Optical Tests of a Large Number of Small COTS Cubes

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Motivation

• The number of required corner cubes for a satellite mission can easily become a cost driver, e.g. in case the required number is high.

• Custom-made corner cubes with defined dihedral angular offsets will likely meet the specifications but are expensive.

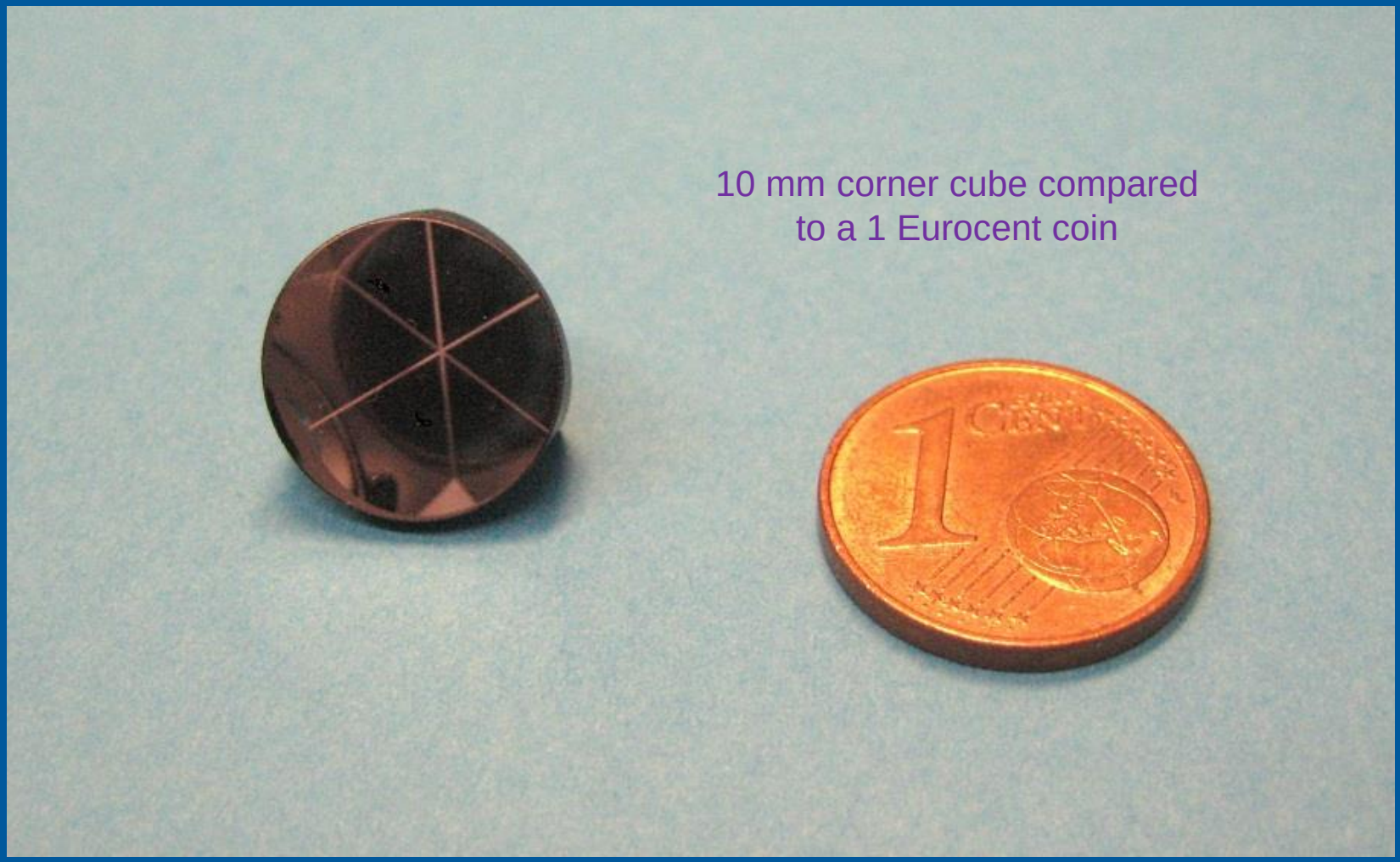
• COTS („commercial off-the-shelf“) with no specified dihedral offset angles cubes are offered at a reasonable price.

BUT:
Will there optical properties meet the specifications of SLR for a given mission?

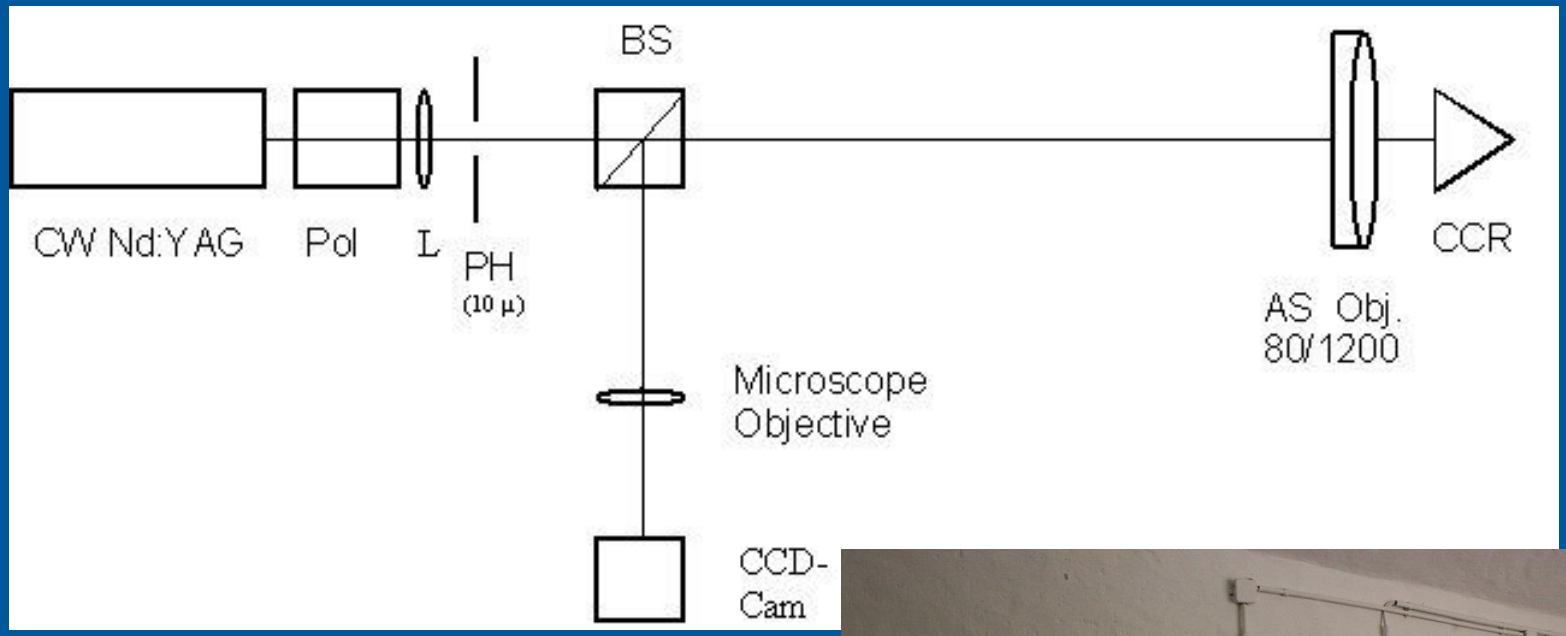
Opportunity:
The Institute of Aeronautics and Astronautics purchased 95 cubes (10 mm aperture, backside coated) for use in nanosatellite projects from *Changchun Hengrun Optoelectronics Tech Co Ltd.* For 31 of them there are ZYGO data available!

