Large Area High Accuracy Thin Film Patterning with LIGHTNING™ II 30mm 3-Axis Scan Heads

1 Introduction

Laser ablation has been widely used for patterning the thin film to either create smallfeatures or generate isolated areas on the part. Laser ablation is using a short-pulsedlaser (usually nanosecond) which is focused on the surface to vaporize the thin film without damaging the substrate. The applications of laser thin film patterning includeITO patterning for flat panel displays, metal film patterning for flexible circuits, and production of photovoltaic cells (CIGS, amorphous silicon).

Traditional laser thin film patterning uses a fixed laser beam with XY stages, which is usually moving at a speed of <0.5m/s. Today the advancement of laser technology provides the laser with higher power and higher frequency; process throughput of thin film patterning can be significantly improved when using a scanner to steer the beam on the target at a speed of 1-5m/s without moving the XY stages. The scanner also providesflexibility to create complex patterns on the film.

One disadvantage of using a 2-axis scanner for thin film patterning is its limited scan area. With f=160mm F-theta, which is mostly used today, the scanning field size is up to120mm (4.7in) square. This will not be able to process inside one scan field for today's tablet or laptop flat panel screen with diagonal size ≥7in. One method to address this issue is to use the XY stage with the scanner, using either a “step-and-shoot” stitching mode or synchronized motion without stitching to achieve large area processing.

This application note presents the use of a Cambridge Technology 3-axis scanning system to perform large field ITO patterning. The scan area is set to 400mm square, anda performance study is carried out on the area of 300mm square.

2 Setup

Laser: IPG YLP-20 fiber laser with wavelength 1.06μm (20-100KHz)

Scan Head: LIGHTNING™ II 30mm 3-axis scan head (tracking delay = 0.13ms)

Controller: SM1000 with 20-bit command

Software: SMD1.4.1 Field

size: 400x400mm

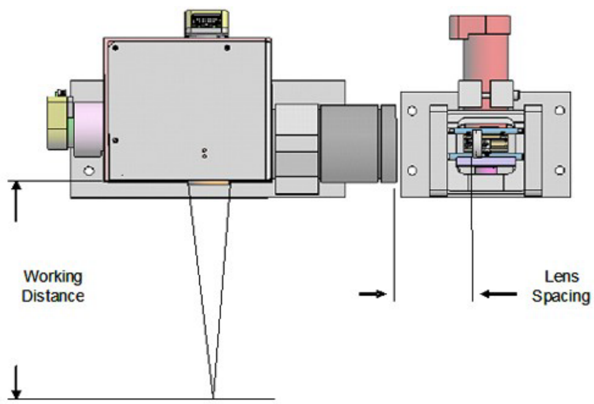

Figure 1 - Setup

3 Test Description

- Application is laser patterning ITO on PET substrate.
- The line pitch is 70µm on target. Field size is 300x300mm.
- Patterning speeds are 1, 2, 3 and 5m/s. Jump speed = 5m/s.
- Poly delay = 0

The test pattern is shown below in Figure 2.

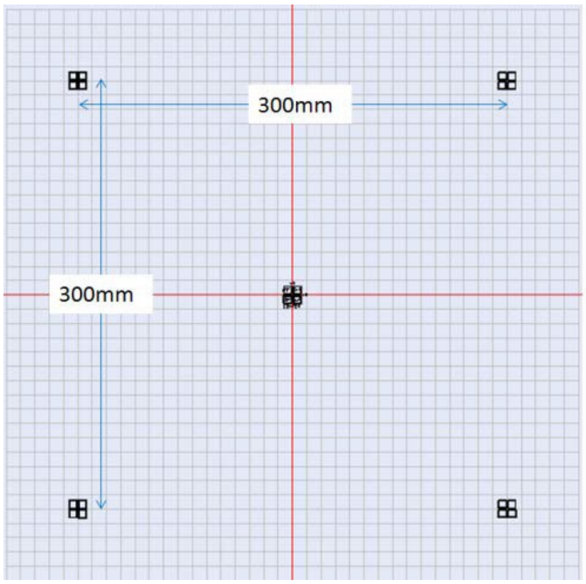

Figure 2 - Field Size

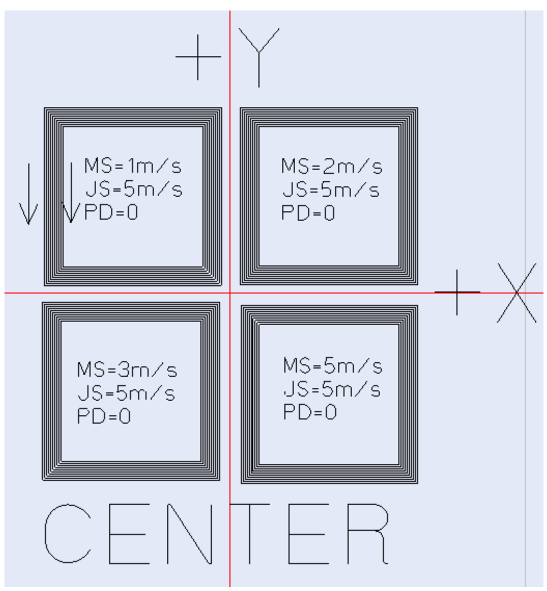

Figure 3 - Test Pattern

There are a total of 4 test items:

1. **Uni-directional patterning**:
    a. **Corner deviation**: determine the deviation from ideal corner location atdifferent speeds
    b. **Corner deviation variation**: determine the corner deviation variation
    c. **Line straightness**: determine the straightness of patterning lines
2. **Bi-directional patterning** on item 1(a), 1(b) and 1(c) mentioned above
3. **Line width consistency on edge of scanning field**: compare results at fourcorners (TL, TR, BL, BR) with results at center of scanning field
4. **16-bit vs 20-bit large field patterning**

4 Test Results

4.1 Uni-directional patterning

Job parameters: Mark Speed = 1, 2, 3, 5m/s, Jump Speed = 5m/s, Poly Delay = 0See marking results from Figure 4 to Figure 9.

