CORNING

Discovering Beyond Imagination

Advancements in ULE®Glass: CTE Metrology Capabilities

Corning: David Navan, Kenneth E. Hrdina, Bradford G. Ackerman, David C. Jenne, & Brian L. Harper

Corning Tropel: Joseph Ellison

Fanning Technical Services: Andrew Fanning

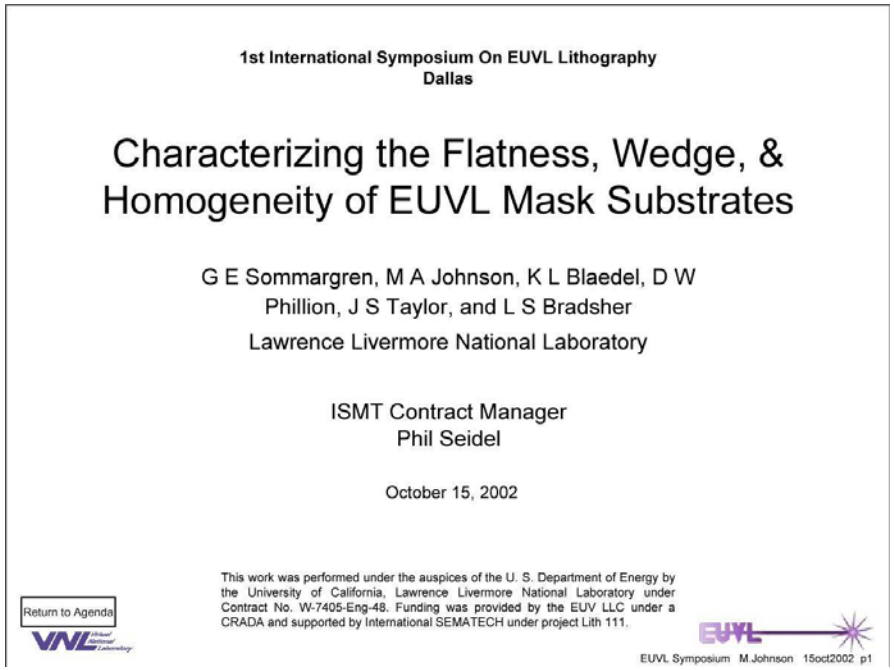
2nd EUVL Symposium

September 29th - October 2nd, 2003

CORNING
Discovering Beyond Imagination

Index Homogeneity as an Alternative Tool to Measure CTE in ULE Glass

Following through with work of Sommargren et al.


1st International Symposium On EUVL Lithography
Dallas

Characterizing the Flatness, Wedge, & Homogeneity of EUVL Mask Substrates

G E Sommargren, M A Johnson, K L Blaedel, D W Phillion, J S Taylor, and L S Bradsher
Lawrence Livermore National Laboratory

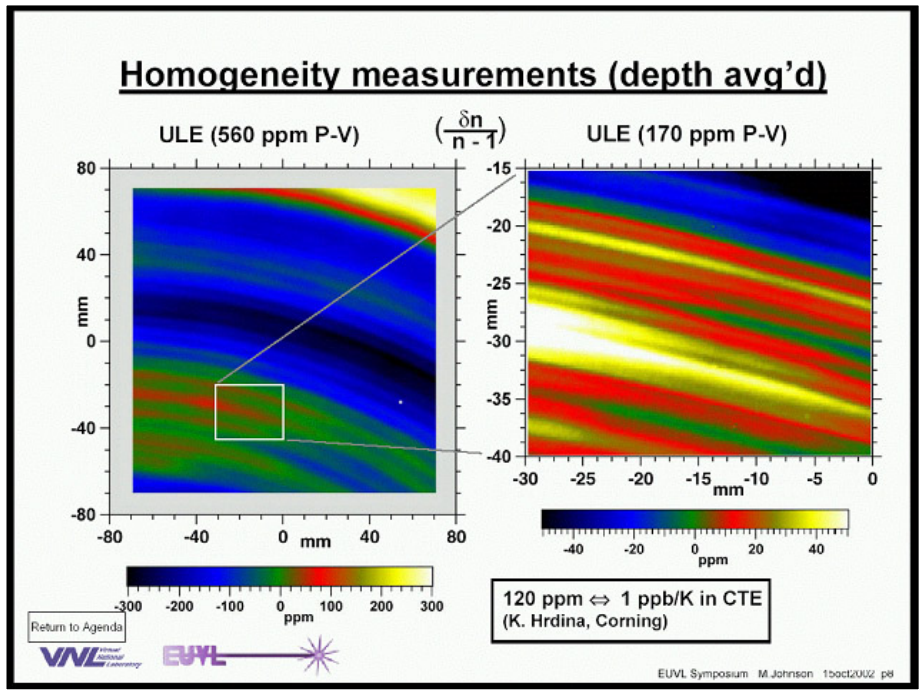
ISMT Contract Manager
Phil Seidel

October 15, 2002

This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48. Funding was provided by the EUV LLC under a CRADA and supported by International SEMATECH under project Lith 111.

Return to Agenda

EUVL Symposium M.Johnson 15oct2002 p1

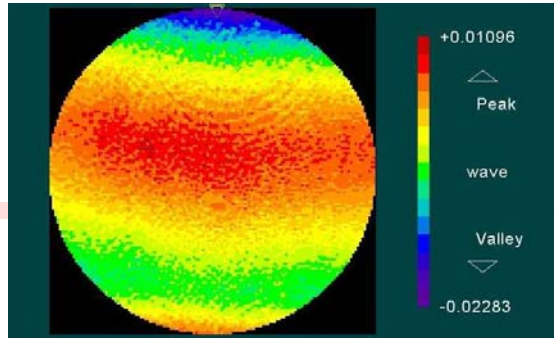


Data and graph courtesy of M. Johnson and G. Sommargren.