JUST TRY!

Which type of cubes we are speaking about?



How to record the Far Field Diffraction Pattern?

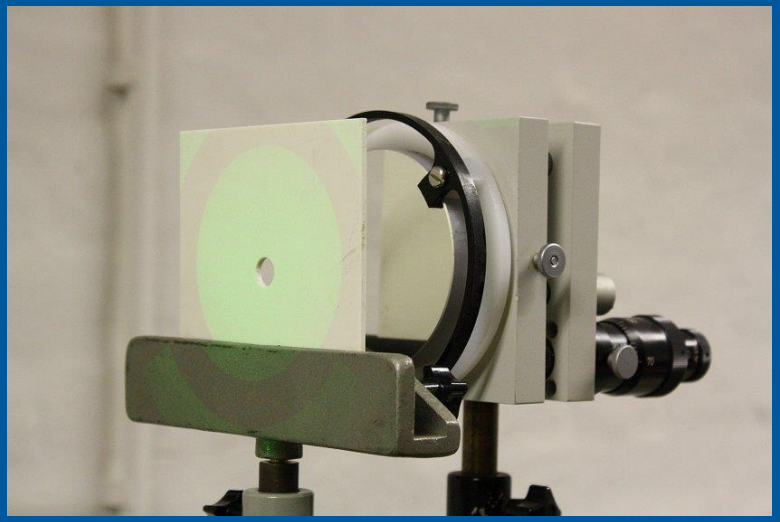


Experimental setup for FFDP recording

The concept of a „reference flat“

The cross section at the center of the diffraction pattern of a circular aperture equals

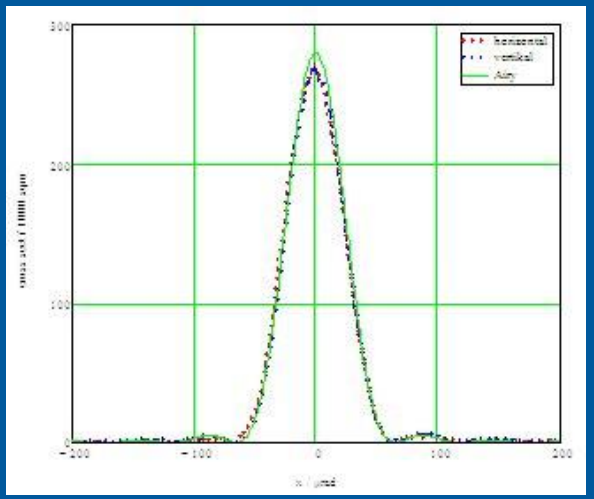
$$c = 4\pi\left(\frac{A}{\lambda}\right)^2 = \frac{\pi}{4}\left(\frac{\pi \cdot D^2}{\lambda}\right)^2$$

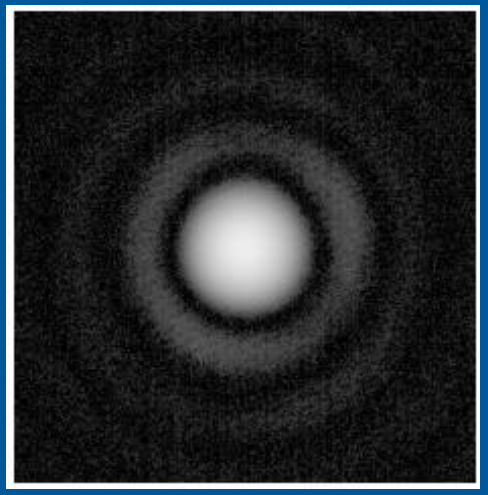


The ratio of the cube intensity at some point in the pattern to the intensity at the center of the pattern of the optical flat gives a measure of the cross section of the cube.

