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Core Optics
Sapphire Development

GariLynn Billingsley
Caltech seminar

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Introduction to Sapphire

- Advanced LIGO baseline Test Mass – Sapphire
  - » Greater Astronomical reach
    - – Thermal characteristics
    - – Mechanical properties
  - » Large, optical quality sapphire is not yet an “off the shelf” item

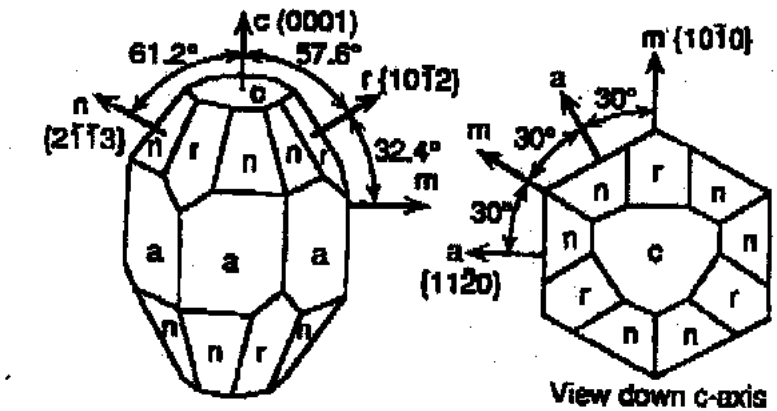

Figure 1. Sapphire (α-Al_2O_3) crystal showing mineralogical and Miller index notation.

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Material Production

- Five experimental growth runs Crystal Systems
  - » Two of five 15” boules are considered good optical quality
  - » Two of five are not
  - » LIGO has bought one “good” and one “not” to test for use as transmissive and non-transmissive test masses
    - – Plan to measure absorption, scatter, homogeneity, Q
  - » CSI is moving on to concentrate on 20” boules
- Shanghai Institute of Optics and Fine Mechanics
  - » Furnace is in place
  - » No large pieces yet
- Rubicon
  - » Just received 150 mm piece for optical testing, and 10 cubes for absorption tests

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Polishing Surface One

- CSIRO and Wave Precision have good results
  - » Microroughness to ~ 1Å
  - » CSIRO better figure (better metrology)

