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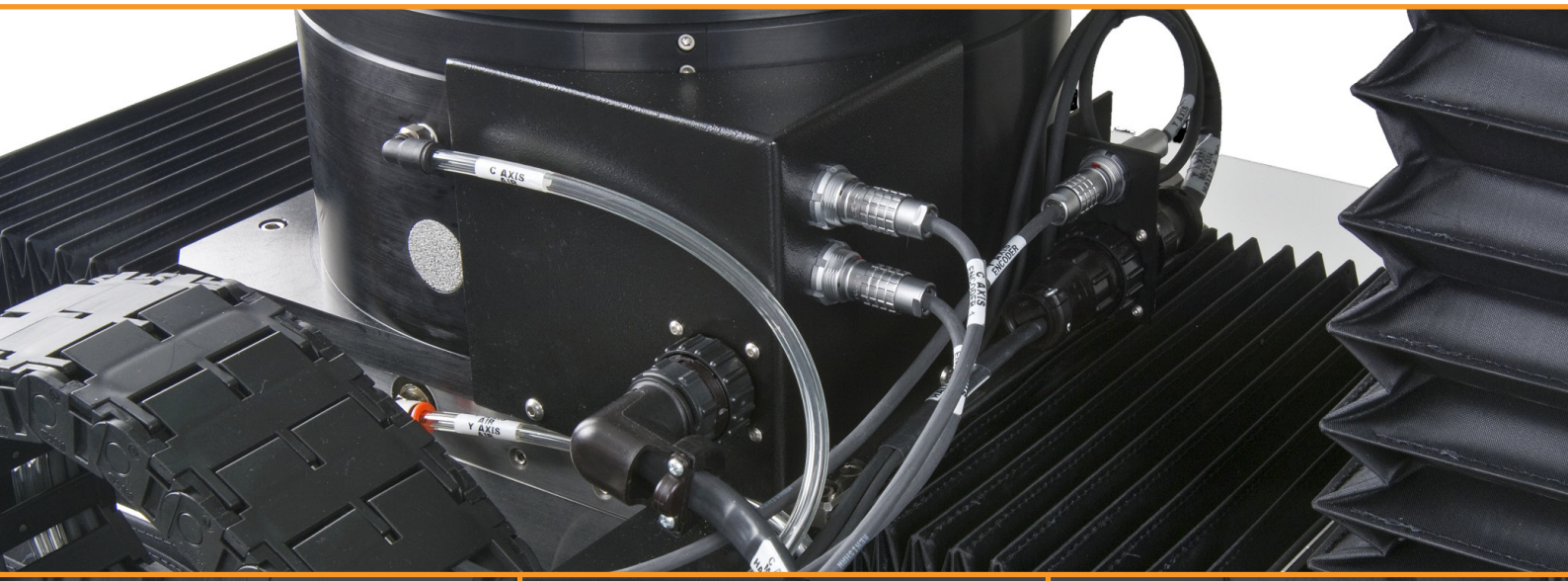
Ultra-accurate lens measuring system features advanced air bearing and encoder technologies



Customer:
ABTech

Industry:
Precision manufacturing

Challenge:
To achieve ultra accuracy and stable positioning in air bearings for CNC optical manufacturing.

Solution:
The high-resolution linear and rotary SiGNUM™ encoder series.

ABTech Manufacturing creates five-axis platform for nanometer/sub-arc sec processing around its ultra-precision air bearings and Renishaw SiGNUM position encoders.

When a leading manufacturer of CNC optical manufacturing technology needed ultra-accurate and stable positioning for a new system for measurement of conformal optics, it turned to ABTech Manufacturing Inc, specializing in custom-made ultra-precision air bearings and motion systems.

To meet tighter customer specifications for positioning resolution, it found the solution, as usual, in new high-resolution linear and rotary optical encoders from Renishaw. The East Swanzey, New Hampshire company created a five-axis optical measurement platform featuring three ABTech linear air bearings, two ABTech rotary air bearings, and Renishaw's ultra-high accuracy SiGNUM series linear and rotary encoders.

Position repeatability and thermal stability

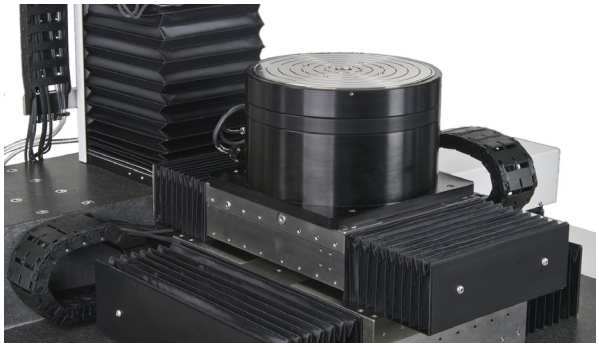
"This was a joint development project with our customer", said Ken Abbott, ABTech's president. "They developed the concept, controller and software, while ABTech designed and built the mechanical system — the multi-axis air bearing platform".

