



# Implementing VIBE™ to Polish Ceramic Materials and Tangent Ogives

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NASA Mirror Technology Days

VIBE is a trademark of Optimax Systems, Inc.



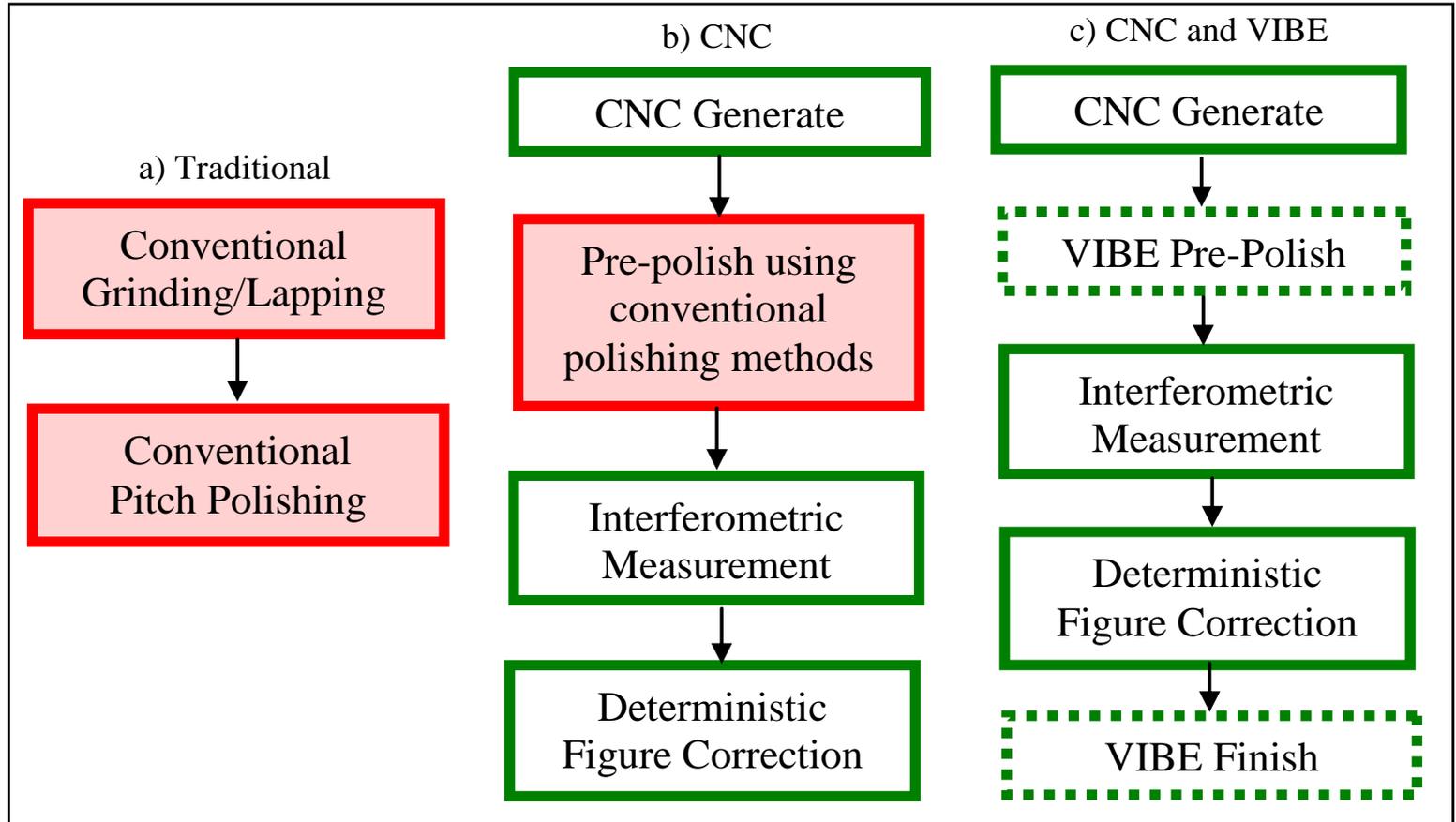
# Outline

- Introduction
  - VIBE technology
  - Hard ceramic materials
- Efficient material removal with VIBE
  - Compare VIBE polishing to conventional polishing CeraLumina™ PCA
  - VIBE polishing of hard ceramic materials
  - VIBE lapping
- Spherical CeraLumina PCA Concentric Dome
- Aerodynamic Infrared Dome