More at http://www.ligo.caltech.edu/~gari/sysmtg.html

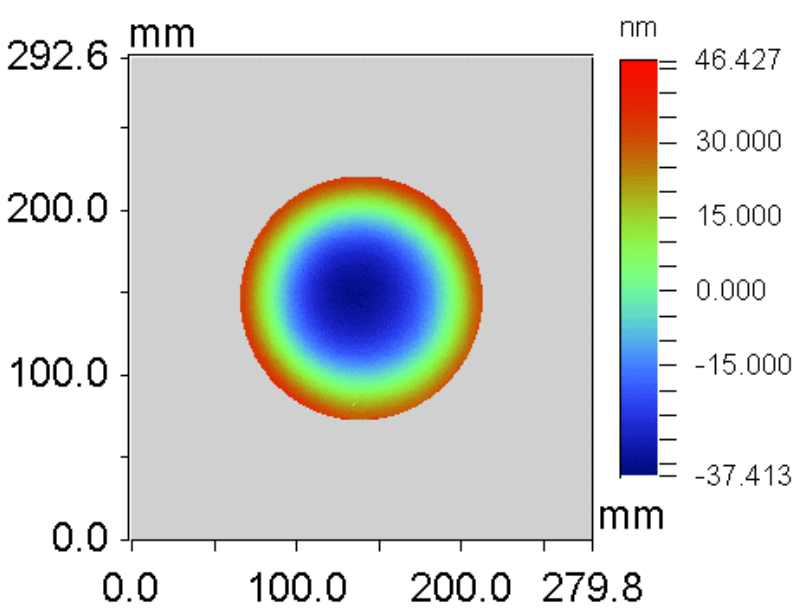
LADI CERTIFICATION DATA

Title: Sapphire A side 1 CSIRO

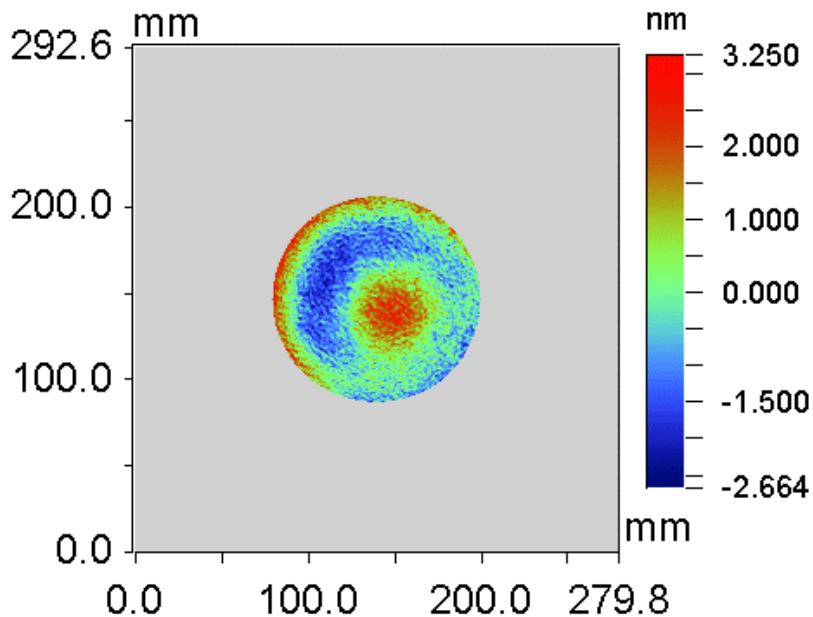
Date: 04/06/01 Astig: 1.8 nm PV: 5.9 nm

Diameter: 120 mm Power: 47.1 nm RMS: 1.0 nm

Tilt Removed

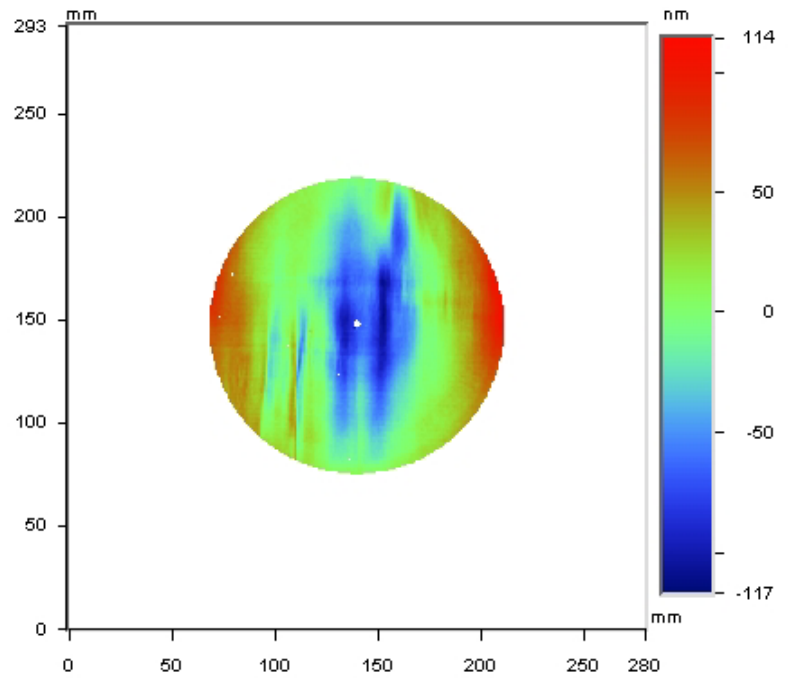


Tilt/Power/Astig Removed



Homogeneity

- Can't get c-axis in sizes 314 mm x 130 mm
- The problem with m- and a-axis sapphire…



Date: 08/11/2000
Time: 14:23:44
Wavelength: 690.700 nm
Pupil: 100.0 %
PV: 231.4251 nm
RMS: 41.4312 nm

X Center: 280.00
Y Center: 280.00
Radius: 143.43 pix
Terms: Tilt
Filters: None
Masks:

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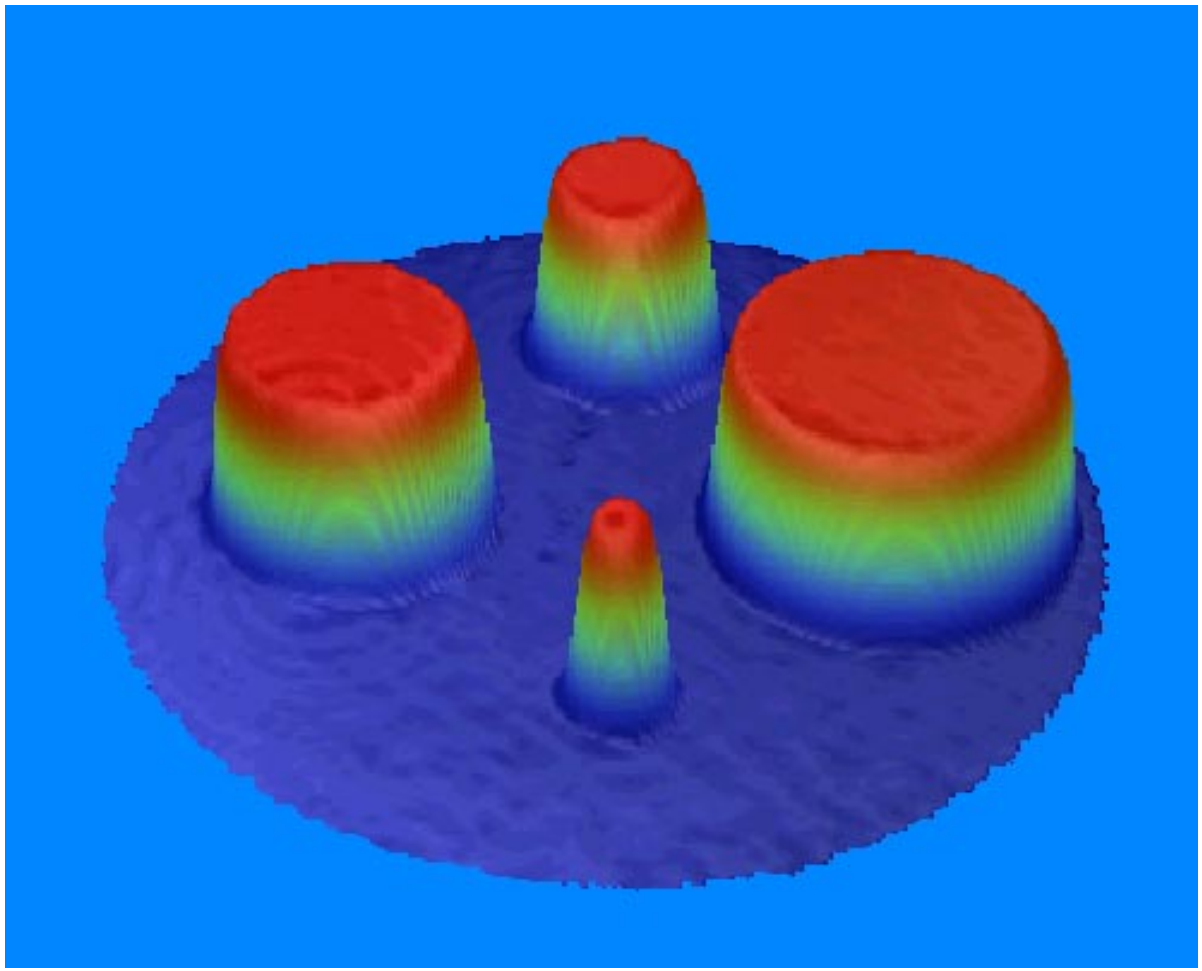
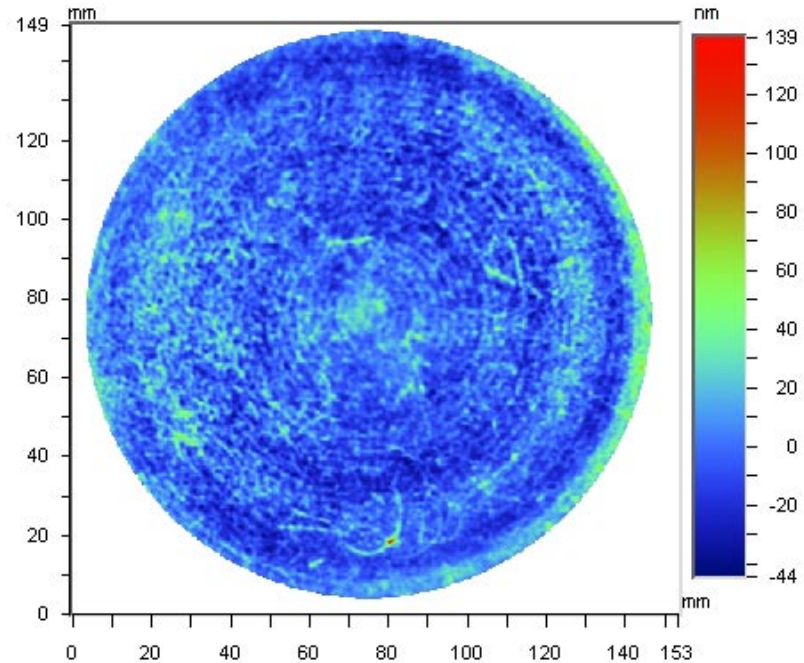
Homogeneity Compensation