In operation, a lens is placed on a high-precision B-axis rotary table for measurement by a non-contact confocal imaging probe mounted horizontally on a rotary C-axis air bearing. Confocal imaging performs microtopographic mapping of the lens geometry and surface.

The system requires that the confocal probe be positioned normal (perpendicular) to each surface point to be measured. The platform created by ABTech accomplishes the exacting repositioning by coordinated motion in up to five axes. The next-generation CNC optics inspection systems require position resolution of 5 nm for the three linear axes.

> "The small size of the Renishaw package allows us to maximize the size of our air bearing pads, which is critical to achieving high stiffness and accuracy."
>
> **ABTech (USA)**

DSi and REXM ultra-high accuracy encoder system



ABTech 5 axis air bearing optical metrology platform

Resolution for rotary motion is 0.009 arcsec/count for the C-axis and 0.018 arcsec/count for the B-axis. Fully programmable 32-bit Windows-based measuring software drives the non-contact probe to automatically collect microtopographic data.

“Overall volumetric system accuracy is mapped and corrected by the customer, so position repeatability and thermal stability were the most important demands on us for this application”, said Abbott. ABTech’s requirements for individual axis position accuracy were:

- Linear — ±1 µm over full travel of 8”
- Rotary — ±1 arc second total error over a 360° move

To achieve that accuracy, Abbott called his Renishaw representative, Tim Goggin. “We’ve been in business about 10 years and have used Renishaw encoders pretty much from the first”, he says.

High accuracy encoders

Goggin recommended an advanced SiGNUM rotary and linear system – the high performance dual-readhead DSi rotary encoder system and the RELM high accuracy linear encoder system. These SiGNUM encoders provide accuracy better than ±1 µm, ±30 nm cyclic error, and resolution down to 5 nm/0.005 arcsec. Dynamic signal control enables the 20 µm scale position encoders to offer “fine pitch” performance without the fragility and optical cleanliness constraints of glass encoders and enable outstanding dependability in manufacturing environments, high tolerance of shock, vibration and temperature (to 85 °C).

Especially important to ABTech, the RELM linear encoder system features a scale of stabilized Invar. This nickel/iron alloy offers exceptionally low coefficient of expansion (˜0.6 µm/m/°C, 0 °C to 30 °C). “This being a metrology system, we were most concerned about thermal stability”, said Abbott. “Most of the machine is fabricated from stainless steel, granite and ceramic to minimize thermal growth. The Invar scales were a perfect fit for this application”.

Accuracy, price, ease of use and physical size were key factors for ABTech in selecting position encoder. “The encoder needs to be small”, Abbott emphasized. The 20 µm Invar scale met those needs with a smaller cross section than glass scales of just 0.059” x 0.591”, along with easier handling and installation without risk of breakage.

The scale incorporates Renishaw’s IN-TRAC™ optical reference mark, providing a bi-directionally repeatable datum point across the entire speed and temperature range without increasing overall system width. Dual optical limits are also available as position markers to indicate end of travel.

Rotary encoder offers better than ±1 arc second

For rotary position accuracy, ABTech selected the DSi (Dual SiGNUM interface) and REXM rotary encoder system, Renishaw’s highest accuracy SiGNUM rotary encoders. Capable of total installed accuracy of better than ±1 arc second, the DSi configuration combines two error-correcting

ABTech 5 axis optical metrology station

REXM stainless steel ring

SiGNUM SR readheads with an ultra-high accuracy REXM ring/scale and provides a customer-selectable propoZ™ reference (index) position which is completely unaffected by bearing wander or power cycling.

“Located in 180° opposition, the two readheads cancel out odd error harmonics, including eccentricity, and compensate for the effect of bearing wander”, explained Goggin. “By combining the incremental signals from the two SiGNUM readheads and using Renishaw’s patented reference mark processing, the DSi appears to the controller as a single, very high accuracy encoder”.

The other element in the accuracy equation, the REXM ring, features a thick cross-section to minimize all installation errors except eccentricity, which is corrected by the DSi. Once the interface has eliminated the effects of eccentricity, the only significant errors remaining are minor even-harmonic distortions in installation, graduation and cyclic error (sub-divisional error – SDE), which are exceedingly small, as low as ±0.5 arc second and ±0.03 arc second respectively. “When the REXM ring is used with the DSi, it is possible to realize a total installed accuracy of better than ±1 arc second”, he said. “In fact, DSi/REXM rotary encoders have achieved total installed accuracies below ±0.25 arc seconds, depending on ring size”.

The one-piece REXM stainless steel ring is available with diameters from 2.047” to 16.417” and has scale graduations marked directly onto the outer periphery. The integral ring/scale locks directly to the rotor, eliminating reversal errors, coupling losses, oscillation, shaft torsion and other hysteresis errors that plague enclosed encoders.