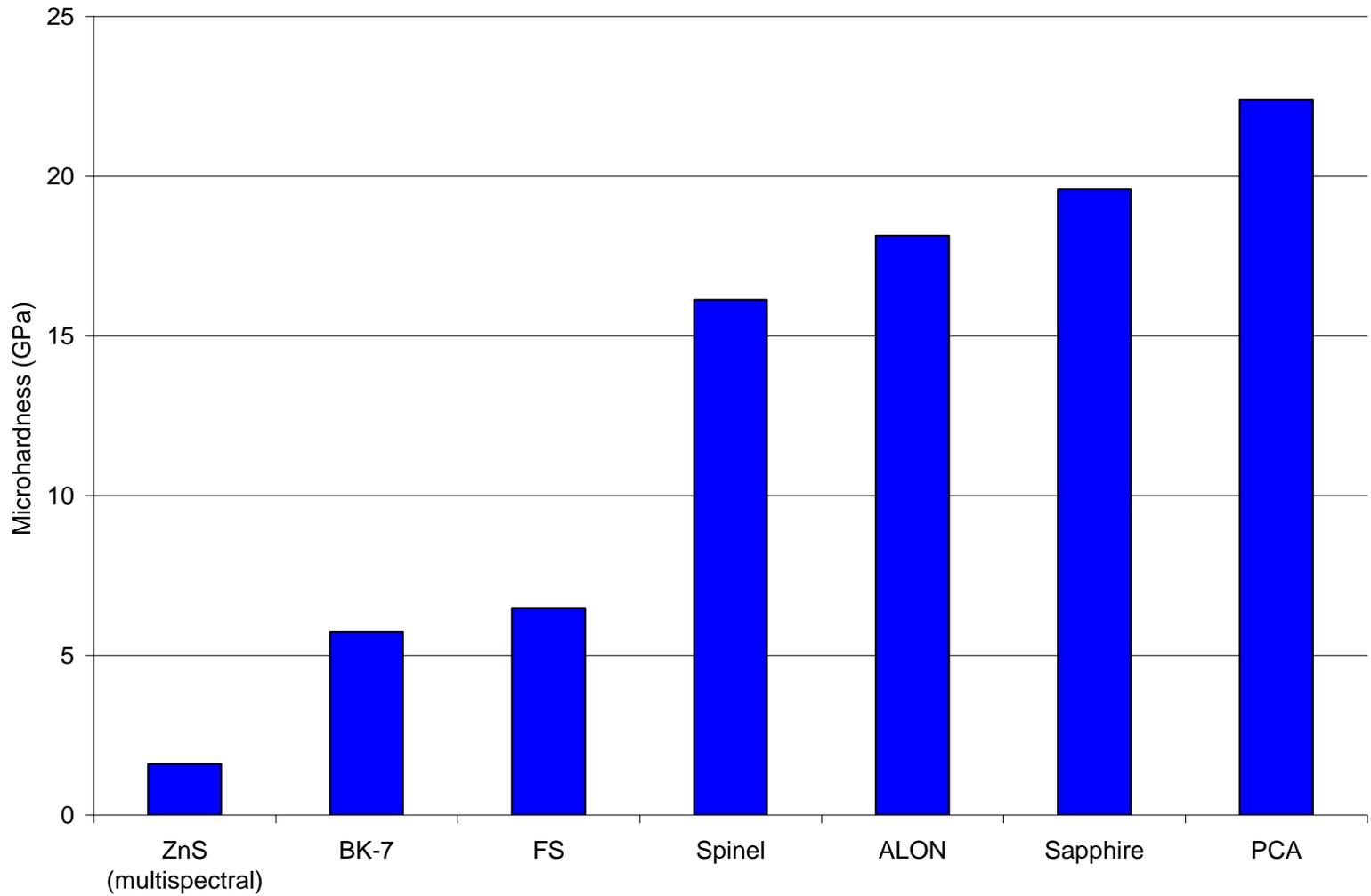
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# Introduction of VIBE into today's CNC manufacturing process



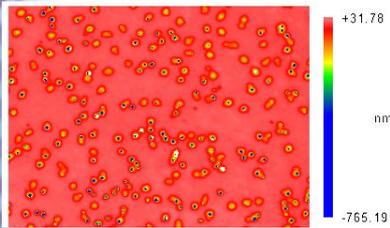
# Comparison of mechanical properties of several IR materials



