Optimal Resolution of Two-Photon Lithography: A Voxel Study

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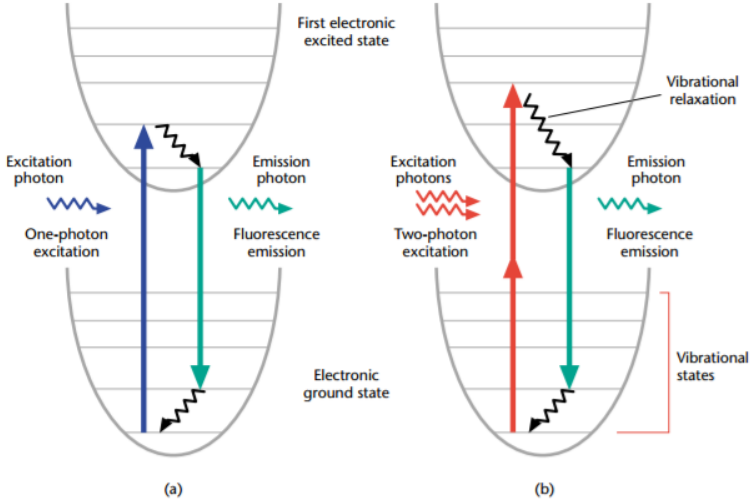
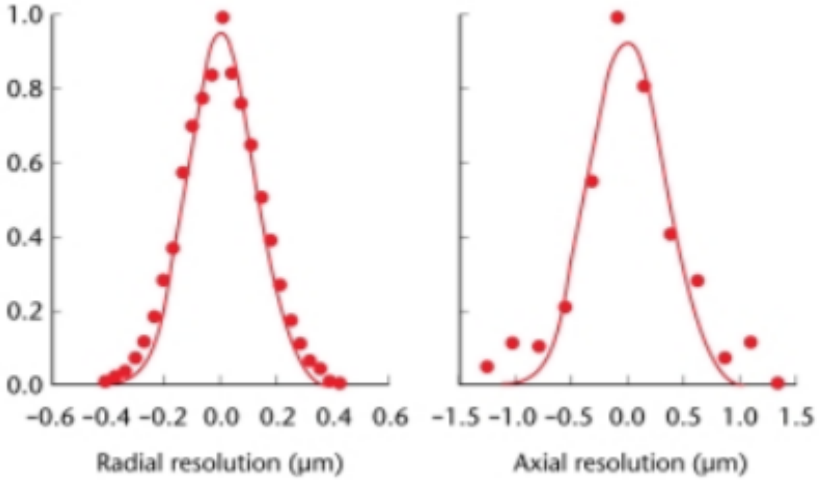
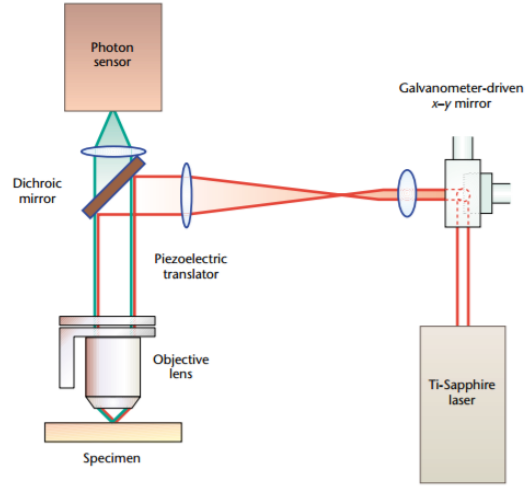
Motivation

- Controlling optimal resolution for 3D structures on the micro and nanoscale
- Process robustness on features below 200 nm and presented process windows
- Determining the structure quality relationship of laser power and scanning speed
- Shape and aspect ratio affects on voxels

2-Photon Lithography Background[1,2]

