ZYGO unveils its high-precision optics capabilities

Although most people know ZYGO for its expertise in metrology and interferometry, the company has a rich history in high-precision optics fabrication. **Jacqueline Hewett** speaks to John Stack, the president of ZYGO's Optical Systems Division, who lifts the lid on what he sees as the best-kept secret in the optics industry.

When you think of the name ZYGO, some of the first words that spring to mind are metrology and interferometry. Dig a little deeper however and you will find a wealth of high-precision optical fabrication knowledge and a treasure-trove of capabilities that have grown in parallel with the firm's metrology business.

"What most people know ZYGO for is metrology and this centres around the vast numbers of interferometric devices around the world that have become the staple diet of the photonics, semiconductor and now flat-panel-display communities," John Stack, president of ZYGO's Optical Systems Division, told *OLE*. "But ZYGO also has a rich history of optical component fabrication and design for manufacturing and assembly (DFMA) capabilities that many in the optics community are just now learning about."

This fabrication experience extends to a wide range of optical components but the company's speciality is in 0.25–1.2 m class optics. "The world of high precision centres around engineering-based manufacturing," added Stack. "What makes ZYGO unique is an ability to produce this class of optics in high volume. The same could be said of our DFMA business and in many cases ZYGO is the only source, or one of just two or three in the world capable of such high-precision volume production."

ZYGO

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The AHMD (top) uses multiple off-axis optical paths. ZYGO manufactures high-precision metre-scale optics (bottom left) for customers including the National Ignition Facility.

Capabilities

- Glass machining of up to 1 m in diameter.
- Rotary polishing of pieces up to 1.2 m in diameter.
- Flats up to $\lambda/50$ peak-to-valley.
- Surface roughness less than 0.2 nm rms.
- Angle tolerances to 0.1 arc sec.
- A scratch-dig of 20–10 on 1 m class size optics.
- MRF (wheels up to 500 mm) of large optics.
- Ability to work with a range of materials including fused silica, sapphire, cleartrans, ceramics and phosphate.

High precision in volume

ZYGO was founded in 1970 and from its inception it has had a deep-rooted emphasis on research and development. The fledgling company started with two strings to its bow that are still evident in today's firm employing 600 people. The first is the fabrication of high-precision plano optics and the second is high-precision metrology, which also relies on high-precision test spheres from the optics group.

"From the very beginning, ZYGO was formed as an optics company," commented Stack. "From that grew what are some unique optical technologies and fabrication techniques. We have also benefited tremendously from the experience and strength of the metrology division." See the tinted box opposite for a list of the Optical Systems division's capabilities.

A good example of ZYGO's high-precision know-how is its long-standing relationship as a supplier to the National Ignition Facility (NIF) – the laser-fusion facility that is being built at Lawrence Livermore National Laboratories, US.

ZYGO supplies NIF with high-precision amplifier slabs and other associated optics on the metre scale such as phase plates and mirrors. "Around 3000 amplifier slabs will be required to fill NIF. These are made of phosphate and have a very high surface-quality specification," explained Stack. "We are the only volume manufacturer

of these types of large optics that is able to meet the NIF requirements."

However, the story doesn't end at NIF as the company's capabilities also include polishing sapphire for use in semiconductor lithography machines, thin-film coating of large optics and reducing the weight (lightweighting) of heavy optical components for aerospace and defence applications.

Stack believes that ZYGO's ability to produce high-quality components in volume stems from manufacturing equipment that has been developed in-house. "From a technology point of view, ZYGO has very highly integrated machines that utilize a variety of proprietary metrology techniques," he said. "The amount of feedback and control allows our manufacturing facilities to do things that no others in the world can do in production."

L-3 Link Simulation & Training

A computer-generated image of a typical view seen by an AHMD user.

