Elemental Scientific LASERS
INNOVATION TO ILLUMINATE

Poster Note

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Complete system level approach to < 1 µm laser ablation system stage return accuracy

Introduction

Hours-long or overnight LA-ICP-MS experiments such as high-throughput, automated zircon analyses and elemental imaging applications continue to increase in popularity. As a result the capabilities of traditional laser ablation hardware have been stretched to their limits. To improve short term stage return accuracy to be fit-for-purpose, a high precision stage can be substituted. Over long, automated runs, experiments have shown that a high-precision stage only approach – without system level implementation – can suffer poor return accuracy. Errors of > 30 µm are often experienced. Automating long runs has the advantage to the user of low human intervention, but the absence of human compensation often exposes stage return accuracy flaws. Elemental Scientific Lasers has observed this increasing requirement and has engineered a system-level solution that encompasses hardware and software. The solution not only improves stage return accuracy over the hour-long experiment scale, but improves stage performance over the lifetime of the platform.

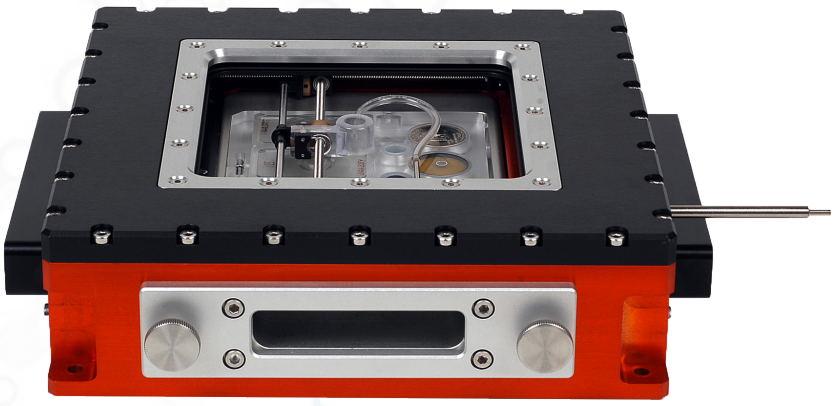

Figure 1. TwoVol2 ablation cell

Figure 2. NWR platform

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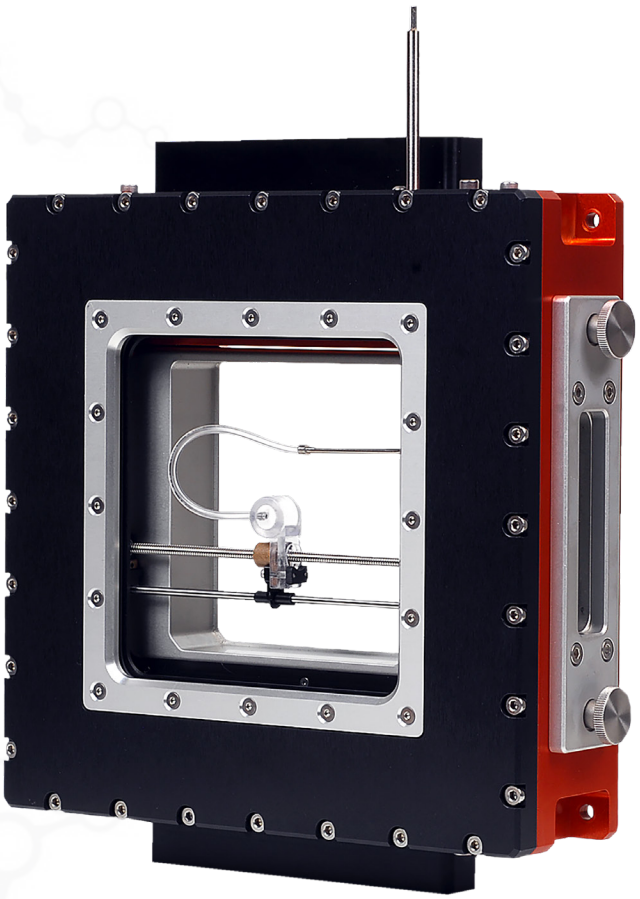