- Compensation studies
  - » CSIRO
    - – Fluid jet polishing
    - – Compensating coating deposition
    - – Ion beam etch
  - » Goodrich (formerly Perkin Elmer, HDOS, Raytheon)
    - – Computer controlled polishing

Ion beam etch wins most sexy approach



Compensating Polish by Goodrich wins most mature approach



Date: 04/16/2002
Time: 14:37:03
Wavelength: 1.064 um
Pupil: 100.0 %
PV: 183.6397 nm
RMS: 14.6141 nm

X Center: 282.00
Y Center: 243.00
Radius: 269.89 pix
Terms: Tilt
Filters: None
Masks: Detector Mask

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Absorption

- Absorption is studied at Stanford – Route, Fejer
  - » 10 ppm/cm required in order to throw out active thermal compensation
  - » Typically 50 ppm/cm in large samples as received
  - » Isolated observations at 10 ppm/cm, existence proof
  - » Annealing Studies have produced 20 – 30 ppm/cm to date
- Response – Active thermal compensation
  - » Ryan Lawrence Thesis at MIT
  - » Dave Ottaway taking over for Ryan Lawrence at MIT
  - » Full cavity experiment at Gin Gin, Western Australia
- Measure profile in full size boule at Lyon 3-03
  - » Ring heater or scanned laser approach depends on these results

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Sapphire Q

- Phil Willems has begun measurement of full size pieces
  - » 314 mm x 130 mm boules measured Q ~ 2×10^8
    - – For a mode with no motion at the barrel

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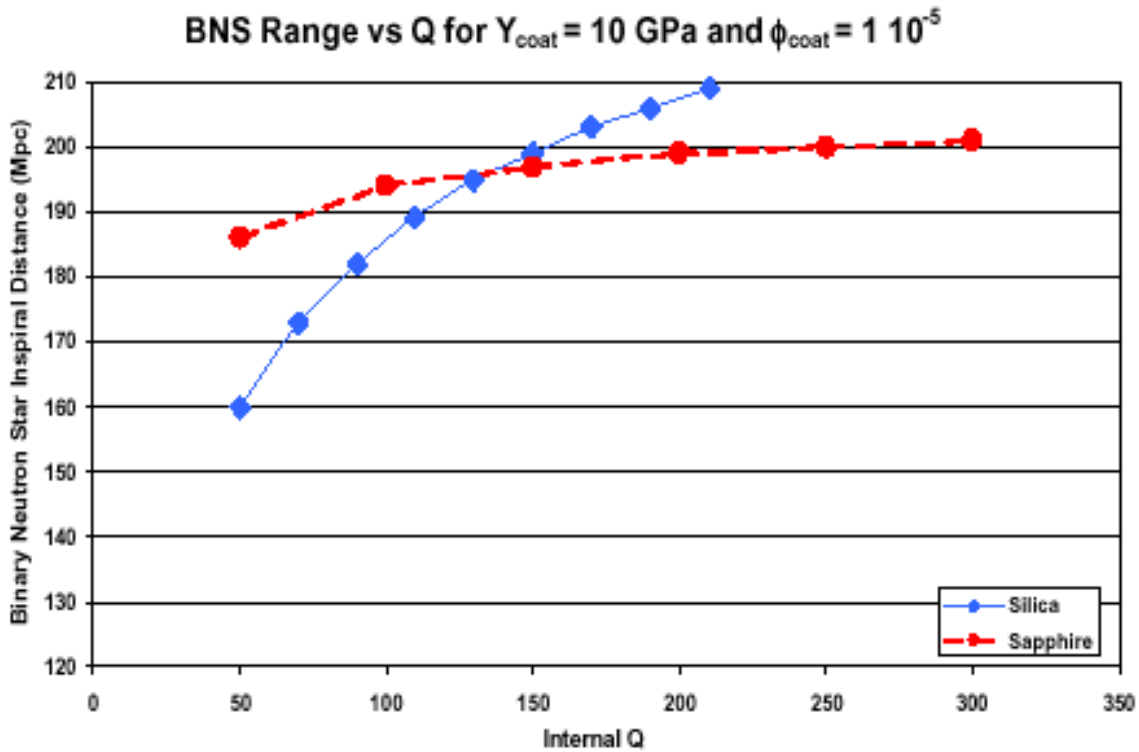
Fused silica-not out of the running

