Second International Conference on Adaptive Optics for Extremely Large telescope

Thin Shell Manufacturing for Large Wavefront correctors

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Sagem - Reosc Department

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Outline

- **Recent development in thin shell manufacturing**
  - Demonstration Prototype for E-ELT M4
  - Monolithic thin shell for E-ELT M4
  - VLT DSM thin shell

- **A early development in the end of the 90s**
  - Composite mirror
  - Optical face sheet:
    - 3mm thin
    - 2 m diameter
Manufacturing Flow Chart

Raw material procurement (thick)
Grinding Optical Surface
Polishing Optical Surface
Surface error interferometric measurement (thick)
External (internal) contour shaping
Thining of the back surface
Grinding back surface
Polishing back surface
Thickness measurement
Coating back surface
Magnets gluing
Coating front surface
Final inspection
Packing / Shipment

Thick mirror

Thin mirror
Mirror requirements

- Dimensions:
  - Length = 960 mm ±0.1mm
  - Width = 165 mm ±0.1mm
  - Thickness = 2 mm+0/-0.1mm
  - Thickness non uniformity  PTV 10µm

- Optical surface
  - Optical surface flat
  - Coating on both surfaces
DP Shell ELT M4

Interferometric test of the optical surface

<table>
<thead>
<tr>
<th>KIND OF CONTROL</th>
<th>SPEC. FROM STR (STR N°3300163316)</th>
<th>RESULTS</th>
<th>CONFORM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scratch and digs</td>
<td>DIN 3140 5/6x0.4 / k2x0.025</td>
<td>DPShell 1 Conform</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DPShell 2 Conform</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DPShell 3 No conform</td>
<td>NO</td>
</tr>
<tr>
<td>Roughness</td>
<td>&lt; 2 nm RMS</td>
<td>DP Shell 1, DP Shell 2, DP Shell 3 1 nm RMS – By comparison</td>
<td>YES</td>
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<tr>
<td>Forces</td>
<td>&lt; 0.1 N</td>
<td>DP Shell 1-L 0.079 N</td>
<td>YES</td>
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<tr>
<td></td>
<td></td>
<td>DP Shell 1-R 0.081 N</td>
<td>YES</td>
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<tr>
<td></td>
<td></td>
<td>DP Shell 2-L 0.08 N</td>
<td>YES</td>
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<tr>
<td></td>
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<td>DP Shell 2-R 0.085 N</td>
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<tr>
<td></td>
<td></td>
<td>DP Shell 3-L 0.065 N</td>
<td>YES</td>
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<tr>
<td></td>
<td></td>
<td>DP Shell 3-R 0.069 N</td>
<td>YES</td>
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<tr>
<td>MSE (sub-aperture analysis)</td>
<td>&lt; 7.5 nm RMS</td>
<td>DP Shell 1-L 2.6 nm RMS</td>
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<tr>
<td></td>
<td></td>
<td>DP Shell 1-R 6.9 nm RMS</td>
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<tr>
<td></td>
<td></td>
<td>DP Shell 2-L 7.6 nm RMS</td>
<td>NO</td>
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<tr>
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<td></td>
<td>DP Shell 2-R 7.2 nm RMS</td>
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<td>DP Shell 3-L 6.7 nm RMS</td>
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<tr>
<td></td>
<td></td>
<td>DP Shell 3-R 5.6 nm RMS</td>
<td>YES</td>
</tr>
</tbody>
</table>
DP Shell ELT M4