Figure 3. TwoVol2 ablation cell

Benefits of the TwoVol2 ablation cell

- Spatial Reproducibility of < 2% RSD
- Tubing curvature independent of sampling position – constant curvature
- Constant cup to sample distance due to non-cantilevered cup support
- Efficient Typhoon purge mechanism
- Leak free operation
- Accessible tubing for easy replacement
- Stage reproducibility of < 1.5 µm achieved by direct mounting of cell on stage
- Complex ablation pattern capability
- Incorporated pinch valve to minimize pulse broadening and sample deposition
- Compatible with off axis, large field of view camera

High precision stages with non-cantilevered sample chamber for direct cell mounting

The TwoVol2 sample chamber utilizes high precision cross-roller stages for maximum resolution in positioning. The chamber is directly centered on these stages instead of being cantilevered, so there is zero torque at every stage position. In a sample chamber that is cantilevered off the stages, these stresses vary, leading to greater stage return errors, especially over time.

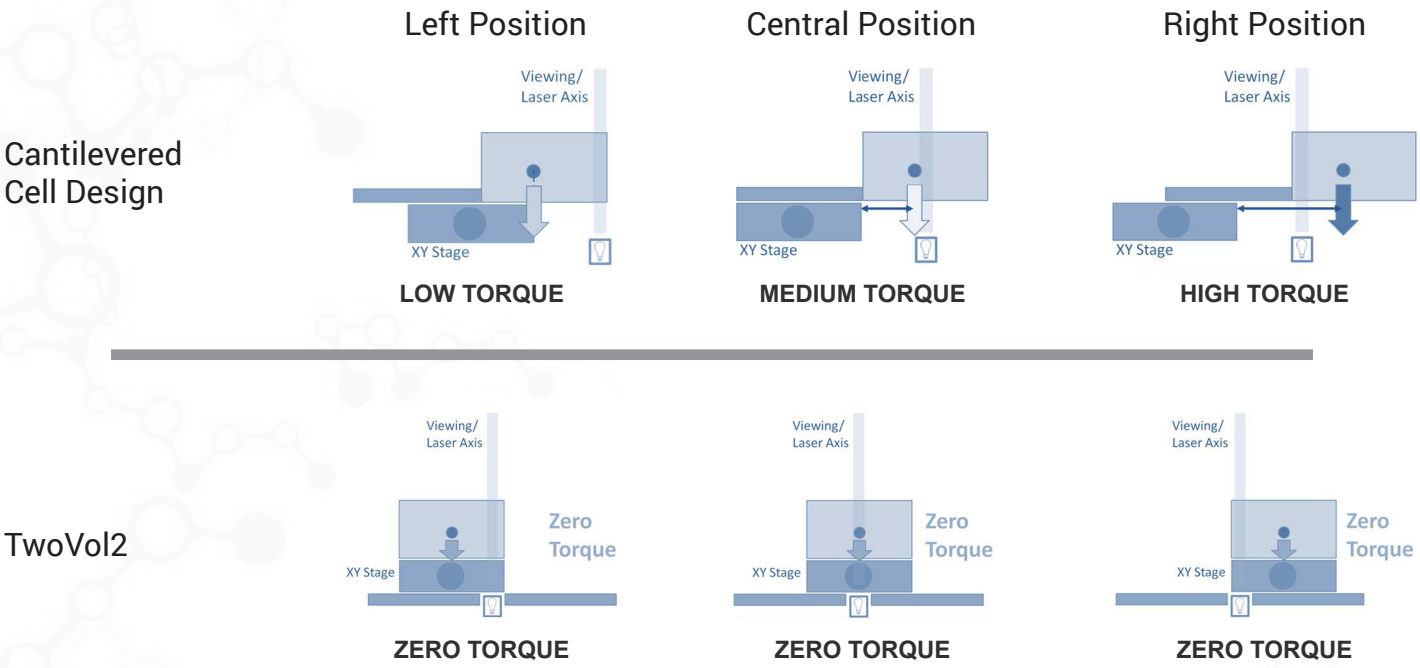


Figure 4. Cantilevered cells (top row) suffer from variable torque depending on position, whereas the TwoVol2 cell from Elemental Scientific (bottom row) that has the stage mounted directly underneath the weight of the chamber is not affected by torque effects at all.