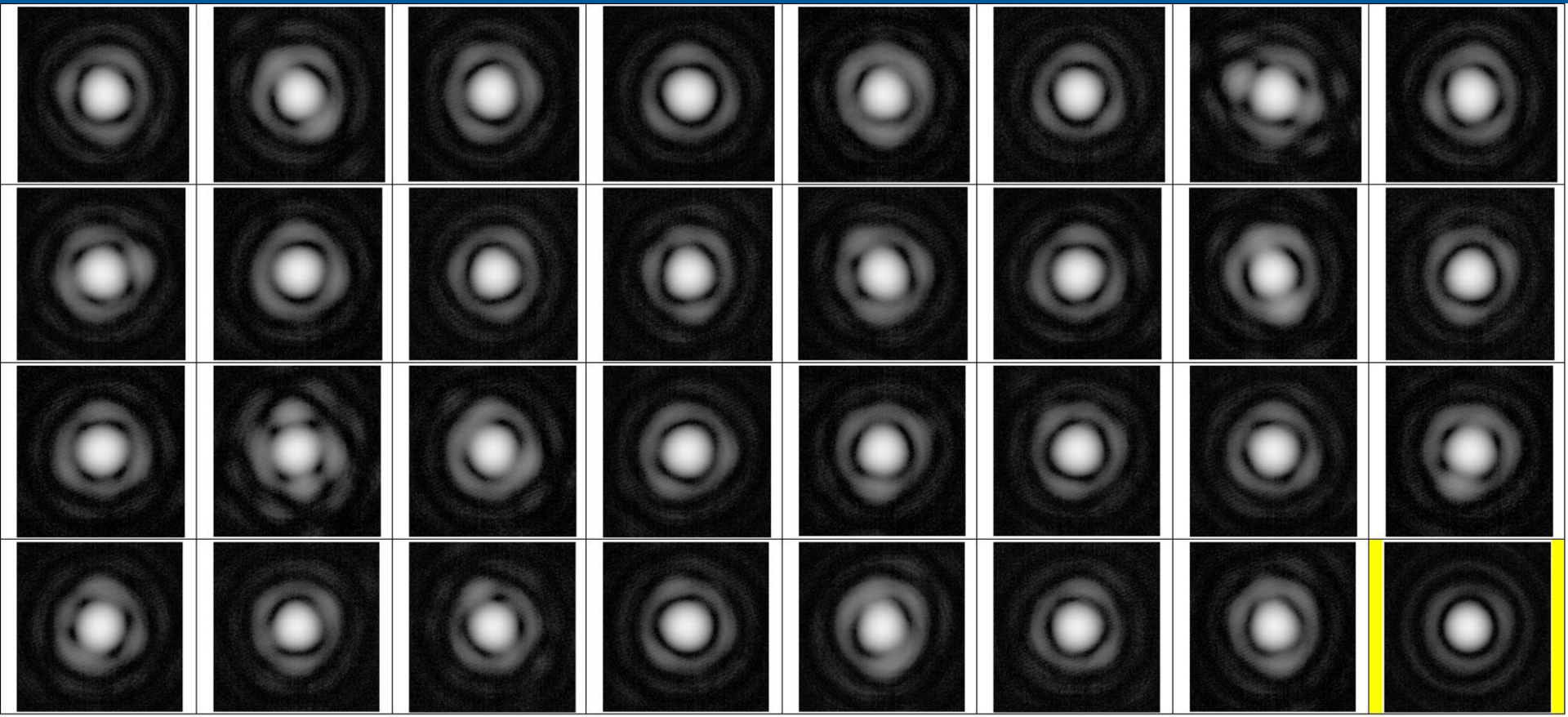
Image processing:

- Record the FFDP of the cube or the reference flat as BMP image.
- Assume the sum of all intensities of Airy function and measurement to be equal (Normation).
- Plot this distribution.

