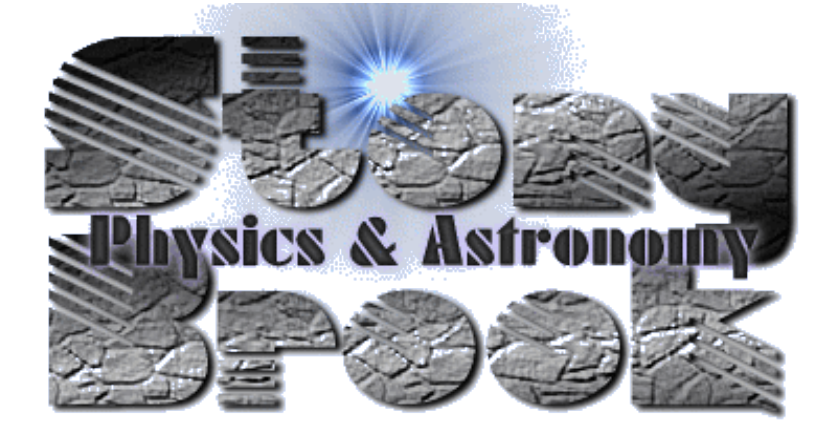


Structures of ~100 nm Size Produced by Atom Lithography with Metastable He



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Abstract

We have performed neutral atom lithography using a bright beam of metastable 2^3S_1 Helium (He^*) that is collimated with the bichromatic force and subsequent optical molasses. Incident He^* atoms damage the molecules of a monolayer of resist by depositing their 20 eV of internal energy in a pattern determined by a mechanical or "optical" mask, and a chemical etch then imprints this pattern on a 20 nm underlying gold layer. We make lines separated by $\lambda/2$ that cover the entire 3×3 mm of the exposed substrate.

Bright He^* Beam

COLLIMATION

Intuitive Approach to the Bichromatic Force

Basic Ideas:

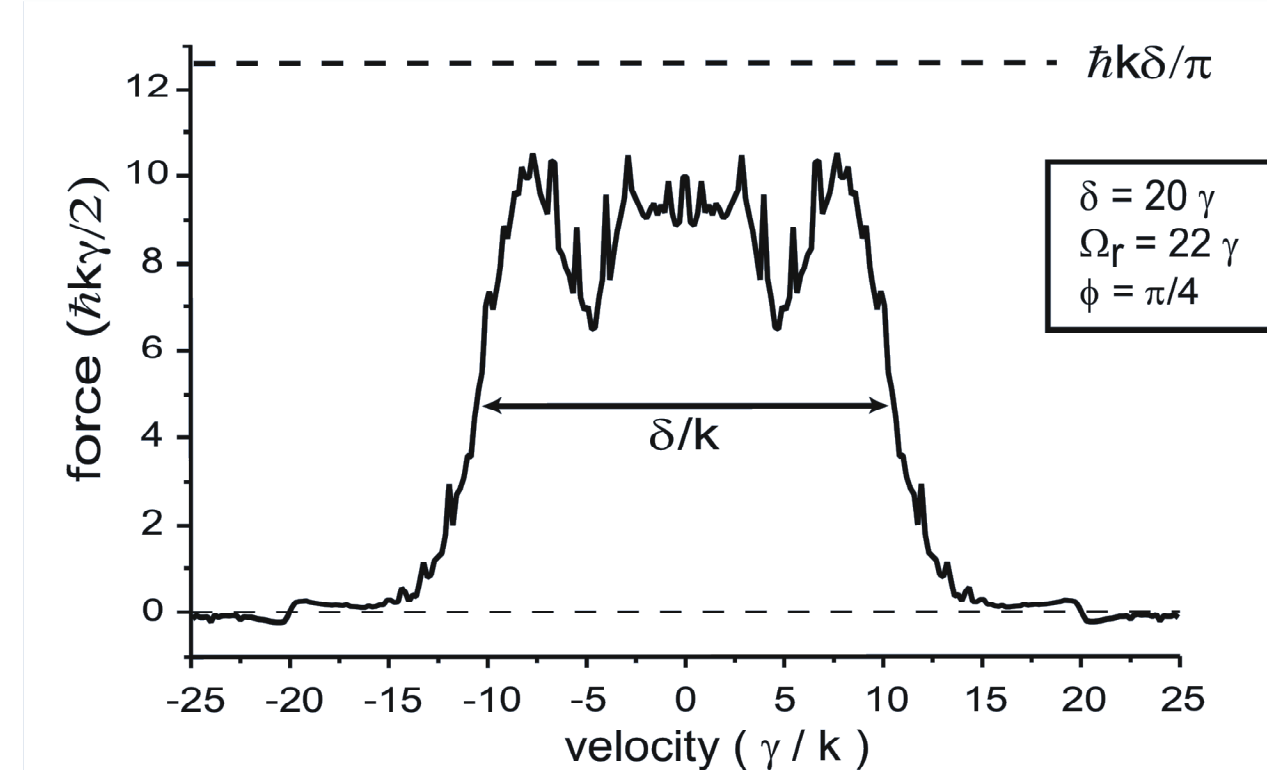
- Control momentum exchange between light field and atom by timing of counter-propagating pi pulses (phase condition).
- De-excitation process is stimulated not spontaneous emission.
- Force is huge compared to scattering force: $F = \frac{\hbar k \delta}{2} \gg \frac{\hbar k \gamma}{2}$
- Bichromatic collimation results in a beam divergence of 9 mrad.

Optical Molasses Stages for Final Collimation

- Final collimation to 1.1 mrad divergence is achieved with several Doppler molasses stages.
- All of the collimation stages use only 8.2 cm of the atomic beamline.