# Outline

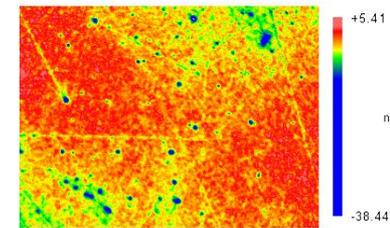
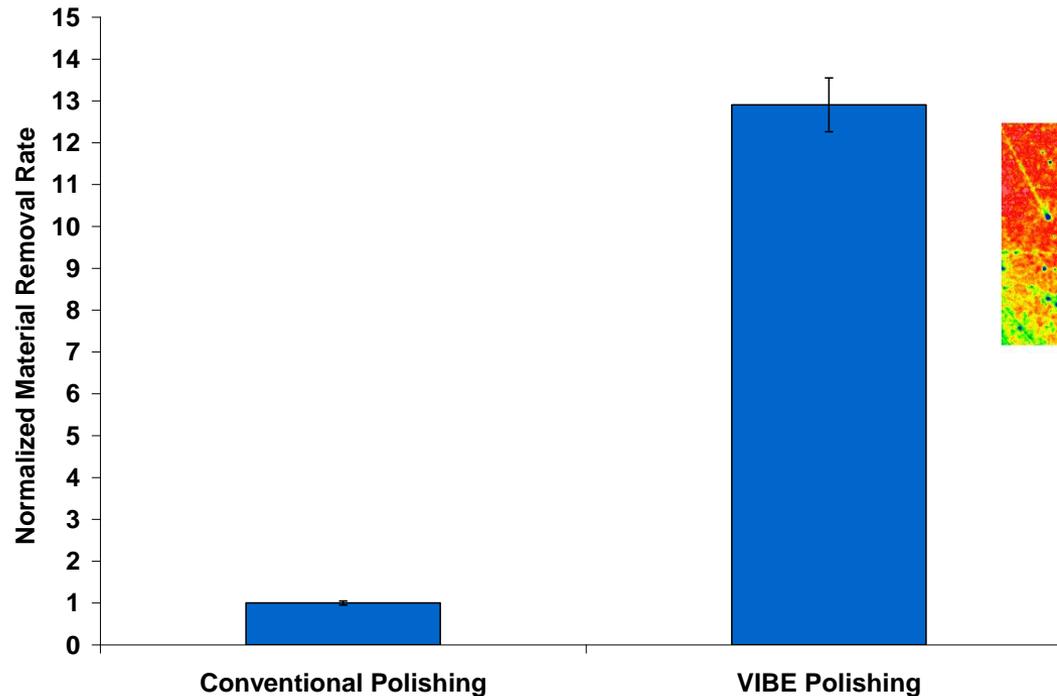
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# VIBE polishes PCA 13x faster than conventional polishing