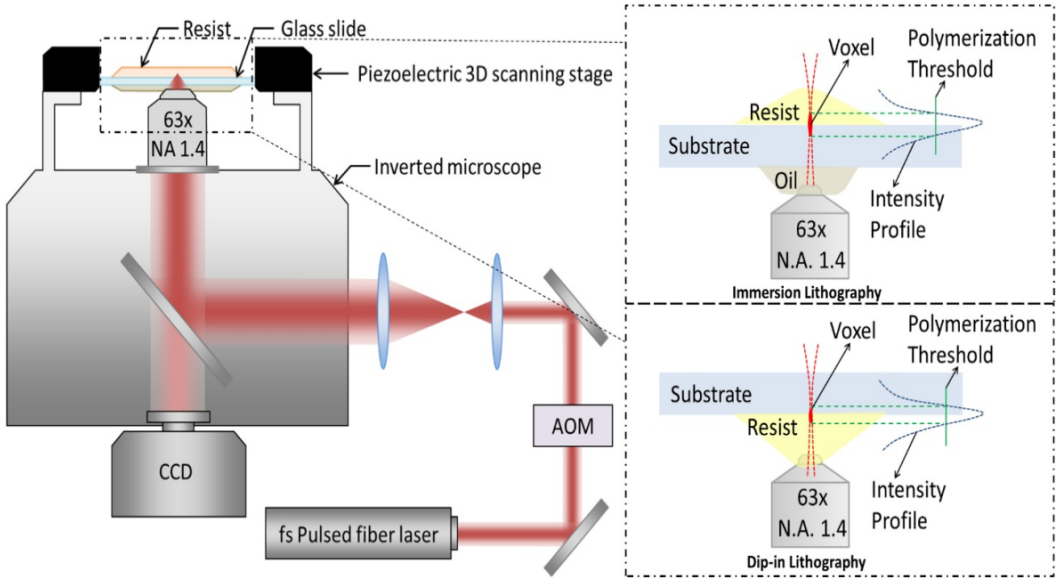






Source: So et 2001

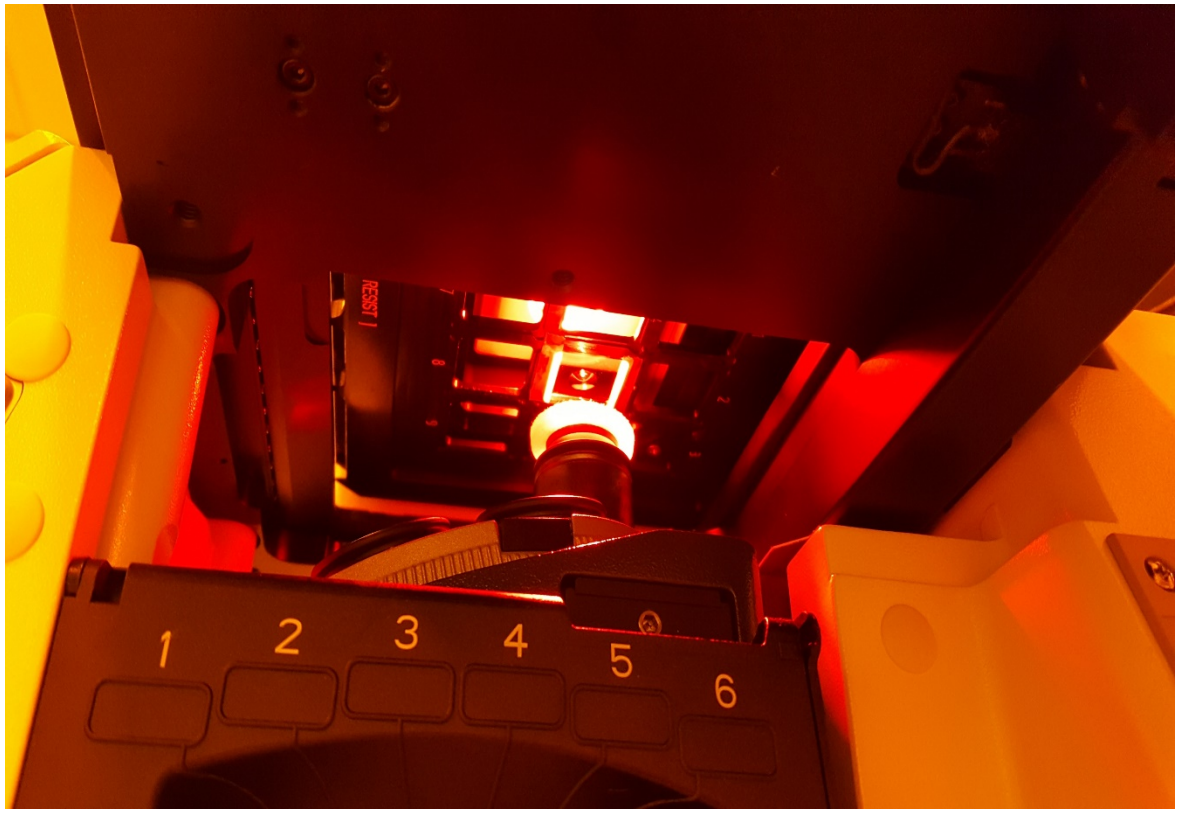
Nano Scribe Tool[3,4]



