

Technical Note: Homogeneity of Sapphire a vs. m axis.
GariLynn Billingsley 8-20-03

LIGO T030177-00-D

Background: Only a, or m-axis sapphire is available in sizes suitable for Advanced LIGO. M-axis was rumored to be easier to polish, but sub-angstrom microroughness has been demonstrated on both a and m surfaces.

After LIGO research encountered the first images of sapphire inhomogeneity in m-axis material (LIGO-P010014), there were rumors that there was no inhomogeneity seen in a-axis material. A-axis material was measured and the inhomogeneity was found to be less than in the three pieces of m-axis material which had been measured. Subsequent measurements of various material indicated that there was significant variation in homogeneity even amongst samples of the same orientation and thickness. It could not be proven whether the inhomogeneity was axis dependent.

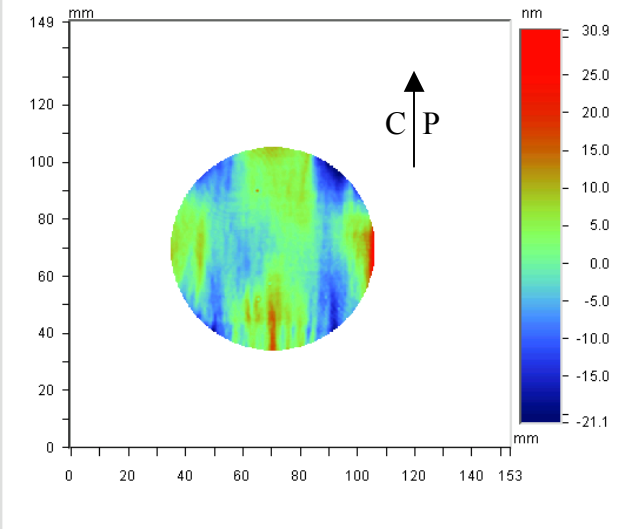
Several measurements of sapphire inhomogeneity have led to the following observations. Inhomogeneity in a and m-axis material has a characteristic striated pattern that appears as an optical path difference with striae parallel to the polarization of the measurement laser. The implication being that each piece of material has two unique inhomogeneity patterns, one for each polarization. Homogeneity is always better when viewing the material with light polarized parallel to the material c-axis.

Approach: An 80mm cube of a-axis (growth) material was polished to allow measurement of the same volume along both the a and m axes. Drawing- LIGO-D030128-A. The cube was measured at Caltech using a WYKO 6000 interferometer. The interferometer is in need of repair since it is out of alignment and cannot be trusted to accurately measure low order terms.

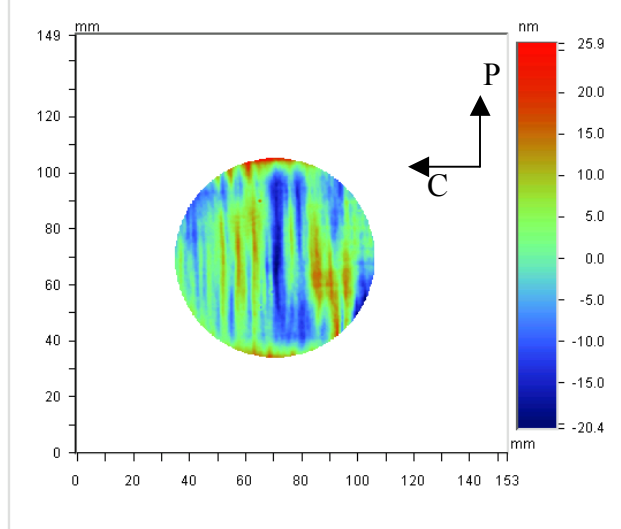
In this instance low order terms tilt, power, astigmatism, coma and spherical aberration were subtracted from the data set. This serves two purposes, one, to eliminate error due to the misalignment of the instrument, and two, to eliminate contributions from surface deformation since surfaces were good enough to be not explicitly subtracted. This approach gives a larger error than explicit measurement and subtraction, on the order of 2 nm rms.