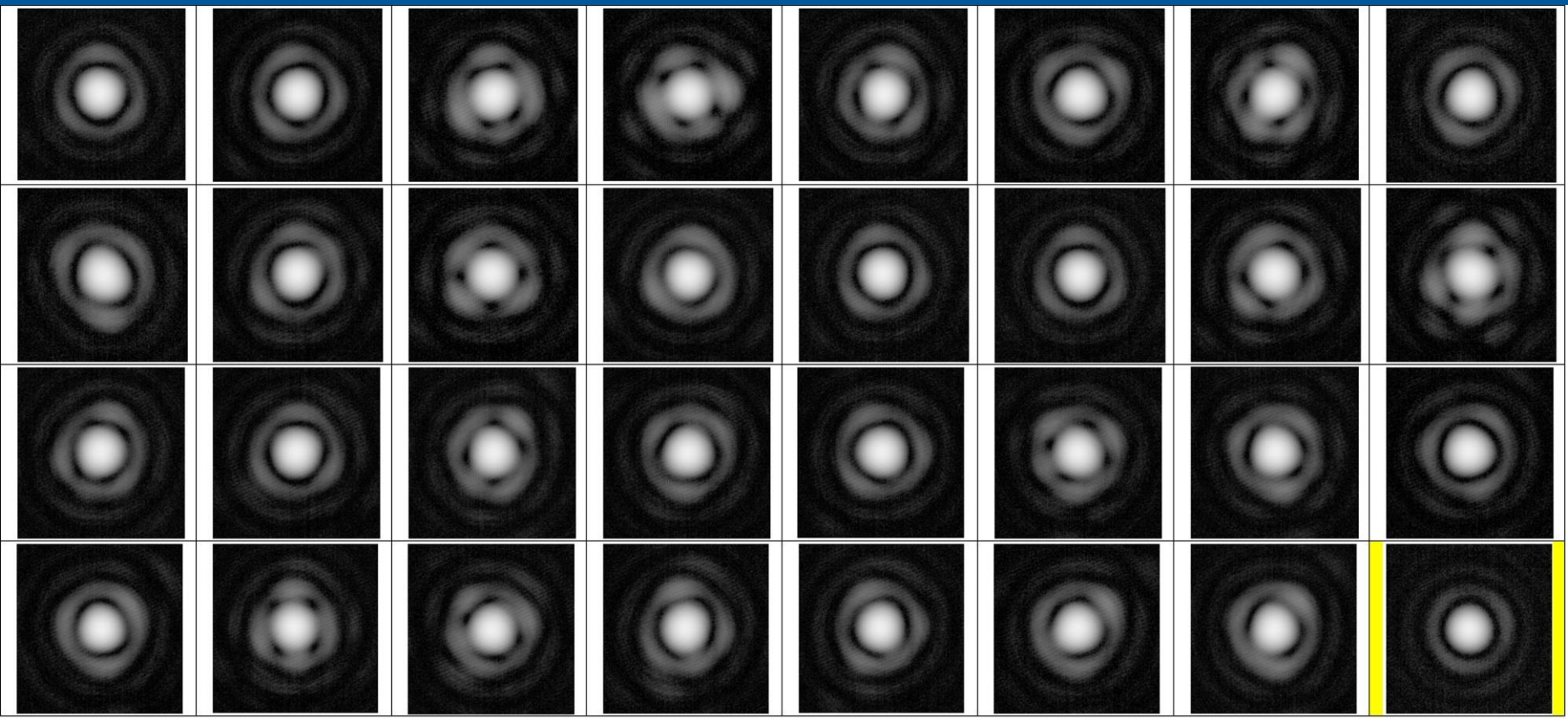




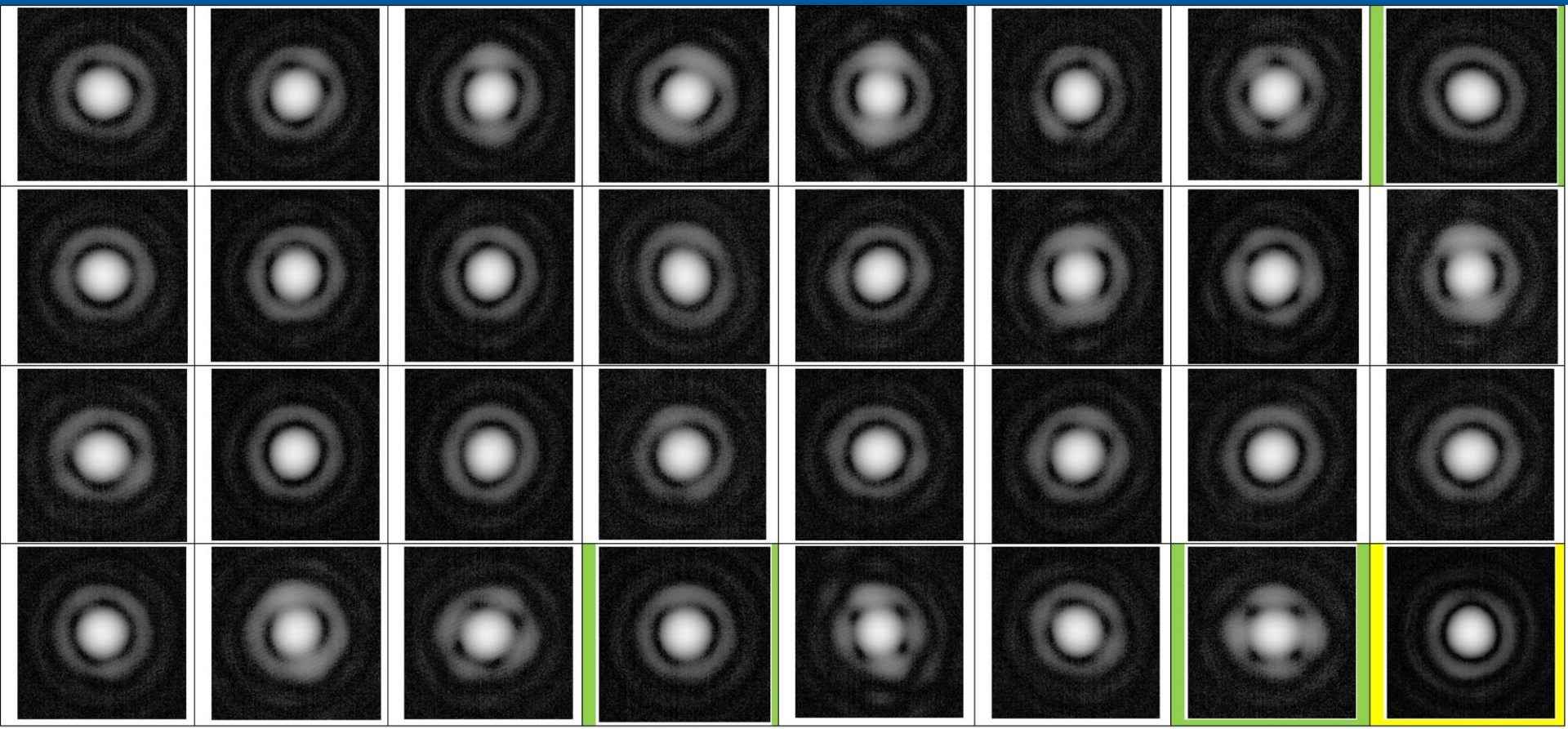
FFDPs Cubes No. 01 - 31



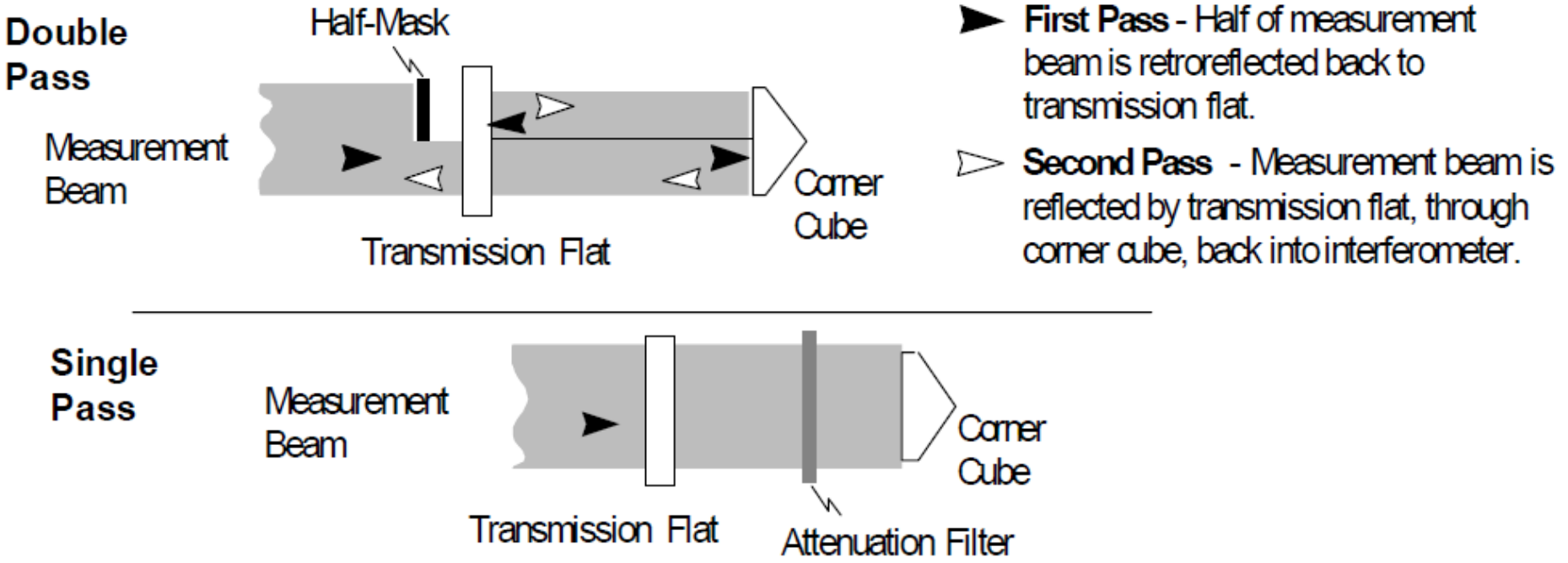
FFDPs Cubes No. 32 - 62



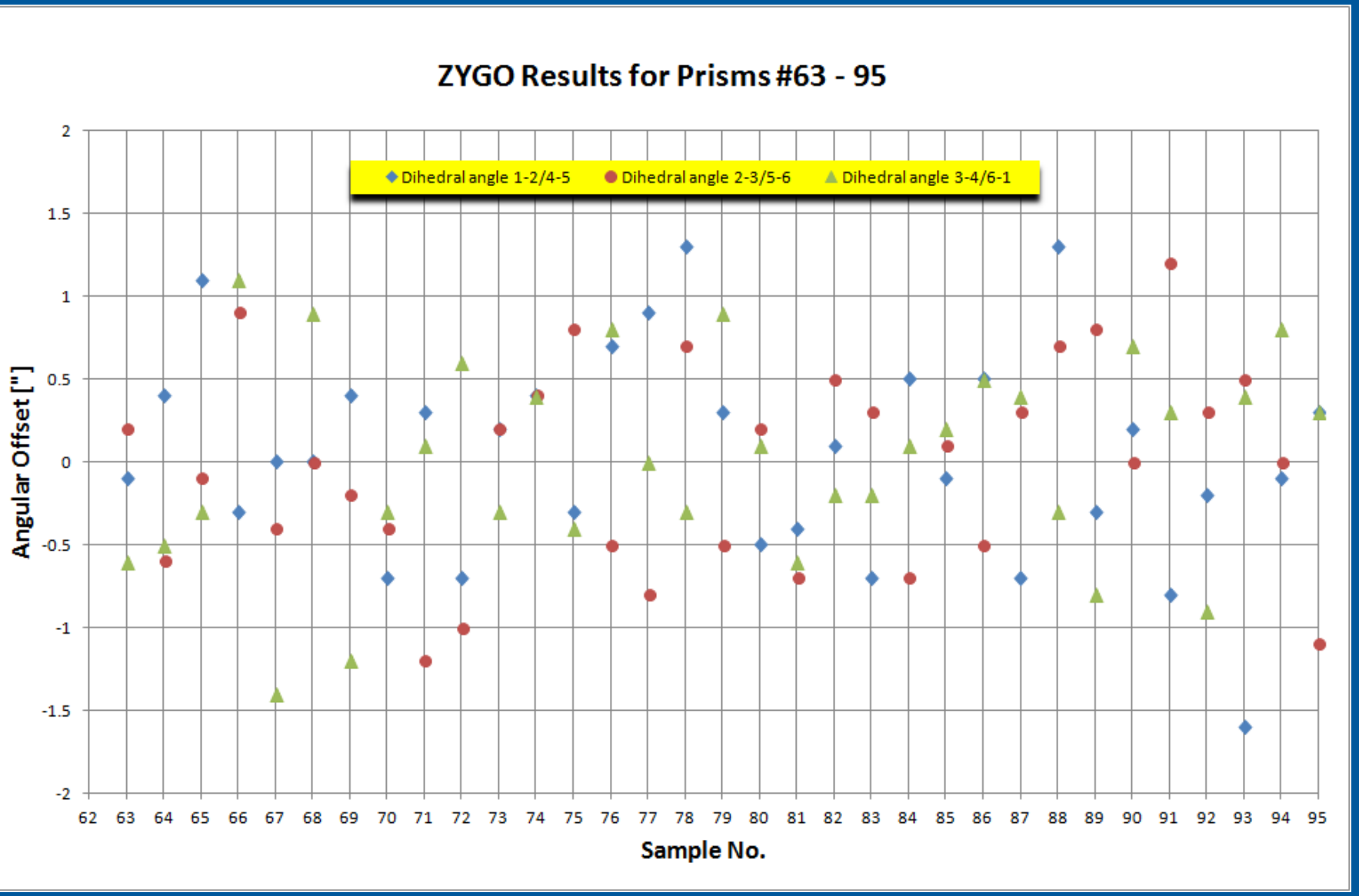
FFDPs Cubes No. 63 - 95