**Conv. polished PCA  
Surface roughness**

**RMS = 48.0nm**

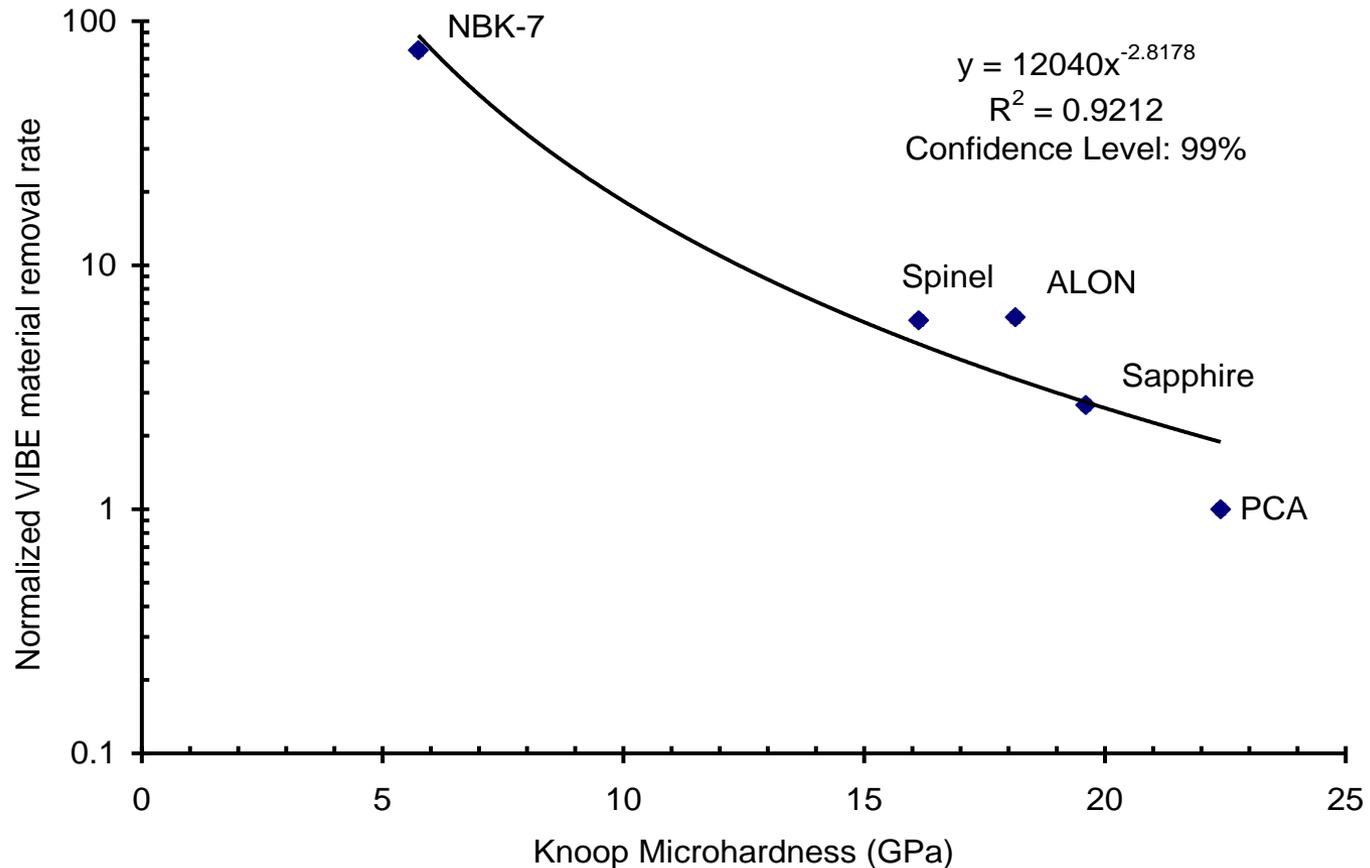


**VIBE polished PCA  
Surface roughness**

**RMS = 1.9nm**

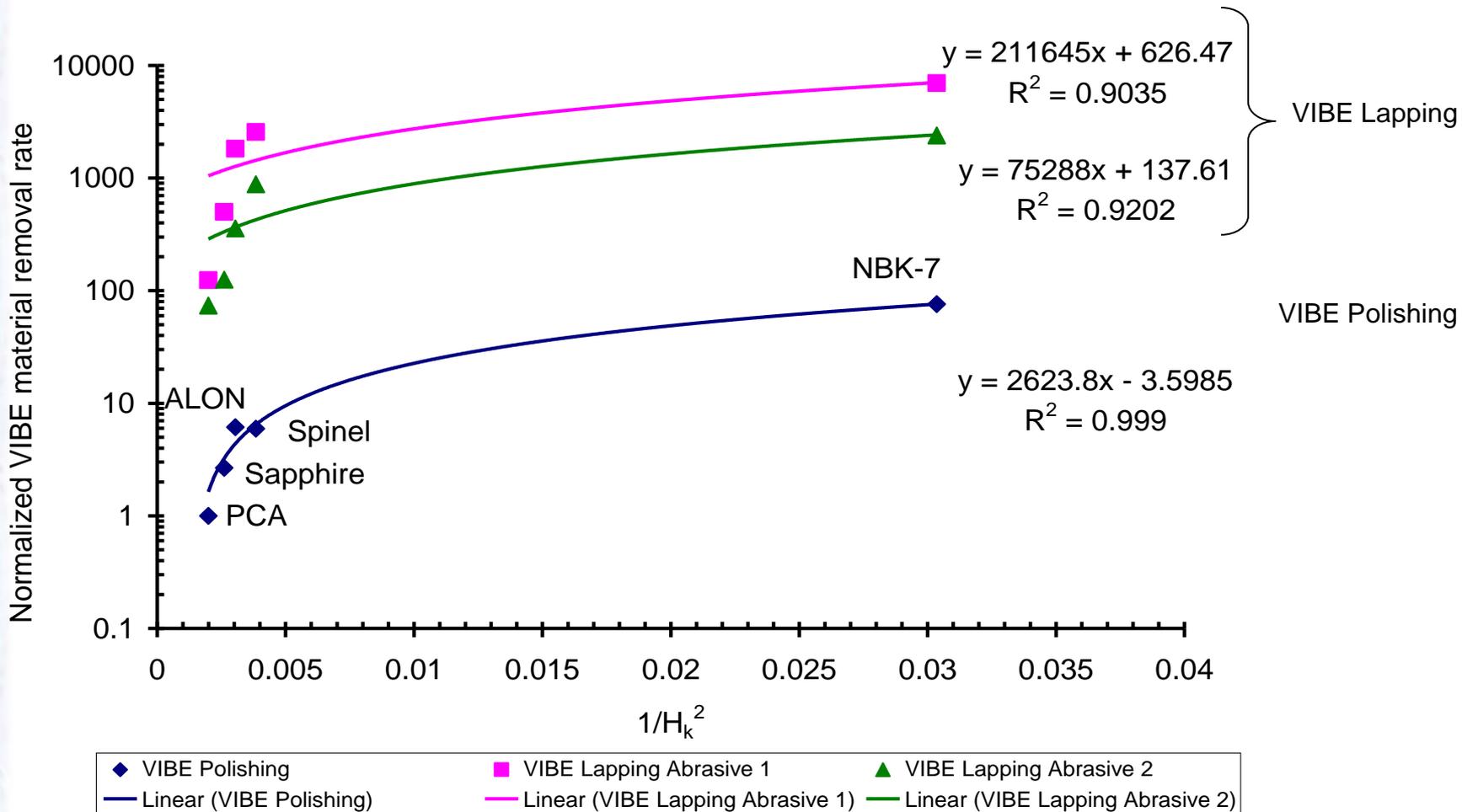
- Material removal rate comparisons made with identical polishing slurries