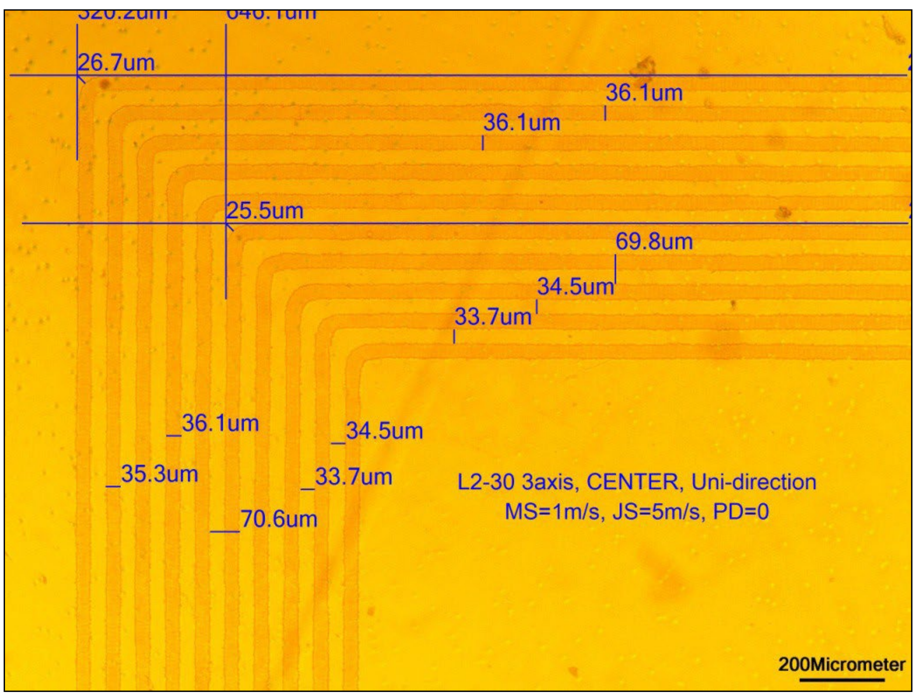

Figure 4 - Mark Speed = 1m/s

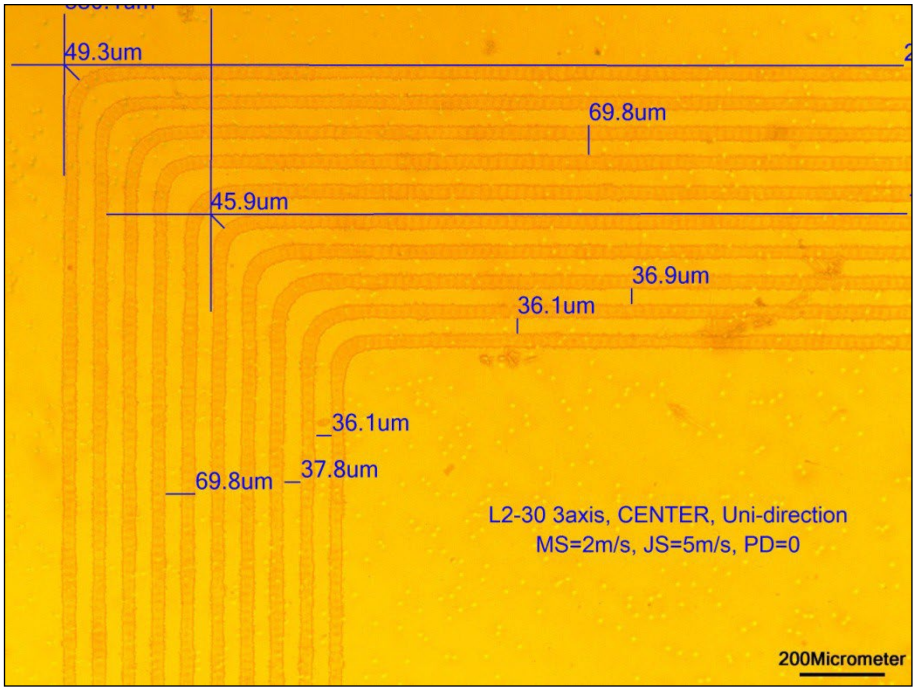

Figure 5 - Mark Speed = 2m/s

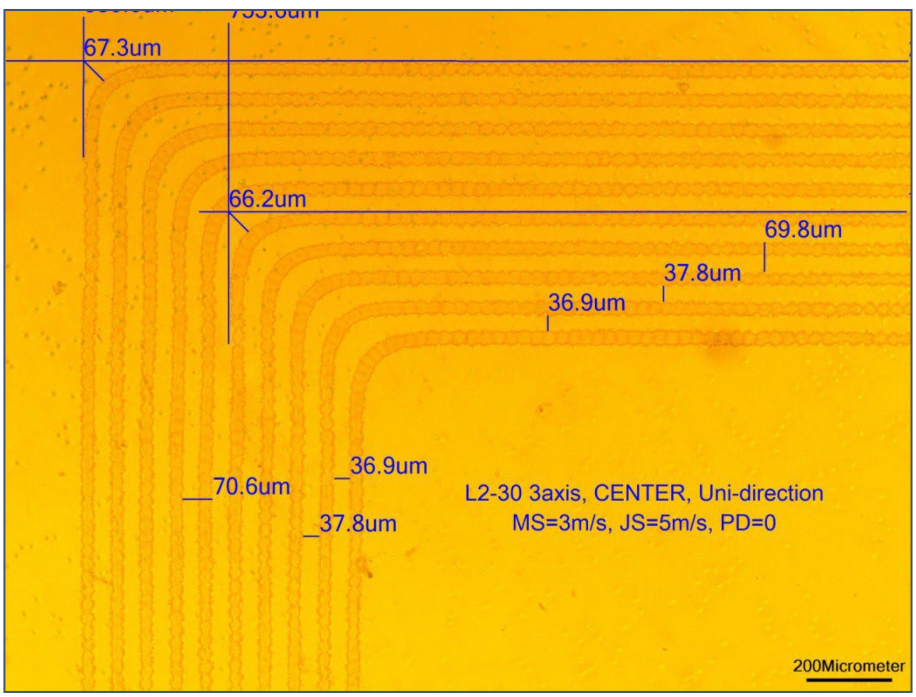

Figure 6 - Mark Speed = 3m/s

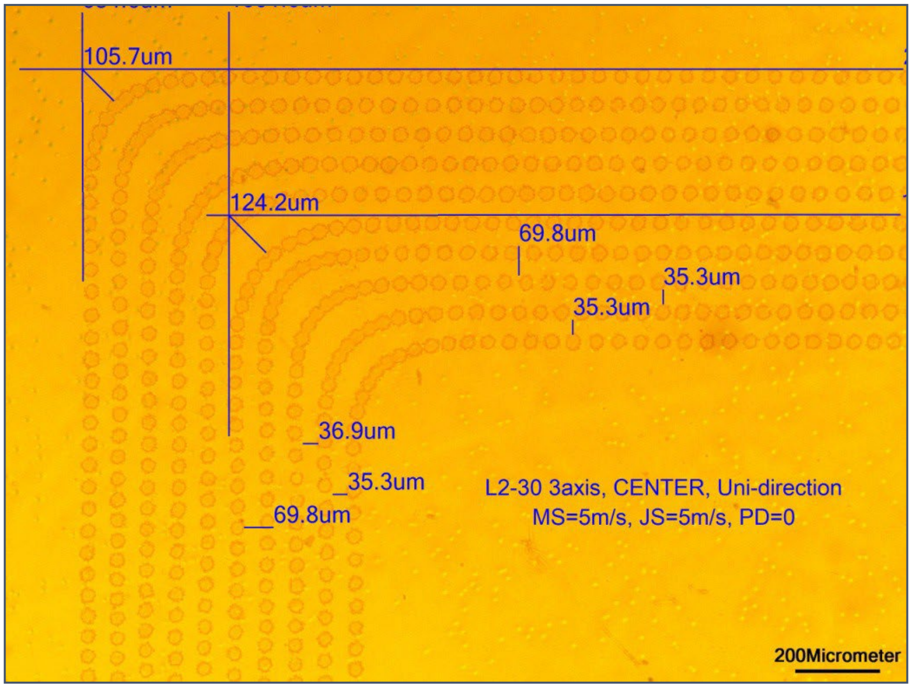

Figure 7 - Mark Speed = 5m/s

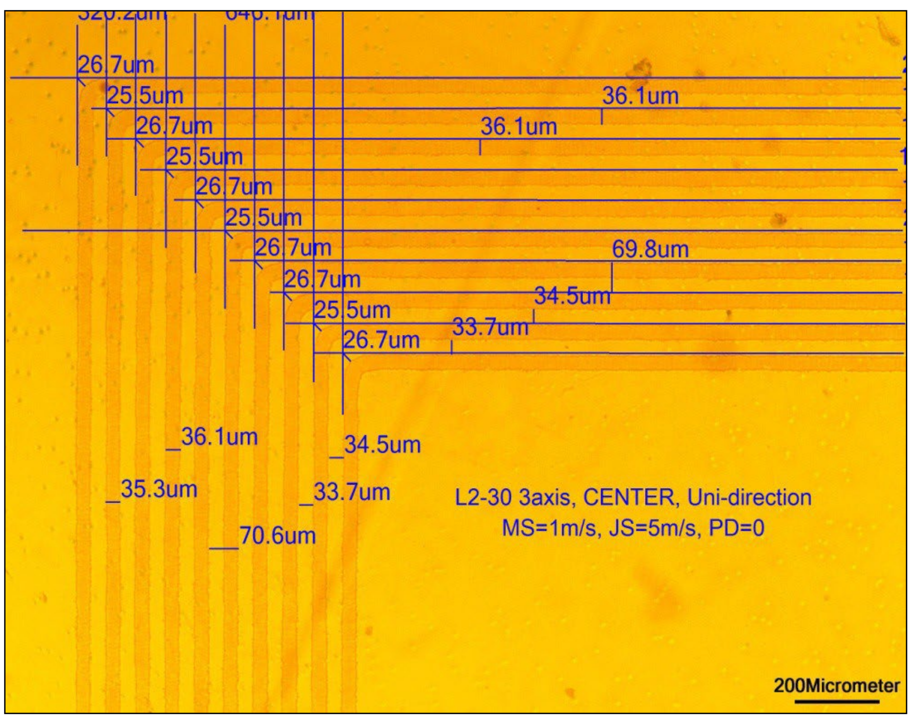

Figure 8 - Corner Deviation at Mark Speed = 1m/s

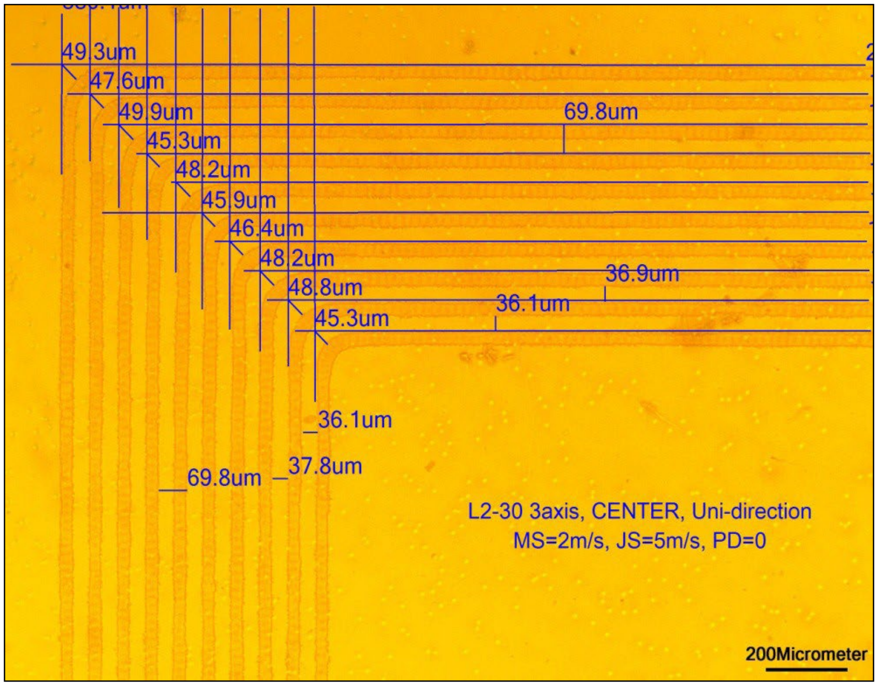

Figure 9 - Corner Deviation at Mark Speed = 2m/s

Short summary:

- Line width is able to stay <40μm for all speeds.
- Line space variation is <±1.5μm.
- Lines are very straight without obvious waviness.
- Corner deviation from ideal sharp corner at 1m/s is ~25μm, and <50μm for 2m/s.
- Corner deviation variation is small too, <2μm for 1m/s and <4μm for 2m/s.

4.2 Bi-directional patterning

Job parameters:
Mark Speed = 1, 2, 3, 5m/s, Jump Speed = 5m/s, Poly Delay (PD) = 0μsSee
marking results from Figure 10 to Figure 13.