The Optical Systems Division is spread across three US-based sites. The first is ZYGO's headquarters in Middlefield, Connecticut; the second is an optical assembly centre in Tucson, Arizona; and the third is a design and prototyping facility in Costa Mesa, California. "The Middlefield facility is second-to-none in terms of high precision and large optics," said Stack. "It is a world-class facility that has grown enormously over the years and is the best-kept secret in the optics industry. Tucson and Costa Mesa are what I would characterize as Tier-1 optical system and assembly facilities, and provide a wide range of high-precision DFMA capabilities. For example, the Tucson facility participated in designing and producing very demanding vacuum relay telescopes in its NIF qualified class 10 clean-room facilities."

The three sites essentially feed through into each other. At the start of the chain Costa Mesa does much of the initial design, prototyping and low-volume production work and develops integrated tooling methods required to make very high-end devices. "This facility has made devices for some of the best optics companies in the world that they were unable to produce on their own," revealed Stack.

Once the prototyping is complete, the technology is transferred to a production manufacturing environment in Tucson. In addition to ISO9001:2000 certification and clean rooms ranging from class 10 to class 100 000, the Tucson site also achieved ISO13485:2003 status in March, which means that it is now certified to manufacture medical products.

"The Tucson facility is virtually unknown and is making some of the highest-end optical-systems devices that are out there," said Stack. "For example, for the medical market we have done precision laser delivery and high-precision imaging and diagnostic systems. For the defence field we have developed helmet-mounted displays and integrated sensor packages."

According to Stack, the medical market is becoming ever-more important to ZYGO. "Our ability to make high-precision medical devices is a real strength and leverages our assembly and engineering capabilities," he said. "We have built and assembled laser-delivery systems for ophthalmic applications that combine the laser and the viewing system. These tend to be very fast systems and the control of production stack-up tolerances tends to be exceptionally challenging."

The final link in the chain is ZYGO's headquarters at Middlefield, where the company is renowned for fabricating both plano and spherical optics ranging in size from 8 mm to over 1 m. Other specialities include thin-film coatings on optics ranging from 1–600 mm and wavelengths from 200–2000 nm, and CNC machining capabilities to reduce the weight of large and heavy optics.

Advanced optical systems

One application that neatly sums up ZYGO's expertise in high-precision optics is the advanced helmet-mounted display (AHMD) that it has developed in conjunction with Link-L3, a provider of intelligence, surveillance and training systems to the defence sector, and optical design specialist Optical Research Associates.

Branded "a major breakthrough in visual display capability", the AHMD is used to train helicopter pilots by immersing them in simulated and virtual-reality situations.

The proprietary design provides the wearer with a field-of-view spanning 100° horizontally and 50° vertically per eye. The projected resolution seen by each eye is 1280 × 1024 pixels and allows users to view full-colour imagery that is said to be unsurpassed by any other helmet-mounted display on the market today.

"This really represents the cutting edge of helmet-mounted display," said Stack. "When you build something like this the alignment is crucial because you are working with multiple off-axis optical paths. The specialized manufacturing techniques required to produce such devices in volume are unique within our industry."

As well as the advanced optical and illumination design, the helmet uses solid-state microdisplays and has a transmissivity greater than 60%, which means that the wearer can clearly view their surroundings in the cockpit or other environment. An eye relief of greater than 50 mm enables users to wear spectacles and the claustrophobic, closed-in feeling that many have experienced with other helmet-mounted displays is said to have been eliminated.

It's not just the optics that the designers have paid careful attention to. The AHMD attaches to the user's helmet in a matter of seconds as well as being lightweight, well-balanced and ergonomic.

"This is a really good example of what ZYGO can do," concluded Stack. "We have a lot of capabilities and the ability to do volume production. There is a whole other part to ZYGO – we love our metrology advantage but the real untold story lies deep within the rich history of ZYGO's optical fabrication and engineering capabilities. In short, the world is ready to be introduced to a 37-year-old secret known as ZYGO Optical Systems Division." □

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