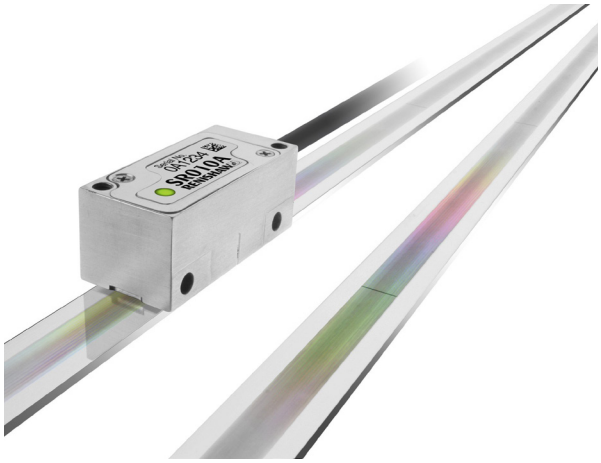
To create the desired propoZ™ reference position, the user drives the axis to the chosen angle and simply presses a button. In this way, propoZ™ technology makes aligning the reference position to the T-slots on a machine tool for example, a far quicker, easier and more accurate process. The selected angle is then stored in the DSi’s memory, where its output position is automatically compensated for error by powerful algorithms, ensuring perfect angular repeatability, even if the center of rotation of the axis moves while the DSi is switched off.

The linear and rotary encoders share SiGNUM encoder design features, including rugged IP64 sealed readheads, dynamic signal processing for excellent reliability, and ultra-low cyclic error (<±30 nm).

Unique, patented Renishaw optics scan and average the contributions from many scale periods and effectively filter out non-periodic features such as dust, dirt and other contamination. The non-contact readheads ride above the scale thus eliminating friction, hysteresis and wear.

Platform stiffness and accuracy

Renishaw’s compact readhead design met ABTech’s tight size constraints. While the five-axis platform is substantial at 53” wide, 38” deep and 66” tall, the individual axes are packed full of motors, encoders and air bearing surfaces, Abbott stressed. “The small size of the Renishaw package allows us to maximize the size of our air bearing pads, which is critical



SiGNUM RELM high accuracy linear scale with SiGNUM SR readhead

to achieving high stiffness and accuracy”. The linear and rotary encoders share the same miniaturized readheads, just 0.583” x 1.417” x 0.650” (HxLxW), while the RELM scale is just 0.591” wide and the REXM scale only 0.394”.

Powerful PC-based SiGNUM software provides comprehensive calibration and set-up optimization with real-time diagnostics. The SiGNUM Si interface connects to the PC via a USB connector. Analysis of the SiGNUM Si interface is available to users at all times, providing information on system configuration such as resolution, clock frequency, error and warning outputs.

The software simplifies installation of the encoder and provides an innovative indicator that enables fine adjustment of the readhead pitch angle, which is particularly useful for readhead set-up on small diameter rings. Integral LEDs on the readhead and interface provide quick, visual feedback to help optimize set-up and real-time system diagnosis.

The new optics measuring system is ABTech’s first project with this customer and is expected to become a production item in the customer’s catalogue providing a welcome on-going business relationship for the New Hampshire company.

High accuracy air bearing system

ABTech specializes in the design and build of custom-engineered, high-accuracy air bearing and mechanical bearing systems, plus entire turnkey platform solutions, for semi-conductor and optics manufacturing.

“We believe we are uniquely flexible in our use of air bearings, mechanical bearings and the design and use of materials to fit the application”, said Abbott. “We are not constrained to set designs, materials or processes”.

ABTech air-bearing technologies are used around the world in research facilities, universities and advanced manufacturing operations. The low-profile designs, combining magnetically preloaded carriages with ultra-precision slides, are ideal for optical production, bio-medical, diamond turning, wafer scanning systems, lithography, computer-to-plate systems, measurement systems and vision system positioning stages.

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"We can give designers critical space savings while providing the needed load capacity, precision positioning, constant velocity, and freedom from friction whilst in a static state", he said. "Our stages are designed for cleanroom environments with appropriate materials, parts cleaning and captured exhausts".

Abbott says that the demand for customization and miniturization is growing as chips and circuits get progressively smaller. "Both components and their manufacturing processes keep shrinking, demanding ever-finer positioning accuracies. That's why we appreciate our relationship with Renishaw, they kept pace with its product development and were ready again with the encoder capabilities we needed".

Abbott also stressed that, "The best product in the world is useless without meaningful technical support behind it. Renishaw has given us excellent support, even though we're a smaller, specialty business".

Close up view of 5 axis air bearing motion system from ABTech

For more information visit **www.renishaw.com/opticalencoders**

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