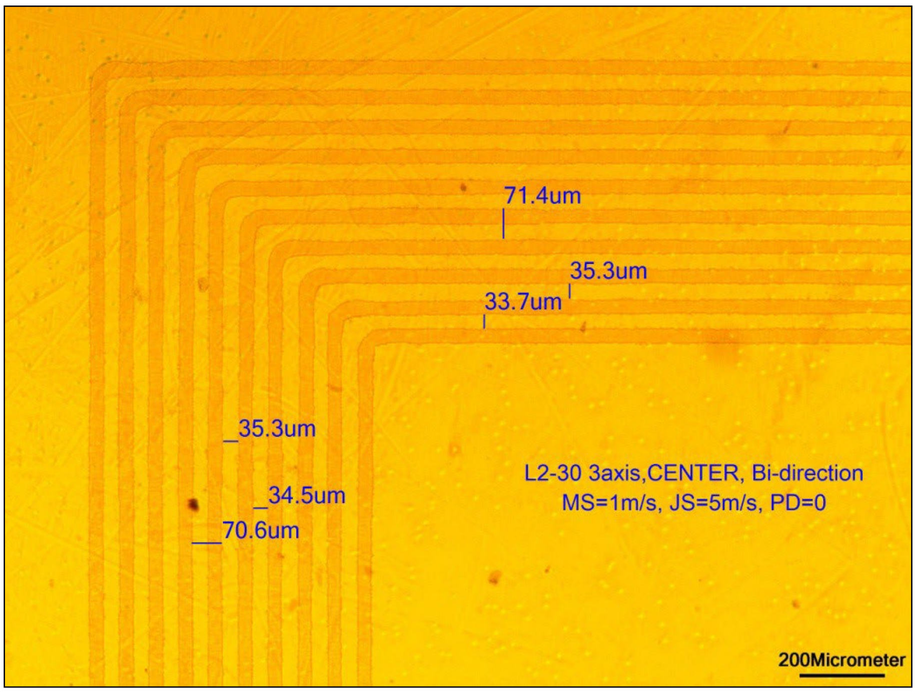

Figure 10 - Mark Speed = 1m/s

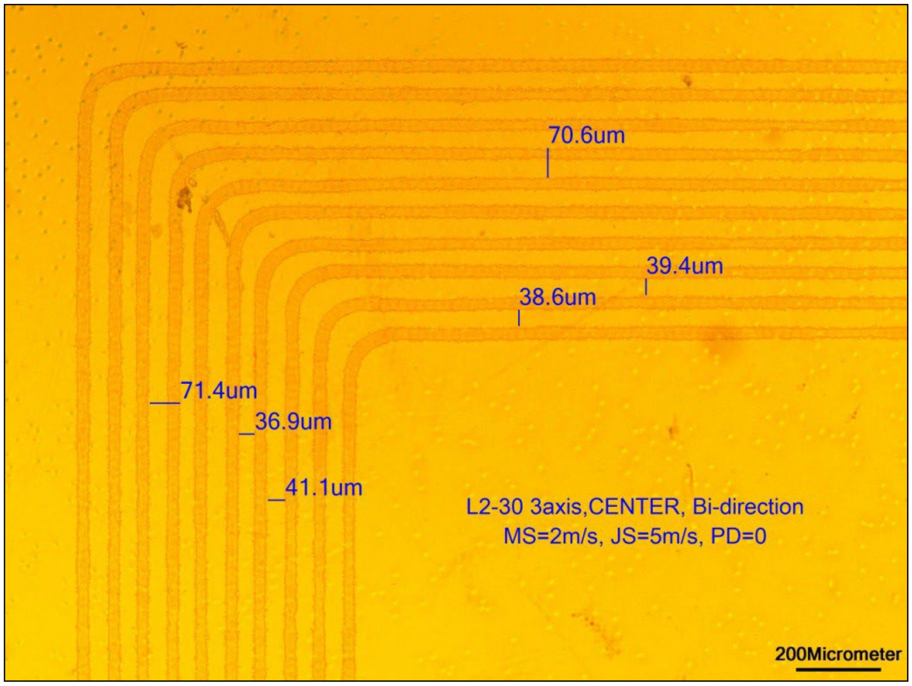

Figure 11 - Mark Speed = 2m/s

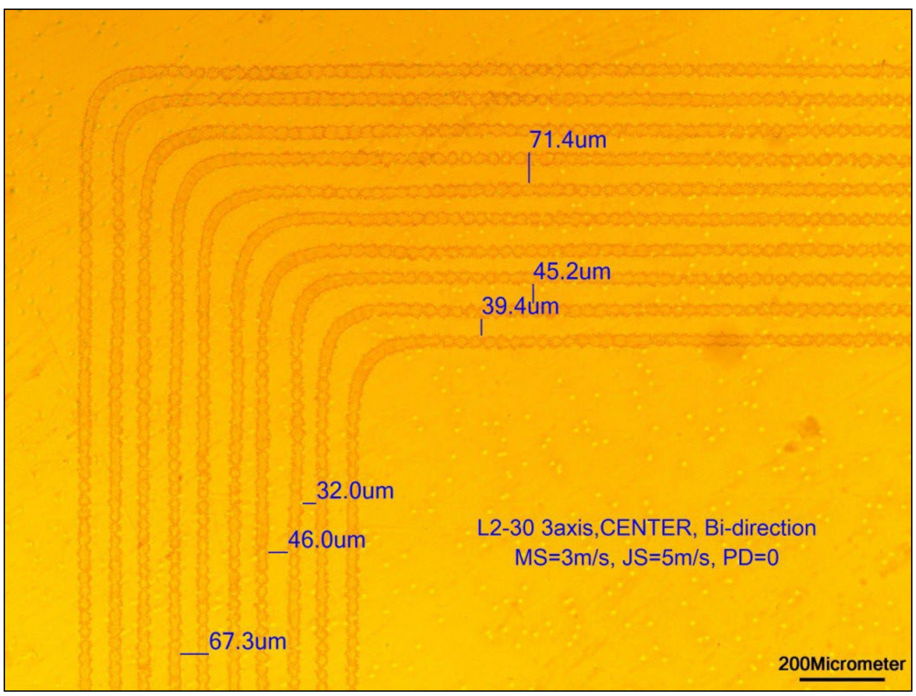

Figure 12 - Mark Speed = 3m/s

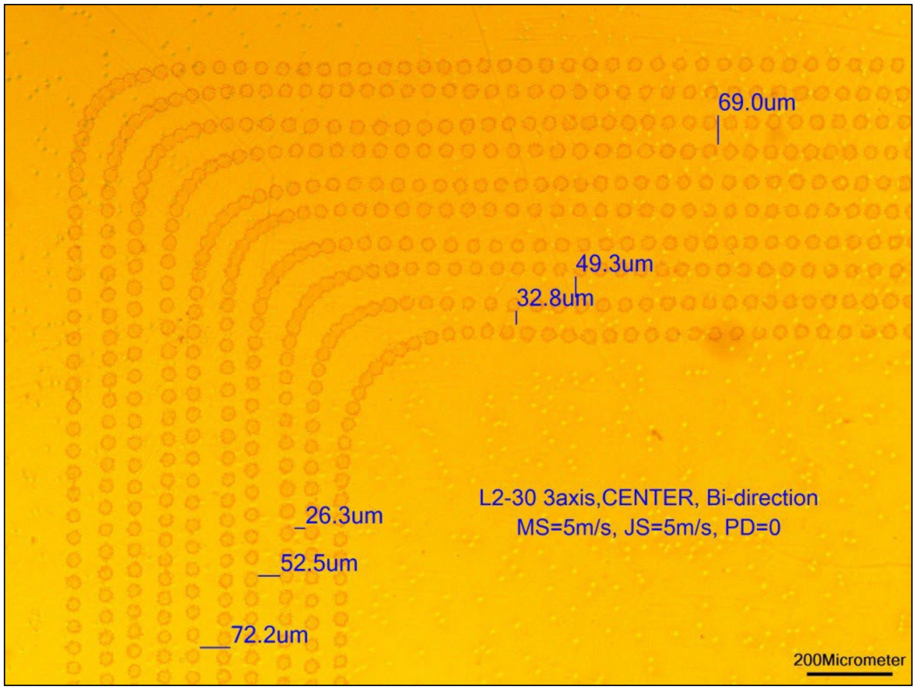

Figure 13 - Mark Speed = 5m/s

Short summary: Line spacing of bi-directional patterning shows 5-20μm variation from1m/s to 5m/s, worse than unidirectional patterning.

4.3 Line width consistency across the 300x300mm field

Job parameters: Mark Speed = 1m/s, Poly Delay (PD) = 0μsJob

pattern is as below, also shown previously in Figure 2.