- **Review of Hrdina et al. SPIE 2003**

- **Current Work:**
  - **Correlate absolute CTE to Absolute Index of Refraction**
  - **Continue to obtain data & refine correlation**

Why Interferometry?



- Bulk glass technique *(not just surface)*
- Non-destructive *(measure actual samples)*
- High spatial resolution *(225 μm used here…<50 μm capable)*
- One precision measurement tool vs. two *(TOF,Thickness)*
- Commonly available tool (*Industry Standard)*
- High precision *(index to few ppm)*
- Ability to measure thin parts

Metrology Tool… Ultrasonic Technique

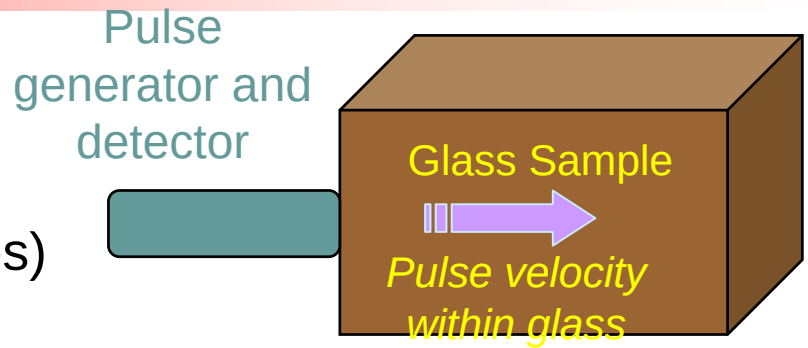
Advantages:

Bulk glass technique (not just surface)

Non-destructive (measure actual samples)

6 mm spatial resolution

±0.4ppb/K precision (100 mm thick)



*Hagy, Applied Optics, 12 [7] July 1973

Limitations:

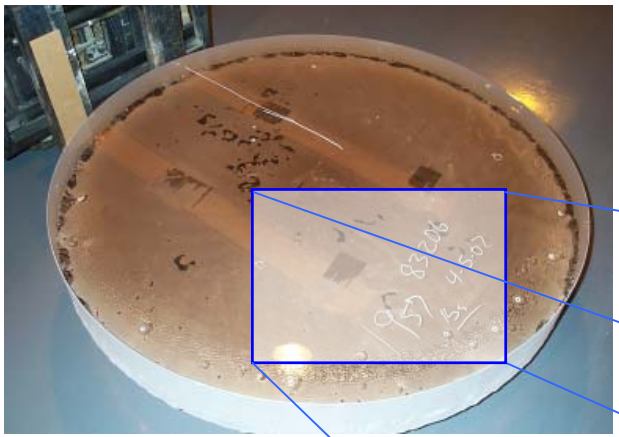
Not used today on photomasks… *too thin*

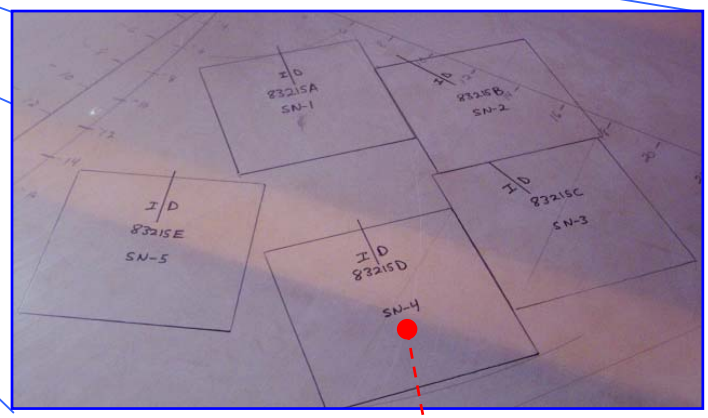
Spatial resolution

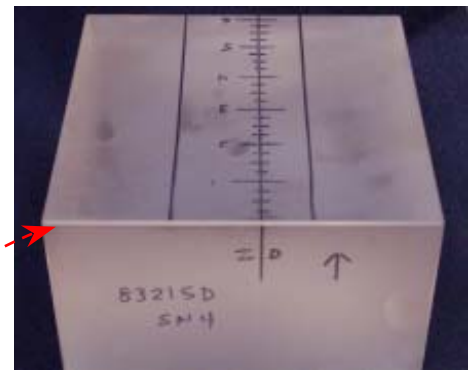
±0.4 ppb/K is large compared to targeted CTE range of less than 1 ppb/K

Requires two measurements… (*TOF, Thick*) *special in-house technique*

Sample Layout & Extraction



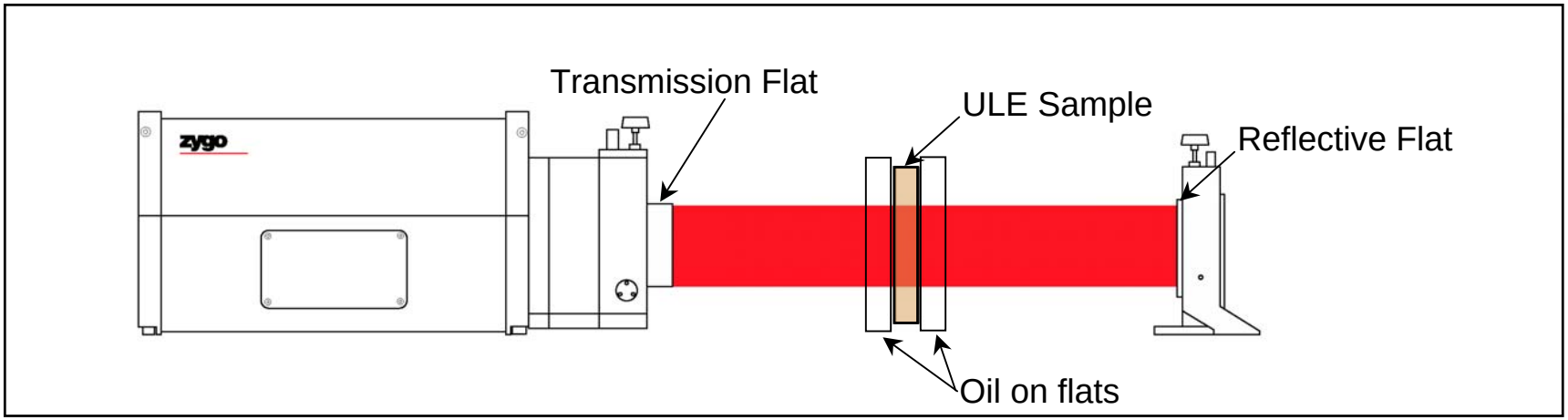




- Samples extracted (152mm x 152mm)
- Ground to thickness 100mm
- 15micron lap top & bottom surfaces

