New, Ultra-Fast Laser Autofocus System offers Throughput with Flexibility

Background

Achieving and maintaining a sharp focus can be a critical task for systems engineers and researchers. Autofocus is important to users of standard microscopes and designers of custom optical columns alike, and some applications require real-time autofocus during processes in which the substrate is moved. Several approaches exist:

- Probe-based mechanisms compensate for drift by measuring the position of the sample plate versus the optical column. Drawbacks include slow speed, cumbersome setup and limited resolution due to slop and stiction at the probe/sample interface— often quite disappointing versus marketing claims. Additionally, it only maintains a mechanical setpoint. It cannot correct for variations in sample thickness, drift between the point of probe measurement and the sample, parfocality errors between objectives, drift in the optics or the column itself, and so on.
- Optical autofocus techniques have the advantage of evaluating the image via the optics. All mechanical, thermal and optical issues which can impact focus, including changes and steps in the sample itself, are compensated. These techniques fall into two broad camps: Image based autofocus relies on software processing of a camera image to command a corrective position change; Laser autofocus is a class of technologies which insert a laser source beam into the optical path as a sensitive optical probe to actually measure focus. In theory, laser autofocus has the best potential for high-bandwidth performance.

Now the engineers at Motion X have developed and refined a novel laser-based mechanism that when combined with PI's PIFOC objective and Z positioners—10X faster than stepper or servo focusers—delivers on the unmatched throughput potential of laser based autofocus. Result: the most responsive, highest-throughput autofocus available, yet its highly configurable approach avoids image degradation and is suitable for commercial and custom microscopes and for substrates ranging from wafers with sensitive coatings to live biological samples.

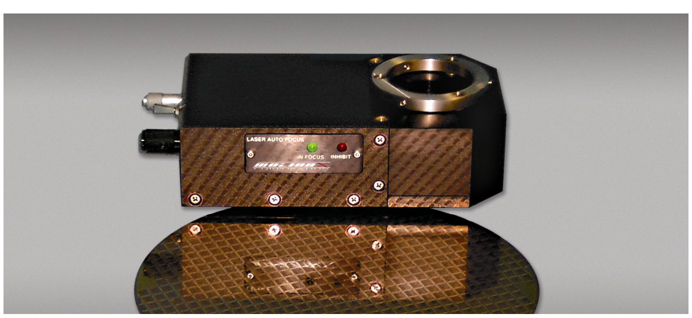

Figure 1. FocusTrac™: an innovative laser autofocus module of unsurpassed speed and compatibility.

Delivering on the Promise

Piezoelectric actuation offers many advantage. First, they are extraordinarily responsive. Their popularity as focusing mechanisms comes from their high speed compared to stepper and servo focusing mechanisms. They are also able to focus quickly to nanoscale precision, where stepper and servo mechanisms cannot perform repeatably or stably. Outside of imaging, piezos' responsiveness and longevity also means they find application in advanced vibration isolation systems and tracking mechanisms. And their resolution is essentially unlimited, so piezos are at the heart of atomic force microscopy and advanced lithography, among other globally strategic applications.

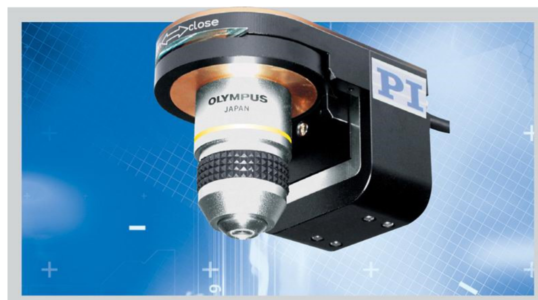

Figure 2. PIFOC objective positioners are the industry standard for focus control.

What's needed for high-bandwidth automated focusing is a suitable sensor with broad configurability, compatibility with a wide range of objective NAs, fast speed, a range of wavelength options to accommodate a wide variety of applications, and connectivity to piezo positioning controllers for ease of use.

The teamwork between PI and Motion X has married Motion X's novel FocusTrac™ system to PI's proven piezo controls and positioners for plug-and-play autofocus capability. Mechanical options include objective positioners, turret positioners and sample-positioning Z stages. FocusTrac™ works with microscopes from industry leaders including Olympus, Leica, Nikon, Zeiss and Mitutoyo. FocusTrac™ is also readily integrated into OEM assemblies.