As expected, VIBE polishing material removal rates increase with decreasing material hardness



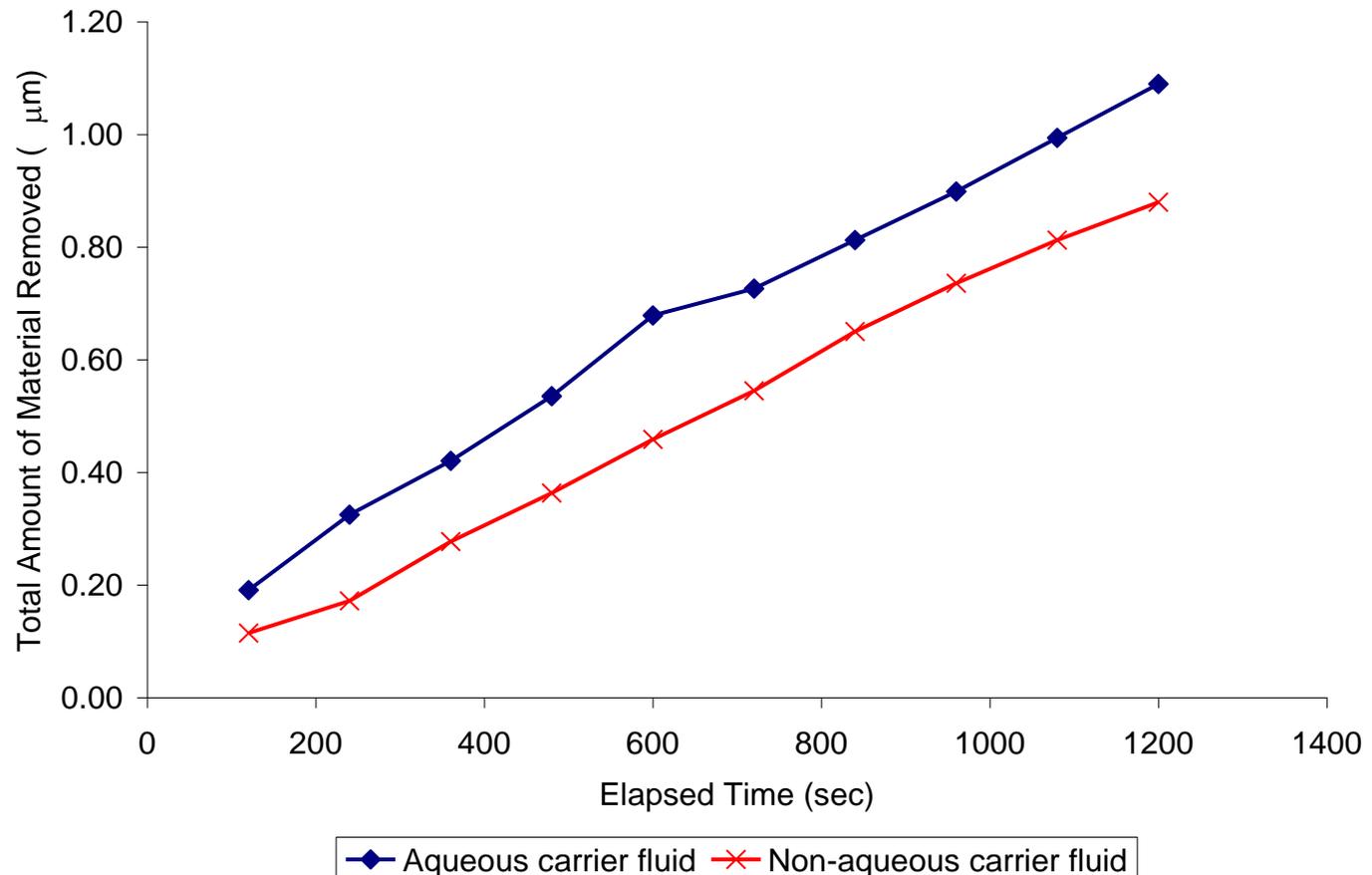
- Relationship similar to Lambropoulos et al. correlation between conventional lapping rates and mechanical material properties  $[E/K_c H_k^2]$