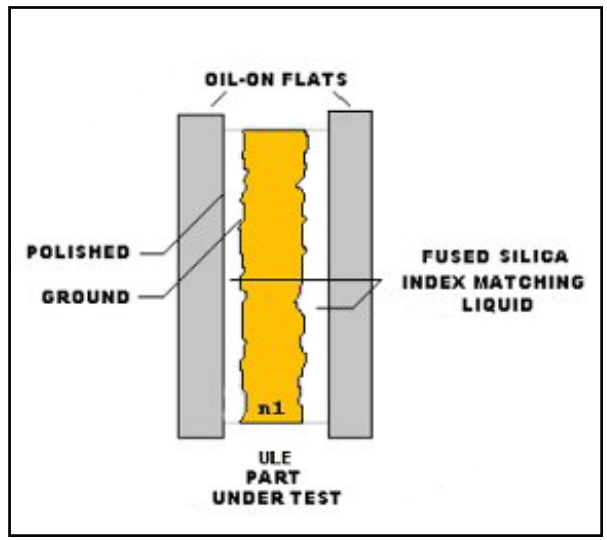
- Raw ULE boule is formed
- Ground top & bottom

Interferometric measurement setup

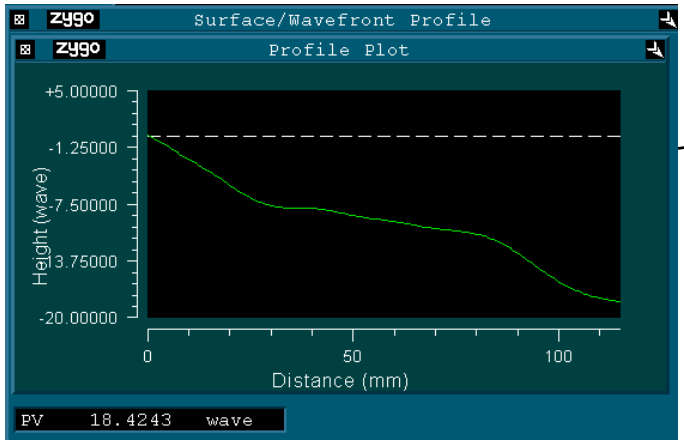


Test conditions & error sources:

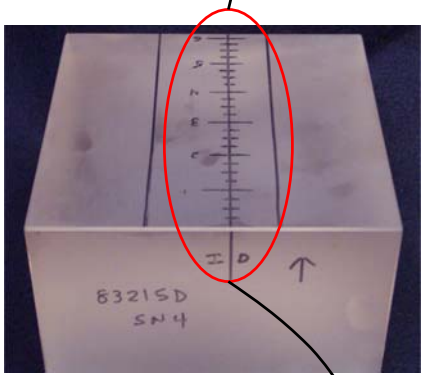
- Repeatability (<2 ppm)
- Temperature control: 22.5°C +/-0.1°C
  - Sample allowed to thermally stabilize
  - dn/dT ULE ~ 10.7 ppm/K result in <2 ppm
- Error from non-matching index oil
  - Flatness ~2.5 micron… *Measured*
    - <1 ppm on 100 mm thicknesses
    - <22 ppm error on 6.5 mm parts



