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Assessment of microscopy moving stage performance down to the 10 nm range using encoded patterns with automated reading

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Abstract
Motorized stages are essential to microscopy and instrumentation. Their accuracy is critical for multiple tasks that are common in microscopy, such as re-localization of observations, accurate mapping, or search of points of interest.
In this paper we present a new approach to stage performance qualification, by using a so-called "nanoGPS" system. This system is based on an encoded pattern slide that is imaged by the microscope camera, and decoded by the "nanoGPS" software. It is used to investigate several microscopy stages.

Calibration, coordinate measuring machine, microscope, positioning

1. Introduction

Motorized stages are essential to microscopy and instrumentation. Their accuracy is critical for multiple tasks that are common in microscopy, such as re-localization of observations, accurate mapping, or search of points of interest.

It is essential to know precisely the characteristics of the stages. Indeed, users want to be sure that the coordinates they get from stages encoders are accurate enough for their purpose.

In this paper we present a new approach to stage performance qualification, by using a so-called "nanoGPS" system. This approach has been first developed for photovoltaic applications but can be apply to other fields as well.

2. The nanoGPS encoder technology

2.1. Principle

The so-called "nanoGPS" position sensor [1] belongs to a lesser known class of sensor based on taking the image of a patterned plate with encoded image information [2]. The pattern plate (see Figure 1) combines some codes (somewhat similar to QR codes) that provide low resolution spatial information, with patterns that provide superlocalization capability. Superlocalization [3] describes the capability to determine the position and orientation of an object with an accuracy that exceeds the resolution of its image, which is made possible when the object has a number of known features. It belongs to the more general family of superresolution techniques [3].

The nanoGPS software is able to decode the position and determinate the angle between the tag and the imaging system [1, 2].

Unlike encoders based on fringe counting techniques on optical scales, such as a number of commercial linear sensors, nanoGPS system reads directly its absolute position on the patterned plate, without the need be moved to a "reference position" to start fringe counting. Another advantage is that it provides 3 position information as a result of a single snapshot of the patterned plate, where 2 linear and 1 rotation encoders would be needed.

In this work, the stage to be investigated is part of an optical microscope (Olympus BX 41) equipped with a 10x objective and a digital camera. The patterned plate is fixed on the stage. In this way, the position of the stage is obtained by taking snapshots with the camera and interpreting the images using the nanoGPS software.

2.2. Performance

Experiments indicate that the nanoGPS system is able to measure the position down to the 10 µm range and the angle down to 10 µrad. Acquisition rate can be as fast as 10 Hz.

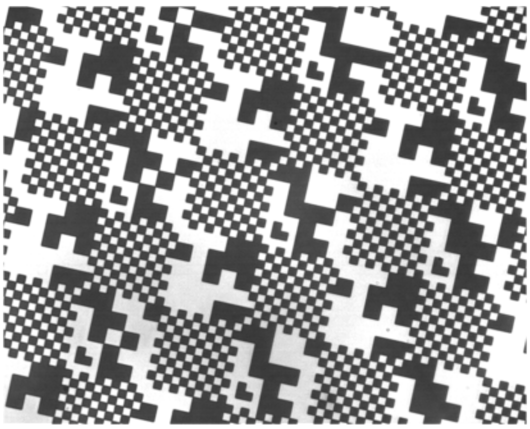


Figure 1. Image of the encoded pattern.

3. Motorized stages qualification

3.1. Accuracy

Accuracies measurements have been made on motorized stages equipped with magnetic encoders.

Stages encoders exhibit significant micrometric errors when compared with the nanoGPS (see Figure 2). We suspect that those magnetic encoders have some defects causing these errors.

3.2. Reproductively and stability

We report that non closed-loop stages have significant drift over repeated trajectories (see Figure 3.c). Moreover, by setting small steps inferior to the micrometer we are able to see that the stages have some difficulties to perform the programmed trajectory (Figure 3.a and b). Thus, we concluded that the tested non closed-loop stages cannot make steps below 200 nm.

However, the nanoGPS was also used as an encoder for closed-loop feedback. We show in Figure 4 that it is possible to correct the trajectory by moving by small steps of about 100 nm. Stage drift over time can reach 400 nm per 10 minutes.

3.3. Table stability

We made stability measurements on anti-vibration and standard tables. As expected, the standard table is very sensitive to environmental noise such as walking in the room or knocking the table. Noise can reach several micrometers.

In the same conditions, noise on an anti-vibration table is submicrometric (Figure 5).

It should be noted that this drift may also be partly attributed to the microscope stand and to the camera, including thermal effects. But the observations are representative of the normal operation of the microscope.