# VIBE lapping has similar correlation with material hardness



- Correlations include polycrystalline materials, single crystalline materials and amorphous glass.
  - Large gap between Spinel and NBK-7 data point – more research is needed

# Although, VIBE removal mechanism is also dependent on carrier fluid chemistry



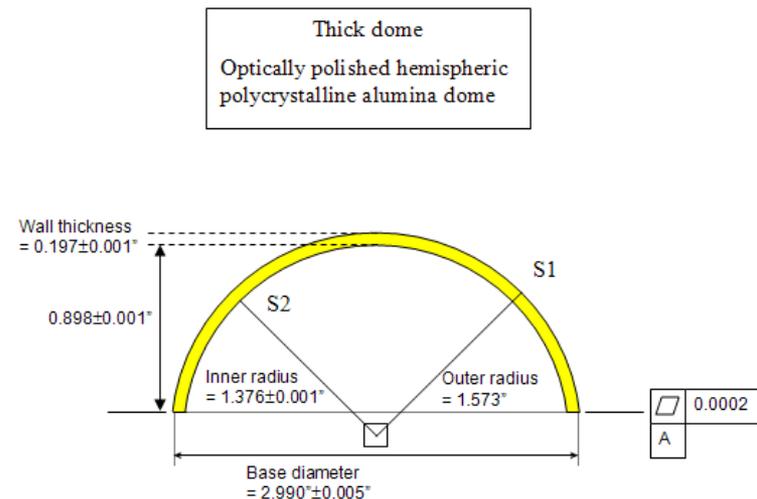
- VIBE lapping experiment with PCA showed 20% higher removal rates by adjusting the carrier fluid chemistry

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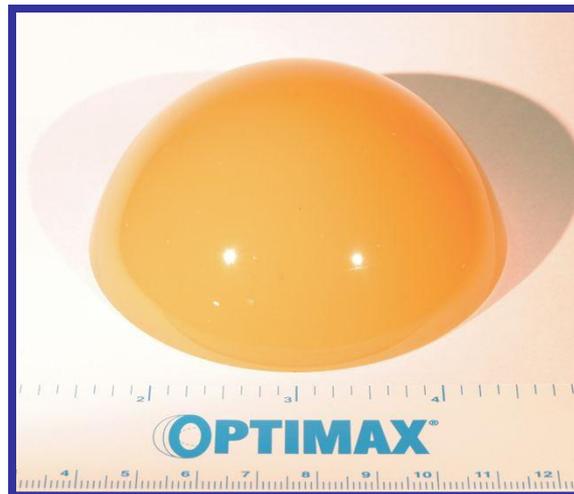
# Spherical Dome Specifications

- **Convex**
  - Radius = 39.95mm
  - Irregularity = 2 fringes over 25.4mm
- **Concave**
  - Radius = 34.95 +/- 0.025mm
  - Irregularity = 2 fringes over 25.4mm
- **Overall**
  - Concentricity
    - Less than 0.025mm
  - CT = 5.001 +/- 5.026 mm
  - Cosmetics: Scratch/Dig less than 80/50
- **Material**
  - CeraLumina PCA



# Optimax's first attempt to finish PCA spherical dome

- Timeline
  - December 8<sup>th</sup> 2009
    - Started generation, created dome to near net shape
  - December 15<sup>th</sup> 2009
    - Sent dome to CeraNova for annealing
  - December 22<sup>nd</sup> 2009
    - Started processing annealed near net shape dome
  - January 8<sup>th</sup> 2010
    - Completed 1<sup>st</sup> CeraLumina Dome in 11 working days!