- Higher Q in FS – performance ~ as good as that of sapphire
  - » Best choice depends on coating
  - » Highest modal Q of a fused silica sample observed to date is approximately 200 million, observed at Syracuse
  - » Annealing studies needed



Modeled using Bench – G. Harry T030007

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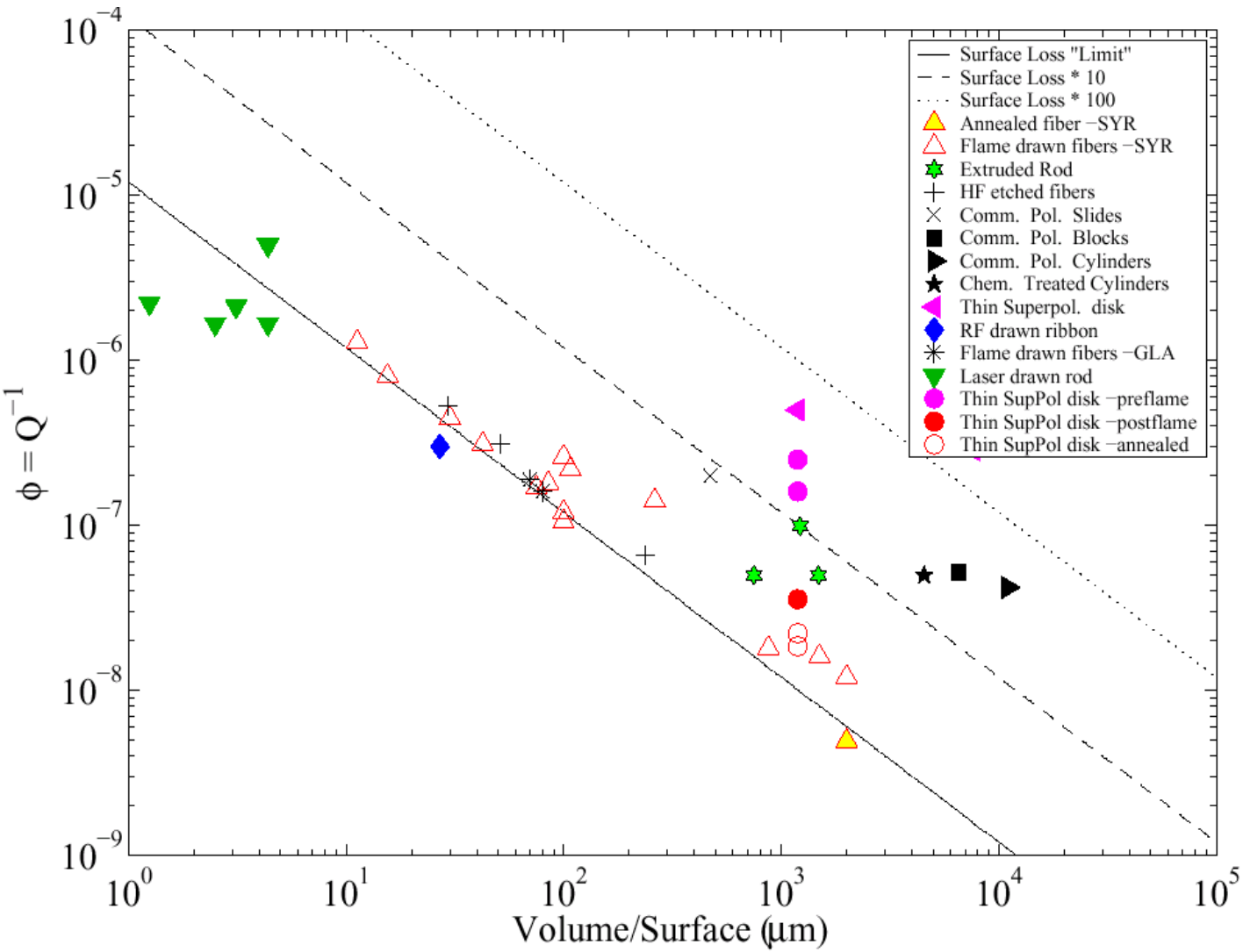
-Steve Penn-