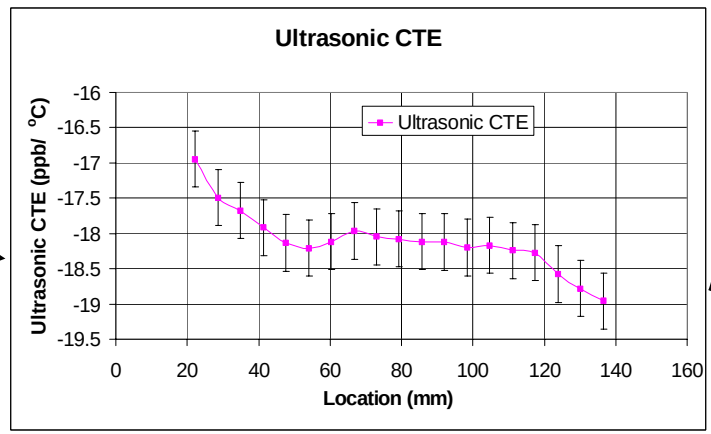
Correlation



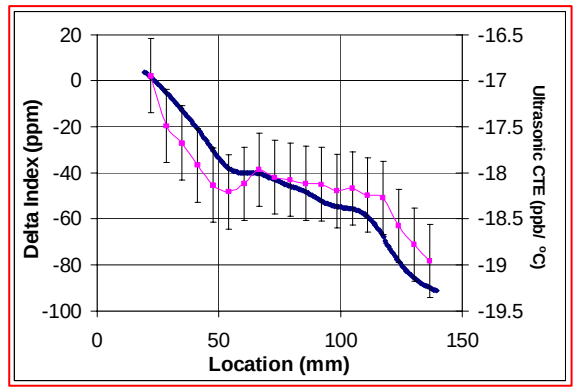
Profile Plot From Wavefront Map



Sample Measurement Location



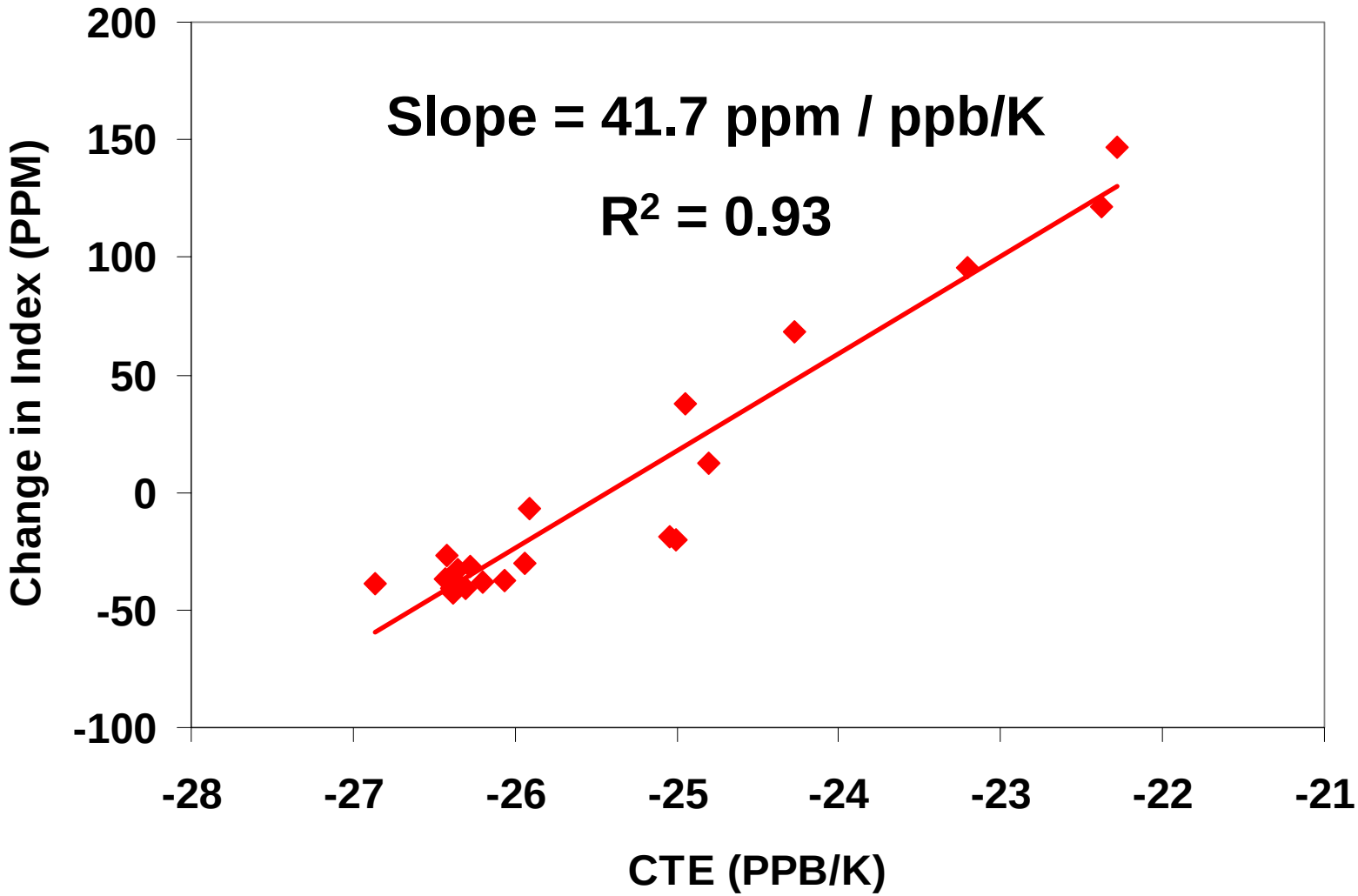
Ultrasonic Measurement Plot



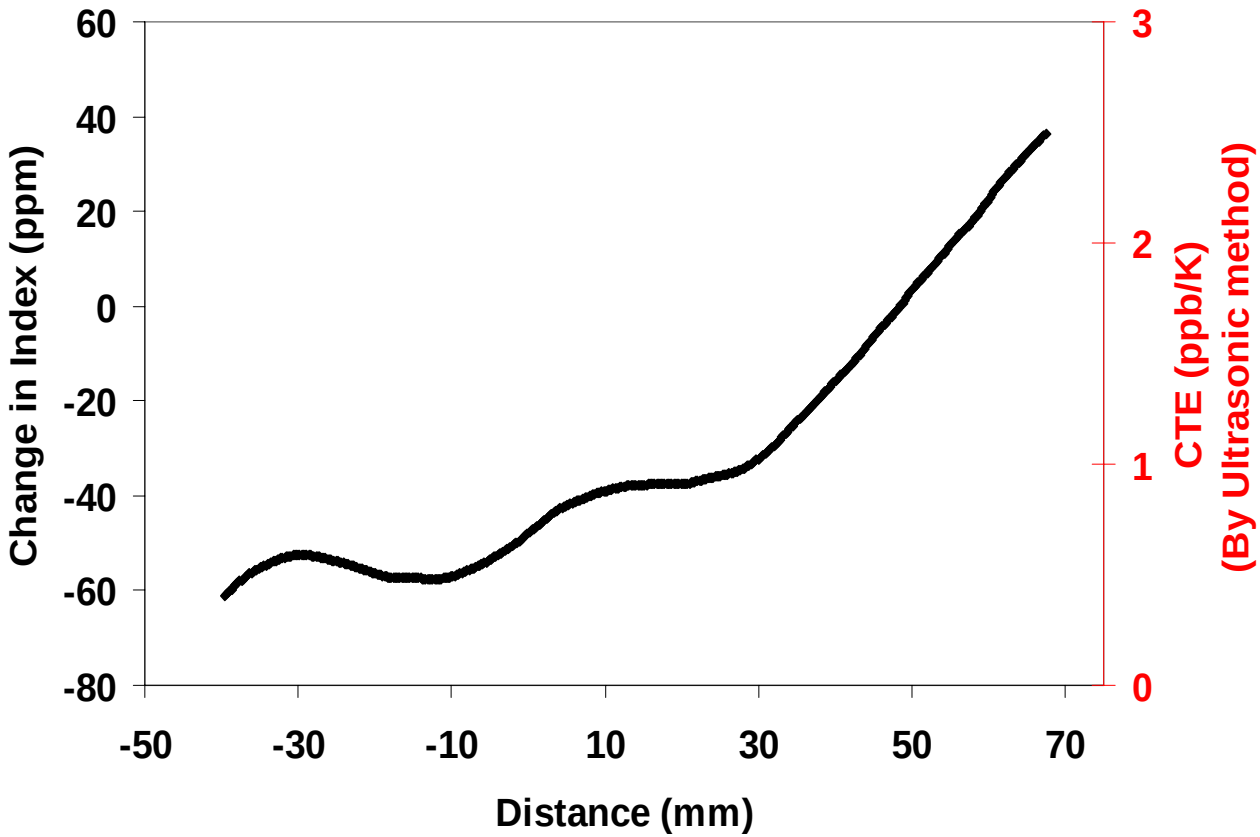
Comparison Plot

ΔIndex profile correlates to CTE profile

Correlation between Δindex and CTE



High Frequency CTE Variations??



Interferometry confirms no high frequency CTE changes in ULE Glass

Summary To Date…..

Sample	ΔCTE of 1 ppb/K = Δindex (ppm) of:	R^2	ΔCTE across part (ppb/K)	
