Development of an innovative optic manufacturing process @ Media Lario

Giuseppe Valsecchi

SEXTEN, Bolzano

ITALY

July 22, 2015

Cold Shaped Optics manufacturing technology

Cold Shaped Optics concept leverages off existing materials and technologies that are combined through a **Media Lario proprietary process** in order to manufacture high-performance reflective optics at a fraction of the cost of traditional grinding and polishing methods.

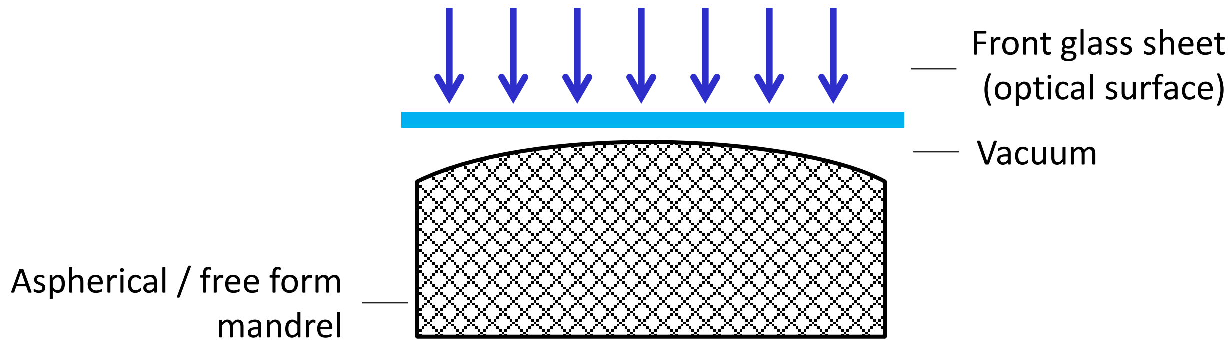
The conventional state-of-the-art manufacturing processes of spherical/aspherical/free form reflective optics consists of the following steps:

- *Production of the glass blank;*
- *Machining and grinding of the blank to approximate shape, inclusive of backside lightening;*
- *Deterministic figuring and polishing.*

Cold Shaped Optics manufacturing technology

Cold Shaped Optics manufacturing technology consists of:

- precisely shaping an **inexpensive thin glass sheet** (≤ 1 mm) over
- a **high-precision mandrel**, and
- **freezing** its shape over a low-cost substrate by means of an epoxy adhesive layer



- ✓ Mandrel determines the shape accuracy of the optical unit
- ✓ Core substrate can easily be manufactured to about 5-10 μm accuracy PTV
- ✓ The manufacturing cycle foreseen for the present process is estimated to be of 1-2 days
- ✓ Cost saving becomes significant due to amortization of the mandrel over several mirrors

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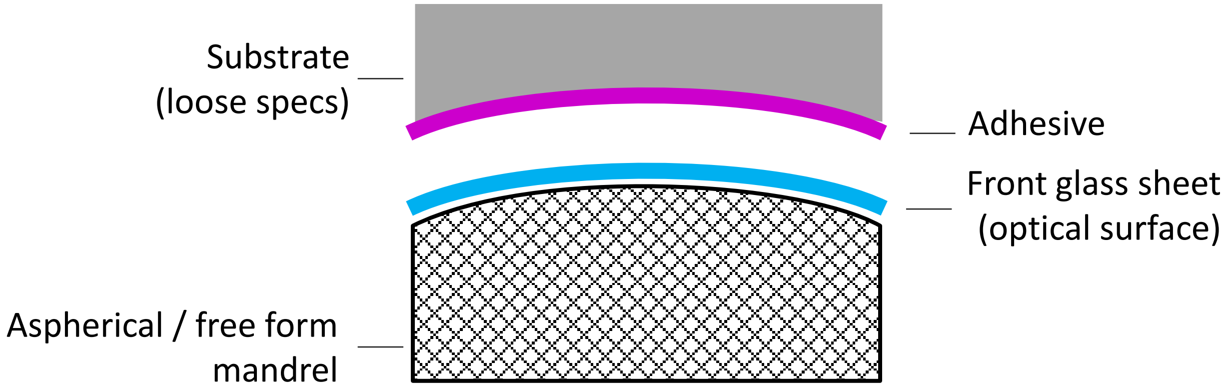

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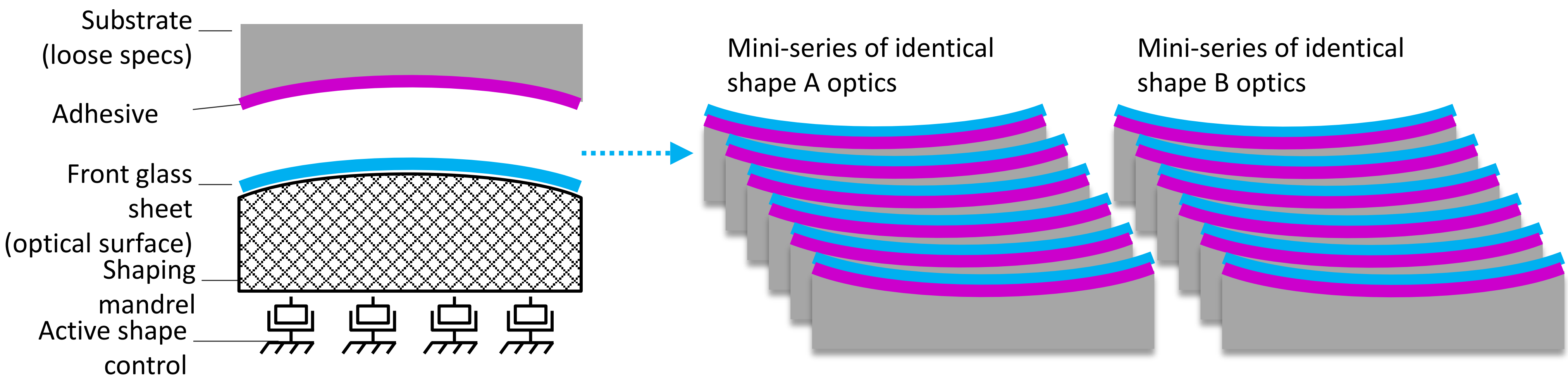
Cold Shaped Optics manufacturing technology

The **high-precision mandrel** could have complex shape and active control.

