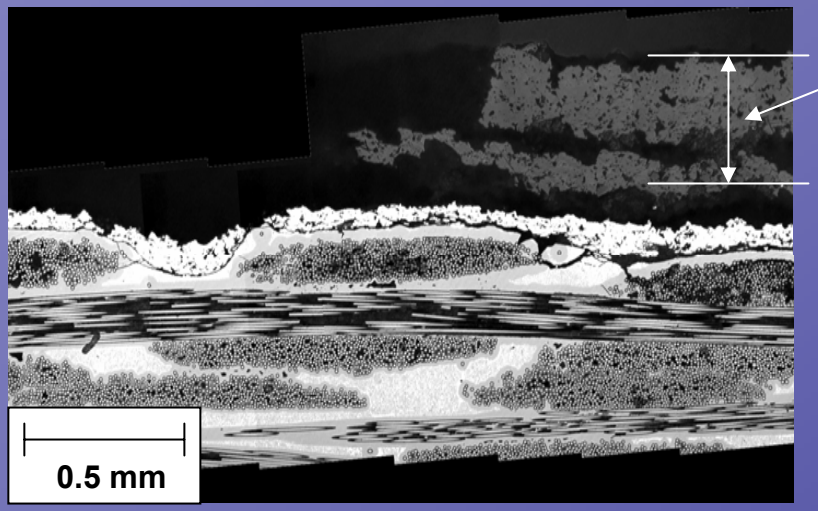
~250 µm below EBC surface



Sample provided by United Technologies Research Center

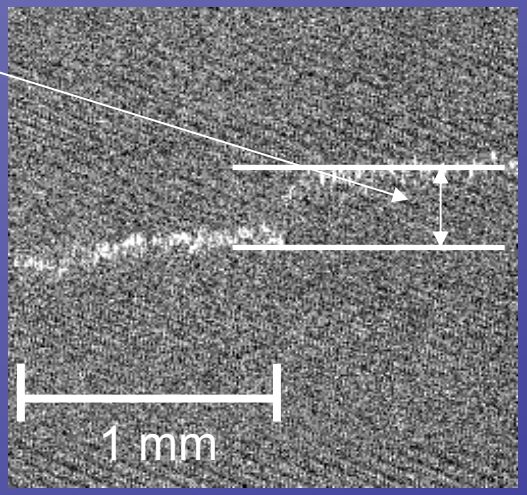
OCT MEASUREMENT OF EBC COATING THICKNESS