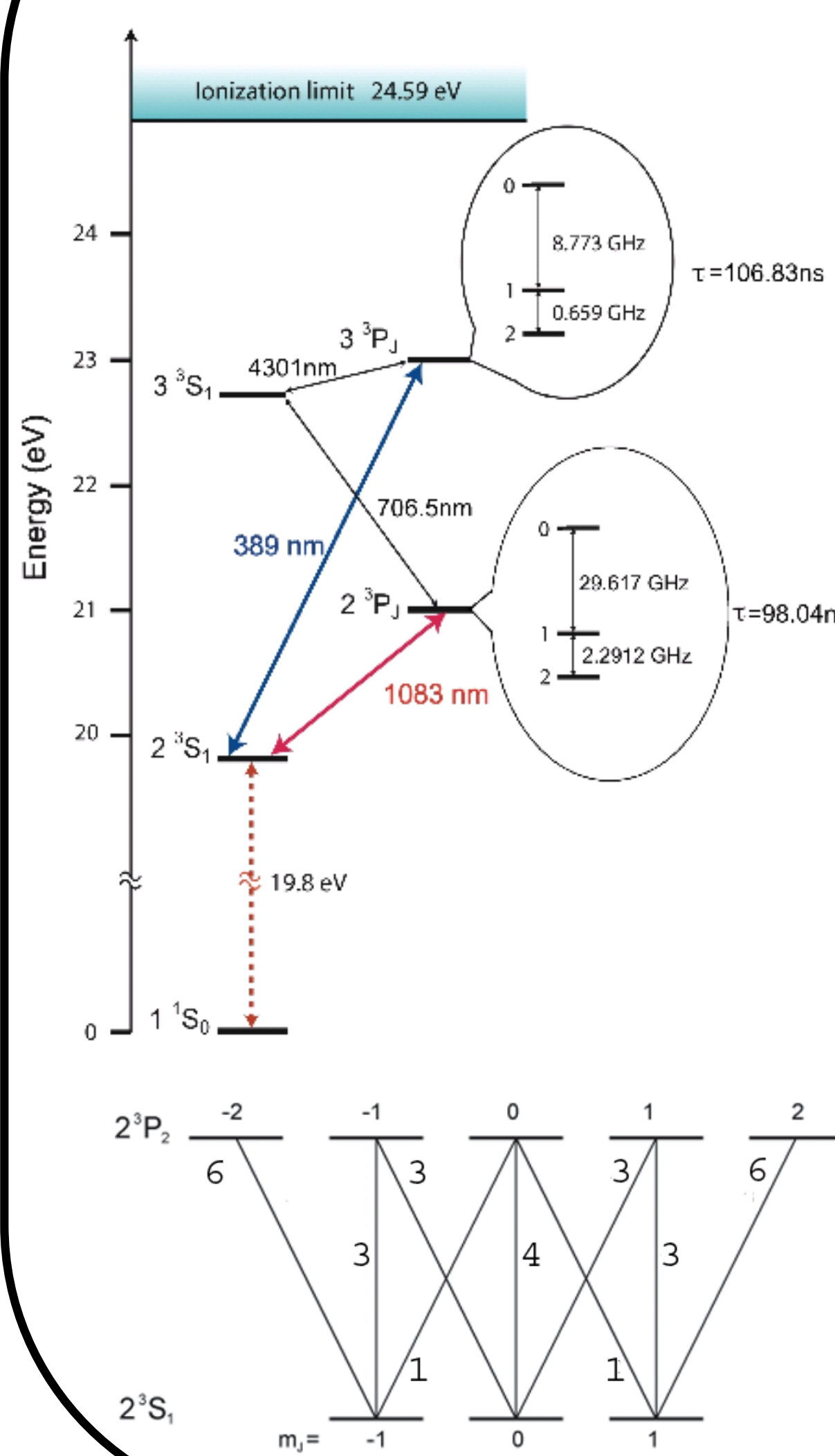
Magnitude of the Bichromatic Force

The force profile is calculated by numerical evaluation of the Optical Bloch Equations