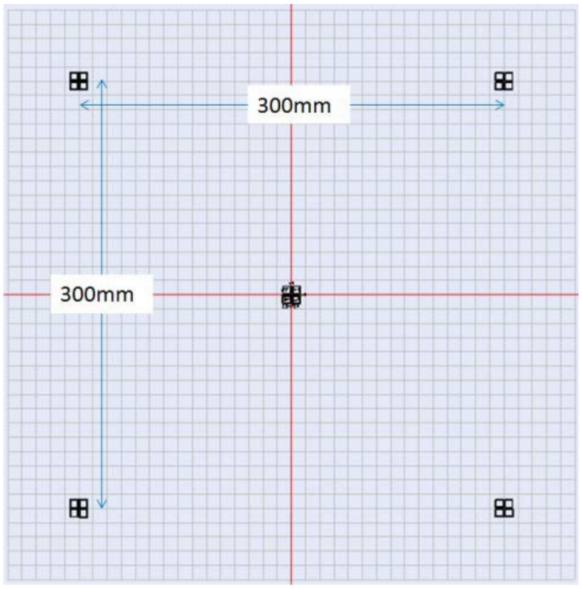

Figure 14 - Field Size

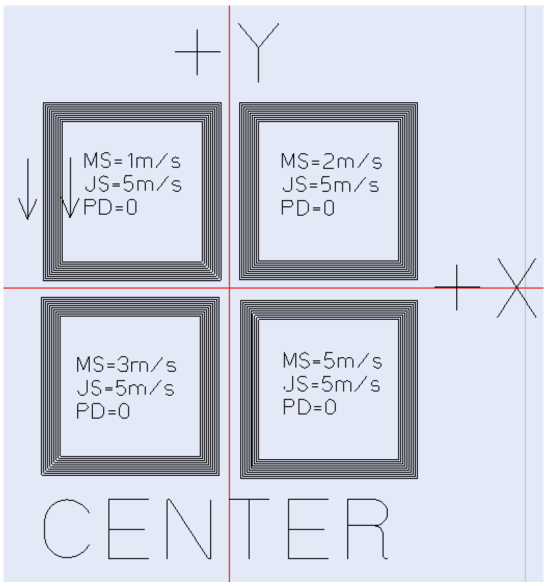

Figure 15 - Test Pattern

See marking results from Figure 16 to Figure 20.

