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Large field scanning solution enables precision for large processing areas

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Abstract

We present a scanning solution combining a scanner and a stage. Its innovative concept enables wide-area marking and processing of large substrates by extending the working field by simultaneously controlling and moving a scan head and an XY-stage. The key advantages include very large field of view, significantly increased throughput possible, no stitching errors, enhanced accuracy and smooth processing with high dynamics and no visible stage vibrations. We will present results of such system which show maximum deviations from the target position of +/-11 µm (focal length of 100mm).

Keywords: *"Laser processing"; Scanning; "Simultaneous Motion";*

1. Introduction and Methodology

Many applications in the field of micro processing require high accuracy on a relatively large working field. The need for high accuracy leads to short focal distances for the scanner lens and therefore to a small field of view. In order to extend the field of view we introduce a system that combines the motion of a scanner with the simultaneous motion of a x-y stage. The system is programmed in the extended working field and automatically divides the motion into a path for the scanner as well as a path for the stage. This decomposition of motion is conducted via a band pass filter that restricts the dynamics of the motion of the stage. The residual motion is then passed to the scanner.

2. Setup

The setup to investigate the simultaneous motion control of a laser scanner and an x-y stage was realized with the following major components (shown in Fig. 1):

- SCANLAB excelliSCAN14 scan system, 100 mm telecentric lens /1/
    - Field size 54 x 54 mm²
    - Repeatability: 40 nm
    - Accuracy at the edge of the field of view: 25 µm due to a non-optimum alignment – for this setup typically this can be reduced to about 5 – 10 µm
    - Following Error: ± 3 µm typically (± 5 µm max.)
    - Max. marking Speed: 2.5 m/s
    - Max. jump Speed: 20 m/s
    - Max. acceleration: 28E3 m/s²
- x-y stage 300x300 mm from BUSCH MICROSYSTEMS (made from granite)
    - Repeatability 0.1µm
    - Accuracy ± 6 µm (can be further improved using a calibration routine)
    - Typical maximum following error during profile (as measured off the encoder): ±0.5µm

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  - Maximum speed: 1 m/s
  - Maximum acceleration: 10 m/s²
- ACS Motion Control SPiiPlusEC Motion Controller with NPM motor drives /3,4/
- SCANLAB RTC6 (Real Time Controller) as controller for the scanner
- SLEC (SCANLAB/EtherCat) communication bridge between the RTC6 scan controller and the SPiiPlusEC stage controller
- SPI G4 20 W fiber laser 1070nm

Trajectory planning /1/ is used to get a path optimized for throughput while maintaining the constraints of the scanner. Trajectory planning is a method that changes the path of the laser spot on the work piece based on the dynamic limitations of the stage and the scanner. Especially sharp corners are blended so that the dynamic limitations of the systems are not exceeded. There is a single interface to the user for both controllers. The distribution of operation of the stage and operation of the scanner is transparent to the user.

The alignment of the laser into the system was not optimal. Therefore, after calibration an absolute positioning error of 25 µm at the edge of the field of view remains. This results in larger than necessary stitching errors. However, it also shows how much more forgiving the system is in the simultaneous motion control mode. No stitching errors are visible and since the scanner typically works near the center of the image field the positioning errors are substantially reduced (see below).

3. Experimental results

Pattern of circles – tiling vs. simultaneous motion

To compare simultaneous motion method with tiling (also known as “stitching”) method, a test pattern of circles (diameter 10mm) was marked.

In one case the pattern was marked with simultaneous motion of x-y stage and scan head, in the other case the pattern was divided into eight 50 x 50 mm² tiles. The simultaneous movement achieved a throughput advantage of 41%. In the tiling/stitching case there is a visible stitching error of up to 25 µm. This is caused by the nonoptimal calibration of the scanner image field, which was mentioned above.

Pattern of diamonds – tiling vs simultaneous motion

To investigate the appearance of stitching errors, the shown test pattern of diamonds was marked (Fig. 2). Fig. 2 a,b shows the stitching errors in two different magnifications. Such stitching errors are not visible for the simultaneous motion Fig 2 c,d.