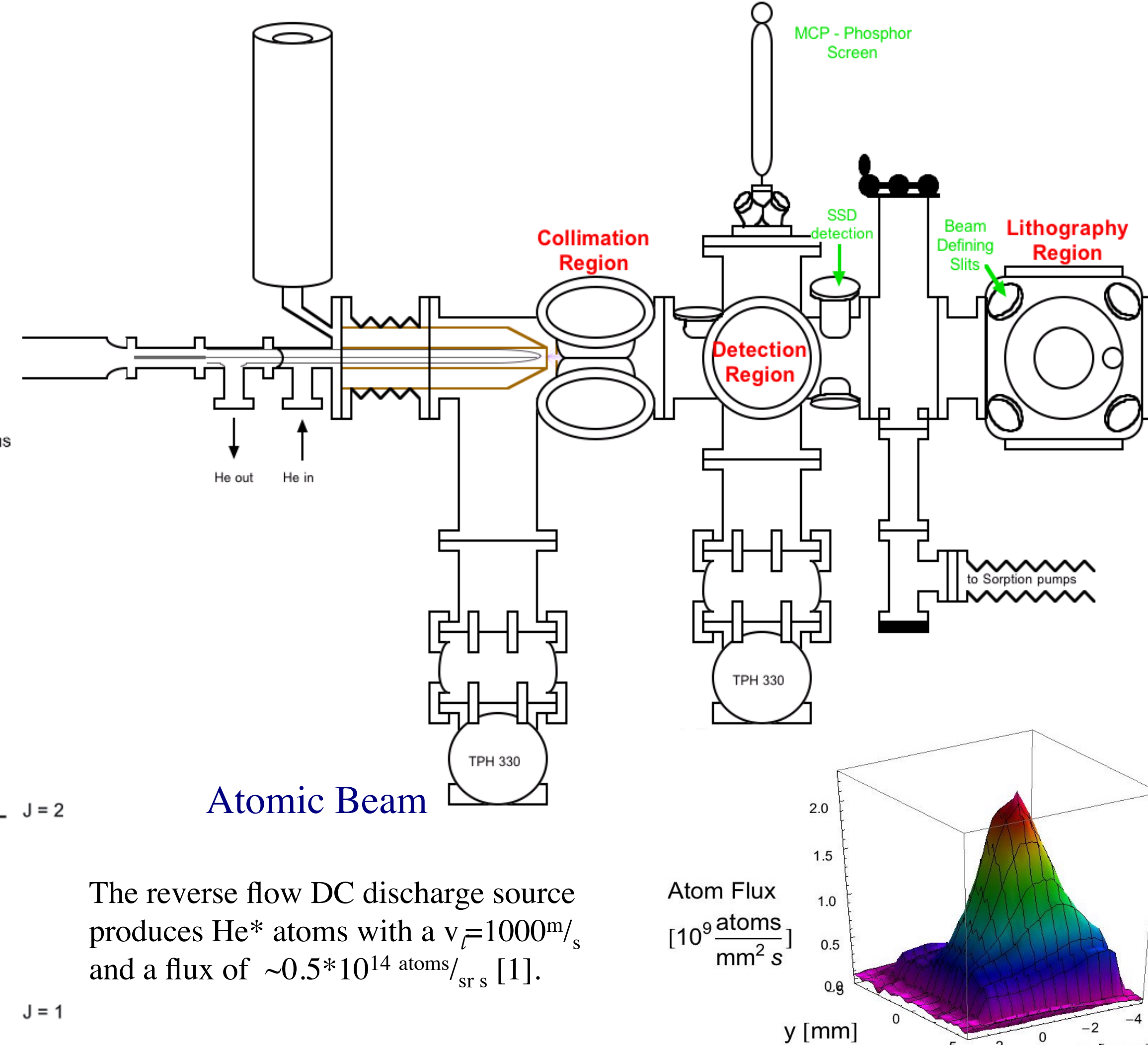


EXPERIMENTAL SETUP

Metastable Helium

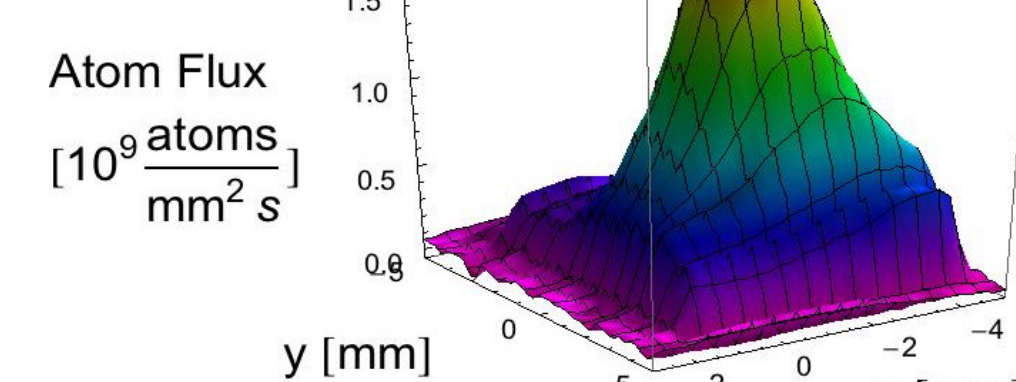


Experimental Chamber



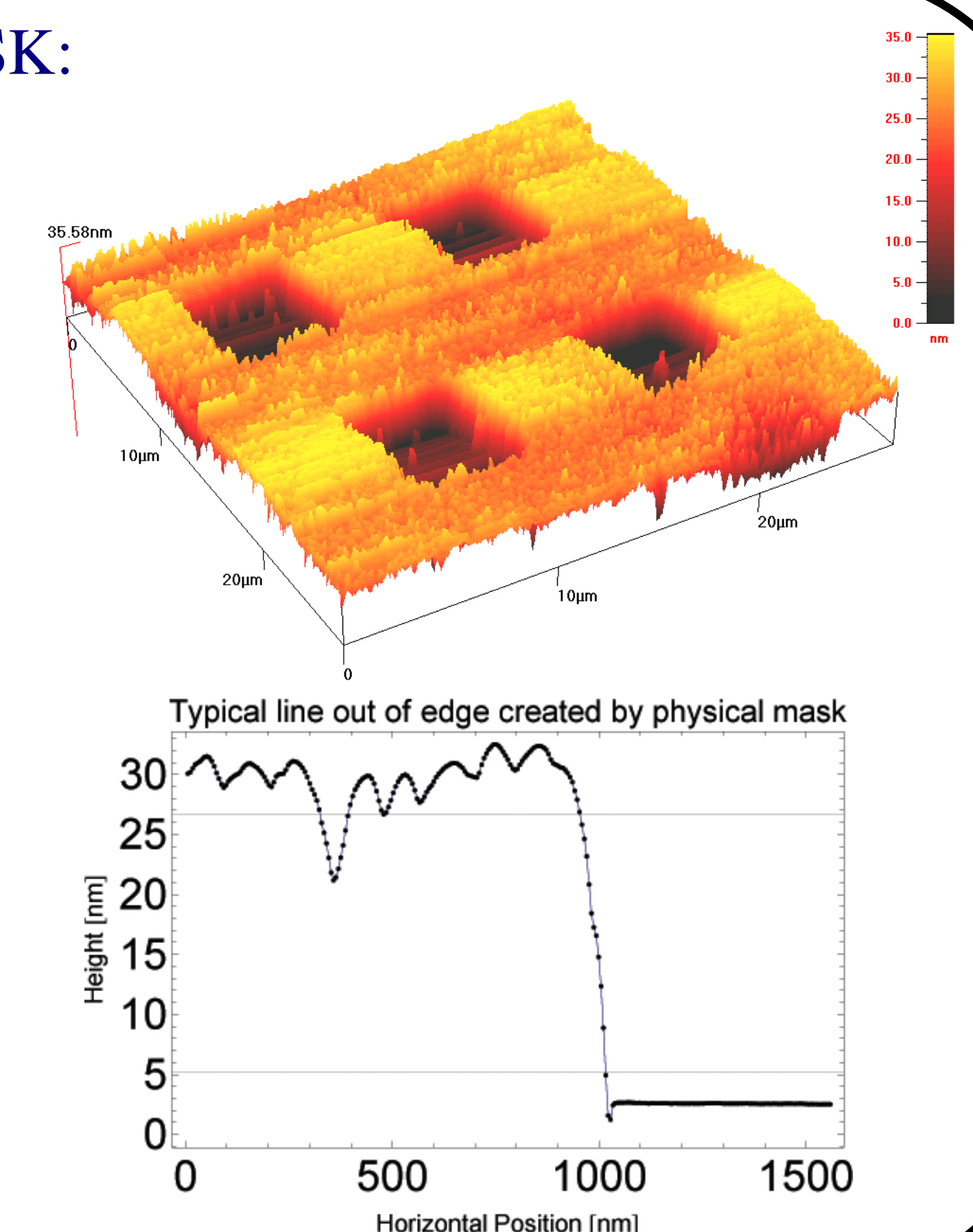