# Optimax's first attempt to finish PCA spherical dome

- **Convex**
  - Radius = 39.953mm (in tolerance)
  - Irregularity = 0.771 fringes over 25.4mm (in tolerance)
- **Concave**
  - Radius = 35.000mm (in tolerance)
  - Irregularity = 0.316mm over 25.4mm (in tolerance)
- **Overall**
  - Concentricity
    - **Less than 4 microns! (In tolerance)**
    - Measured mechanically on center and four places on the edge
  - CT = 4.959mm (17 $\mu$ m thin)
  - Cosmetics: Scratch/Dig less than 60/40 (in tolerance)

# Optimax polished PCA spherical domes

Yield: 3 for 3

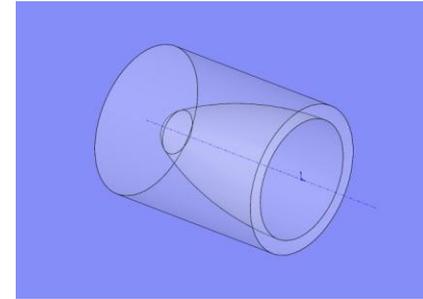


# Outline

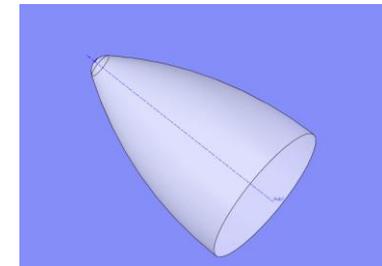
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# VIBE polishing tangent ogives

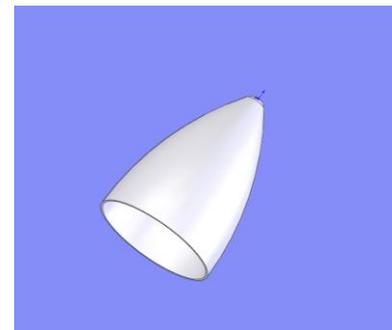
- Concave ogive VIBE polishing
  - Complete



- Convex ogive VIBE polishing
  - Platform currently under construction



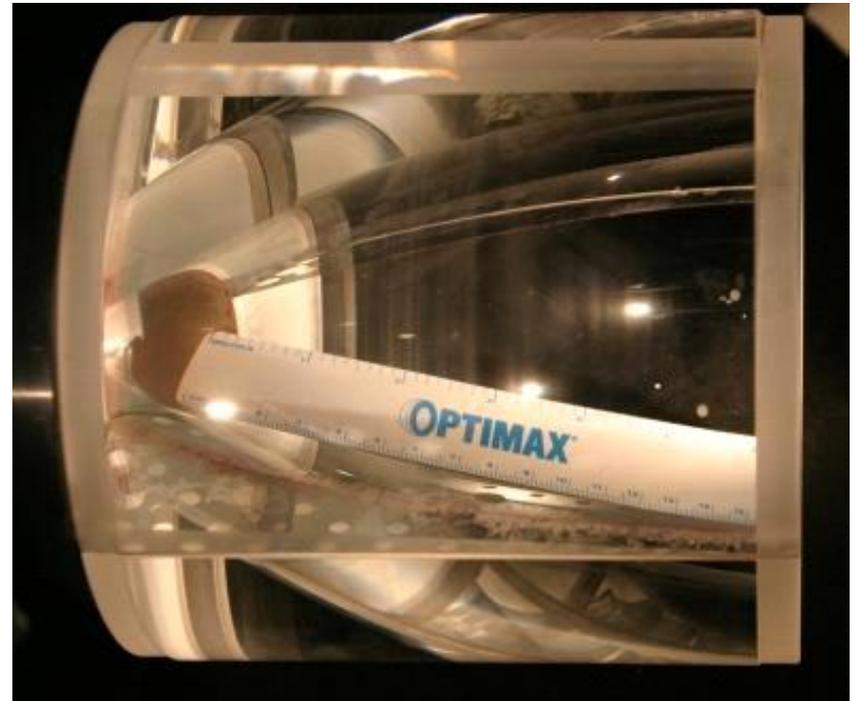
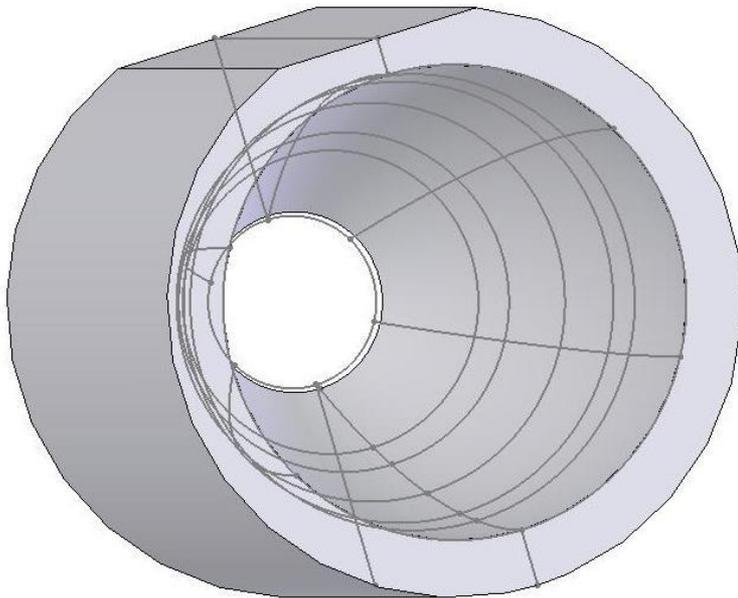
- VIBE polish “thicker” N-BK7 ogive
  - Estimated completion Q1 2011