Mirror installation on the blocking body
DP Shell ELT M4

Back side thinning by machining and grinding

Ultrasonic devise
Final thickness measurement

<table>
<thead>
<tr>
<th>All values in mm</th>
<th>Measured values</th>
<th>Map processed by Warpp</th>
<th>Tilt removed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Min      Max    PIV</td>
<td>Min      Max    PIV    RMS</td>
<td>PIV    RMS</td>
</tr>
<tr>
<td>DPS1-D</td>
<td>1.942    1.953  0.011</td>
<td>1.943    1.953  0.0099  0.0014</td>
<td>0.0103  0.0014</td>
</tr>
<tr>
<td>DPS1-G</td>
<td>1.943    1.954  0.011</td>
<td>1.944    1.953  0.0010  0.0014</td>
<td>0.0101  0.0014</td>
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<tr>
<td>DPS2-D</td>
<td>1.945    1.954  0.009</td>
<td>1.945    1.954  0.0085  0.0014</td>
<td>0.0079  0.0013</td>
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<tr>
<td>DPS2-G</td>
<td>1.945    1.954  0.009</td>
<td>1.945    1.953  0.0077  0.0011</td>
<td>0.0077  0.0011</td>
</tr>
<tr>
<td>DPS3-D</td>
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<td>1.943    1.955  0.0116  0.0013</td>
<td>0.0110  0.0012</td>
</tr>
<tr>
<td>DPS3-G</td>
<td>1.944    1.956  0.012</td>
<td>1.945    1.956  0.0110  0.0015</td>
<td>0.0098  0.0014</td>
</tr>
</tbody>
</table>
Validation of the thin mirror lifting and handling tools
Reflective metallic coating on both sides

- Pattern deposition on the back surface using lift-off engraving techniques,
- Continuous coating on the front surface

Resin deposition

Mirror handling tool inside the coating chamber

Mirror lifted with the magnets
DP Shell ELT M4

Phasing validation by Microgate-ADS:
E-ELT M4 Monolithic Mirror Demonstrator

- **Objectives**
  - Demonstrate the mirror feasibility (thinning, handling, turning, cleaning, shipment, etc.) of 2.7m diameter – 2mm thin plate.

- **Main mirror requirement**
  - Material
    - Borrofloat glass
  - Dimensions:
    - $\Omega_{\text{out}} = 2740\text{mm} \pm 0.1\text{mm}$ et $\Omega_{\text{inn}} = 620\text{mm} \pm 0.1\text{mm}$
    - Thickness = $2\text{mm} +0 / -0.1\text{mm}$
    - Thickness non uniformity 10µm PTV
  - Shape: plano - plano
  - No Optical requirement (optical surface is not processed)
E-ELT M4 monolithic Mirror Demonstrator

Machining on NC: external and internal diameters
E-ELT M4 monolithic Mirror Demonstrator

Thickness measurement with an ultrasonic device: 6300 measurement points

Thinning, Grinding and polishing of the back surface
Final polishing of 1/6 of the mirror

Before final polishing
1.952mm < thickness < 2.009mm

After final polishing
1.943mm < thickness < 1.960mm

- Results on 3 series of measurement:
  - \(<\text{thickness}> = 1.953\text{mm} \pm 8\mu\text{m}\)
  - Measurement repeatability \(\pm 3\mu\text{m}\)
E-ELT M4 monolithic Mirror Demonstrator

Removal from Blocking Body and turning
E-ELT M4 monolithic Mirror Demonstrator

Transportation tests: the thin shell has survived!
Main requirements

- Dimensions:
  - Øout = 1120mm ±0.5mm and Øint = 96mm ±0.1mm
  - Øopt ext = 1116mm ±0.5mm and Øopt = 106mm ±0.5mm
  - Average thickness = 2mm ±0 / - 0.1mm
  - Deviation form the average thickness 2 µm PV

- Optical surface:
  - Convex hyperbolic
  - Radius of curvature 4553.57mm ± 10mm
  - Conic constant -1.66926 ± 0.003

- Back surface:
  - Concave spherical
  - Radius of curvature 4575.3mm ± 0.5mm

Optical surface requirement:
- Max force <0.2N
- Surface error after flattening <9.7nm RMS
Test of the optical surface

- Combination of 3D measurement for LSF
- Sub aperture interferometric measurements for MSF and HSF
- Recombination in a single surface map
  - Aspheric profile
  - Irregularity surface profile
VLT DSM Mirror

- Simulation of an active correction
  - residual < 9.7nm RMS surface error
VLT DSM Mirror

- Simulation of an active correction
  - Max force $< 0.2N$
VLT DSM Mirror

- External and internal diameter machining on NC machine

- Initial step of thinning on a NC machine
VLT DSM Mirror

Installation on the Blocking Body and thinning by lapping and polishing down to 2mm
VLT DSM Mirror

⇒ Automatic measurement with an ultrasonic device

- Raw measurement
- Final correction map after correction of front surface aspheric shape and difference in radius of curvature between front and back surfaces
- Thickness map After tilt correction
VLT DSM Mirror / Current Status

Thickness surface profile: PTV 21 μm,