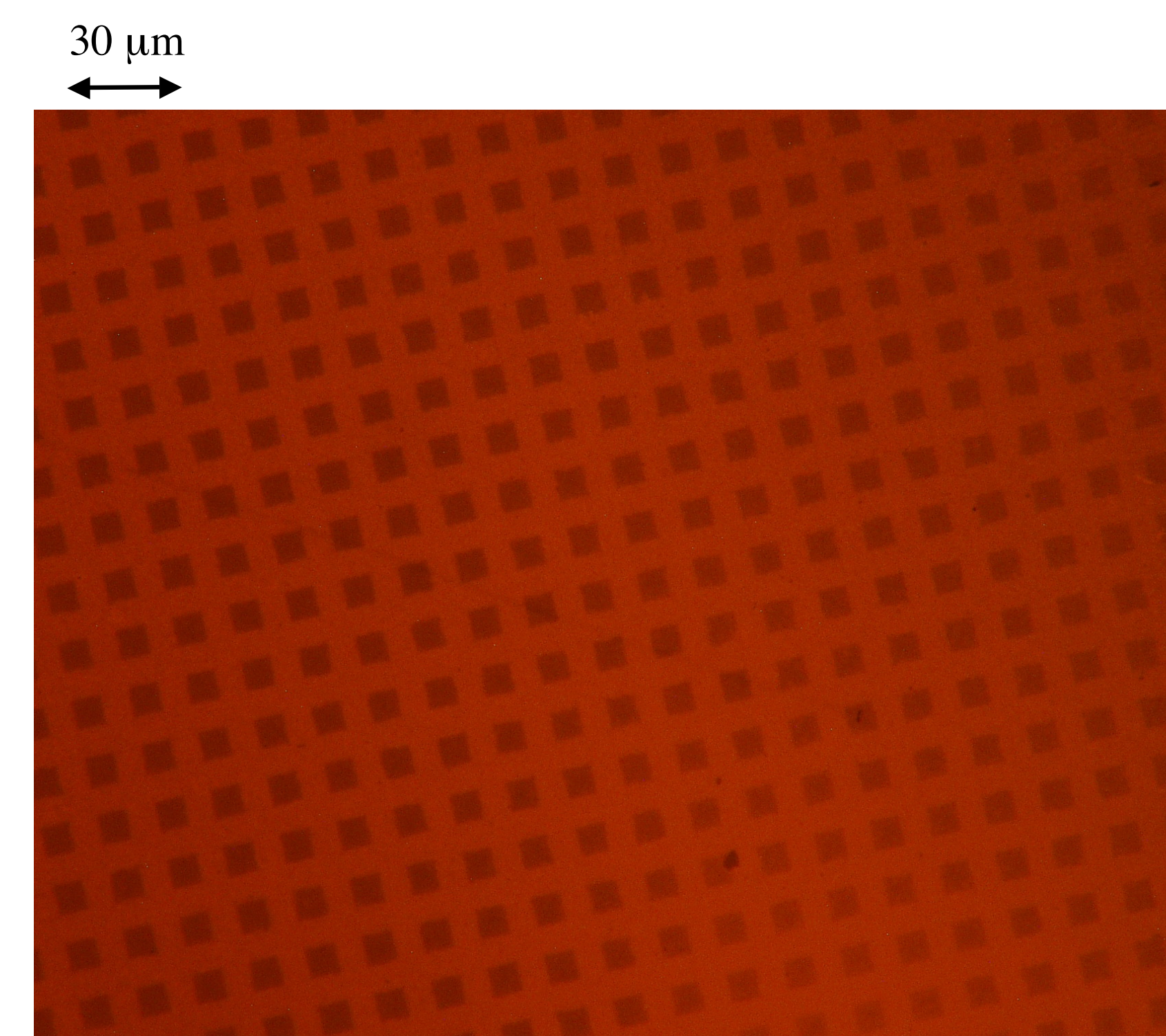
Atomic Beam

The reverse flow DC discharge source produces He^* atoms with a $v \approx 1000$ m/s and a flux of $\sim 0.5 \times 10^{14}$ atoms/s [1].