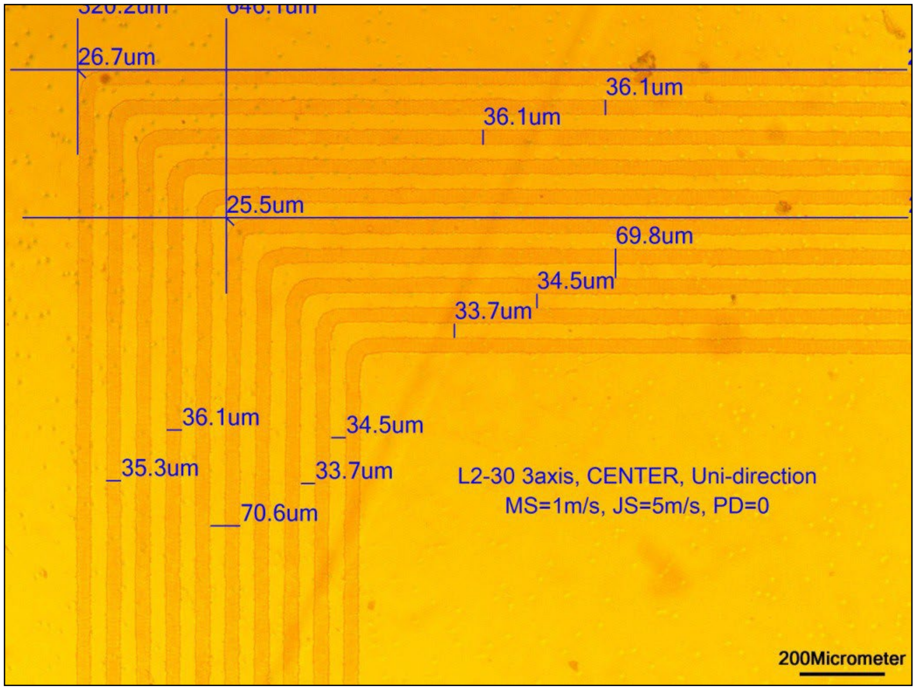

Figure 16 - Marking Result in the Center

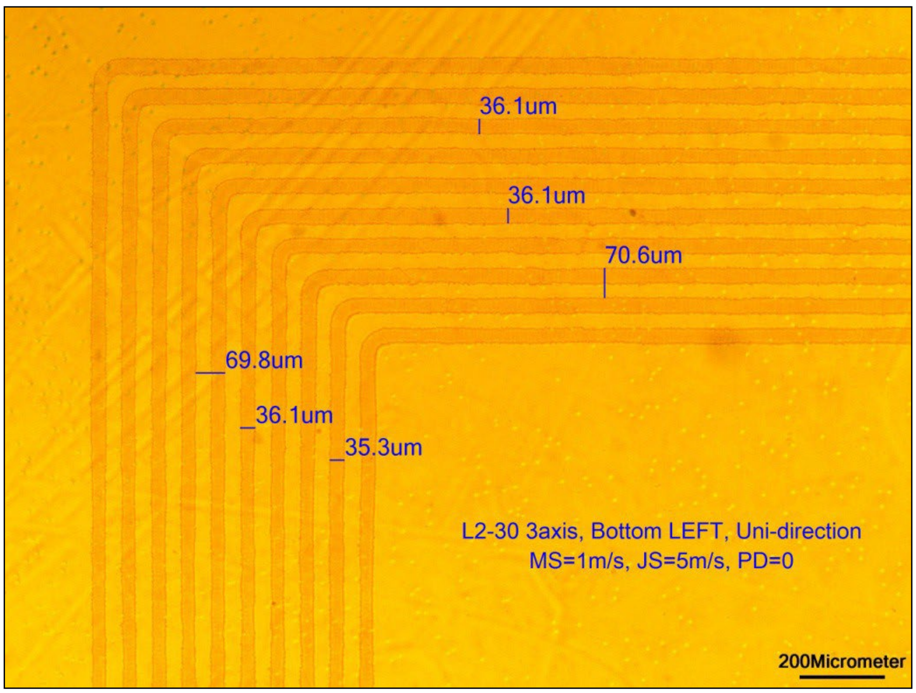

Figure 17 - Marking Result at the Bottom Left

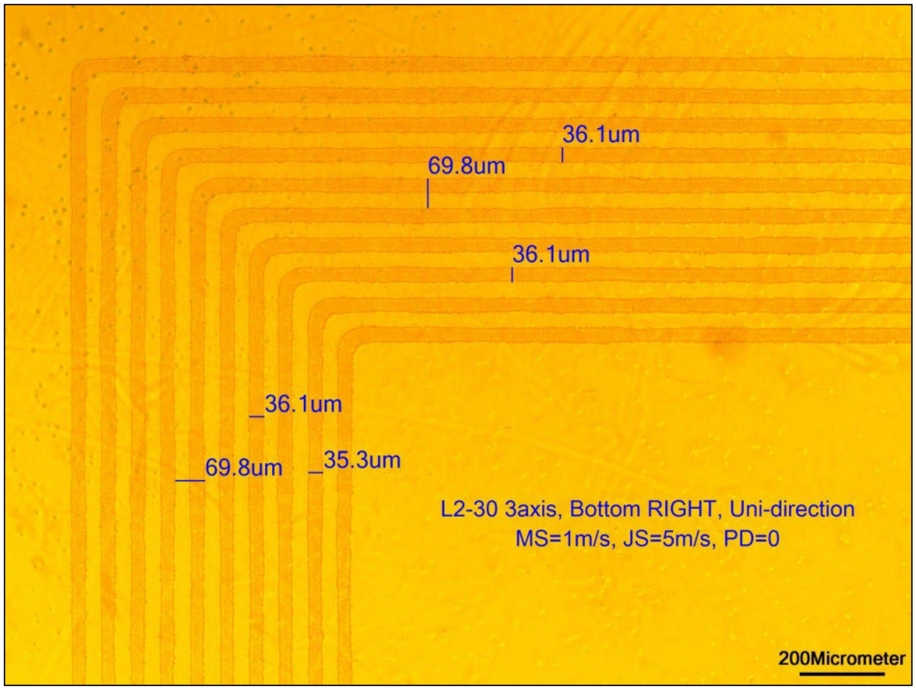

Figure 18 - Marking Result at the Bottom Right

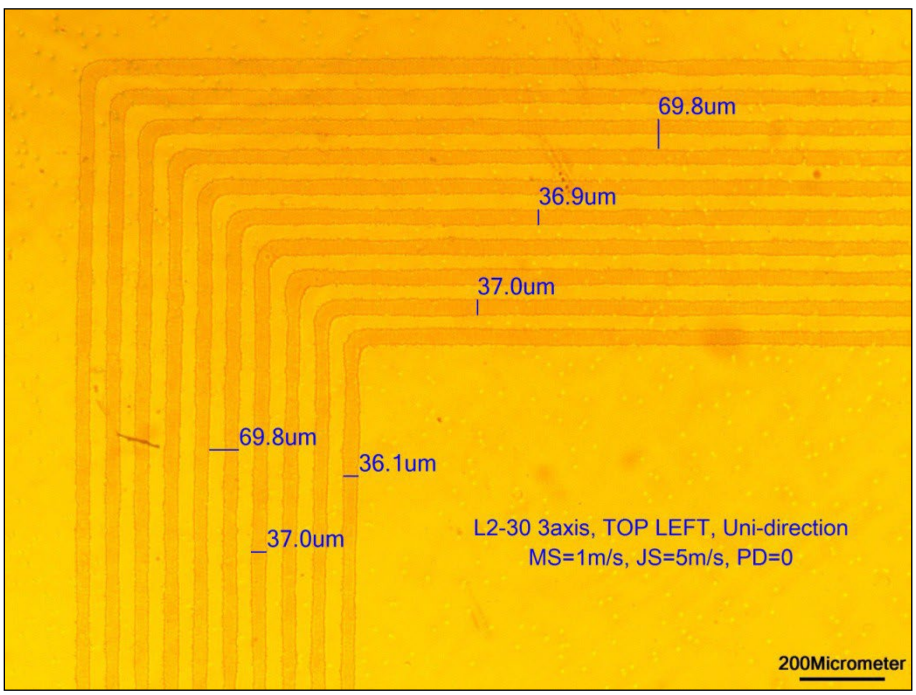

Figure 19 - Marking Result at the Top Left

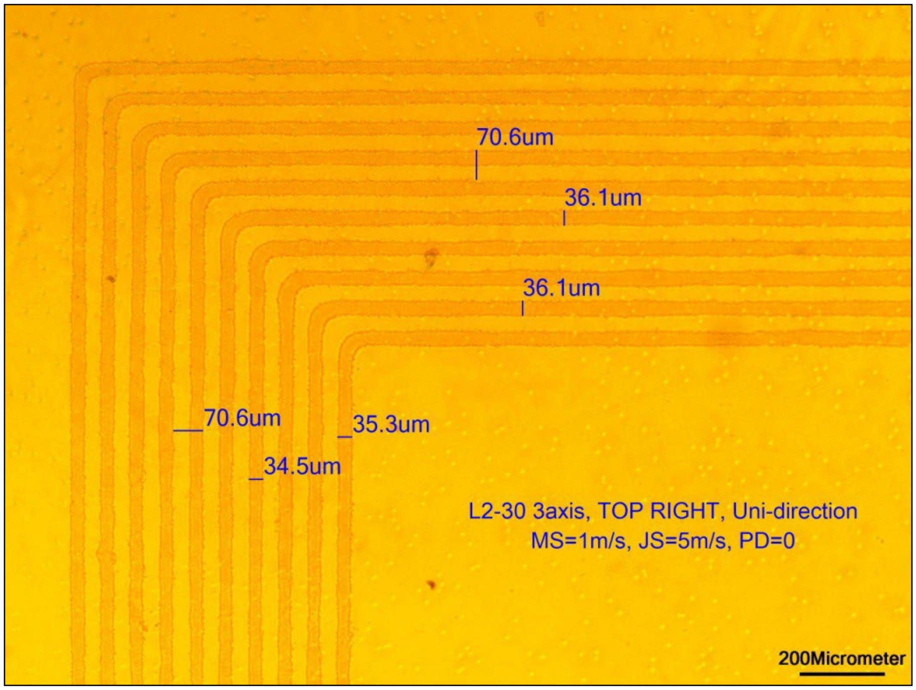

Figure 20 - Marking Result at the Top Right

Short summary: Line width at the corners of the field shows ≤2μm variation comparedto center of field, much less than the theoretically expected variations due to oblique incident angles. This could be due to two factors:

1. Beam shape distortion at edge of field due to non-normal incident angle decreasesenergy density and results in narrower marked lines on the substrate than the theoretical line width.
2. Field flattening calibration

4.4 16-bit vs 20-bit in large field patterning