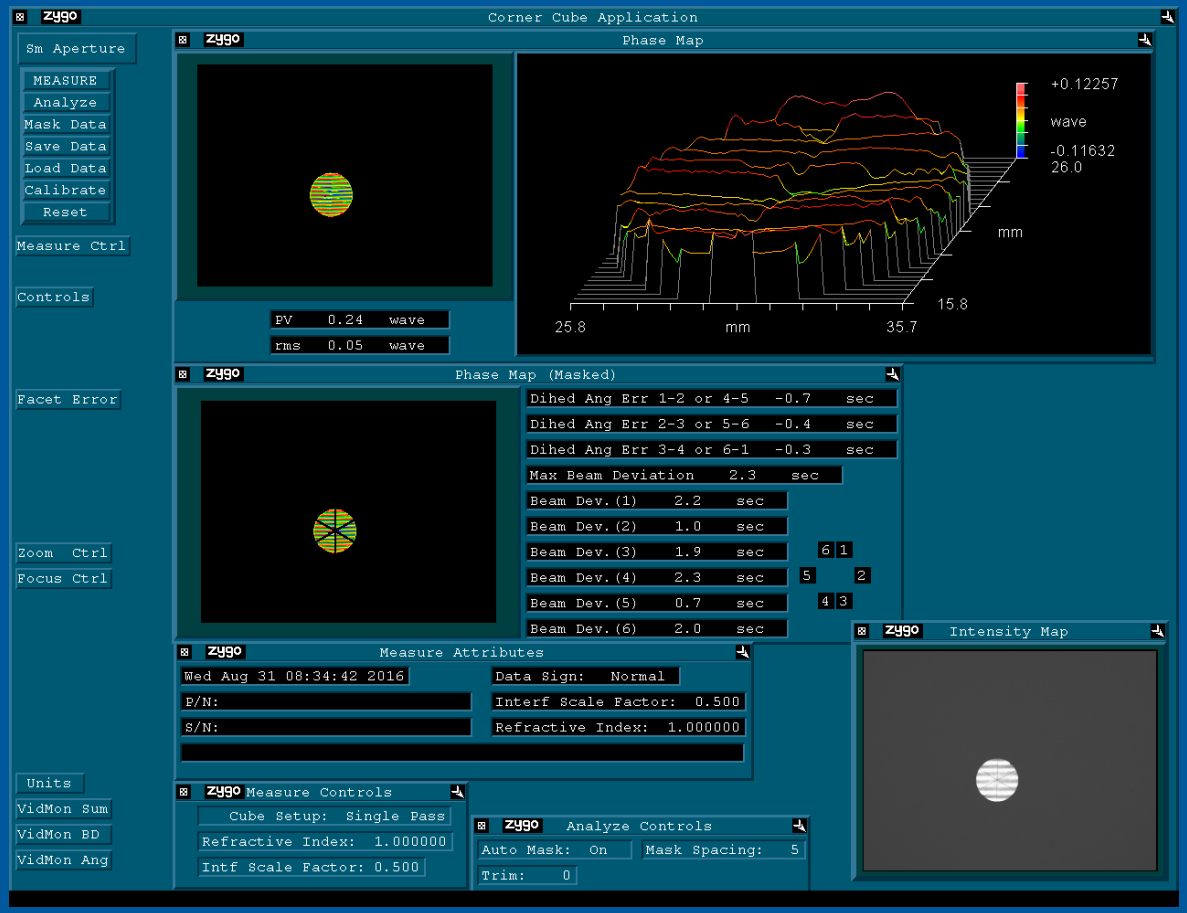
ZYGO Interferometer – Single and Double Pass Technique

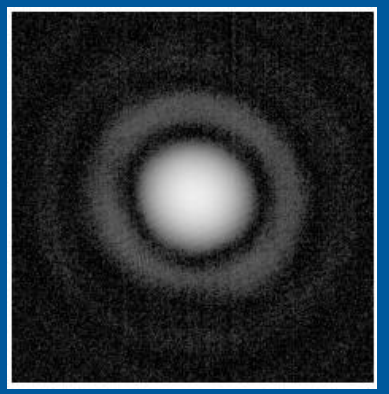


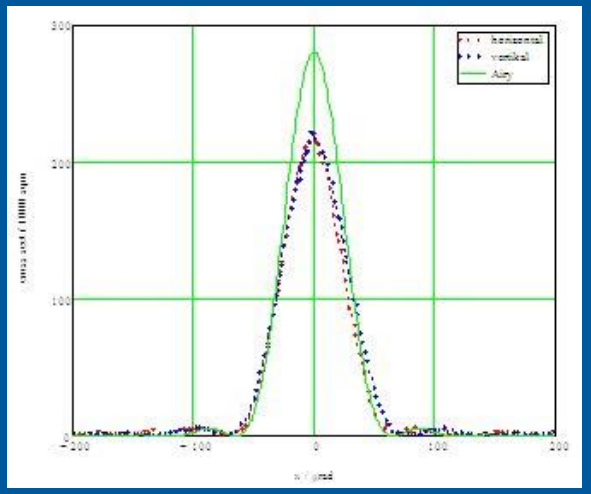
- Double Pass: asymmetrical wavefront errors introduced by the interferometer cancel out
- Single Pass: used for small cubes, asymmetrical wavefront errors do *not* cancel out!


ZYGO Results for Prisms #63 - 95
Dihedral angle 1-2/4-5
Dihedral angle 2-3/5-6
Dihedral angle 3-4/6-1
Angular Offset ["]
Sample No.
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95