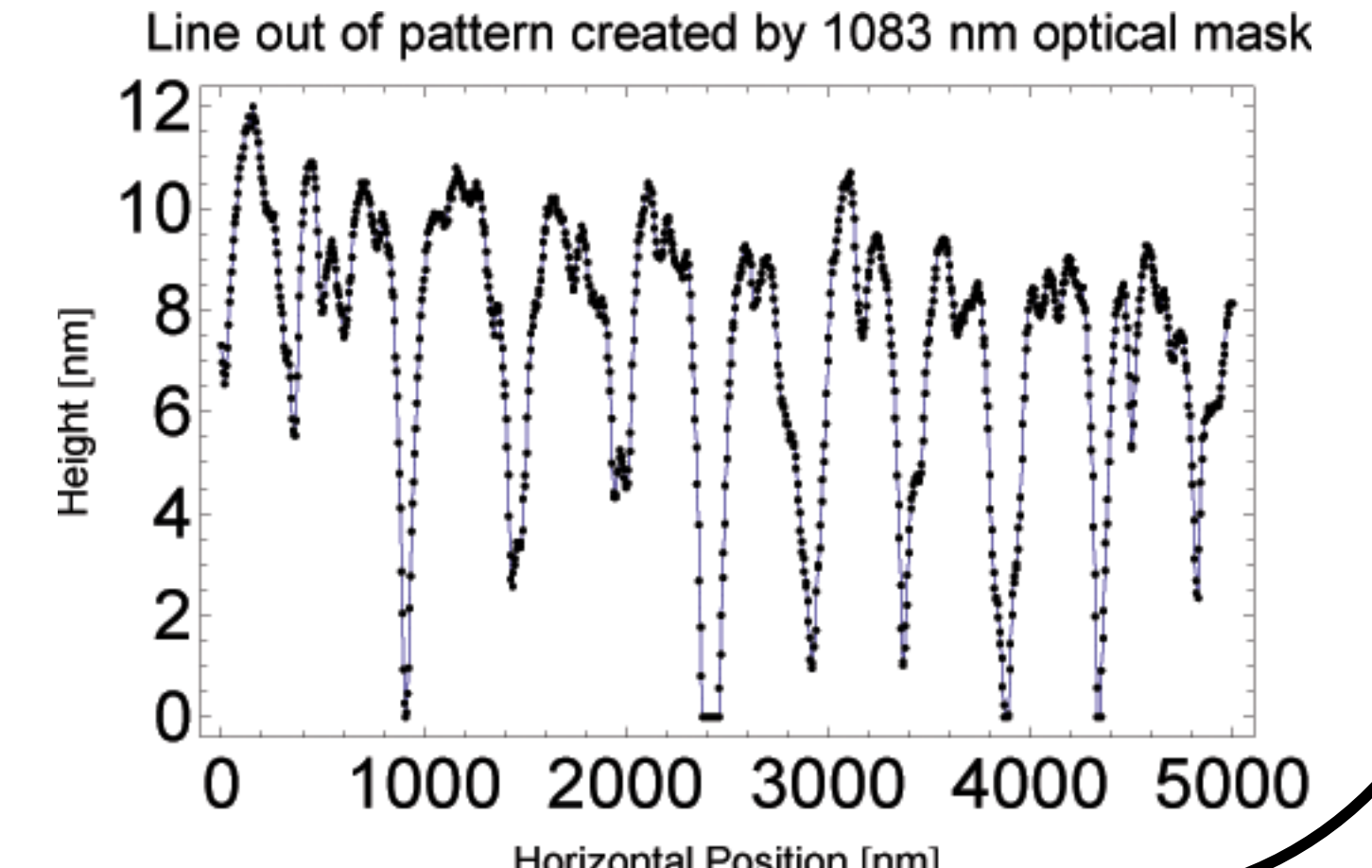
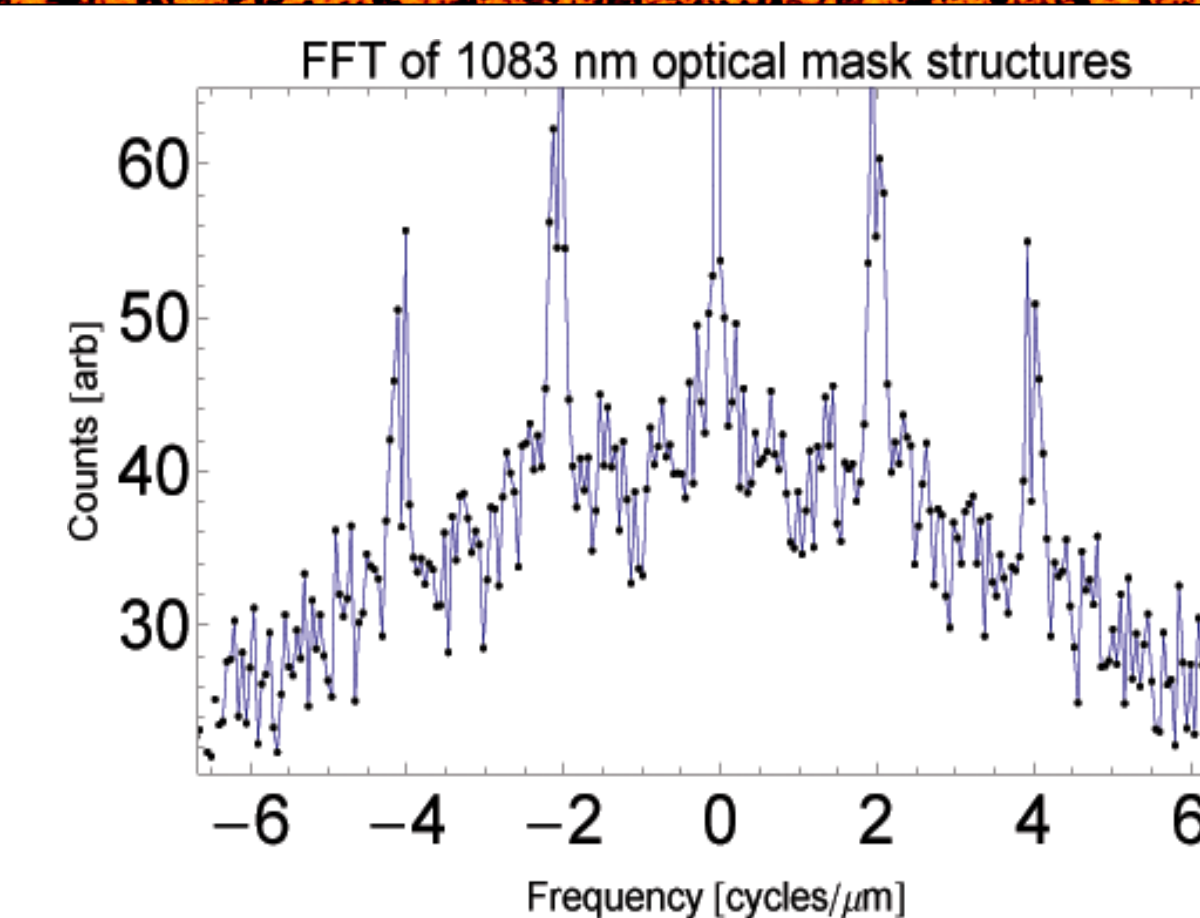