The angular scanning range of the LII-30 3-axis system is ±11deg-mechanical or 0.384rad-mechanical or 0.768rad-optical. For a 16-bit controller, the command resolution is 12µrad optical or 5.5µm on target with 445mm working distance. For a 20-bit controller, the resolution is 0.73µrad optical or 0.33µm on target with 445mm working distance.

Line-to-line pitch is set to 70µm and the space between lines is only <35µm. With 16-bitresolution, line position will show ±6µm variation due to the command resolution of the controller, resulting uneven line spacing as shown below in Figure 21.

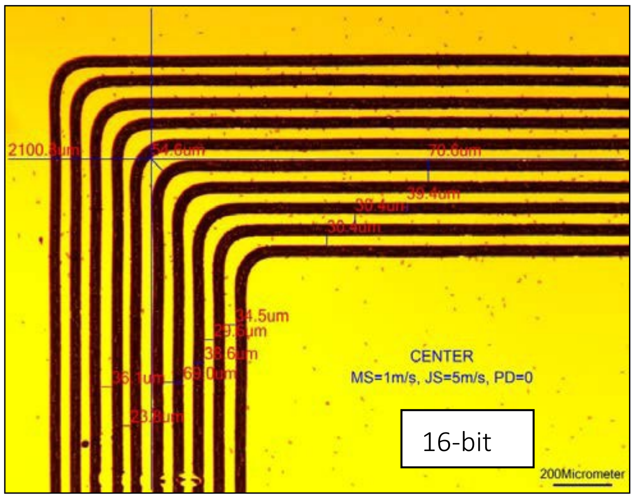

Figure 21 - Marking Result with a 16-bit Controller

But with 20-bit resolution, line spacing is uniform as shown below in Figure 22.

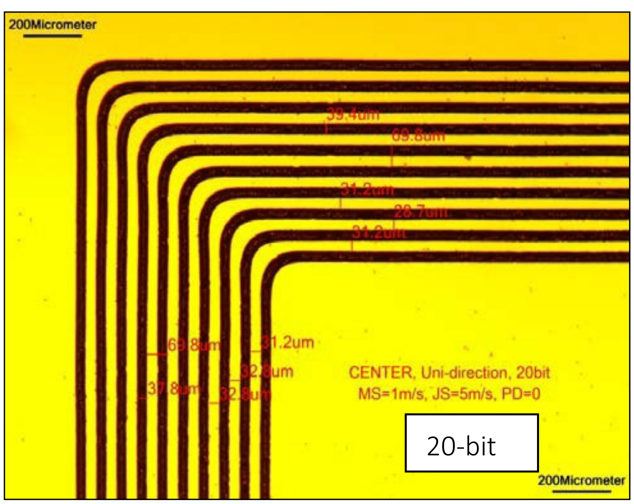

Figure 22 - Marking Result with a 20-bit Controller

Note at the time this test was done, Cambridge Technology had not developed the 24-bitcontroller ScanMaster Controller yet. So only marking comparison between 16-bit and 20-bit was performed. With the new ScanMaster Controller 24-bit command resolution, line spacing uniformity is even better.

5 Conclusion

The LIGHTNING II 30mm 3-axis scan head is able to achieve large field size and small spotsize at the same time, as well as excellent accuracy, speed, and repeatability. The LIGHTNING II scan head also has extremely low thermal drift. All these together make theLIGHTNING II scan head a perfect candidate for large area thin film patterning applications. The 3-axis scan head can be easily reconfigured to have different field sizes(200-1200mm) to meet various process requirements.

In addition, Cambridge Technology controllers with 20-bit and even 24-bit resolution help resolve small features at large field sizes and help maintain even line spacing acrossthe field.