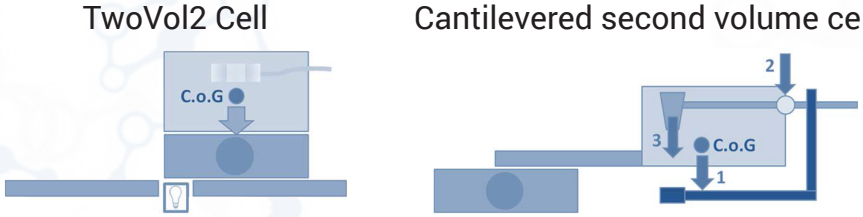


Figure 5. Variable torque in cantilevered ablation cells has a major effect on the function of the second volume. The TwoVol2 cell from Elemental Scientific (left) has zero torque and a cup that is not connected to the main stage movement. The cantilevered ablation cells (right) apply different forces onto the cup depending on cell position.

High precision stages with non-cantilevered sample chamber *(continued)*

A 7.5-hour experiment[1] without user intervention showed that incorrectly-implemented high precision stages have a stage return accuracy of > 30 µm (Fig.7). With correct implementation (non-cantilevered mounting) return accuracy can be reduced to **4 µm** (Fig. 6). The 10,000 spot test (Fig. 7) used a high precision stage with incorrect implementation (cantilevered mounting). Errors of up to 35 µm were observed prior to corrected positions via ImageLock.