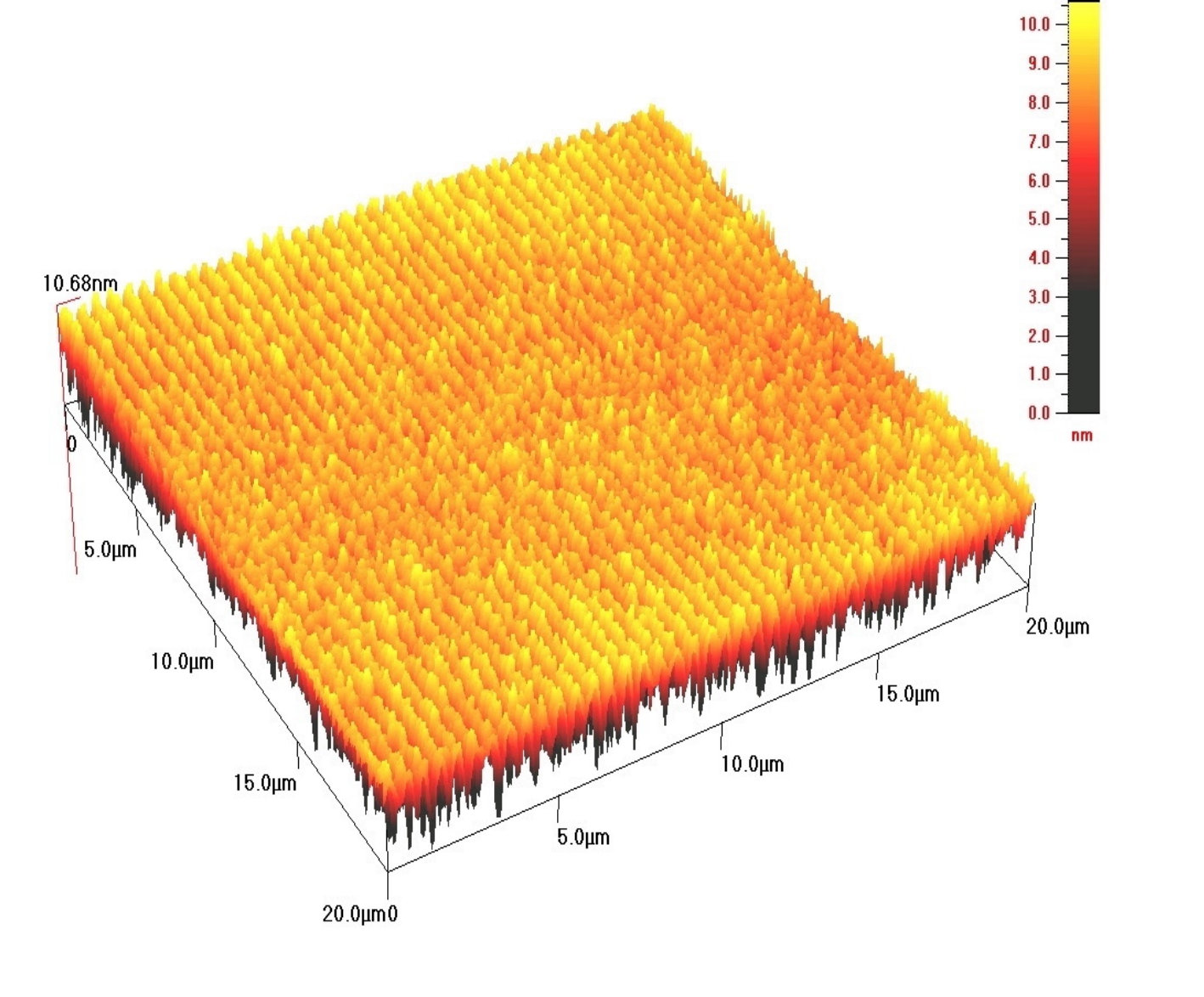
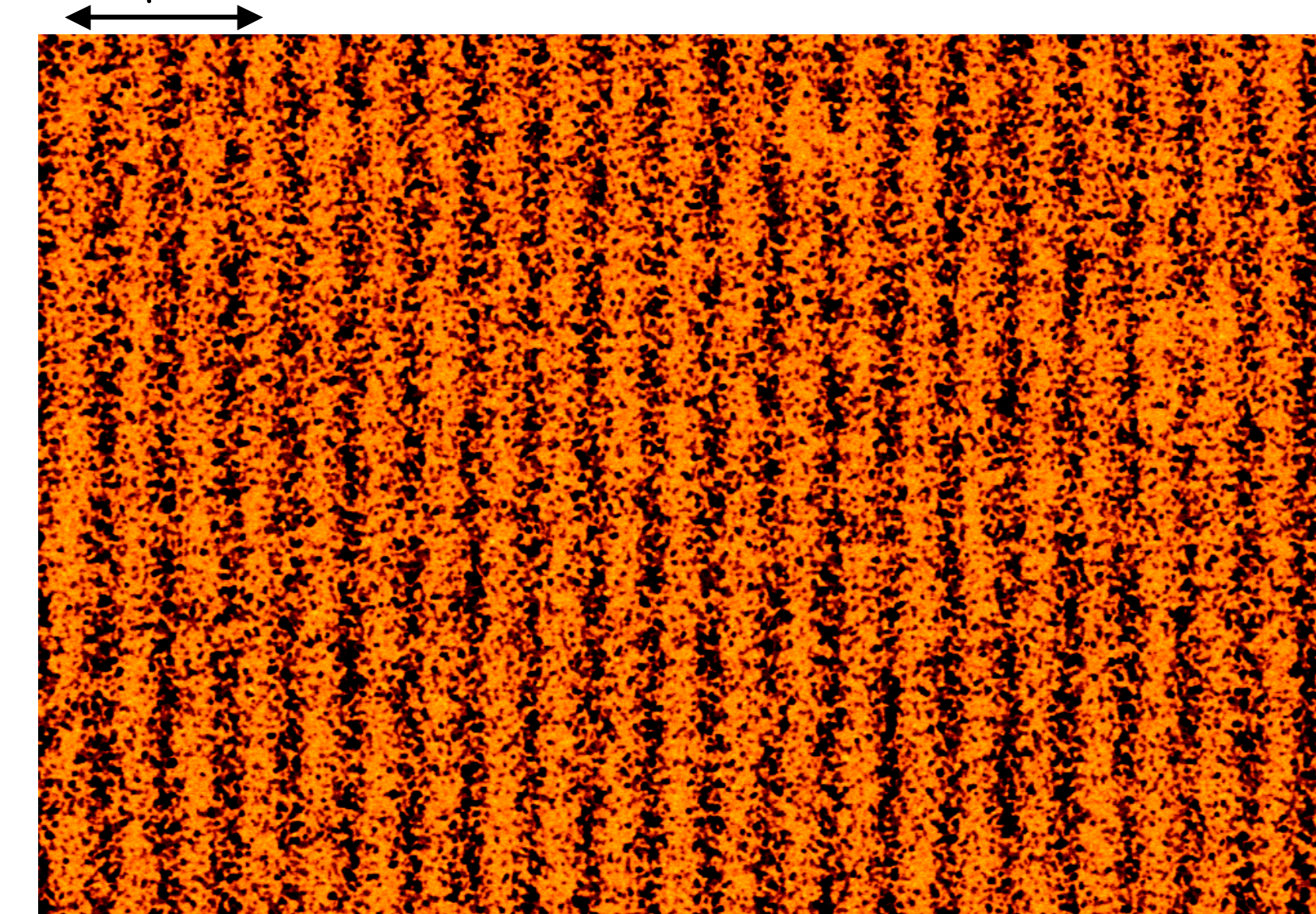