The active control system allows to modify the shape of the mandrel according to required changes in segmented mirror shape to comply with the radial position of each segment.



The **core substrate** can be made of many different materials like aluminum alloys, silicon carbide, or different grades of glass, even lightweighted.

Compatibly of the glass foil and substrate materials requires a verification of the CTE mismatching

Why the cold shaping is possible, now?

Two main reasons:

1. Glass sheets with thickness in the range of 0.05-1 mm, dimensions up to 1.5 m, and roughness of 1 nm RMS, not requiring successive polishing, are inexpensively and readily available in the glass industry due to their utilization in the production of flat panel displays.

2. New generations of adhesives filled with low CTE materials are showing low viscosity and low shrinkage

Glass Eagle 04 sample uncoated 200x62mm, roughness characterization

Methods and Procedures
Shape accuracy tested by Wyko 6000,
Roughness by CCI

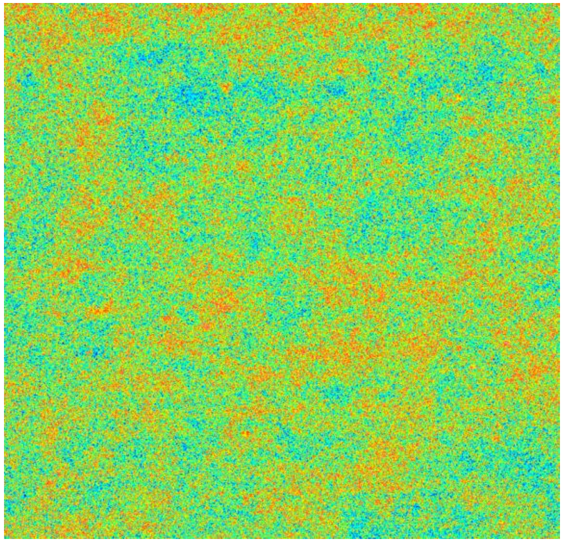
Test Equipment
The following tools were used during the measurements:
Wyko 6000
Taylor & Hobson CCI : 50x, 10x, 2.5x magnifications

Results

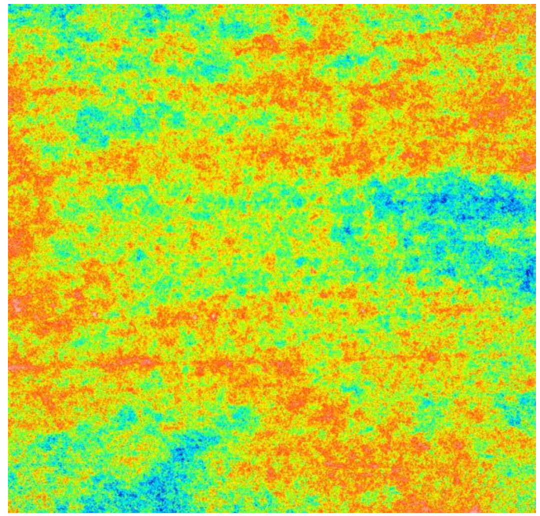
The average roughness results of about ten glass foils are summarized in the following table:

	Backside RMS Roughness (nm)	Front side RMS Roughness (nm)
50x	0.44	0.43
10x	0.26	0.26
2.5x	1.00	0.94

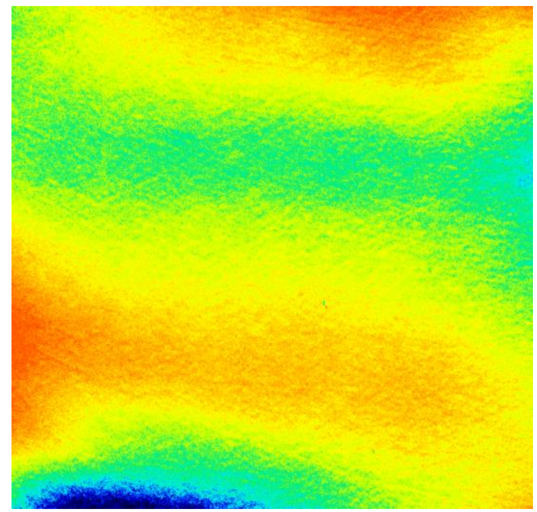
Glass Eagle 04 sample uncoated 200x62mm, front side and backside



50x objective, window 0.3mmx0.3mm, backside



10x objective, window1.5mmx1.5mm, backside



2.5x objective, window 6mmx6mm, backside

Structural analysis and Stress simulations

Material : AF32TM Schott glass.

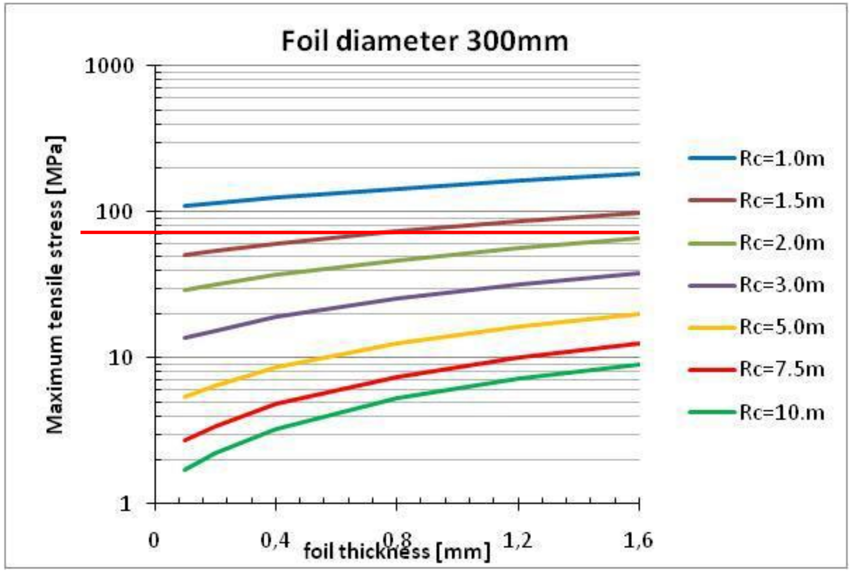
mechanical properties:

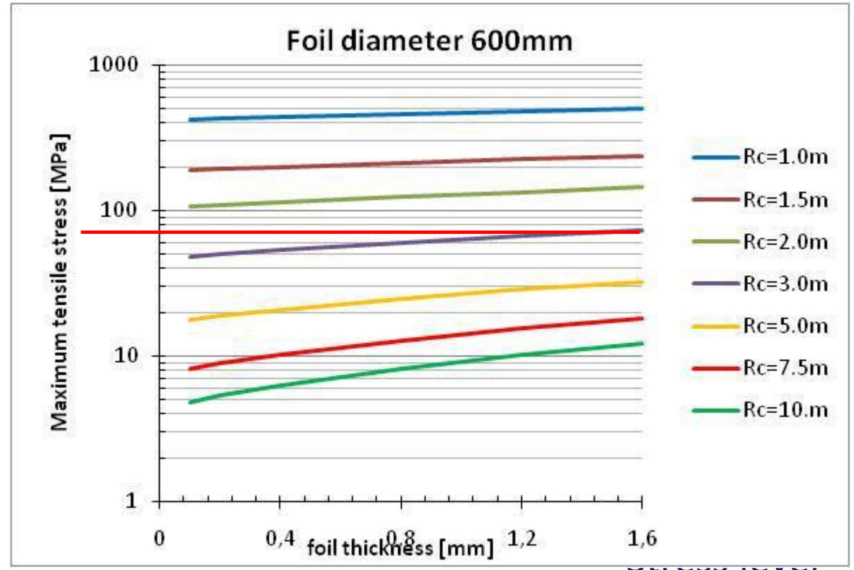
- Density 2.43 g/cm3
- Young's modulus 74.8 GPa
- Poisson ratio 0.238
- CTE 3.2×10-6 K-1

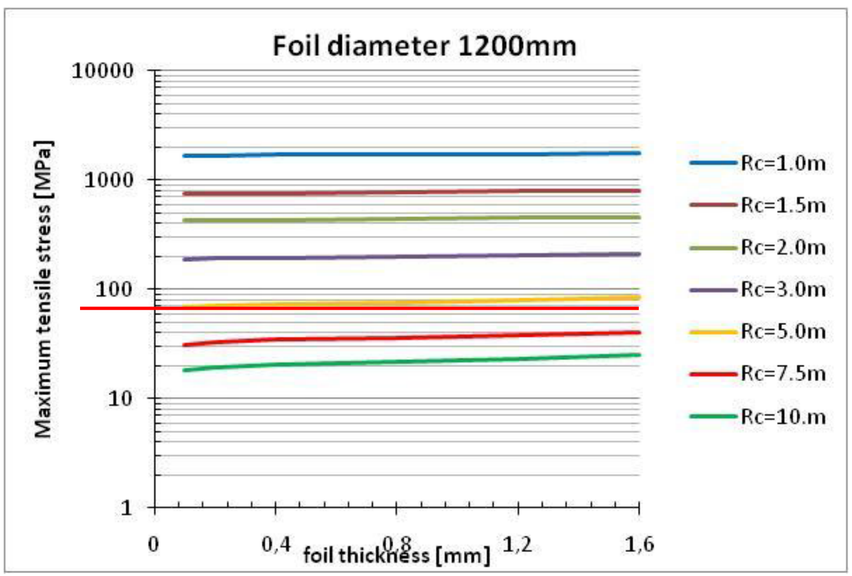
	R_P=150mm	R_P=300mm	R_P=450mm	R_P=600mm	R_P=750mm
R_C=1m	11.229	44.664	99.553	174.664	268.311
R_C=1.5m	7.494	29.900	66.995	118.409	183.626
R_C=2m	5.622	22.458	50.412	89.327	138.985
R_C=3m	3.749	14.988	33.687	59.800	93.263
R_C=5m	2.250	8.997	20.236	35.957	56.145
R_C=7.5m	1.500	5.999	13.496	23.987	37.469
R_C=10m	1.125	4.500	10.123	17.995	28.112

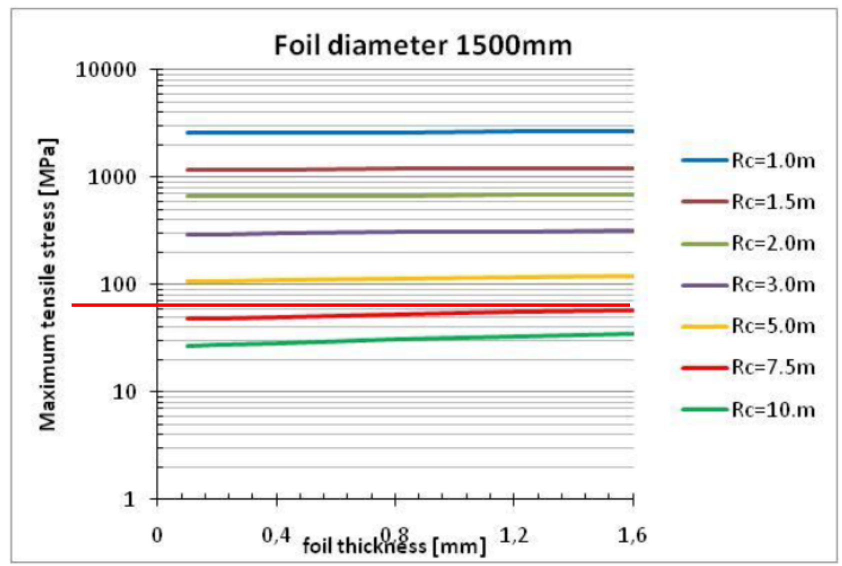
SAG in mm

Maximum principal tensile stresses in the glass, in the final cold shaping configuration, as function of mirror diameter and glass thickness





