Cost-Effective High-Precision Magnetically Levitated Positioning Stage Technology

Jos de Klerk[1], Rob Verkooijen[1], Ton Peijnenburg[1], Rob Boereboom[1], Francesco Patti[1], Thomas van der Zijden[2]

[1]VDL ETG T&D, The Netherlands

[2]VDL ETG New Business Development, The Netherlands

jos.de.klerk@vdletg.com

INTRODUCTION

To enable and follow the trend of the ever decreasing minimum feature sizes, the wafer positioning accuracy, the throughput and the contamination levels need to improve. This does not only hold for lithography equipment but also for metrology equipment like CD SEMs, optical defectivity measurement tools and e-beam defectivity review tools. Although the performance requirements of wafer stages in metrology equipment are less demanding than lithography equipment, improvements are needed nevertheless. Commercially available wafer stages using air bearings and roller bearings have reached their performance limits. New wafer stage MagLev based technology has been developed by VDL ETG that does bring the required performance improvements while maintaining a cost-of-goods level that is comparable to high end air bearing systems.

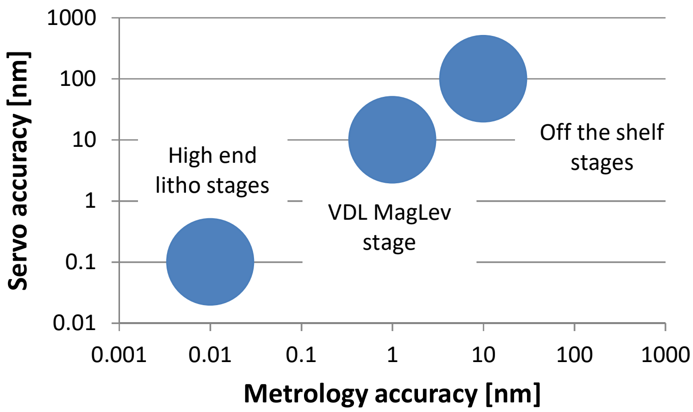

FIGURE 1. Servo (or position) accuracy and metrology accuracy of the VDL stage wrt to other stages. Metrology accuracy is typically one order of magnitude smaller than the servo accuracy.

THE KEY DESIGN PRINCIPLES

Starting principle was to use MagLev technology for better performance with less particle generation and with a lower complexity than current systems available in the market. The following principles are key to reduce complexity and to improve reliability and performance:

- A 6 DoF actuator design with integrated water cooling
- One of the 6 DoF actuation functionalities can be used to actuate a long stroke movement. This reduces the amount of required actuators and sensors and reduces the system complexity (i.e. no need to stack multiple actuation modules)

- The stator of the actuator long stroke is used as a balance mass for high dynamic and/or high productivity motion systems
- Usage of magnetic actuators for much less particle generation compared to roller bearing systems and air bearing systems
- Drive in the centre of mass to avoid imbalances
- Vibration isolation between the environment and the moving part by using the low stiffness properties of Maglev actuators

Additionally, for applications in e-beam systems, the following principles are used to reduce magnetic field variations:

- Magnetic sources far away from the wafer level and magnetically shielded
- Closed magnetic circuits to minimize fields outside the actuators

A top part (the chuck) free from magnetic materials

THE MAGLEV CONCEPT DESIGN

The concept design, of what we called 'the demonstrator', is shown in the following figure. The blue block is the chuck that holds the wafer. The dark grey part consists of an array of permanent magnets and it also acts as a balance mass. The light grey part, called the slider, contains, amongst others, the z-actuators which are reluctance motors combined with permanent magnets to compensate weight.

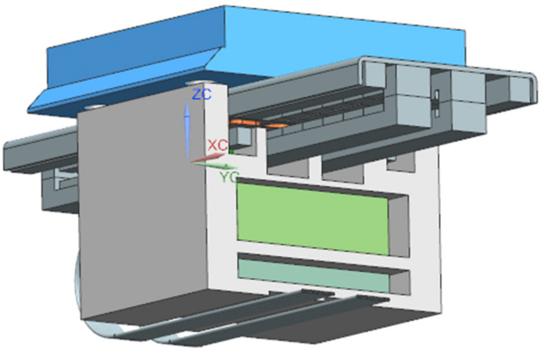

FIGURE 6. Concept design of the demonstrator.

The slider also contains the coil plate assembly. This assembly contains all actuators and is temperature conditioned by means of water cooling.

FIGURE 7. The coil plate assembly.

A 6 degrees-of-freedom distance measurement interferometer system has been added to measure position ranges larger than 300mm. The concept is shown in the following figure.