1	42.3	0.90	3.6	
2	39.9	0.95	3.1	
3	49.2	0.91	2.9	
4	41.4	0.93	4.6	
5	41.1	0.92	2.4	
6	53.6	0.87	2.0	*New Data*
7	49.9	0.90	1.8	
8	61.3	0.83	1.6	
Average:	**47.3**	**0.90**	**2.8**	

Large Standard Deviation due to small ΔCTE

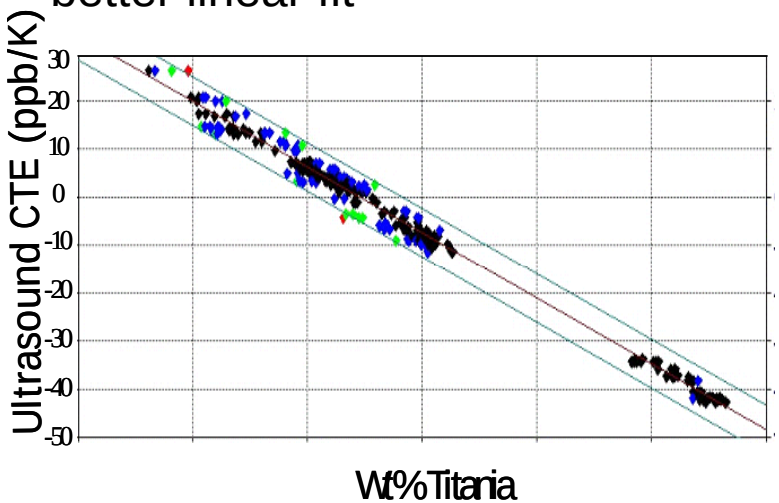
ΔIndex of 47.3 ± 7.6 ppm = ΔCTE of 1 ppb/K

- Review of Hrdina et al. SPIE 2003

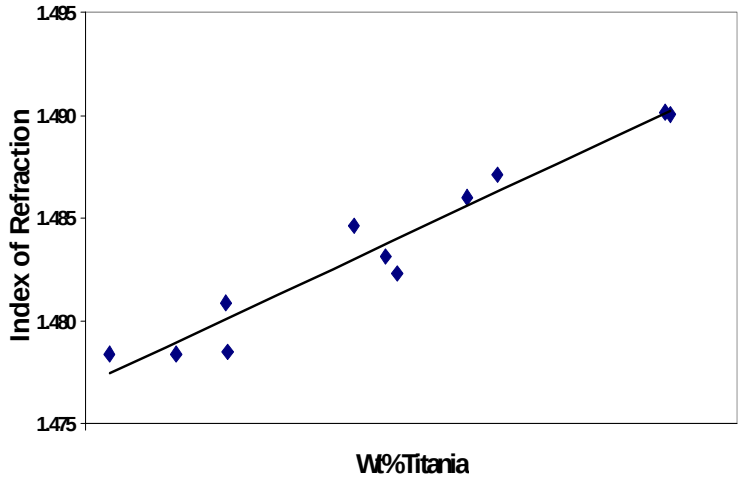
- **Current Work:**
  - **Correlate absolute CTE to Absolute Index of Refraction**
  - Continue to obtain data & refine correlation

Historical……..