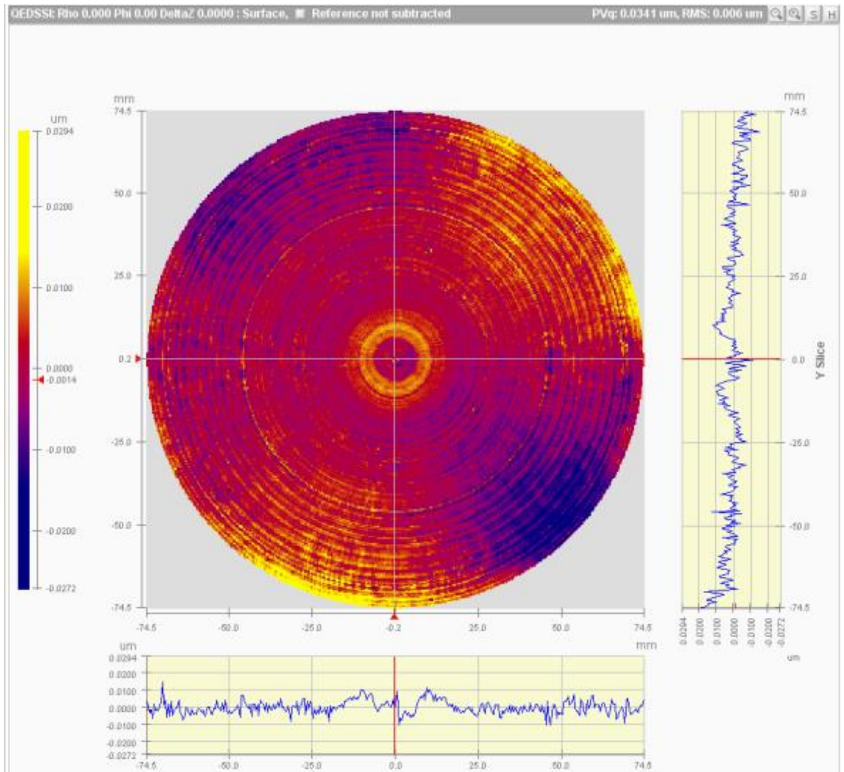


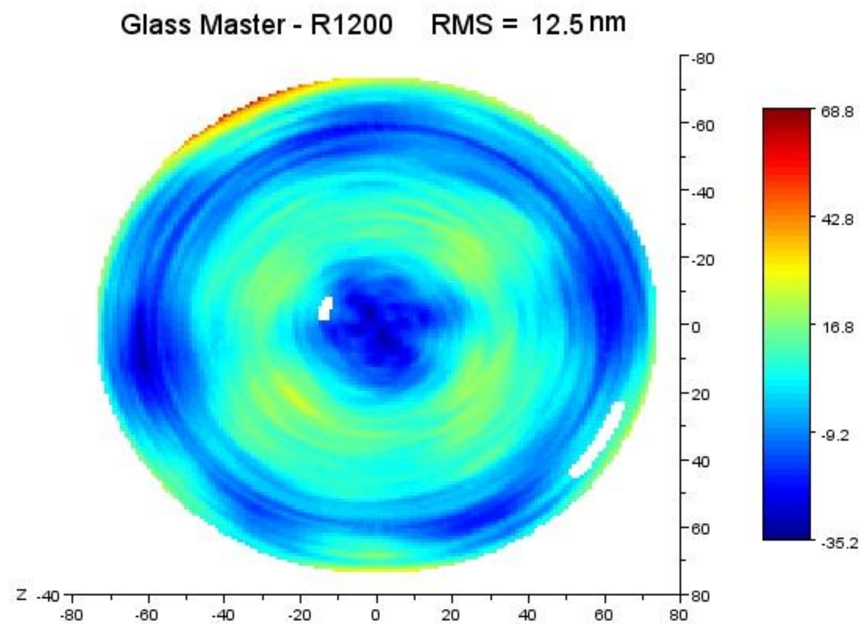


Available mandrels used for proof of concept (ϕ 150 and 250 mm)