The following images are of the same cube of material, analyzed over a circular aperture for proper subtraction of low order terms. The change in image left to right is due to a 90° counter-clockwise rotation of the material. The change in image up to down is due to a clockwise rotation of the material about the C axis (as viewed from above or from the left.) In each case the polarization direction remains constant. Each image is an average of six data sets. Material viewed along the a-axis is labeled a-axis.

Conclusions: The ratio of inhomogeneity between the a and m-axes is identical at ~0.60, within the tolerance of the measurement. A-axis material does appear to be more homogeneous than m-axis material.

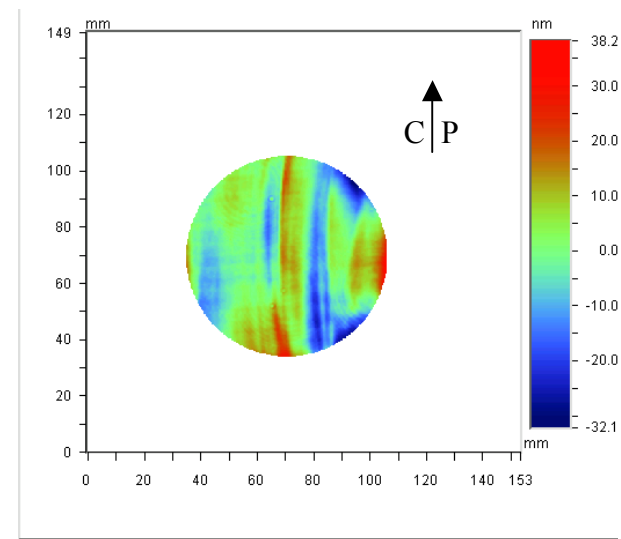


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 Time: 15:59:18 Y Center: 223.00
 Wavelength: 1.064 um Radius: 134.00 pix
 Pupil: 100.0 % Terms: Tilt Power Astig Coma Sa3
PV: 51.9847 nm Filters: None
RMS: 5.5208 nm Masks: Analysis Mask

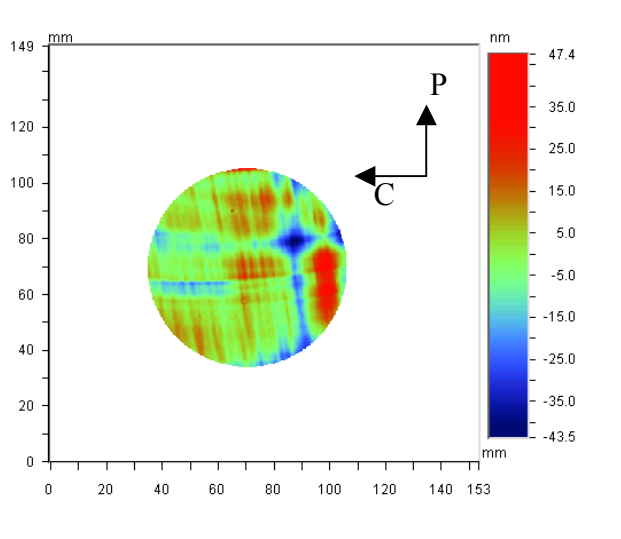


Date: 08/19/2003 X Center: 265.00
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 Pupil: 100.0 % Terms: Tilt Power Astig Coma Sa3
PV: 46.2480 nm Filters: None
RMS: 6.4608 nm Masks: Analysis Mask

A-axis with polarization parallel to C-axis, and perpendicular to C-axis.



Date: 08/18/2003 X Center: 265.00
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 Wavelength: 1.064 um Radius: 134.00 pix
 Pupil: 100.0 % Terms: Tilt Power Astig Coma Sa3
PV: 70.2747 nm Filters: None
RMS: 9.0278 nm Masks: Analysis Mask



Date: 08/19/2003 X Center: 265.00
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 Wavelength: 1.064 um Radius: 134.00 pix
 Pupil: 100.0 % Terms: Tilt Power Astig Coma Sa3
PV: 90.9100 nm Filters: None
RMS: 10.3485 nm Masks: Analysis Mask

M-axis with polarization parallel to C-axis, and perpendicular to C-axis.