Nanoscale Patterning

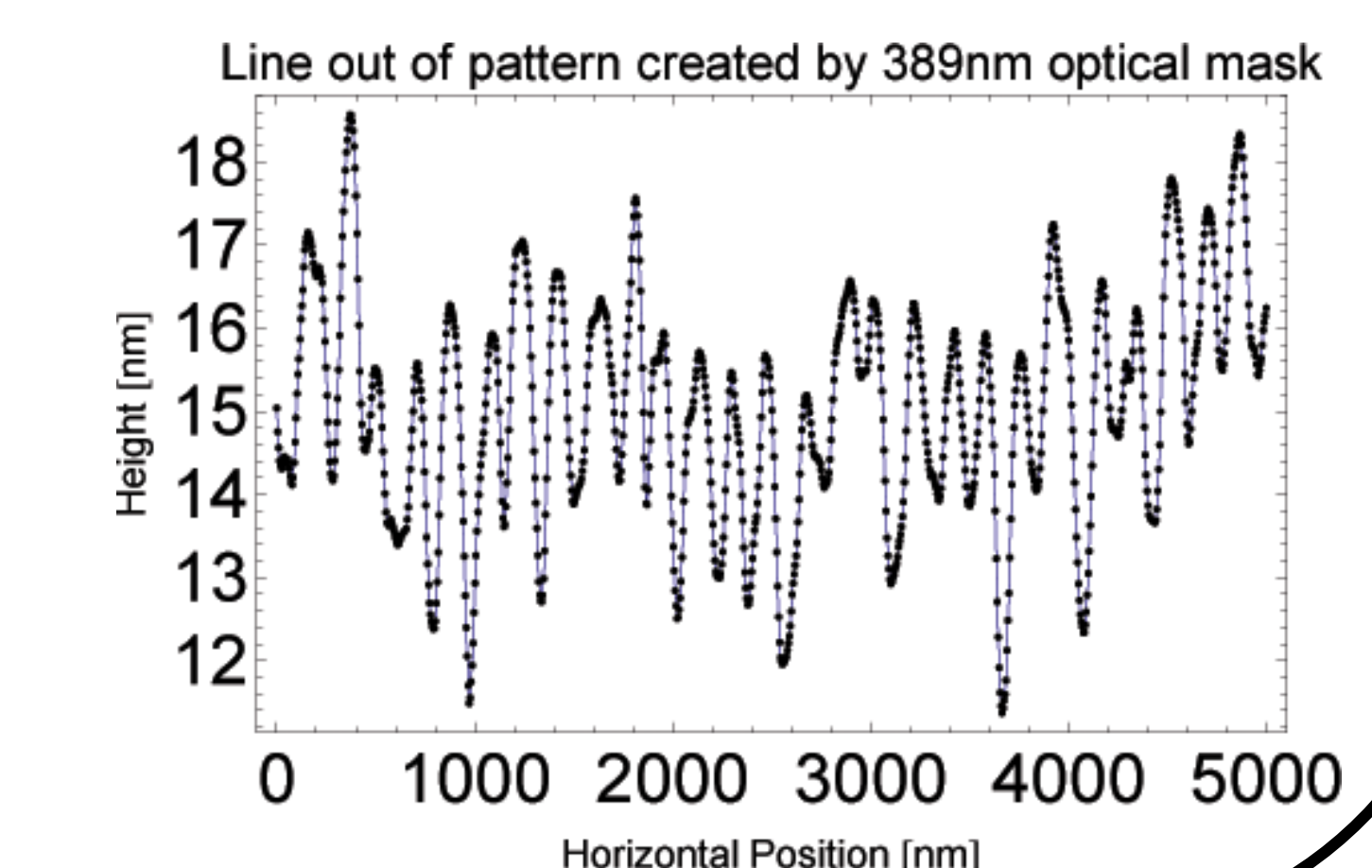