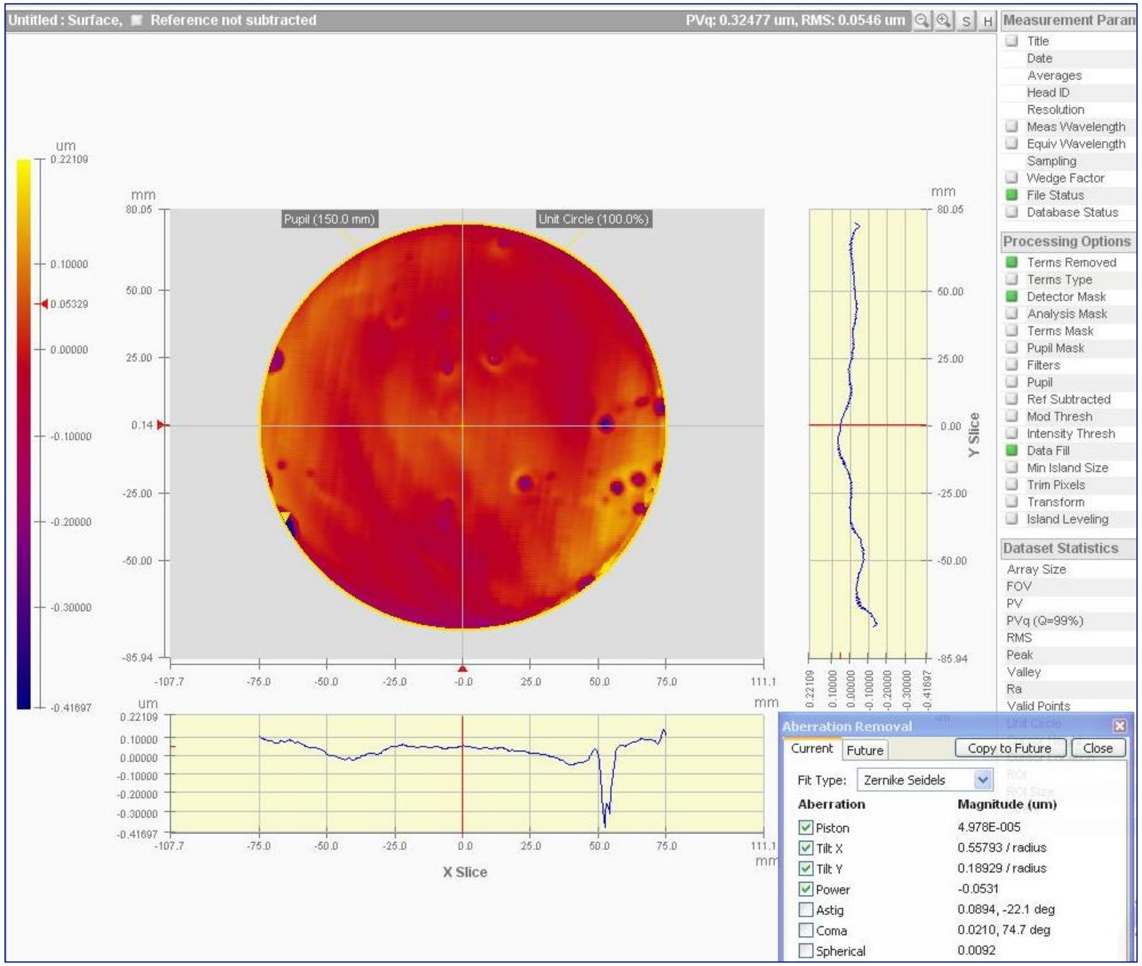
Mandrel = MUM 3
Diameter = 150 mm
Accuracy = 34 nm PTV; 7nm RMS
ROC = 375 mm
Material : Al-NiP

Mandrel = SP1200
Diameter = 250mm (150 mm used)
Accuracy (150mm)= 80 nm PTV; 12.5nm RMS
Accuracy (250mm)= 245 nm PTV; 25nm RMS
ROC = 1200 mm
Material : BK7





Cold Shaped mirror: 150 mm diameter with Al lightweight structure



Mirror: *SP1200 Rep 11*

Diameter: *150mm*

Configuration:

- *0.4mm Glass foil*
- *Epoxy*
- *Lightweighted Al back up structure*

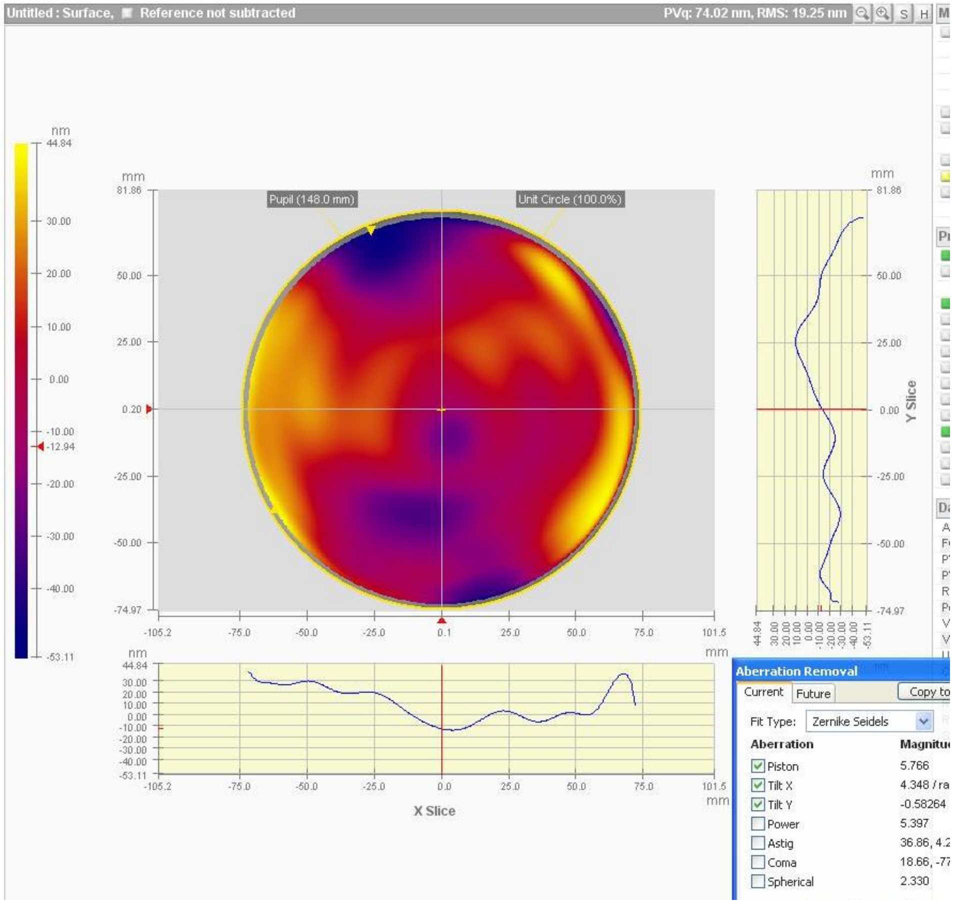
Shape Results:

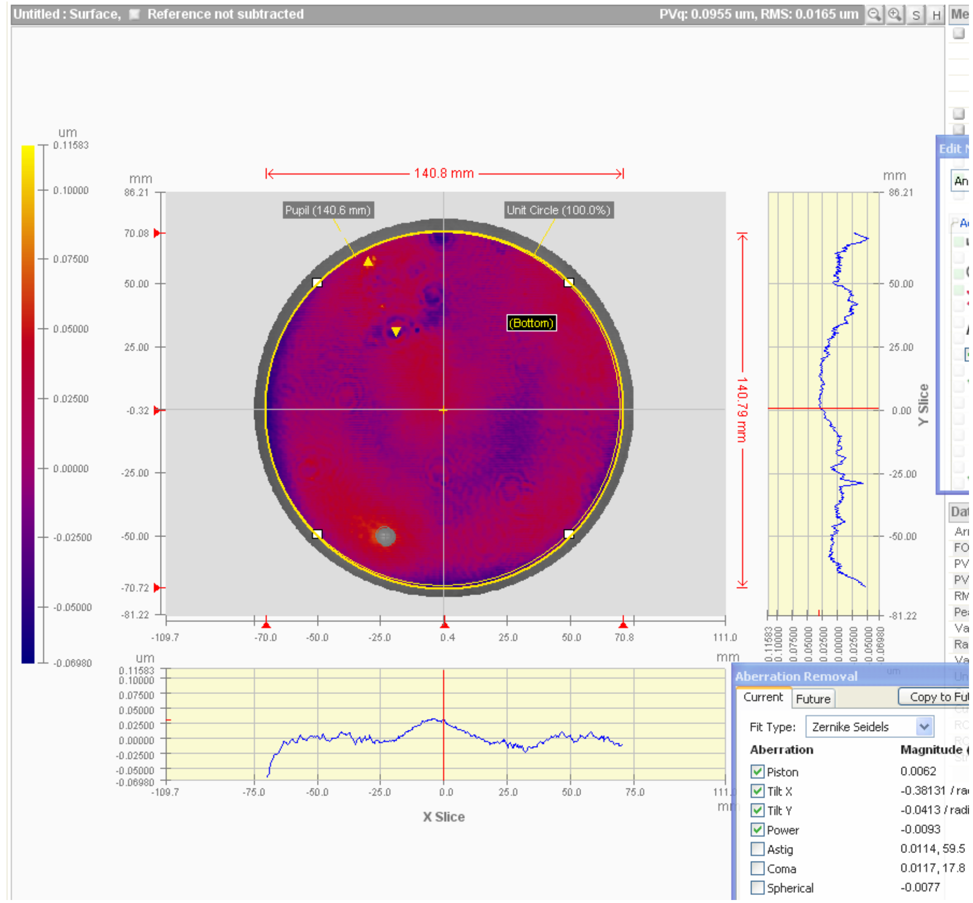
55 nm RMS

324 nm PTV

Interferometer measurement of the ∅150mm cold-shaped spherical mirror showing a surface shape error of 55 nm RMS

Using eformed Nickel skin instead of Glass foil.....