- Based on historical data:
  - CTE decreases as %Titania increases
  - Refractive Index increases as %Titania increases,
  - Therefore - CTE will decrease as Refractive index increases
- Current work is to measure Refractive index & CTE measurements over several parts
- This will increase the plotted range, of Refractive Index vs. CTE, and build a better linear fit



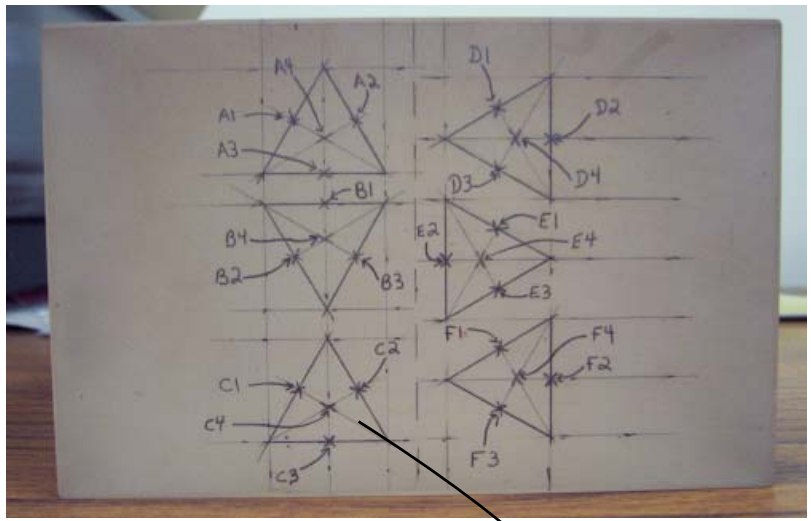
*Hrdina et al.; *SPIE March 2002*

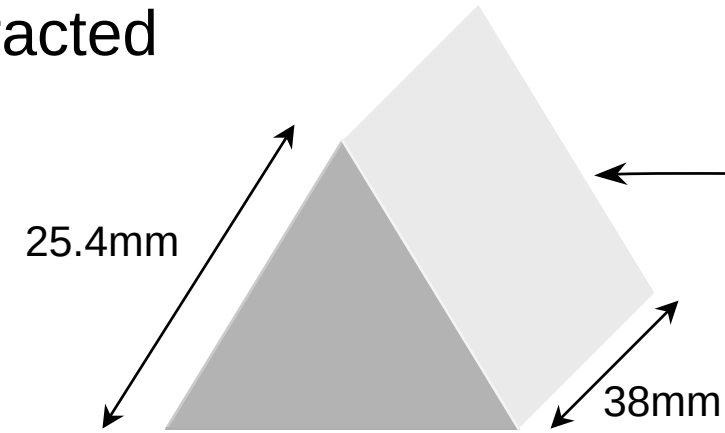


Schultz*; 1968 (Corning Internal data).*

Sample Extraction

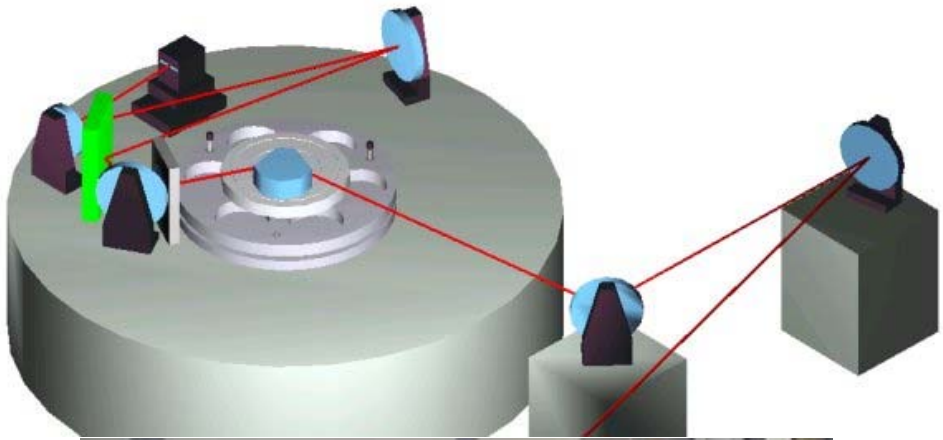
- Ultrasonic measurements obtained in bulk form, prior to prism extraction
- Samples were extracted w/ different orientations to the Striae
- Prisms extracted





Angle of Minimum Deviation Measurement Setup

- Accurately measure the actual prism angle
- Accurately measure the angle of minimum deviation
- Calculate the Absolute Refractive Index (ARI) of the sample



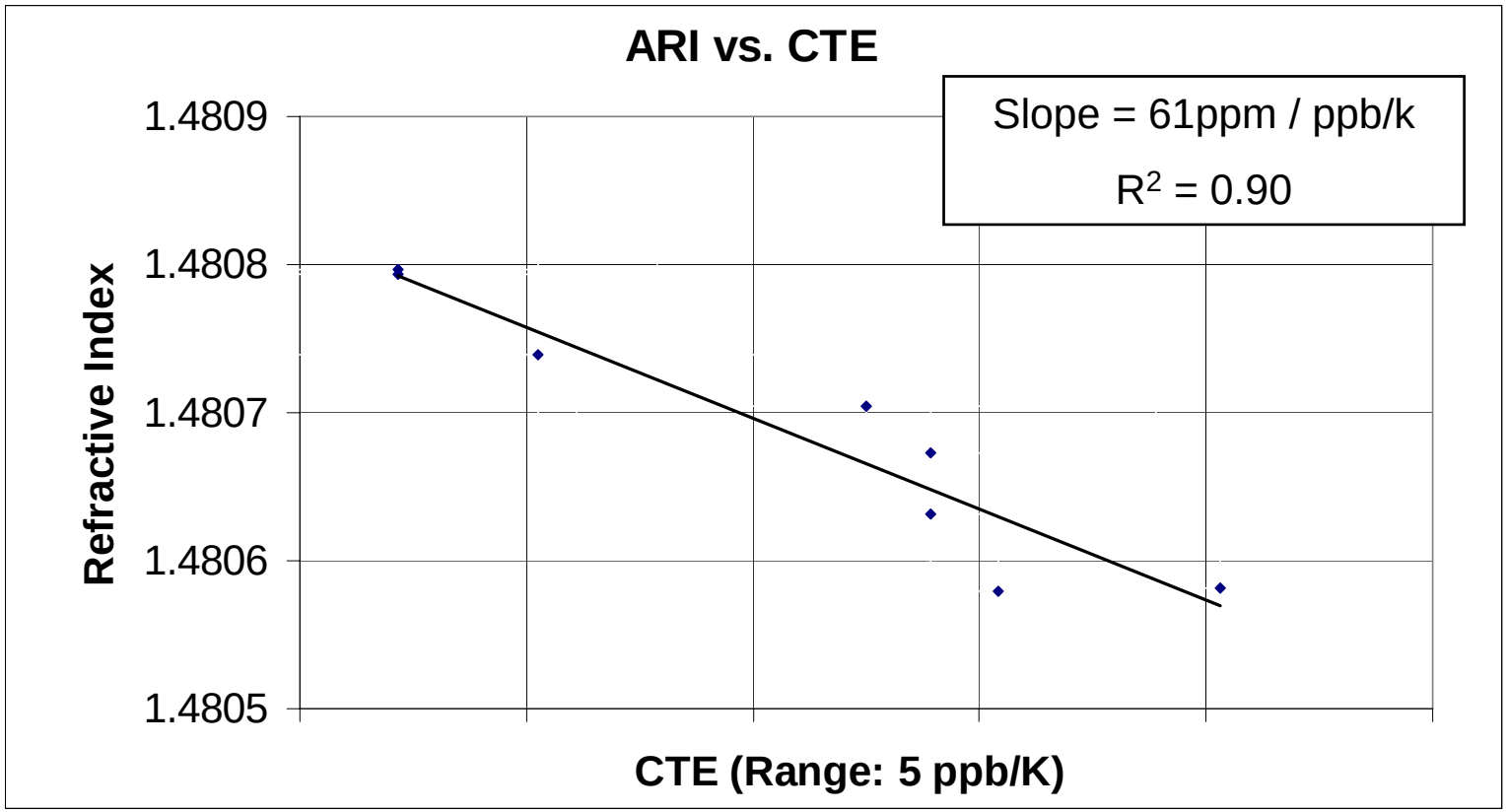
Measurements performed at Corning Tropel