Source: Guney et al 2016

Sample Preparation and Development

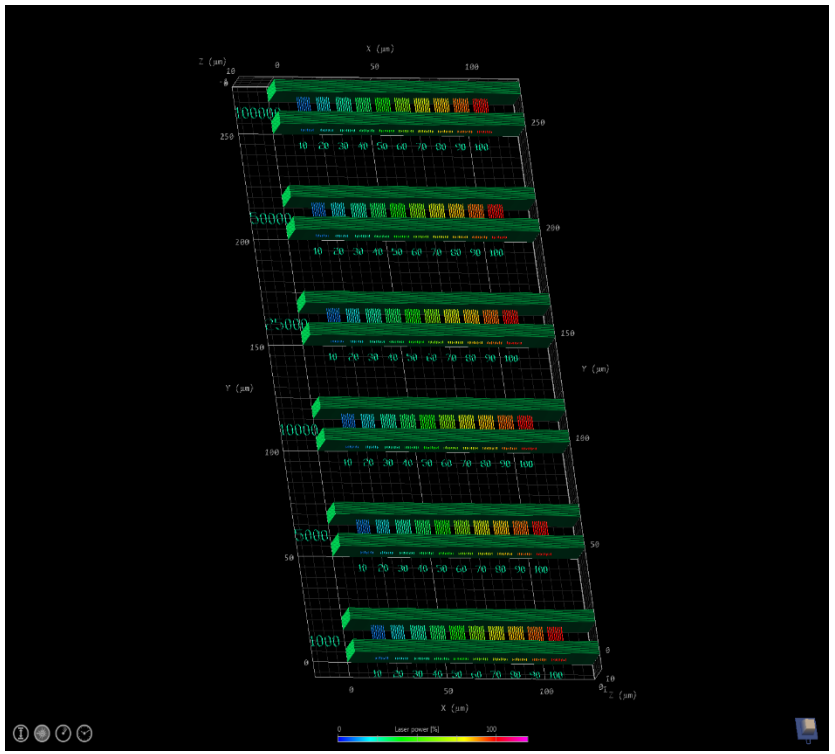
Preparation

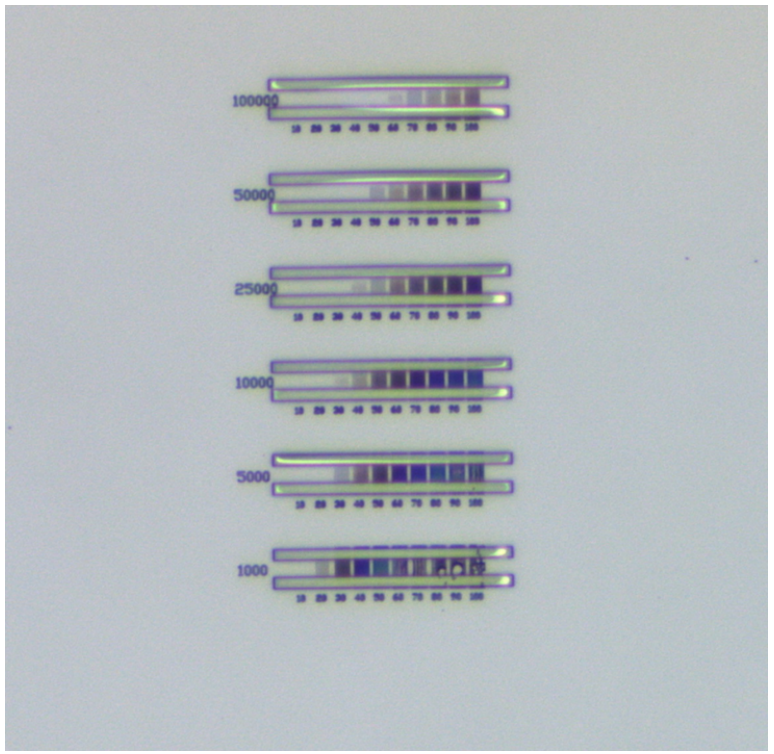


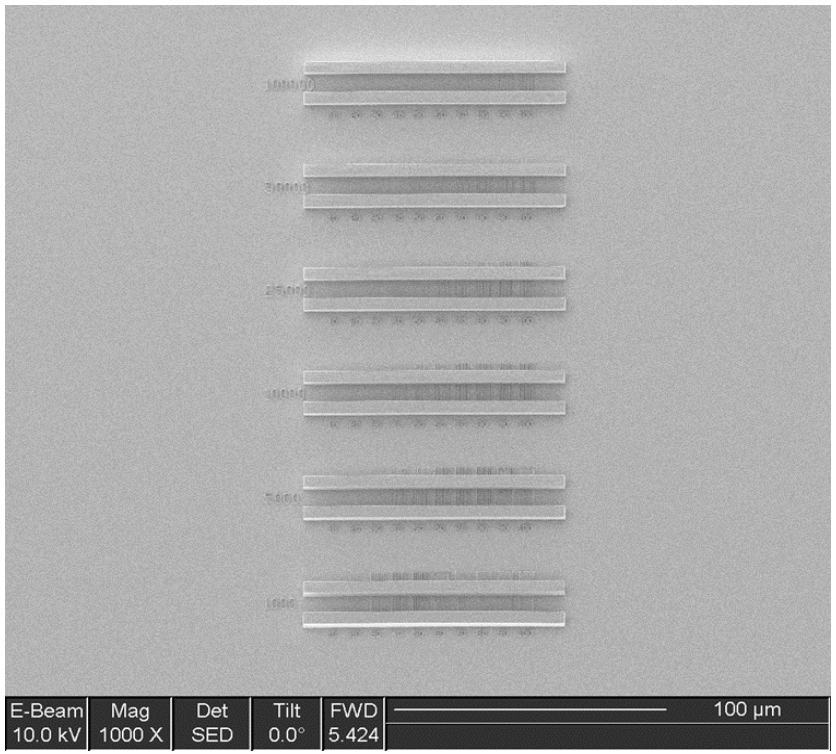
Printing