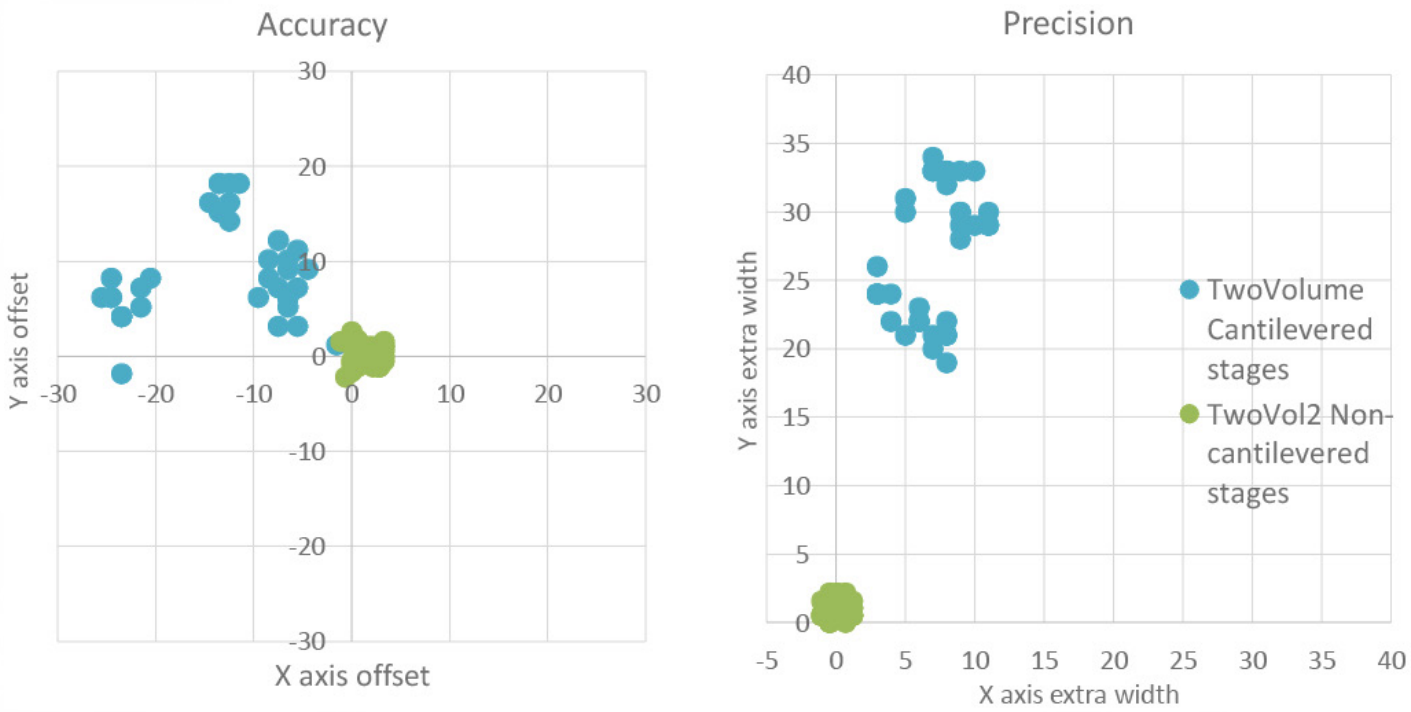


Figure 6. These graphs show the impact a non-cantilevered stage (zero torque) has on accuracy and precision compared to a cantilevered stage (varied torque) over a long-term experiment (7.5 hours). The results are from a 700 spot test from 70 different locations throughout the chamber. Accuracy error with the cantilevered stage was up to 27 µm and precision error was up to 35 µm. With the non-cantilevered stage, accuracy error was within 4 µm and precision error was within 3 µm.