ARI Measurement

- Calculations take into consideration:
  - Atmospheric Pressure
  - Humidity
  - Temperature
- Data is normalized to 22°C dry air
- Measured at 632.8nm wavelength
- Equipment accuracy 3ppm
- Striae effected sample measurements in one direction

Results

- Initial data set shows promising results

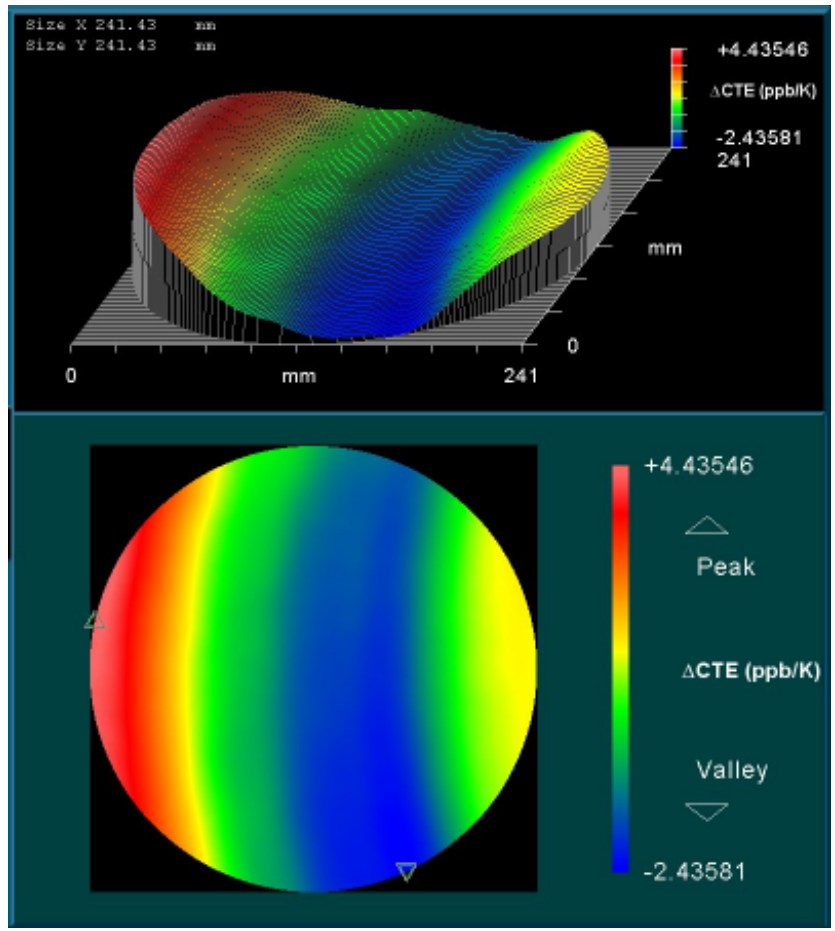


- Review of Hrdina et al. SPIE 2003

- **Current Work:**
  - Correlate absolute CTE to Absolute Index of Refraction
  - **Continue to obtain data & refine correlation**