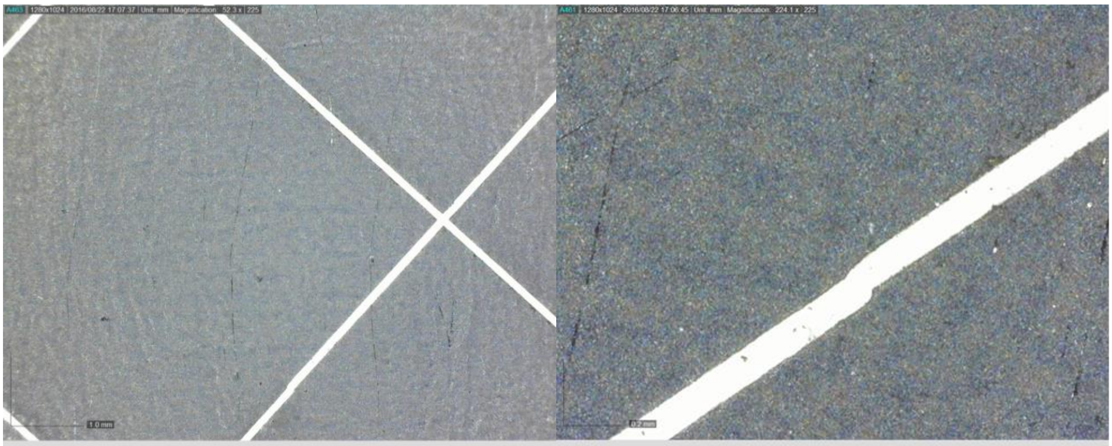

Fig 2 a, b – Pattern of diamonds after tiling motion: Stitching errors

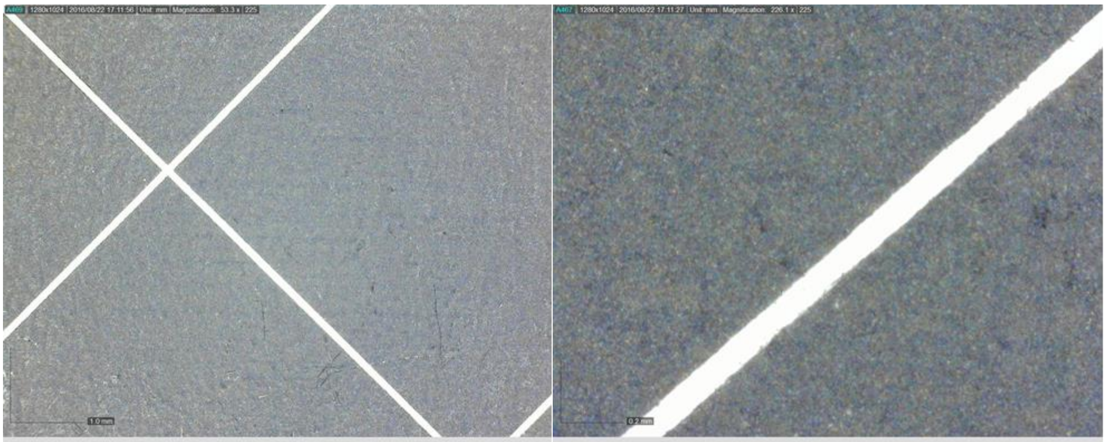

Fig 2 c,d – Pattern of diamonds with simultaneous motion: No stitching errors

Throughput results and drilling of holes

Application	Time tiling motion	Time simultaneous motion	Percentage saved
Circles	5.63 s	3.30 s	41%
Diamond shaped pattern	3.92 s	2.96 s	24%
Hole drilling (jump & shoot)	5.2 s (estimated)	4.42 s for 10,000 holes	15%
Hole drilling (repeated circles / trepanning)	12,2 s (estimated)	11,86 s for 5,000 holes	2 %

Table 1 – Improvement of throughput for different patterns

Table 1 shows the time for tiling vs. simultaneous motion for the different patterns shown above and two different hole drilling experiments. In addition to the patterns of circles and diamonds (already discussed above) two experiments for the drilling of holes have been carried out.

The first test (jump & shoot) shows that it possible to offer simultaneous motion for drilling on a large image plane. Drilling of 10,000 holes (1 mm distance) on an area of 50 x 200 mm was achieved in 4.42 seconds. This would correspond to 2262 holes per second. An estimate on the stitching motion for these 10,000 holes yields 5.2 seconds (3 movements of the table with 263 ms each). This would result in a throughput advantage of 15% for simultaneous movement

In the second test (repeated circles / trepanning) 5,000 holes were distributed over an area of 50 x 100 mm² (distance: 1mm). These holes consist of circles with a diameter of 200 µm that are repeated 3 times (trepanning). An estimate on the duration of a stitching motion yields 12.12 s (one 50 mm table movement with 263 ms + time of the scanner motion). This is a throughput advantage of only 2% of the simultaneous motion. This low value for the improvement is due to the long duration of the marking in the field of view of the scanner, the single tiling motion and the high density of holes.

It is clearly visible that the throughput advantage is higher for those patterns that require more tiling motions. During the hole drilling of the repeated circles only one tiling motion is necessary, and the density of holes is rather high. This results in a throughput advantage of only 2%. On the other hand, for the patterns of circles and diamonds the simultaneous motion results in a substantially higher throughput.

During both hole drilling experiments the density of holes is rather high with the distance of 1 mm between each hole. In a real-life case we expect the density of holes to be much lower resulting in a higher throughput advantage. In general, the increased throughput comes with another advantage – compared to the stitching approach, much smoother motions of the x-y stage can be observed (e.g. 0.25 g vs. 1 g acceleration). This can lead to less structural oscillations and therefore an increased overall accuracy. Furthermore, it can allow using stage axes with reduced dynamics and therefore with smaller motors thus saving cost.