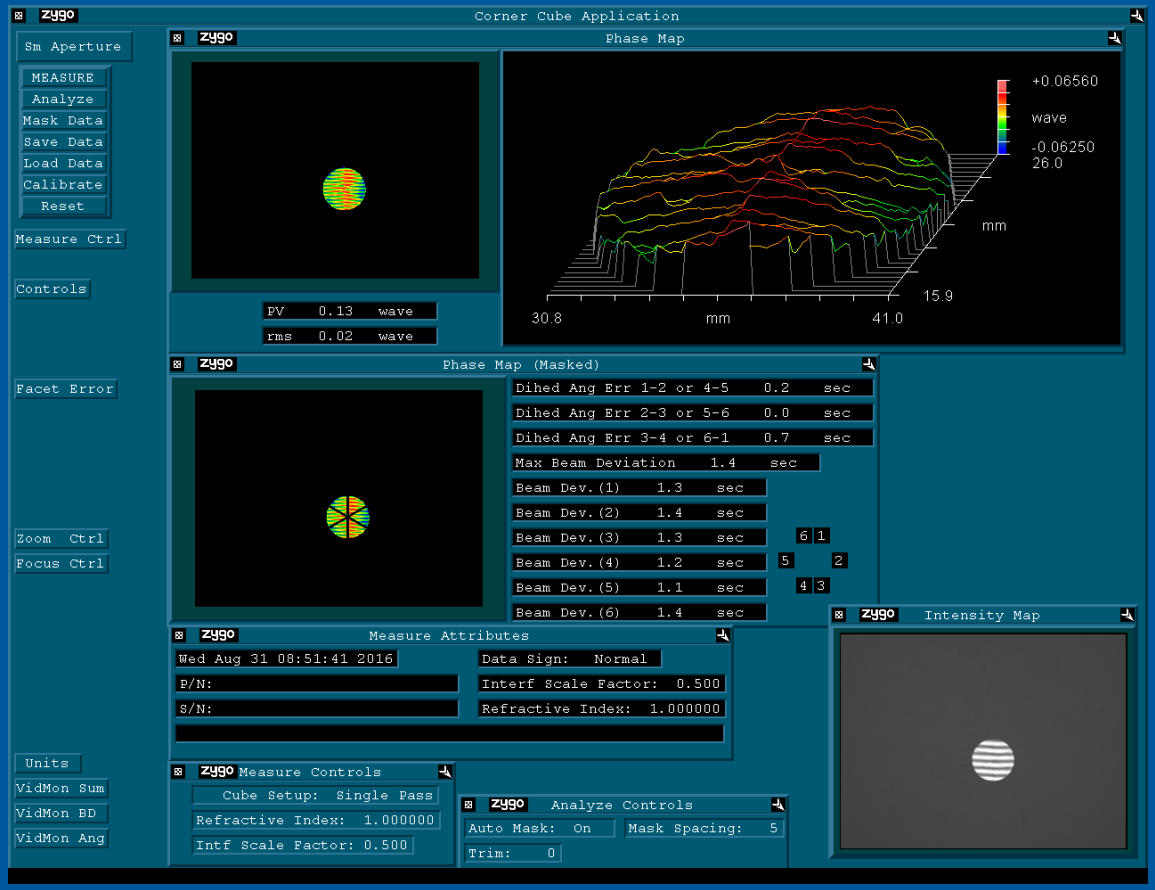
Prism #70

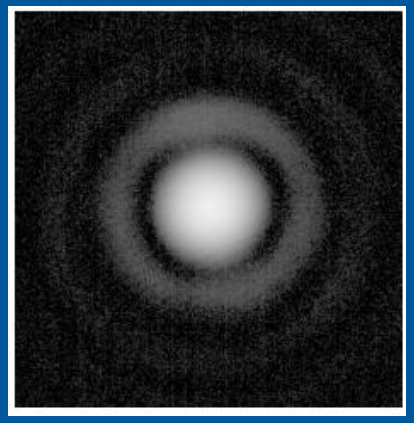

Corner Cube Application
Sm Aperture
MEASURE
Analyze
Mask Data
Save Data
Load Data
Calibrate
Reset
Measure Ctrl
Controls
Facet Error
Zoom Ctrl
Focus Ctrl
Units
VidMon Sum
VidMon BD
VidMon Ang
Phase Map
+0.12257
wave
-0.11632
26.0
mm
25.8
mm
35.7
15.8
PV 0.24 wave
rms 0.05 wave
Phase Map (Masked)
Dihed Ang Err 1-2 or 4-5 -0.7 sec
Dihed Ang Err 2-3 or 5-6 -0.4 sec
Dihed Ang Err 3-4 or 6-1 -0.3 sec
Max Beam Deviation 2.3 sec
Beam Dev. (1) 2.2 sec
Beam Dev. (2) 1.0 sec
Beam Dev. (3) 1.9 sec
Beam Dev. (4) 2.3 sec
Beam Dev. (5) 0.7 sec
Beam Dev. (6) 2.0 sec
Intensity Map
Measure Attributes
Wed Aug 31 08:34:42 2016
P/N:
S/N:
Data Sign: Normal
Interf Scale Factor: 0.500
Refractive Index: 1.000000
Measure Controls
Cube Setup: Single Pass
Refractive Index: 1.000000
Intf Scale Factor: 0.500
Analyze Controls
Auto Mask: On
Mask Spacing: 5
Trim: 0