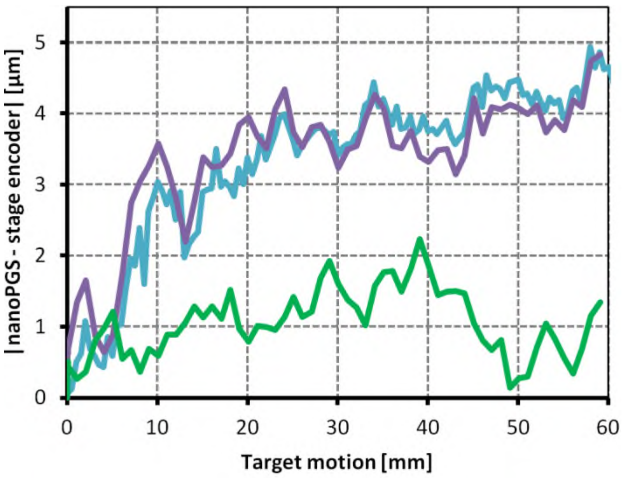
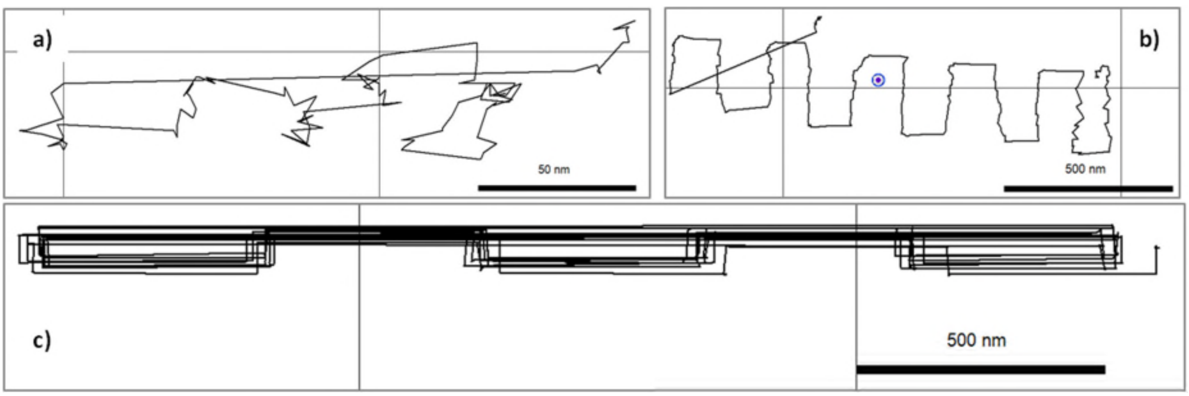


Figure 2. Stage error vs target motion. Blue and purple lines represent the same stage trajectory measured with two different encoded slide. The green line represents a different stage trajectory.

Figure 3. Trajectories of a non closed-loop stage. The step motion target set is a) 100 nm, b) 200 nm and c) 500 nm.



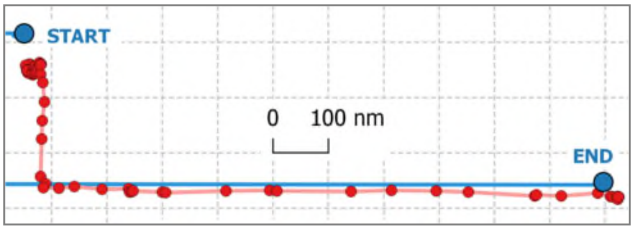


Figure 4. Stage back and forth from START to END in blue. Manual correction by 100 nm steps in red.

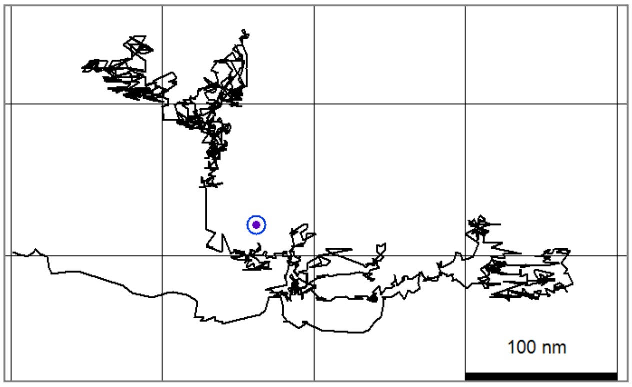


Figure 5. Stages drift on an anti-vibration table over 20 minutes.

5. Conclusion

In this paper, we showed that the nanoGPS is an effective system to qualify motorized stages. It provides information regarding stages accuracy, repeatability and can perhaps be used as feedback device.

Acknowledgement

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