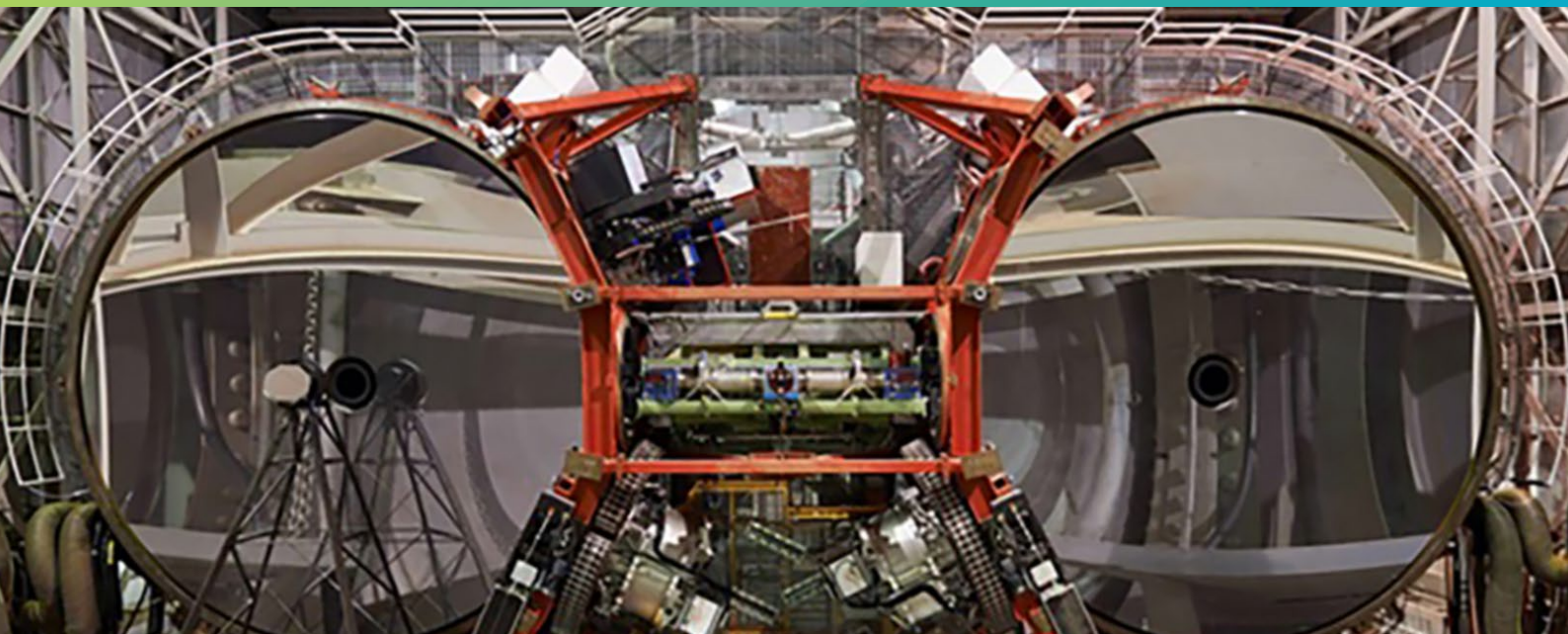


Hexagons Absolute Multiline System enhances vision of world's largest infrared telescope