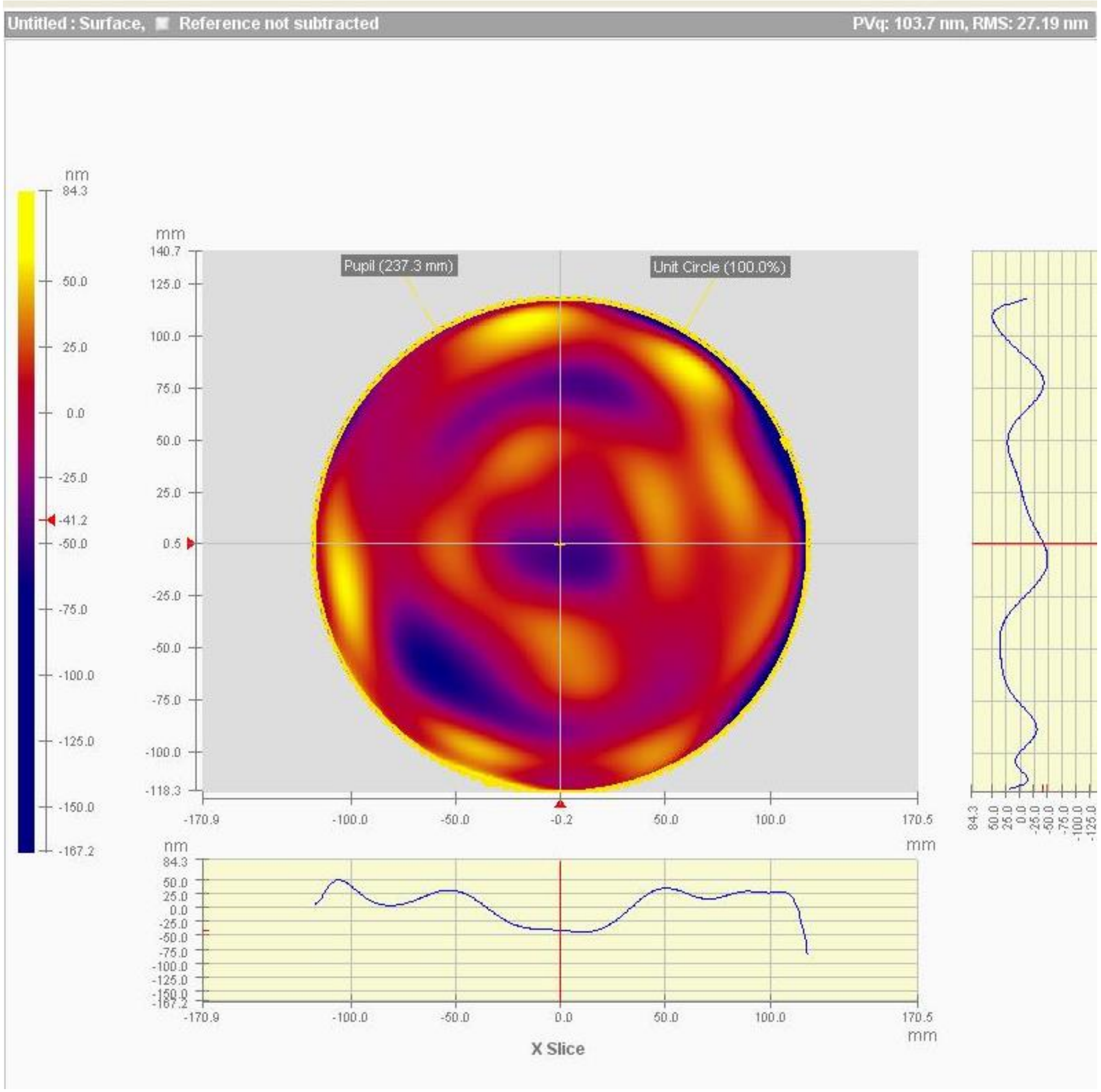
MUM 3 Rep 8
150mm diameter

Shape:
74nm PTV; 19 nm RMS

SP1200 Rep 2:
150mm diameter

Shape:
95nm PTV; 16 nm RMS

Cold Shaped mirror: 250 mm diameter with Al lightweight structure



Mirror: *SP1200 Rep 11*

Diameter: *250mm*

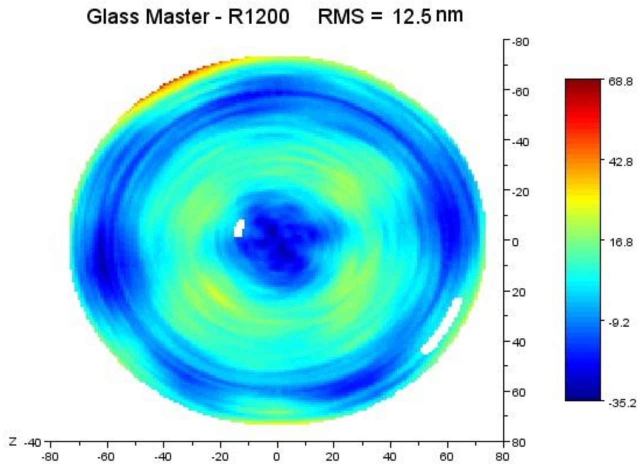
Configuration:

- *100 micron of eformed Nickel*
- *Epoxy*
- *Lightweighted Al back up structure*

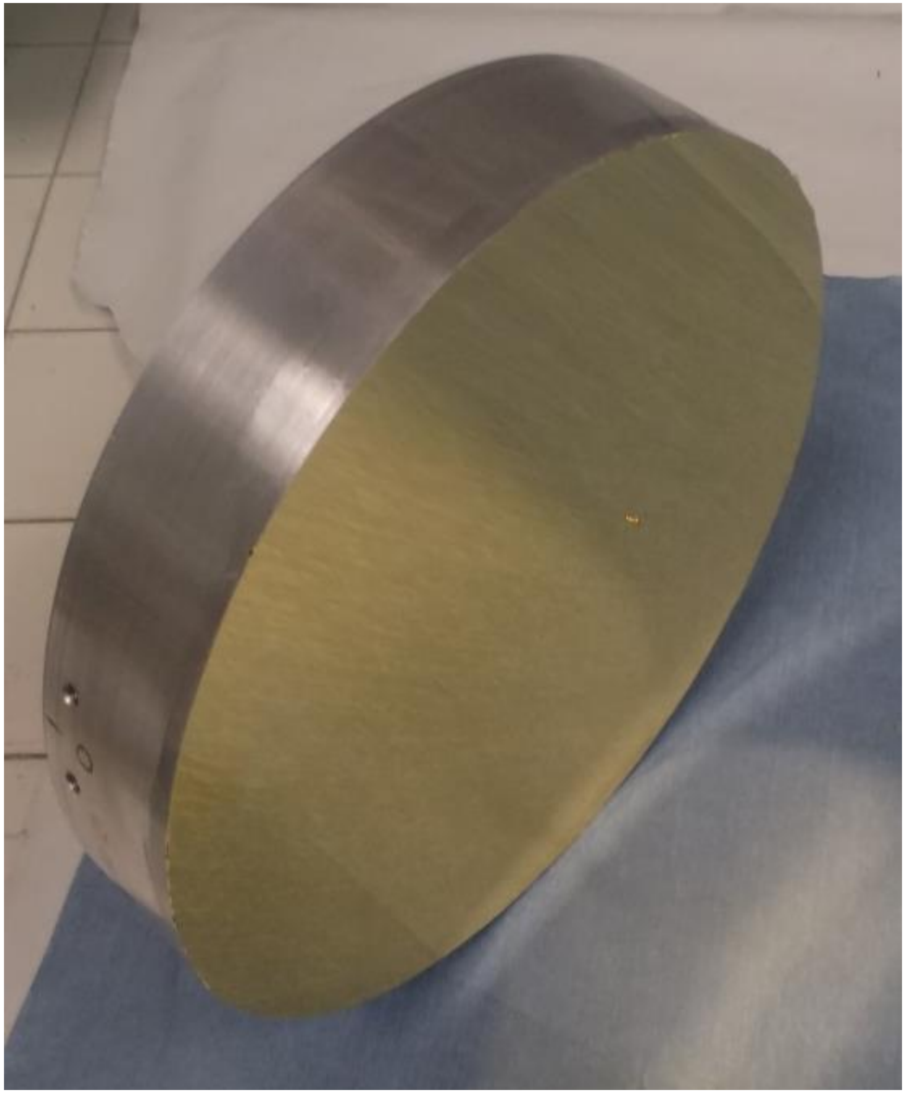
Shape Results:

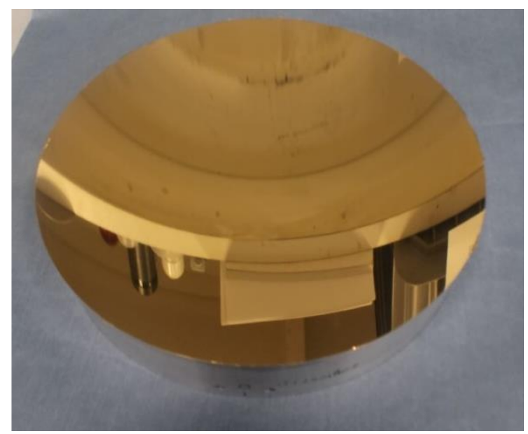
27 nm RMS

103 nm PTV



Cold Shaped mirror: 250 mm diameter with Al lightweight structure





Results

- ✓ We are very proud of the accuracy achieved on the first prototype mirrors. The present results are strictly dependent of the mandrel quality.