5x Cross Sectional Optical Micrograph



EBC layer

OCT Cross-Sectional Image

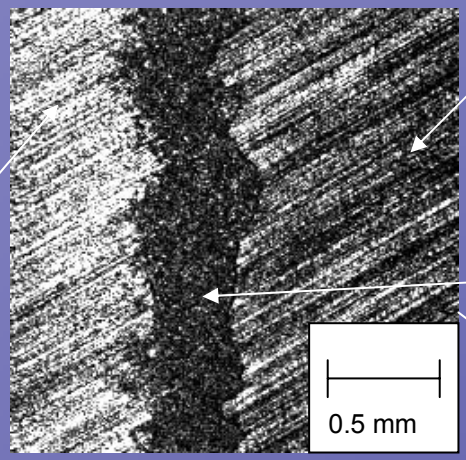


EBC Thickness Measurements	
Micrograph	0.29 mm
OCT	0.25 mm

All measurements +/- 10 µm

Application of OCT to EB-PVD YSZ TBC

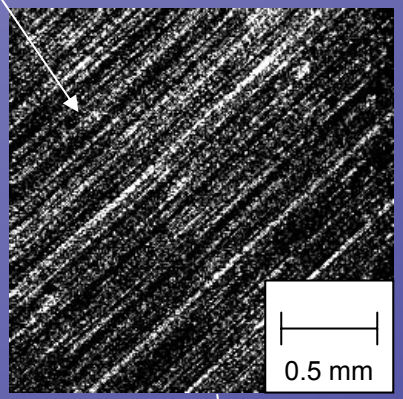
Composite of data from 0-300 um depths



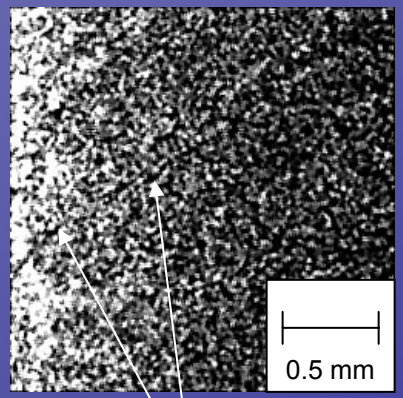
Machining damage To approx. 200 µm

Horizontal Cross Sections

TBC Surface

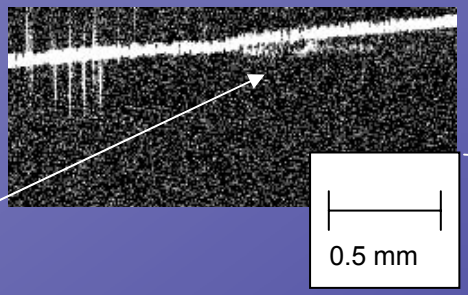


260 um Below TBC Surface

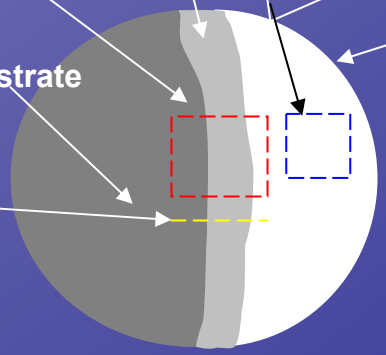


Subsurface cracks

Vertical Cross-Section



TBC/BC interface



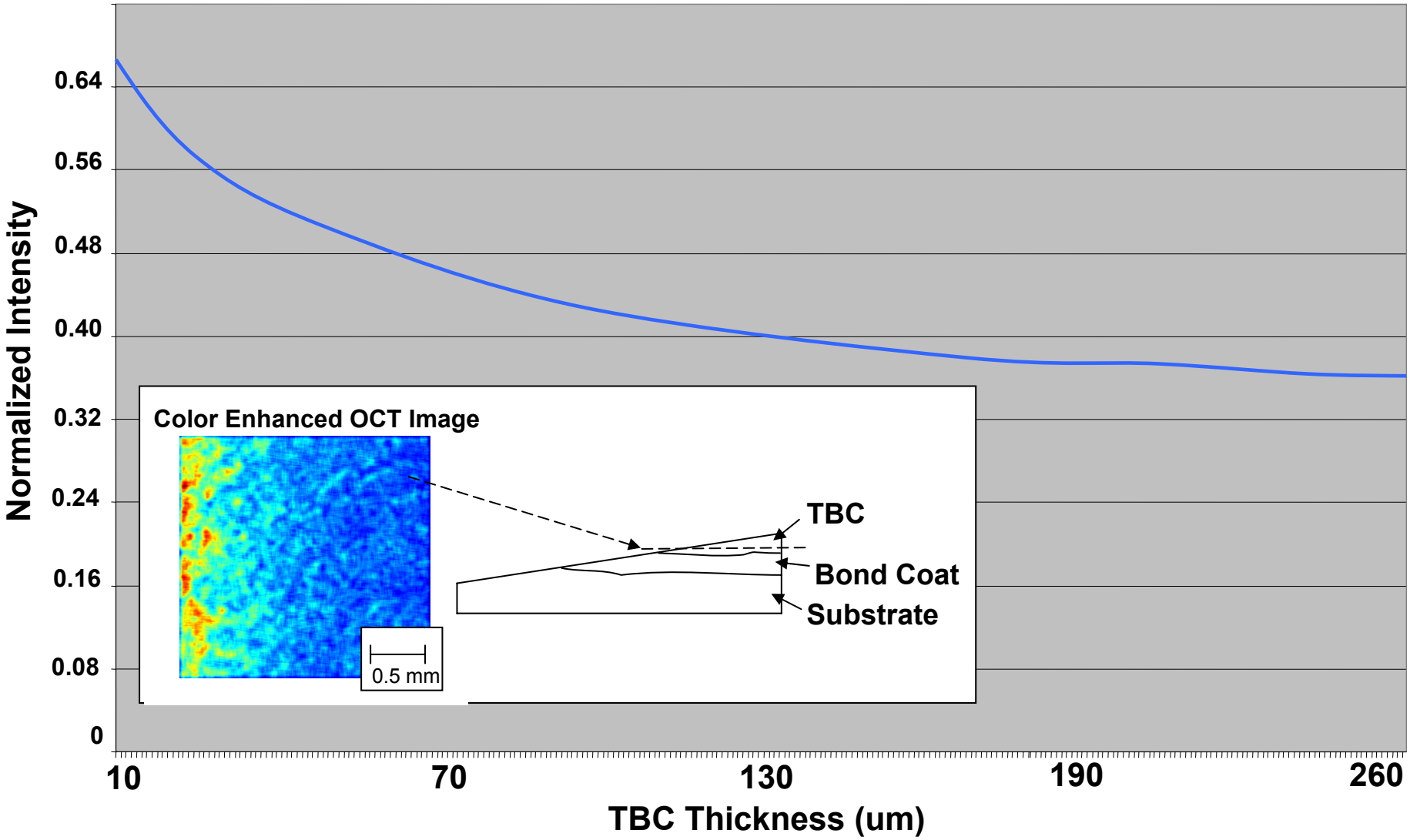
Top View

Perpendicular Cross Section

Sample provided by GE Power Systems

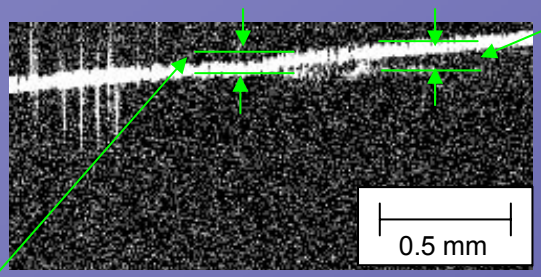
25 mm diameter sample polished to expose bond coat and substrate (EB-PVD YSZ TBC on N5 Superalloy with MCrAlY bond coat)