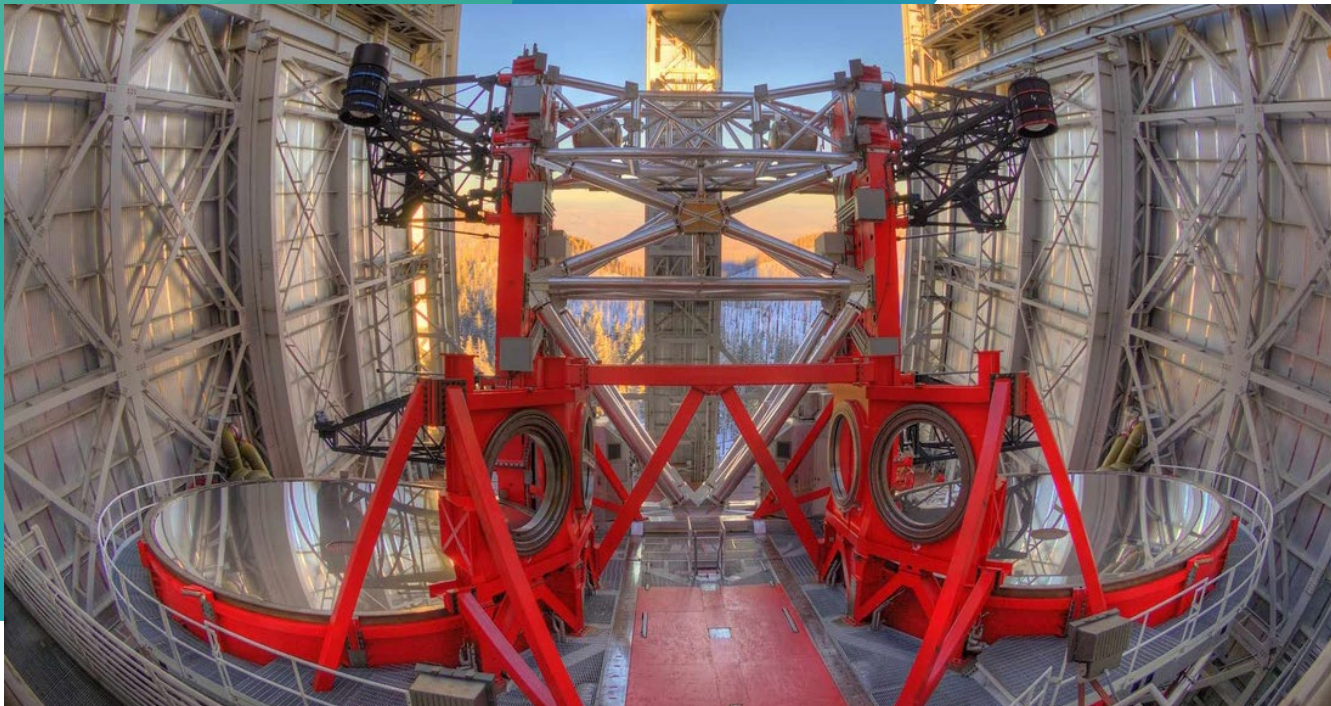
The Large Binocular Telescope (LBT), Mount Graham, USA



Absolute distance interferometer measuring system ensures micrometre-level precision when aligning complex optics

In astronomy, precise telescope optics are crucial for success. Yet, achieving and maintaining micrometre-level alignment of mirrors poses significant challenges. At the Large Binocular Telescope (LBT), Hexagon's ABSOLUTE MULTILINE TECHNOLOGY was selected for a system to actively align the telescope's main optical components. Maintaining alignment is now much easier, enhancing both image quality and observation efficiency. Given its success, the system will also be implemented at the new Giant Magellan Telescope in Chile.

The Large Binocular Telescope (LBT), located on Mount Graham in Arizona, USA comprises two 8.4 m Gregorian telescopes mounted on a common gimbal.



View in the telescope dome

The combined light-gathering power of these two telescopes is equivalent to that of a single telescope with an 11.8 metre aperture, making it the largest optical-infrared telescope ever made. When light from the two telescopes is combined interferometrically, the “interferometric baseline” is 22.5 metres, allowing an angular resolution approaching ten times that of the Hubble Space Telescope. With these attributes, the LBT is the first of the emerging generation of Extremely Large Telescopes.

To achieve optimum imaging performance, the large telescope mirrors must be kept in very precise states of alignment to each other and to the scientific instruments, that analyse the telescope images. Errors in the order of microns of absolute position over 10-metre scale distances can cause significant image degradation.

Today’s approach to telescope alignment is to utilise wavefront sensors, which analyse the degradation of stellar images and deduce from this analysis the alignment state of the telescope. However, there are several problems with this approach to alignment.