- ✓ We are at the beginning of the development but the results are very encouraging, 15-27 nm rms on 250mm mirror diameter

- ✓ With one mandrel we can produce many mirrors in 1-2 days cycle time, metrology included.

- ✓ We are convinced that this manufacturing technology will change the way to manufacture the optical mirrors.

Next Steps

Media Lario will continue to push the development of this innovative production process.

- ✓ Perform test in clean rooms to avoid particulate issue
- ✓ Test new mandrel materials
- ✓ Procure and test aspherical mandrels
- ✓ Procure and test back up structure made of lightweight materials…SiC, glass
- ✓ Perform vibration and thermal cycling test to increase the TRL
- ✓ Strengthen cooperation's with Institutes (i.e. INAF OAB, IASF Milano) and Universities

X-ray Telescope Experience

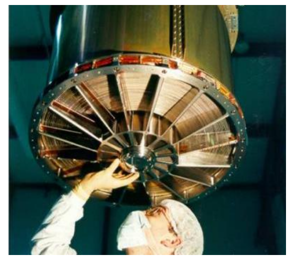
1993 — **Beppo SAX (ASI)**

- 4 mirror modules
- 30 mirrors/module
- Thickness: 0.4-2 mm
- HEW: 60 “

1995 — **JET-X → SWIFT (NASA-ASI)**

- 1 mirror module
- 12 mirrors/module
- Thickness: 0.4-1.5 mm
- HEW: 15 “

1999 — **XMM (ESA)**
The most powerful X-ray telescope ever built



- 3 mirror modules
- 58 mirrors/module
- Thickness: 0.5-1 mm
- HEW: 13”

2010 — **NHXM technology development (ASI)**

- New mandrel technology
- Aperiodic multilayer for hard-X ray reflection

2013 — **EROSITA (MPE)**

- 7 mirror modules
- 54 mirrors/module
- Thickness: 0.2-0.5 mm
- HEW: 14”

2015 - 2022

Media Lario has been selected as a supplier to ESA’s ATHENA program !

Our components have enabled nearly all X-ray space missions of the last 20 years

Large Terrestrial Telescopes

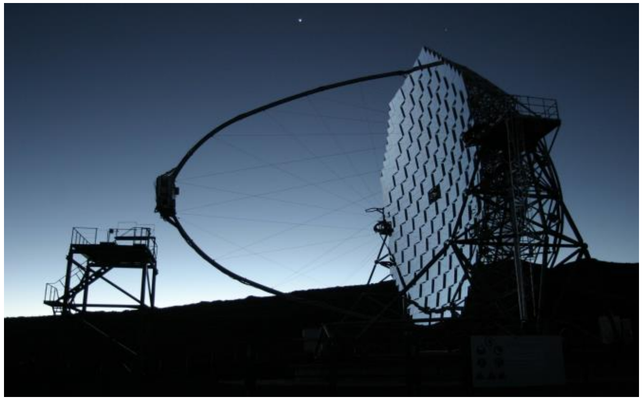
LMT – Large Milimeter wave Telescope on Mount Sierra Negra, Pueblo, Mexico

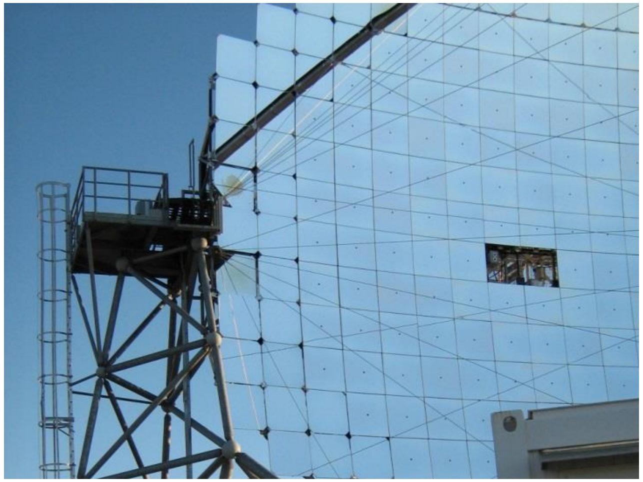
Nickel Panels for Large Radio Telescopes

- **Laminate structures composed of two electroformed Nickel skins bonded to Aluminum honeycomb core**
  - **Typical surface accuracy: 10 µm**
  - **Typical surface area: 2 m^2**
  - **Weight: 10 kg/m^2**
- **Field proven technology and performance on total primary mirror surfaces of 4800 m^2**
  - **2003: 15 panels produced for IRAM**
  - **2005-07: 800 panels produced for LMT (rings 1-3)**
  - **2006-12: 3,000 panels produced for ALMA**
  - **2013-15: producing 800 panels for LMT (rings 4-5)**
  - **2015: producing segmented secondary mirror for LMT**

Our nickel panels perform in Millimeter Wave spectrum in the most demanding environments

Glass Mirrors for Cherenkov Telescopes





- **Cold-shaped glass panel technology**
  - Laminate structure composed of two glass skins bonded to an Aluminum honeycomb core
  - Typical surface accuracy: 10 μm
  - Weight: 10 kg/m^2
- **Field proven technology and performance**
  - 2006: 10 panels produced for HESS
  - 2007: 108 panels produced for MAGIC II
  - 2012: 25 prototype panels produced for CTA-MST
  - 2014: 72 panels produced for MAGIC I
  - 2014: 5 prototype panels produced for CTA-SCT

Our panels on Cherenkov Telescopes has established our reputation in Gamma Ray astronomy

Thanks!