Accuracy for the simultaneous motion

To measure simultaneous accuracy, a grid of 13x13 points over a range of ±144 mm in both directions (distance 24 mm) was marked using simultaneous motion. The stage moves in a meander shape through the points while the scanner is marking crosses in a zig-zag-shape at about plus and minus 75 % the scanner field of view. Via this approach a demanding example (stage dynamics and used field of view) which allows evaluation of the accuracy of the simultaneous motion is generated.

Table 2-4 and Fig. 3 shows the accuracy achieved using simultaneous motion. The stage motion is a meander shaped motion shown as a green line in lower left corner of the figure. The Scanner motion consists of point to point jumps in a zig-zag pattern resulting in the pattern shown. The accuracy achieved with simultaneous motion is 11µm max deviation.

The simultaneous accuracy consists of many contributing errors, e.g. static errors, following errors, structural resonances, etc. Here the accuracy seems to be mainly influenced by the static scan system and stage accuracies.

	x-axis	y-axis	radial
Min.	-2.0 µm	-5.0 µm	0.0 µm
Max.	5.0 µm	1.0 µm	5.4 µm
Standard deviation	1.3 µm	1.1 µm	1.4 µm
Mean	0.9 µm	-0.7 µm	1.6 µm

Table 2 – Static error of the scan system

	x-axis	y-axis	radial
Min.	-4.2 µm	-5.1 µm	0.0 µm
Max.	6.1 µm	4.7 µm	6.6 µm
Standard deviation	1.6 µm	1.8 µm	1.2 µm
Mean	0.1 µm	0.8 µm	2.2 µm

Table 3 – Static error of xy stage

	x-axis	y-axis	radial
Min.	-7.8 µm	-9.7 µm	0.0 µm
Max.	8.9 µm	4.1 µm	11.0 µm
Standard deviation	2.9 µm	3.1 µm	2.6 µm
Mean	-0.8 µm	-3.5 µm	4.9 µm

Table 4 - Accuracy achieved in simultaneous motion

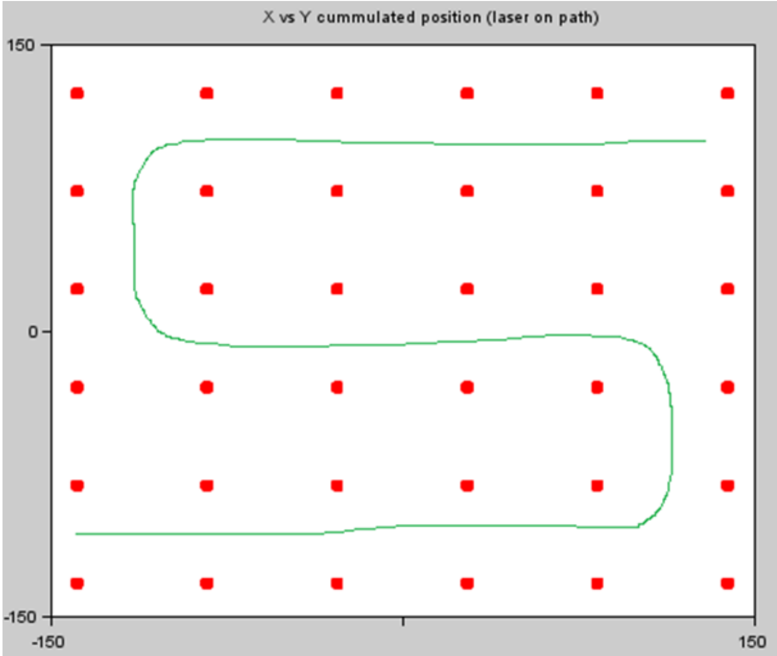

Fig 3 – Schematic representation of the stage path (green) and the simultaneous motion path (red) not true to dimensions and details

4. Conclusion

The simultaneous motion control of a laser scanner and an x-y stage allows for a throughput increase of up to 41% depending on the pattern. Stitching errors can be avoided by simultaneous motion and the accuracy of the marking is generally improved through the reduced field of view that the scanner must address. We present results of the simultaneous motion which show maximum deviations from the target position of +/-11 µm for a focal length of 100 mm. In general, the simultaneous motion shows improvements over the tiling motion that makes it a promising technology.

5. References

/1/ A. Unterholzner, M. Breit, „Scanner-Steuerung für ungebremsten Laser-Speed“, Mikroproduktion 03/2015

/2/ M. Apanasenko, B. Kramer, Z. Kirshenboim , “NanoPWMTM Servo Drives Replace Linear Servo Drives In High Performance Positioning Applications”, DesignWorld, 06/2014

/3/ J. Goerges, B. Kramer. “Maximizing performance of precision motion stages in industrial applications”, Linear Motion Tips, Oct, 2017, https://www.linearmotiontips.com/maximizing-performance-precision-motion-stages-industrial-applications/