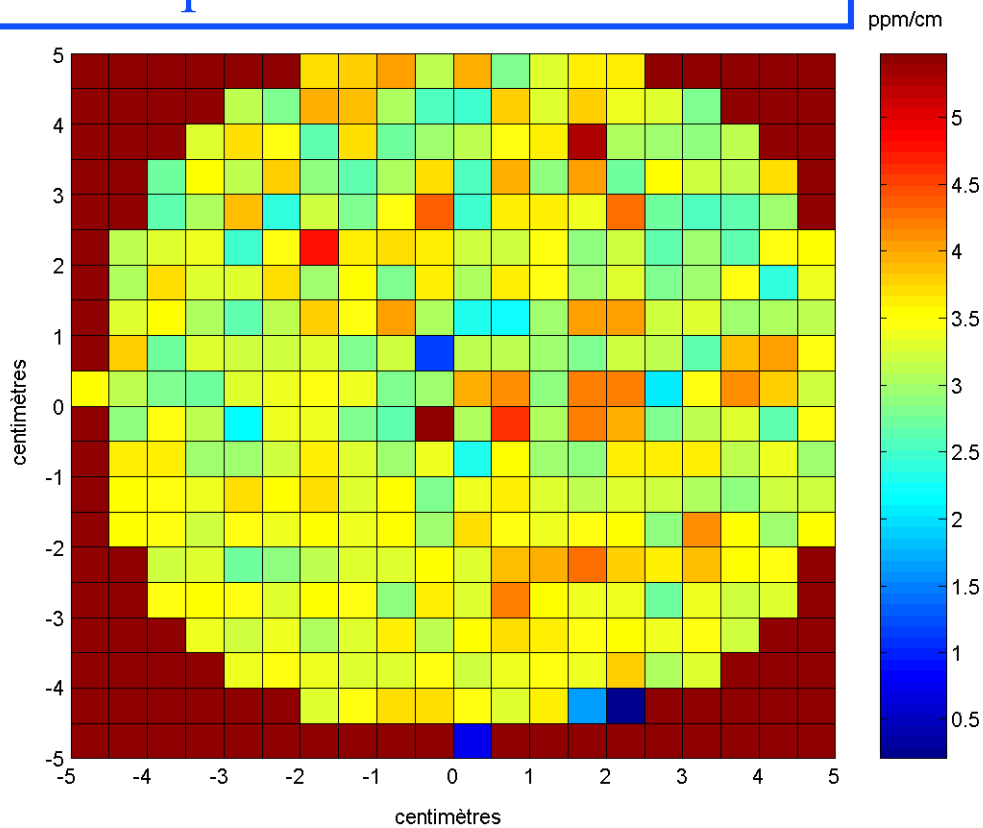
Surface loss limited Q for full size FS ~ 4×10^9

presume the bulk loss will dominate at some point



Measurements on fused silica

Bulk absorption map. Φ 300 mm Heraeus Substrate



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Challenges

- Scatter, Absorption in large sapphire is unknown
  - » Testing February-June
  - » Rigorous calculation of acceptable Recycling Cavity loss
- New FS Q data opens up a new line of inquiry
  - » Annealing studies
  - » Surface studies
- High thermoelastic noise in sapphire is reduced with a large beam footprint (D'Ambrosio et al)
  - » Providing good polish is obtainable to edge of large optics
  - » Investigate control of such a cavity – benchtop?

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Schedule Milestones

- Delivery of first two large sapphire substrates Feb ‘03
- Measurement of first two large sapphire substrates
  - Q, Phil Willems, CIT – In process
  - Absorption map, SMA Lyon
  - Scatter map, SMA Lyon or CIT (instrument being built at CIT)
  - Homogeneity, CIT
- Material down-select – July ’03
- Install LASTI test masses – October ‘04