Development

GWL, Optical, and FIB Imaging

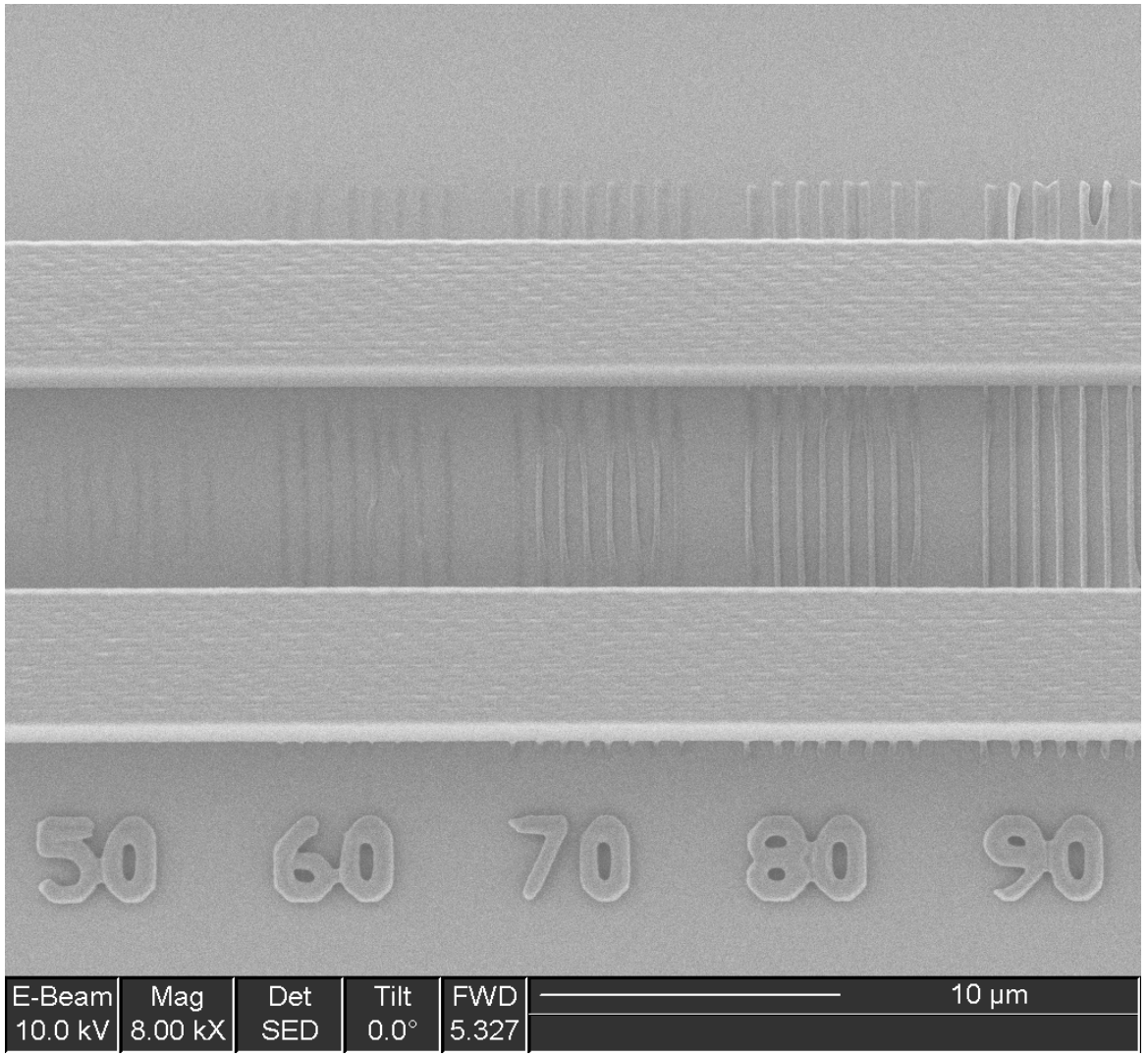






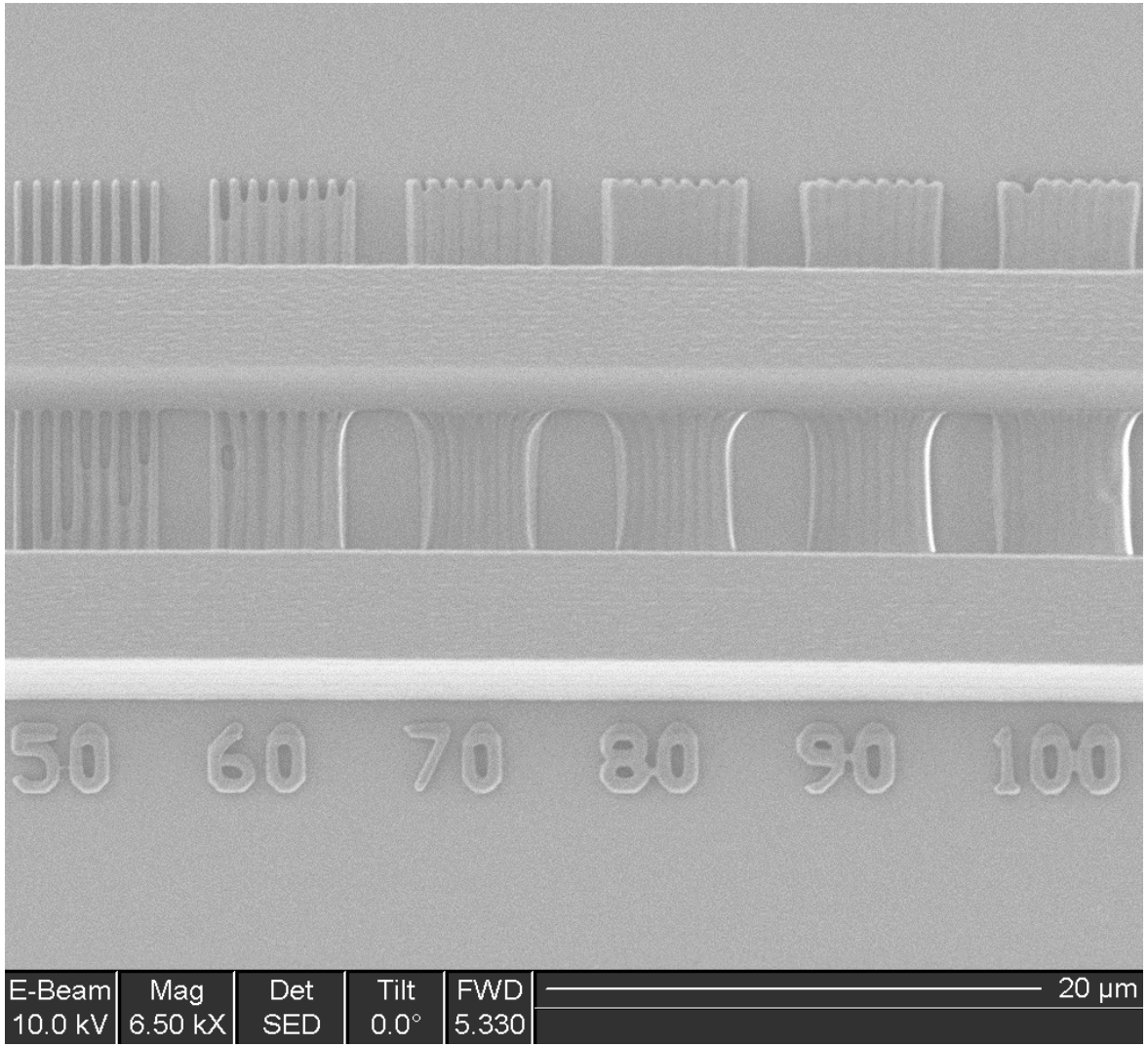
Under-exposure Effect

- Imperfections at laser powers below 70 for scan speed of 50000. The effect seen in the micrograph happens because the amount of energy (combination of power and speed) not enough to cross-link the resist completely. (low cutoff point in the plots shown later).