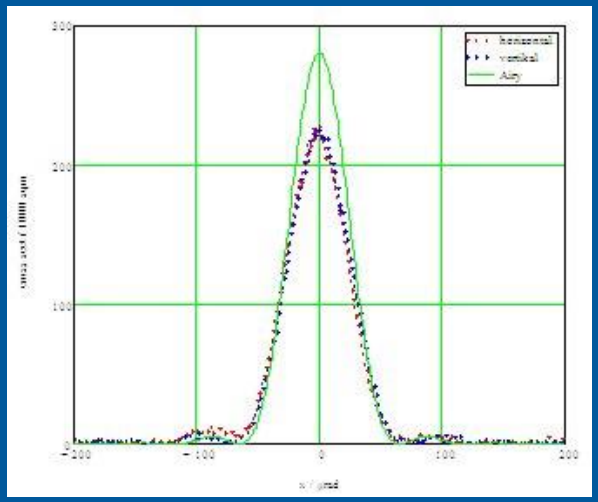



horizontal
vertical
Airy

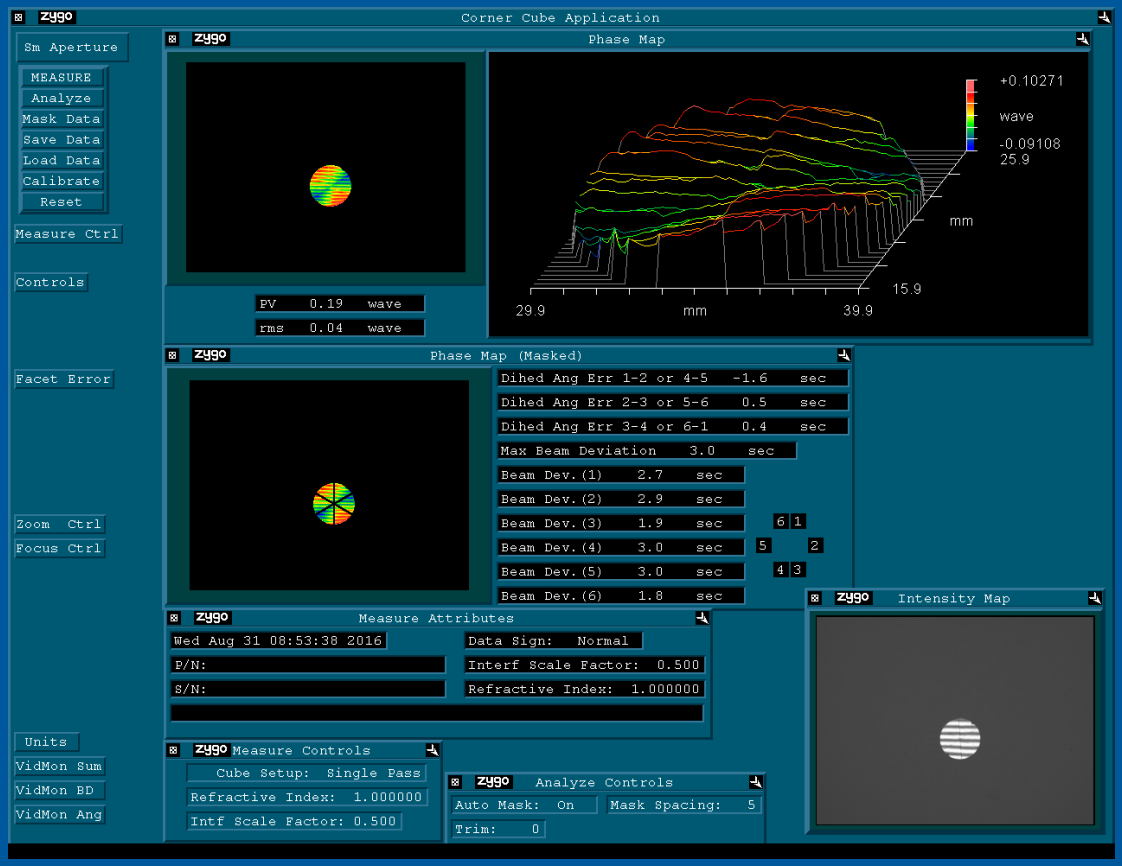
Prism #90

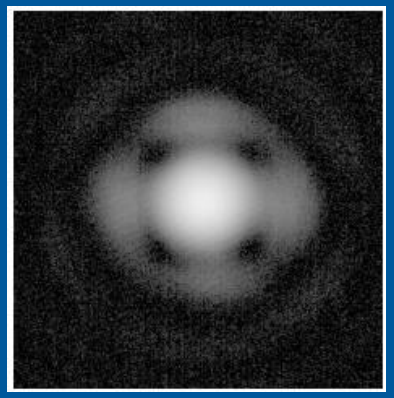

Corner Cube Application
Sm Aperture
MEASURE
Analyze
Mask Data
Save Data
Load Data
Calibrate
Reset
Measure Ctrl
Controls
Facet Error
Zoom Ctrl
Focus Ctrl
Units
VidMon Sum
VidMon BD
VidMon Ang
Phase Map
+0.06560
wave
-0.06250
26.0
mm
30.8
mm
41.0
15.9
PV 0.13 wave
rms 0.02 wave
Phase Map (Masked)
Dihed Ang Err 1-2 or 4-5 0.2 sec
Dihed Ang Err 2-3 or 5-6 0.0 sec
Dihed Ang Err 3-4 or 6-1 0.7 sec
Max Beam Deviation 1.4 sec
Beam Dev.(1) 1.3 sec
Beam Dev.(2) 1.4 sec
Beam Dev.(3) 1.3 sec
Beam Dev.(4) 1.2 sec
Beam Dev.(5) 1.1 sec
Beam Dev.(6) 1.4 sec
Intensity Map
Measure Attributes
Wed Aug 31 08:51:41 2016
Data Sign: Normal
P/N:
Interf Scale Factor: 0.500
S/N:
Refractive Index: 1.000000
Measure Controls
Cube Setup: Single Pass
Refractive Index: 1.000000
Intf Scale Factor: 0.500
Analyze Controls
Auto Mask: On
Mask Spacing: 5
Trim: 0

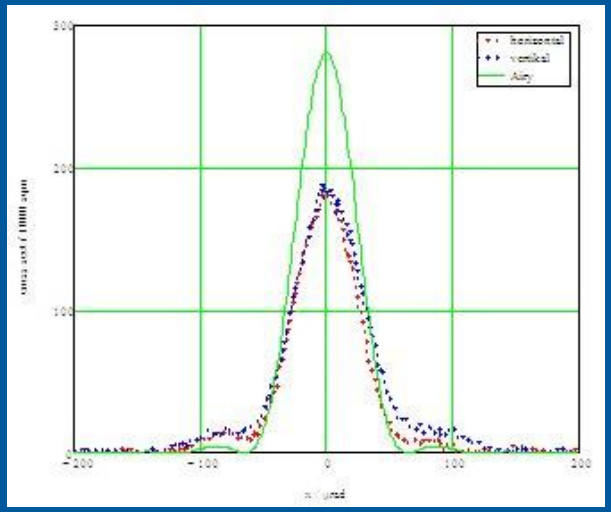



horizontal
vertical
Airy

Prism #93


Corner Cube Application
Sm Aperture
MEASURE
Analyze
Mask Data
Save Data
Load Data
Calibrate
Reset
Measure Ctrl
Controls
Facet Error
Zoom Ctrl
Focus Ctrl
Units
VidMon Sum
VidMon BD
VidMon Ang
Phase Map
+0.10271
wave
-0.09108
25.9
mm
15.9
29.9
mm
39.9
PV 0.19 wave
rms 0.04 wave
Phase Map (Masked)
Dihed Ang Err 1-2 or 4-5 -1.6 sec
Dihed Ang Err 2-3 or 5-6 0.5 sec
Dihed Ang Err 3-4 or 6-1 0.4 sec
Max Beam Deviation 3.0 sec
Beam Dev. (1) 2.7 sec
Beam Dev. (2) 2.9 sec
Beam Dev. (3) 1.9 sec
Beam Dev. (4) 3.0 sec
Beam Dev. (5) 3.0 sec
Beam Dev. (6) 1.8 sec
Intensity Map
Measure Attributes
Wed Aug 31 08:53:38 2016
Data Sign: Normal
P/N:
Interf Scale Factor: 0.500
S/N:
Refractive Index: 1.000000
Measure Controls
Cube Setup: Single Pass
Refractive Index: 1.000000
Intf Scale Factor: 0.500
Analyze Controls
Auto Mask: On
Mask Spacing: 5
Trim: 0





Conclusions

Most of the tested samples show a quite acceptable FFDP pattern with only slightly reduced cross section as compared to a reference flat.

The measured offsets of the dihedral angles are mostly below ±1 arc second.

The use of such type of corner cubes for satellite missions can be recommended.