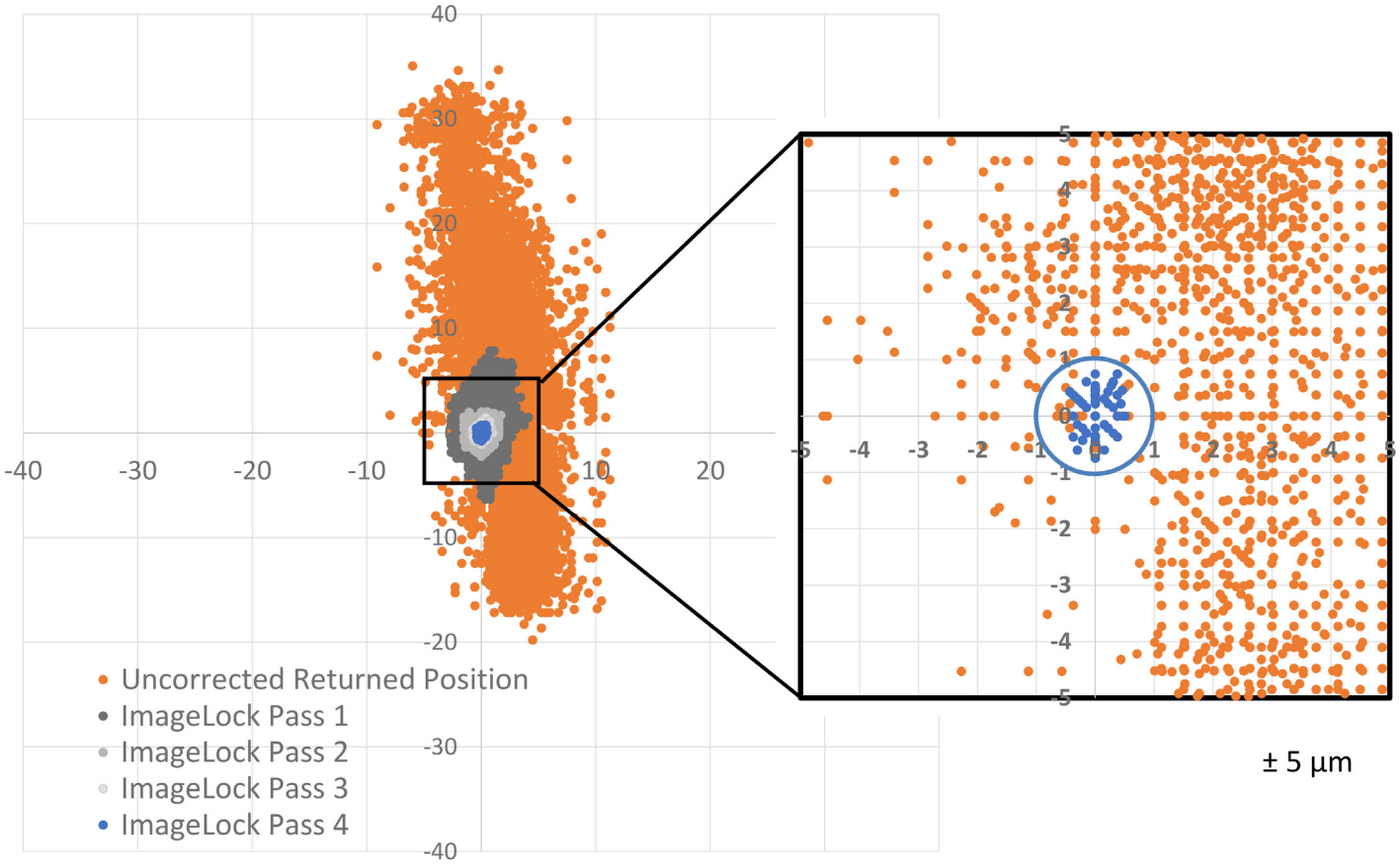
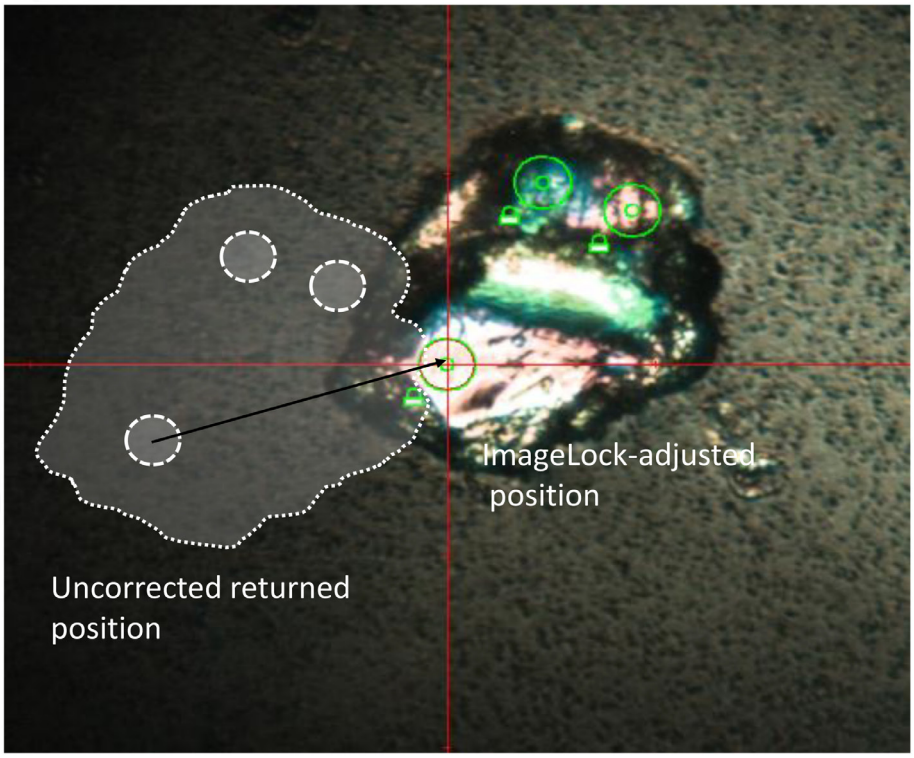


Figure 7. This graph shows a 10,000 spot pattern which demonstrates the effect of ImageLock on a system with high precision stages but utilize a cantilever. ImageLock takes the stage return accuracy from above 35 µm to below 1 µm. The inset shows only the original and final offsets. The blue circle indicates 1µm error.