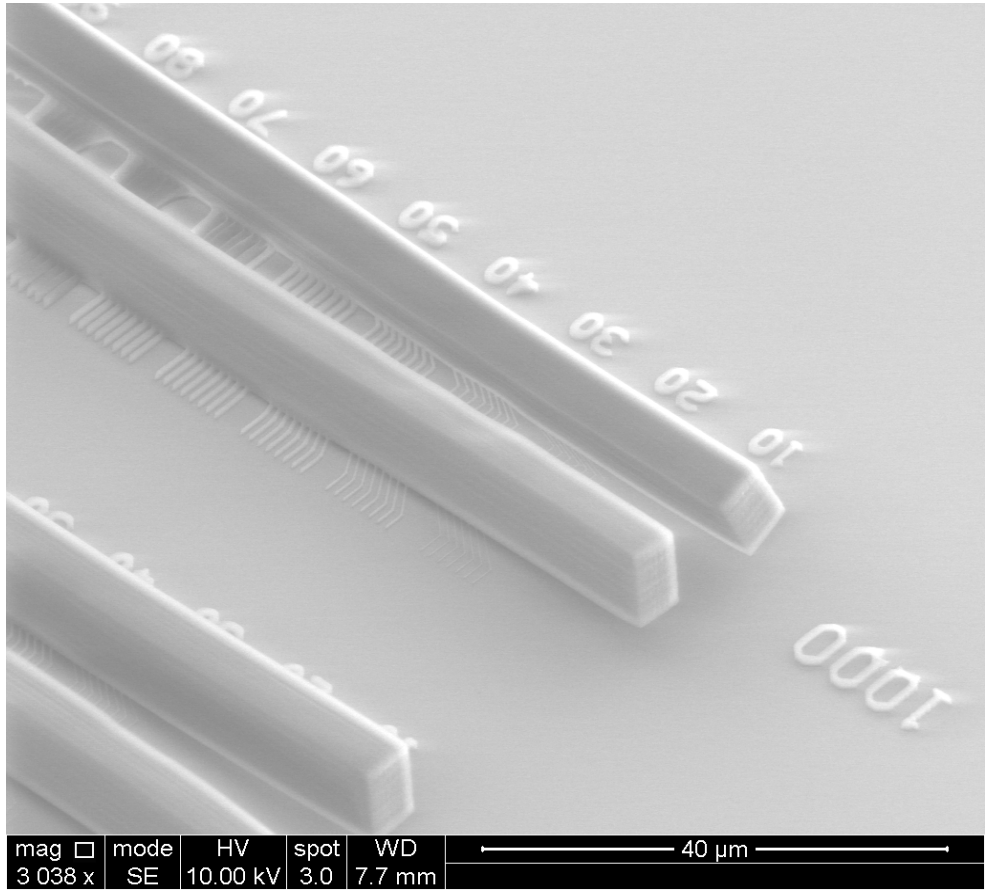


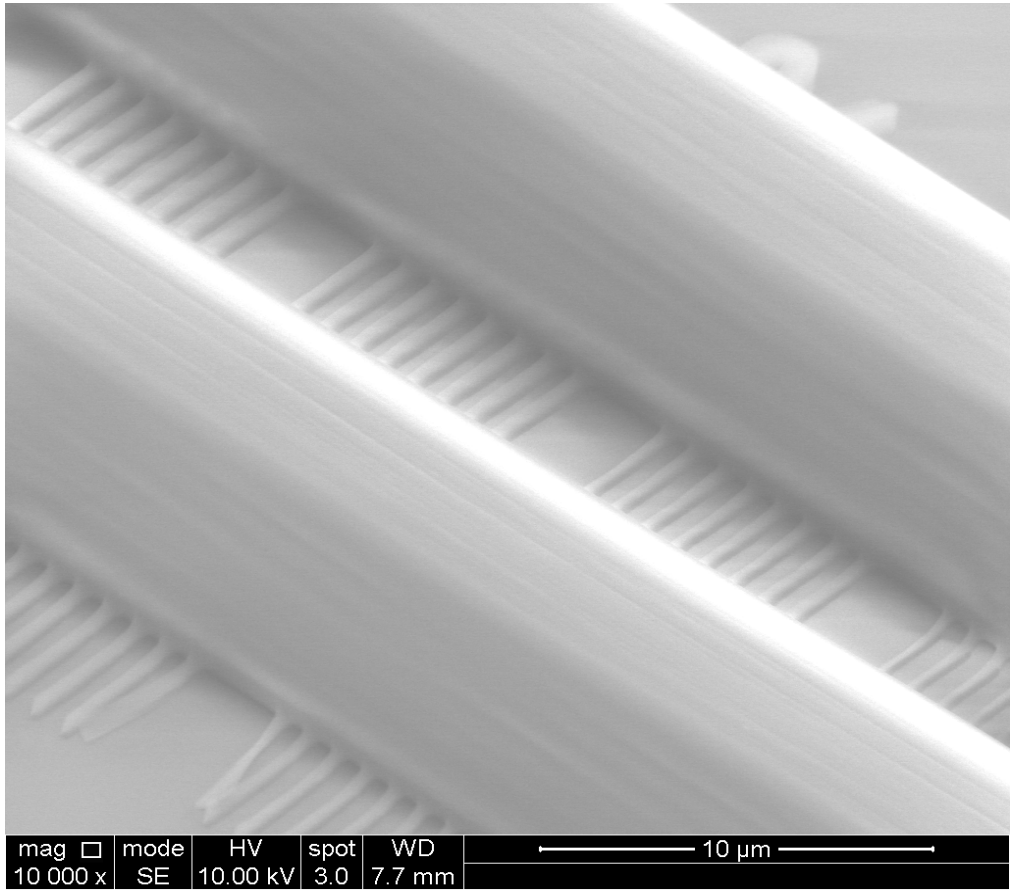
Over-exposure Effect

- Imperfections at laser powers above 60 for scan speed of 1000. The effect seen in the micrograph happens because of the capillary forces of the developer and small gap between features due to over-exposure. (high cutoff point in the plots shown later).