EFFECT OF COATING THICKNESS ON AVERAGE GRAY SCALE VALUE



OCT DATA COMPARED TO OPTICAL MICROGRAPHS

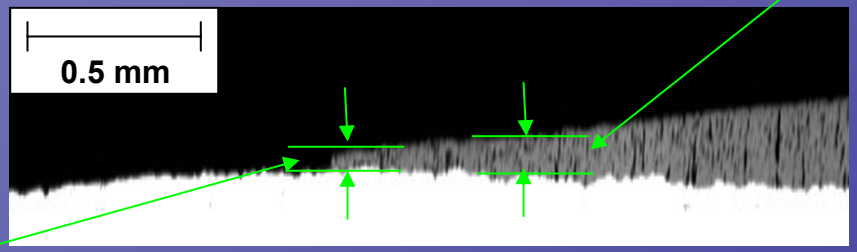
OCT Vertical Cross-Section



Dimension B

Dimension A

Optical Micrograph (5X)



Dimension B

Dimension A

TBC Thickness Measurements	Dim. A	Dim. B
Micrograph	25 µm	44 µm
OCT	20 µm	50 µm

OCT measurements taken from middle of white line

CONCLUSIONS

- OCT can obtain coating thickness measurements that compare to those obtained with optical microscopy without the need to destroy the sample

- OCT can be detect subsurface cracks and provide information about the depth of the plane of the crack

- OCT is applicable to both EB-PVD TBCs and selected EBCs on ceramic/ceramic substrates

- The signal-to-noise ratio of typical OCT systems needs to be improved for continuing applications in ceramic materials especially for ceramic coatings.

- Theoretical models will be developed to verify experimental data