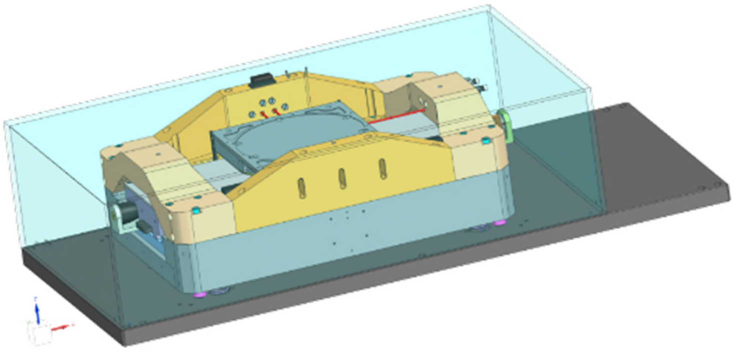

FIGURE 8. The design including a 6 DoF distance metrology system.

RESULTS

Measurement result are shown in the following figures. Figure 9 shows the settling behaviour after an acceleration of 25 m/s^2 and a speed of 1 m/s.

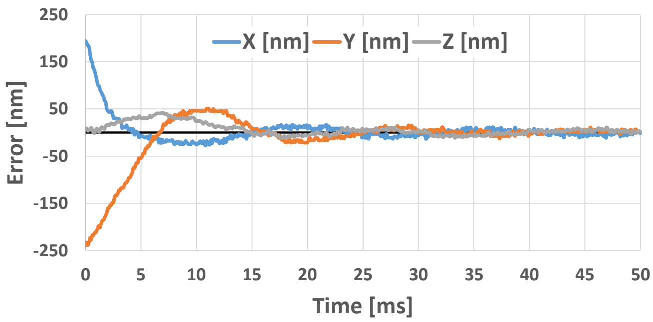

FIGURE 9. Settling behaviour. After 20ms settling time, the errors are below ± 15nm.

The following figures show the standstill position errors. The horizontal black lines are ± 3σ values.

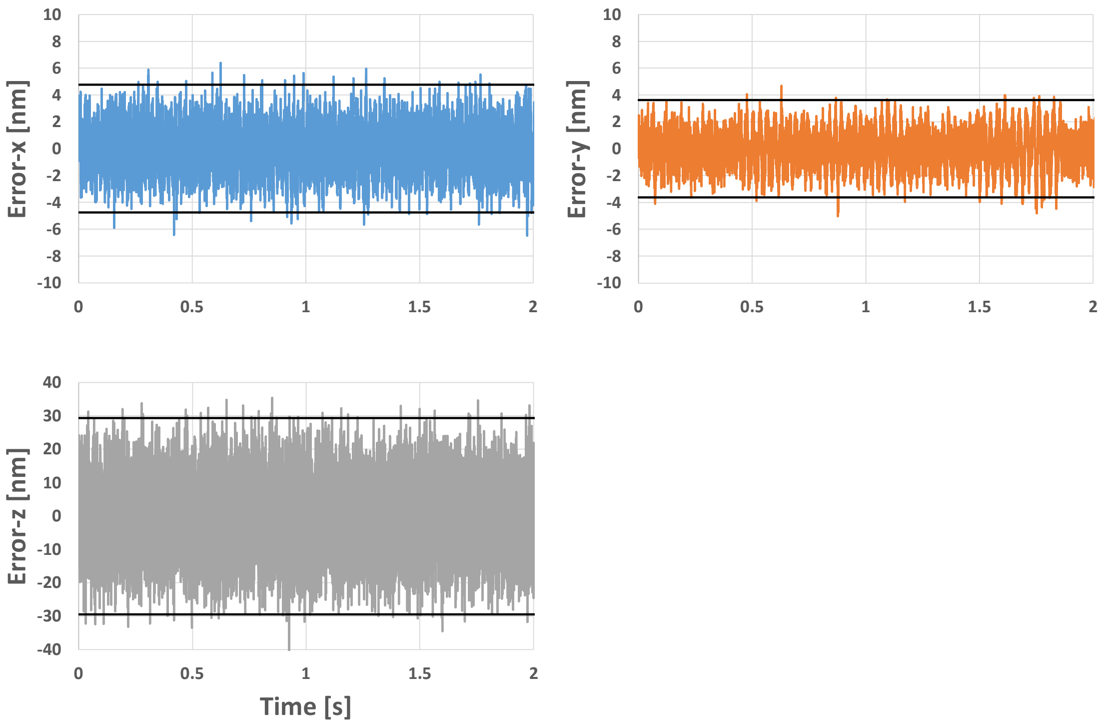

FIGURE 10. Measured position error in x, y and z. The 3σ values are 4.8, 3.6 and 29.4nm, resp..

SUMMARY

A MagLev concept has been realized with a demonstrated positioning performance better than 5nm in xy and 30nm in z (3σ values). Several cost-effective design solutions have been implemented, for example, the water cooled coil plate assembly, the 6 DoF interferometer system and the integrated balance mass.

With the technology that has been developed, VDL ETG is capable to design and manufacture customer specific high end positioning solutions that surpass the performance of air bearing and roller bearing systems and this at a similar cost level.

REFERENCES

[1] A.T.A. Peijnenburg et. al., Magnetic levitation systems compared to conventional bearing systems, Philips Applied Technologies, MNE-2005