Firstly, the degradation of stellar images arises from multiple error sources, and it is a non-trivial task to disentangle such sources as atmospheric noise, mirror shape deformation and mirror decentre and rotation errors. In fact, for a two-mirror telescope, at least three wavefront sensors are required to disentangle ambiguities in various modes of misalignment and mirror deformation – a fact that was only realized technically after numerous

major telescopes were fielded in the 1990s with only one wavefront sensor.

Secondly, with a telescope structure as large as that of the LBT, optical deflections arising from changing orientations in gravity and thermal variations can give rise to errors that are beyond the capture range of the wavefront sensors.

A new telescope project, the 2-billion-dollar Giant Magellan Telescope, is building on the technical heritage of the LBT, and will incorporate seven 8.4 metre diameter mirrors to produce one 24-metre aperture telescope.

In 2016, this project developed an alignment plan that incorporated Hexagon’s ETALON ABSOLUTE MULTILINE TECHNOLOGY as a baseline alignment tool, to ensure that the wavefront sensors would always be fed with stellar images within their capture ranges.

It was recognised that a significant prototyping effort would first be required to mature this novel technical approach to telescope alignment to a state of “on-sky” readiness. The LBT was identified as a perfect testbed for developing this alignment system.

Thus, the LBT Telescope Metrology System (TMS) – a laser-truss-based metrology system for the active alignment of telescope main optical components – was born. An ABSOLUTE MULTILINE system was purchased in 2017 and integrated into the telescope control system.

The system consists of a network of collimators mounted along the edge of the primary mirror's edge and retroreflectors mounted on the Large Binocular Camera (LBC) hub. This setup enables laser interferometric absolute distance measurements every approximately 30 seconds that are used to adjust the position of the primary mirrors

The TMS maintains the relative position and orientation of each primary mirror and its respective LBC to within a few microns over slews and over time. The effectiveness of the technology in assisting in telescope alignment has been extensively validated, with results published in several scientific papers. And the outcome is that the LBT has a new, much better way of maintaining telescope alignment.

This direct metrology system runs reliably and accurately, night after night, acquiring and maintaining the alignment of the optical components of the LBT with unprecedented accuracy, with noise level at just a few microns. Several long-standing performance issues of the LBT have been solved by the system, and following this success, the system is being rolled out to assist in all telescope observational modes.

Significant interest in this technical approach to telescope alignment is developing, with other major astronomical observatories already adopting the method or beginning technical studies to this end.

"The success of Hexagon's metrology system on the LBT has been well-noted by other major observatories," says Dr. Andrew Rakich, Metrology Designer at the Giant Magellan Telescope and LBT and one of the initiators of this project.

"The Hexagon ABSOLUTE MULTILINE system provides a robust and highly accurate solution, and it has a bright future in the field of astronomical telescope alignment."

Corroborating this assessment, his colleague Dr Heejoo Choi received the prestigious Kevin P. Thomson award for optical design in 2022 for integrating Hexagon's system in the LBT control loop and the resulting gains in image quality.

A number of other large telescopes have followed the LBT example by integrating the Hexagon solution into the optical alignment system of their telescopes.



Main unit of the Absolute Multiline System

Absolute Multiline System

Features:

- Absolute distance measurement from a few Millimeter (close range configuration) up to 30 m (normal configuration) or more
- Measurement uncertainty (95%) = $0.3 \mu\text{m/m}$
- Up to 124 synchronous channels
- Robust sensors available
- Measuring fibers up to 7 km in length
- Additional channels by means of sequential multiplexing via fiber switches
- Operates in harsh environments

“Hexagon’s ABSOLUTE MULTILINE system provides a robust and highly accurate solution, and it has a bright future in the field of astronomical telescope alignment.”

Dr. Andrew Rakich,
Metrology Designer,
Giant Magellan Telescope and LBT



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Our technologies are shaping production and people-related ecosystems to become increasingly connected and autonomous – ensuring a scalable, sustainable future.

Hexagon's Manufacturing Intelligence division provides solutions that use data from design and engineering, production and metrology to make manufacturing smarter.

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