- VIBE polish PCA ogive

# VIBE polishing tangent ogive: concave

- Material: NBK-7
- Finished surface was within  $5\mu\text{m}$  of nominal curve



# Conclusion and Future work

- VIBE is an order of magnitude faster than conventional polishing methods for hard ceramic materials
  - Successfully polished three PCA spherical domes
    - less than two microns concentricity
  - Successfully demonstrated VIBE polishing concave tangent ogive
- 
- Additional work to completely understand VIBE removal mechanism
  - Completion of VIBE platform to polish convex portion of tangent ogive
  - Expectation: completed successful completion of PCA tangent ogive by Q3 2011

# Acknowledgements

- Mark Parish – CeraNova Corporation
- Dan Ficarro
- James Bardo
- John Gardner
  
- Navy SBIR program for funding this work

# Implementing VIBE™ to Polish Ceramic Materials and Tangent Ogives

Optimax Systems, Inc.  
Ontario, NY

## INNOVATION

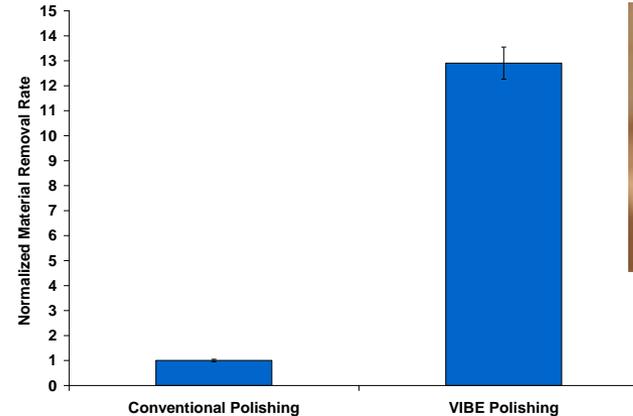
The Optimax VIBE process is a full-aperture, high speed, conformal polishing process incorporating high frequency and random motion to *create material high removal rates* on hard ceramic, glass and crystalline materials.

## ACCOMPLISHMENTS

- ◆ Currently in year 1 of Phase II SBIR – Prototype Stage
- ◆ We have demonstrated VIBE has 10 – 30x higher removal rates than conventional polishing
- ◆ We have successfully demonstrated VIBE polishing the concave portion of an ogive
- ◆ We were able to produce three for three PCA concentric spherical domes

## COMMERCIALIZATION

- ◆ Optimax VIBE™ Technology
- ◆ U.S Patent Number 6942554 B1
- ◆ Primary target applications: Optical imaging systems using hard optical ceramic and crystalline materials
- ◆ Optimax currently provides high precision optics to the aerospace, defense, medical and imaging markets, VIBE technology will enhance our capabilities
- ◆ Current customers are designing using softer materials due to high cost and long processing times associated with hard ceramic materials
- ◆ VIBE pre-polishing can also be utilized for any optical material to reduce the processing time associated with pre-polishing before final sub-aperture deterministic finishing processes



*Sub-aperture polished surface before and after VIBE finishing*

## GOVERNMENT/SCIENCE APPLICATIONS

- ◆ Hard optical ceramic material applications
  - ◆ Infrared aerodynamic domes
  - ◆ Hemispherical and Spherical concentric domes
  - ◆ Transparent Armor
  - ◆ Conformal IR windows
  - ◆ Infrared Lenses
- ◆ Cost effective polishing solution
  - ◆ VIBE can be introduced to reduce cost by reducing manufacturing time
- ◆ Optical glass, crystal and polycrystalline applications

# Optimax polished PCA spherical domes

Yield: 3 for 3