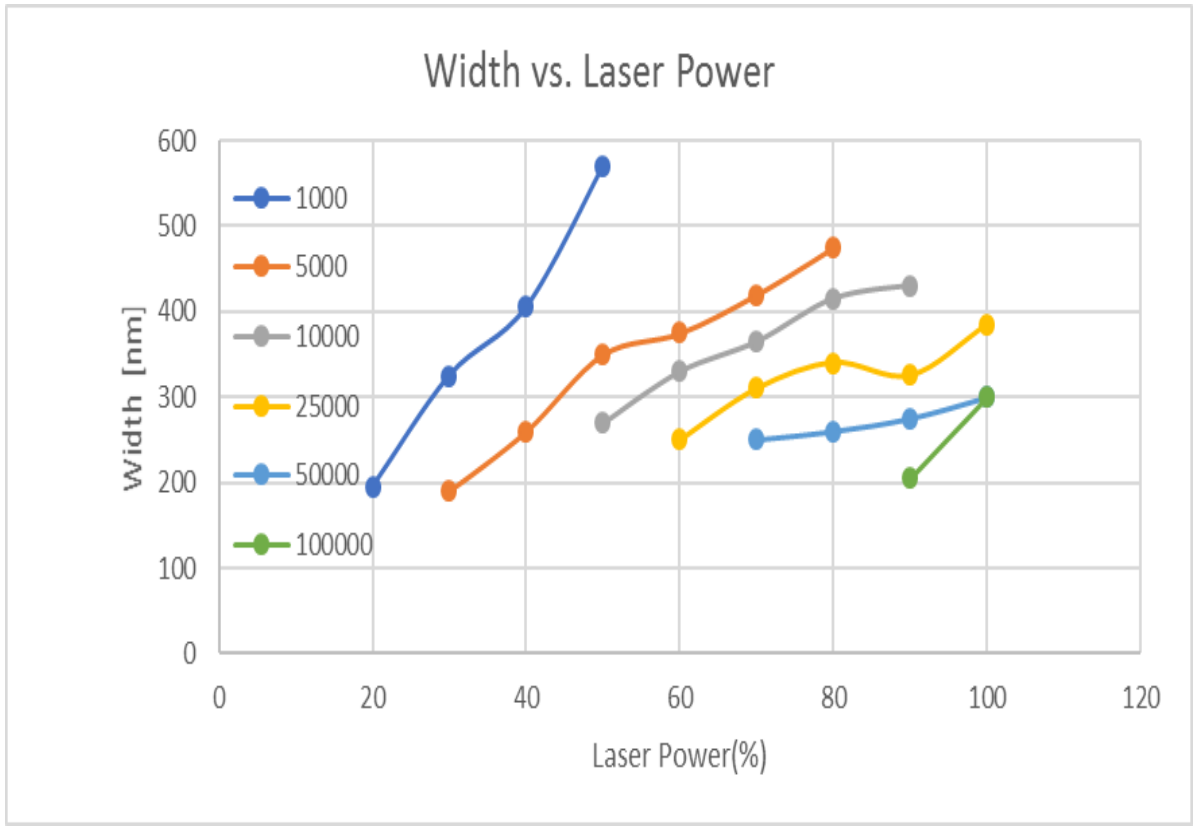


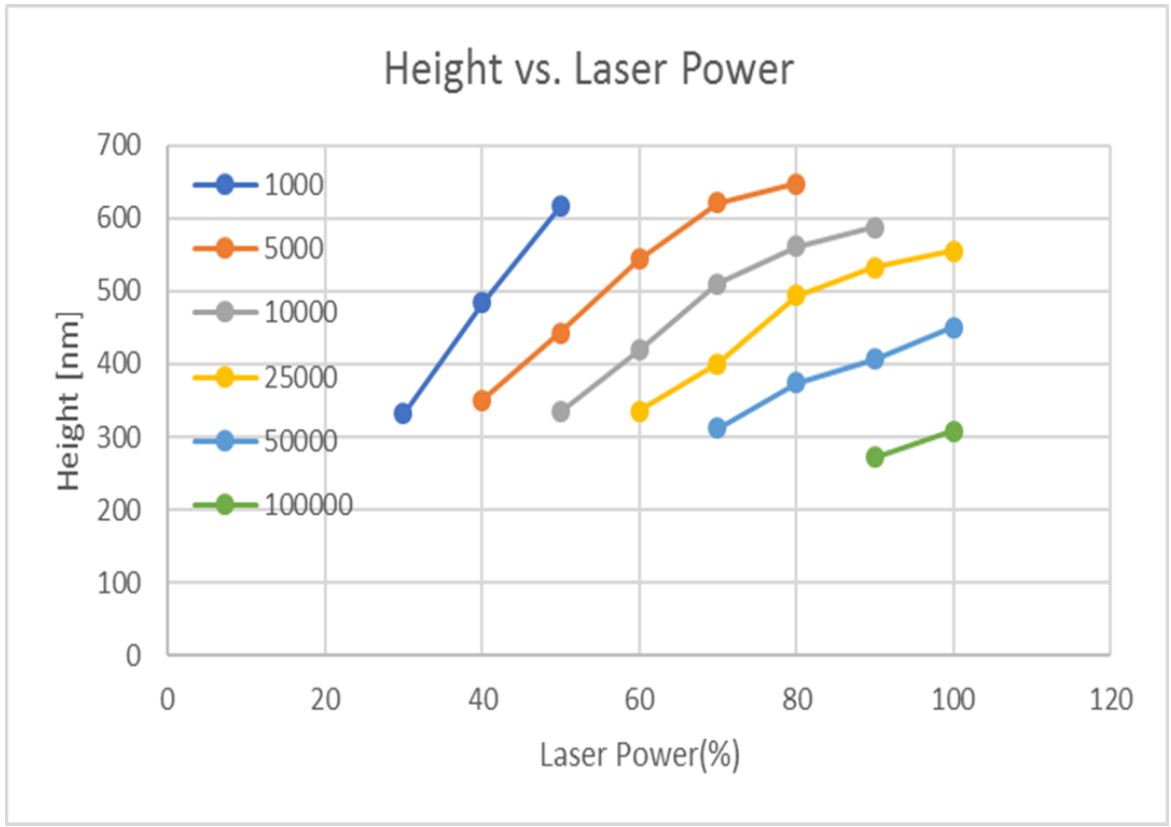
Delamination and Misalignment



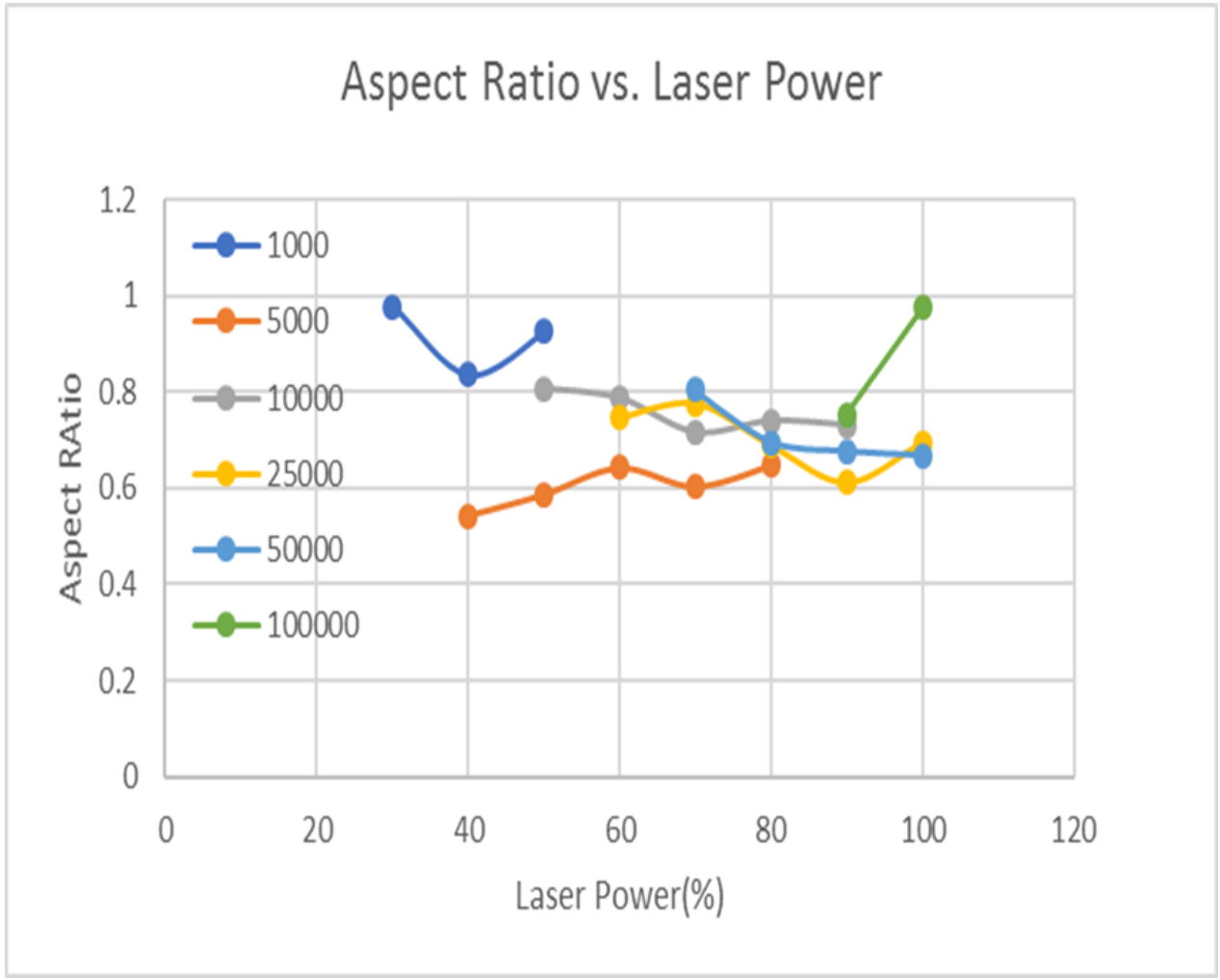


Line Width and Height





Aspect Ratio vs. Laser Power



- Note: A 100 % LP corresponds to a power value of 50 mW.

Key Learnings

- Small features can be consistently achieved by choosing appropriate scan speed and laser power.
- Depending on the choice of scan speed and laser power, voxel shape changes from cubic to high aspect ratio spheroid.

Width	Size
Smallest feature	195 nm
Largest feature	570 nm
Height	**Size**
Smallest feature	274 nm
Largest feature	648 nm
Aspect Ratio (height/width)	
Smallest	0.54
Largest	0.98

Summary

- Features below 200 nm are obtained and their process window are presented for process robustness.
- Laser powers corresponding to higher scan speed are characterized for robust structures. This decreases the overall write time.
- Voxels in shapes from cube-alike to high aspect ratio spheroid are characterized. This allows a better control of resolution.

The Next Steps

- Adjust the ladder code so that lines are floating in between blocks
- Reduce the amount delamination of ladders at higher scan speeds
- Expand the range of laser power and scan speeds to observe more optimal shifts in resolution
- Do exposure latitudes for other photoresists(IP-S, IP-L 780, etc.)

References

1. So, P. T. *Encyclopedia of Life Sciences* **2001**.

2.Perry, J. W.; Cumpston, B. H.; Ananthavel, S. P.; Barlow, S.; Dyer, D. L.; Ehrlich, J. E.; Erskine, L. L.; Heikal, A. A.; Kuebler, S. M.; Lee, I.-Y. S.; Mccord-Maughon, D.; Qin, J.; Röckel, H.; Rumi, M.; Wu, X.-L.; Marder, S. R. Nature 1999, 398 (6722), 51–54.

3. Photonic Professional GT http://www.nanoscribe.de/en/products/photonic-professional-gt/ (accessed Jul 31, 2017).

4. Guney, M. G.; Fedder, G. K. Journal of Micromechanics and Microengineering 2016, 26 (10), 105011.

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