ImageLock

In addition to the recent hardware modifications to improve stage return accuracy, Elemental Scientific has also approached the issue from a software perspective. The result is ImageLock, an Elemental Scientific-patented feature included in the ActiveView software. ImageLock uses image recognition on each pattern as it is placed. When moving to a locked pattern, ImageLock pattern recognition evaluates the uncorrected position and adjusts the stages so the crosshairs land directly over the intended target. Once adjusted, ImageLock measures again and iteratively improves if necessary. The whole process is complete within seconds.

This process is illustrated in Figure 8: the user places a spot with ImageLock. Upon returning to the spot later, the stages might land off the zircon (outlined in gray) but ImageLock adjusts the stages so the ablation occurs at the correct location. This has been shown experimentally[2] on zircon samples resulting in an improvement from < 12 µm errors to **< 1 µm** errors in stage return accuracy.



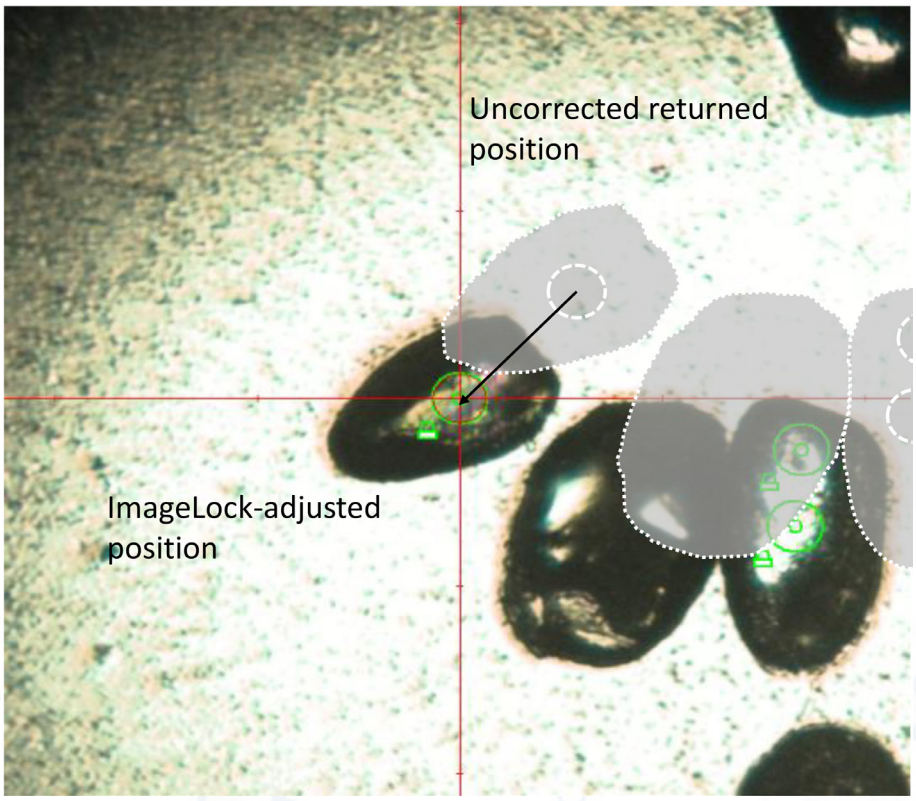


Figure 8. Demonstrations of ImageLock functionality on zircon samples

Chamber tray stabilizers

New guides in the form of tracks and pins have been added to the TwoVol2 sample chamber insert, to guide the tray into the same position time after time. This limits movement in the TwoVol2 by improving the connection between the sample chamber insert and the stages. It also improves the repeatability of position when the chamber insert is removed and replaced.

Figure 9. Spring-loaded sample insert

Conclusions

The challenge of improving stage return accuracy was broken down into its components:

- High precision stage
- Direct cell mounting
- ImageLock pattern recognition
- Chamber tray stabilizers

The result of these combined strategies is a laser ablation system that is capable of producing sub-micron stage return accuracies over the lifetime of the instrument. The system is always ablating exactly where it is supposed to.

References:

1. Stage return accuracy of TwoVol2 chamber on the NWR Platform, EWLA 2014
2. Long-term laser ablation system stage return accuracy EWCPS 2015

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