Implementation

FocusTrac™ introduces a collimated laser source beam into the optical path of a microscope system via a custom designed dichroic narrow-band beamsplitter. The beamsplitter is highly reflective of the laser source at an incident angle of 45° and highly transmissive to other visible and infrared wavelengths, so the laser beam does not affect the image. Also, Motion X offers various wavelengths which the customer can select for optic compatibility and to ensure against any impact in imaging performance. The beam is directed through the objective to the sample, where it bounces back and is directed to a position sensitive detector. A real-time error signal is thereby generated and presented to the PI piezo controller. It is processed as a sensor input, and the controller actuates the piezo to bring the observed out-of-focus error signal to null. A front-panel offset knob and BNC input allow focusing to a defined offset from the sensor null position if desired, allowing easy accommodation of cover slips and coatings.

Figure 3. FocusTrac™ is compatible with a broad array of objective and sample Z positioners.

Since both the FocusTrac™ sensor output and the PI controller's servo methodology are based on high-bandwidth, real-time analog circuits, the responsiveness of the system is virtually instantaneous, and image optimization operates continuously. Tracking a wedged or wavy surfaces is automatic and fast. Step-height changes in the sample are accommodated swiftly and without hunting and overshoot. Both random and cyclic flatness errors are compensated—ideal for spinning-substrate applications in semiconductor and data storage production and metrology.

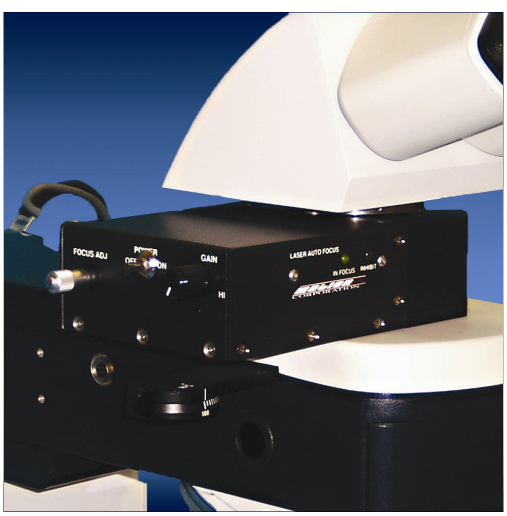

Figure 4. FocusTrac™ is easily integrated into the optical path

One benefit of the FocusTrac™ methodology is easy accommodation of different laser wavelengths. For sensitive life science and microelectronic applications, a laser wavelength compatible with the sample can be chosen. FocusTrac™ can also be configured to image the laser onto the sample as a spot or as a line. The line image has the distinct advantage of integrating the focus information over the entire topology of the field of view, ensuring accuracy with samples such as high-relief wafers found in MEMS and printer-head fabrication. Meanwhile, PIFOC configurations are available to accommodate virtually any objective thread and travel need; a selection of PIFOC microscopy Z stages is offered for applications where focusing via sample motion is desired, and P-601 OEM lever mechanisms offer cost-effective positioning solutions for custom optical trains.

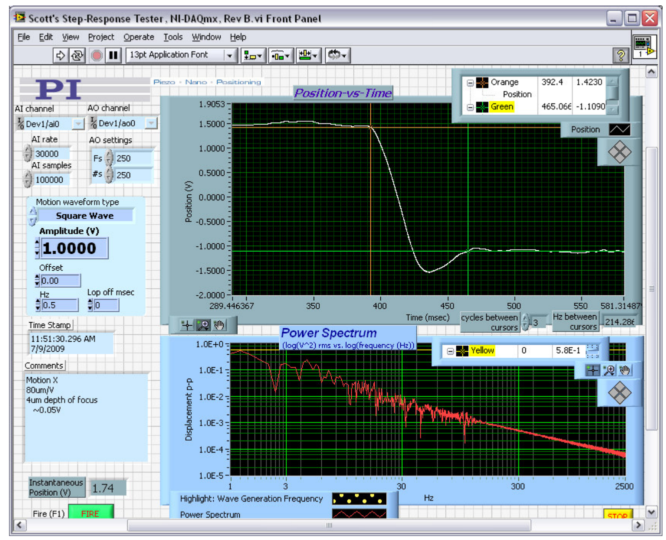

Figure 5. Typical step/settle response for 250µm wafer edge with 10X objective and PI P-725 400µm travel PIFOC fast objective positioner using FocusTrac™. Wafer was mounted on motorized scanning stage at 12mm/sec. For this application, settling to within the objective's depth of field completes in ~70msec. Real-time position data from Polytec laser vibrometer. Objective position stability with scanning stage stopped was observed to be <20nm.

Conclusion

Applications requiring the fastest possible autofocus with real-time continuous optimization can now be addressed by the combination of Motion X FocusTrac™ and PI objective and Z positioners. Both are highly configurable and compatible with popular microscopes as well as custom and OEM optical assemblies.

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