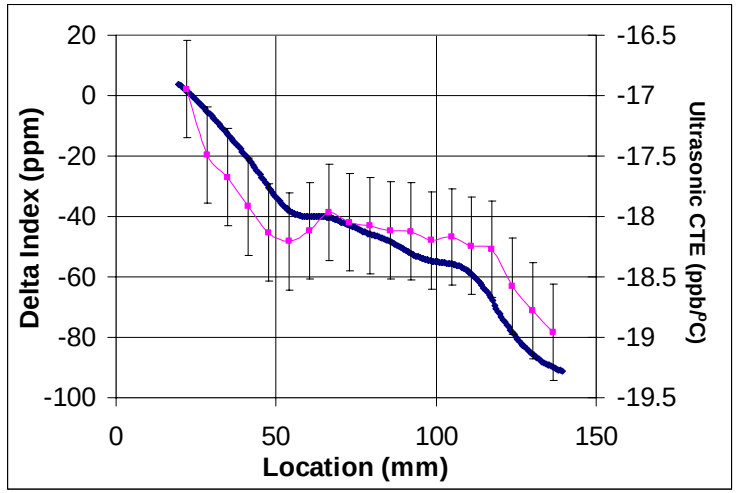
Measuring parts

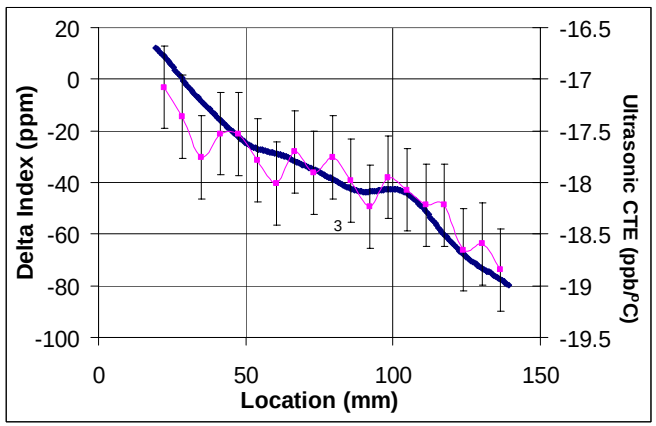
- Build confidence in correlation
- Characterize material
- Example:
  - 250mm dia. x 51.5mm thick
  - ΔCTE: < 7 ppb/k

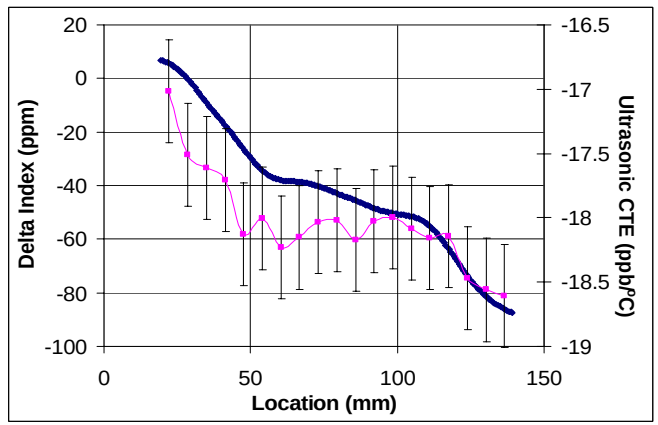


Index Homogeneity vs Ultrasonic CTE

- Recent Measurements
- Continue to find good correlation

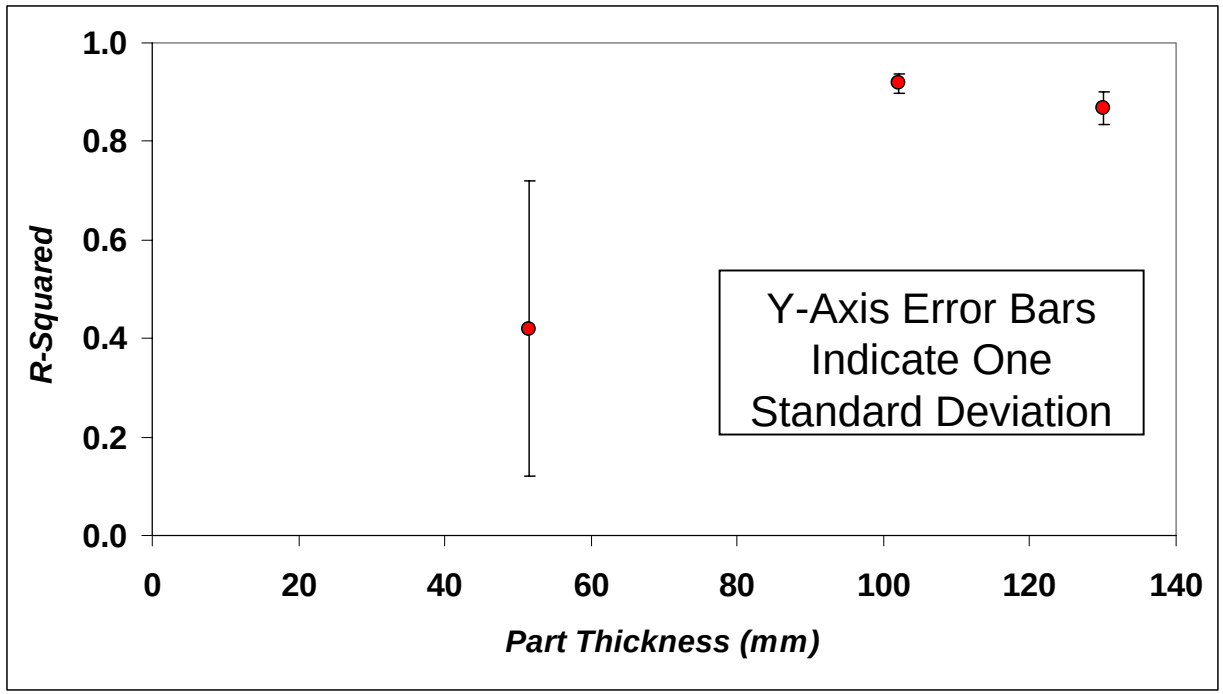






Part thickness and measurement accuracy

- Ultrasonic accuracy decreases for thickness less than 100mm (this is known)
- The plotted R^2 values confirm this
- Interferometry offers reliable measurement for thin parts once correlation is finalized



Future Work

- Absolute Refractive Index Measurements
  - ARI measurements of ULE samples with different CTE values (samples in process)
  - Refine and reduce uncertainty of Refractive Index vs. CTE relationship based on the ARI data
  - Measure reduced Striae material
- Interferometric Measurements
  - Continue to perfect interferometric measurement technique
  - Measure reduced Striae material

Summary

- Continue find good correlation between ΔIndex & ΔCTE
- Initial ARI results show correlation as well

CORNING

Discovering Beyond Imagination