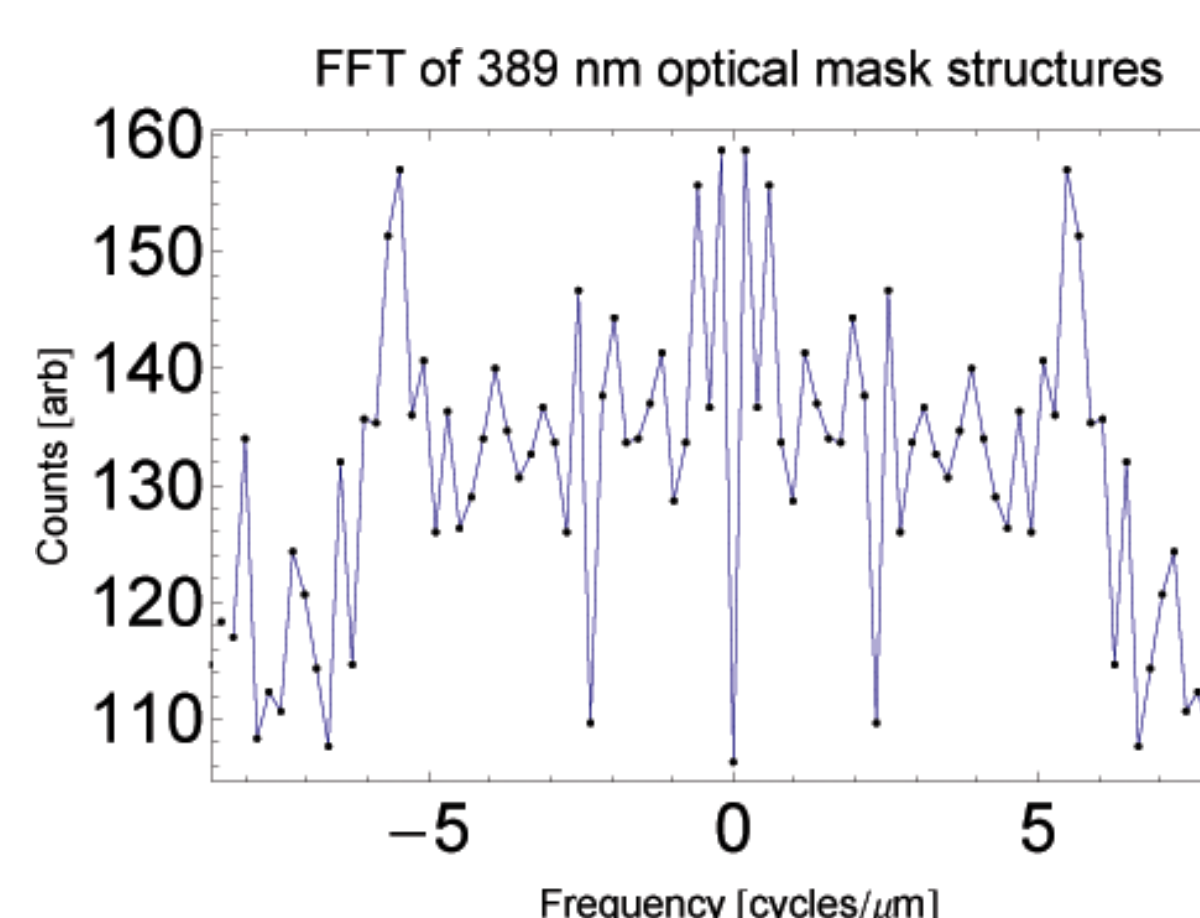
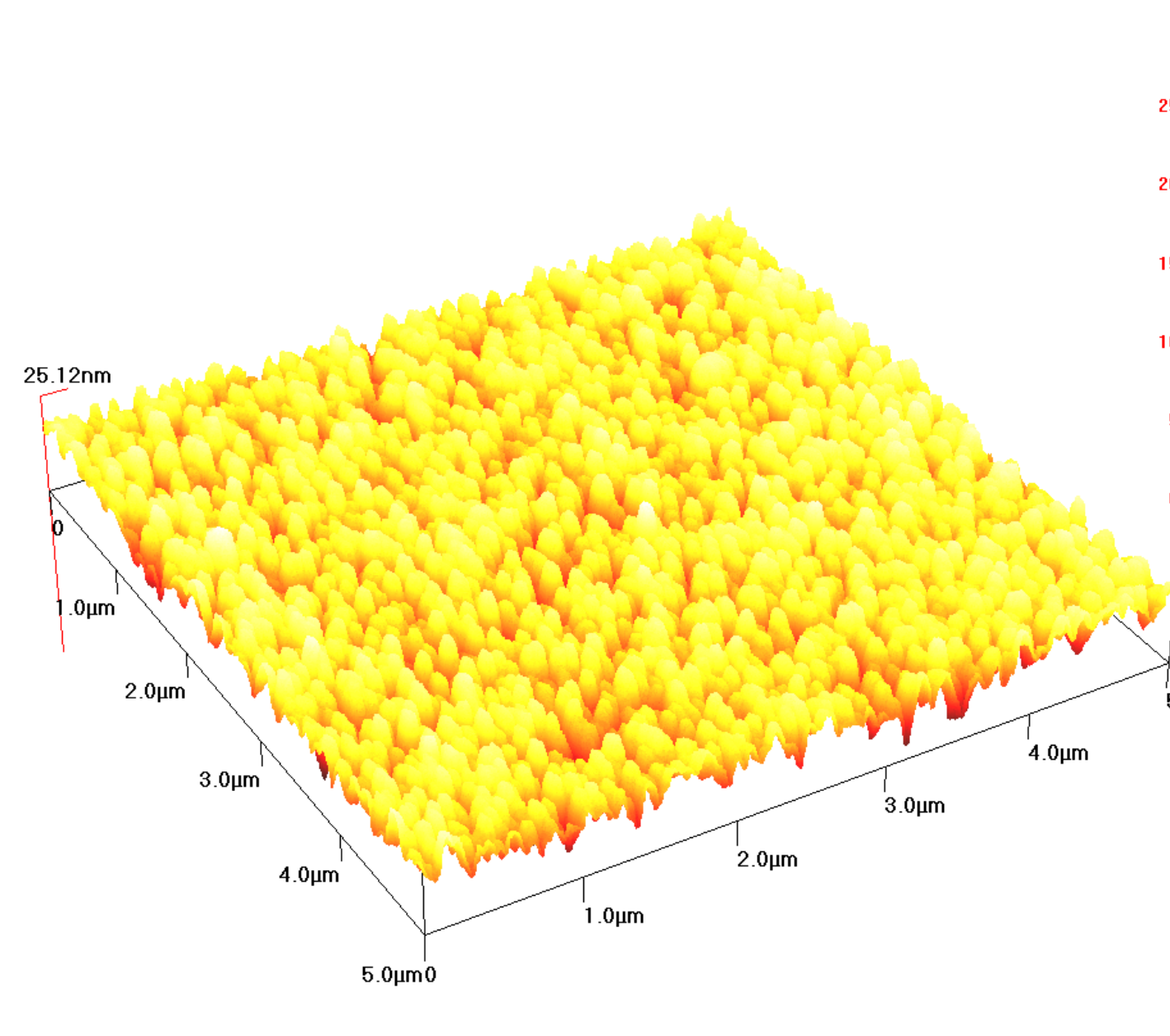
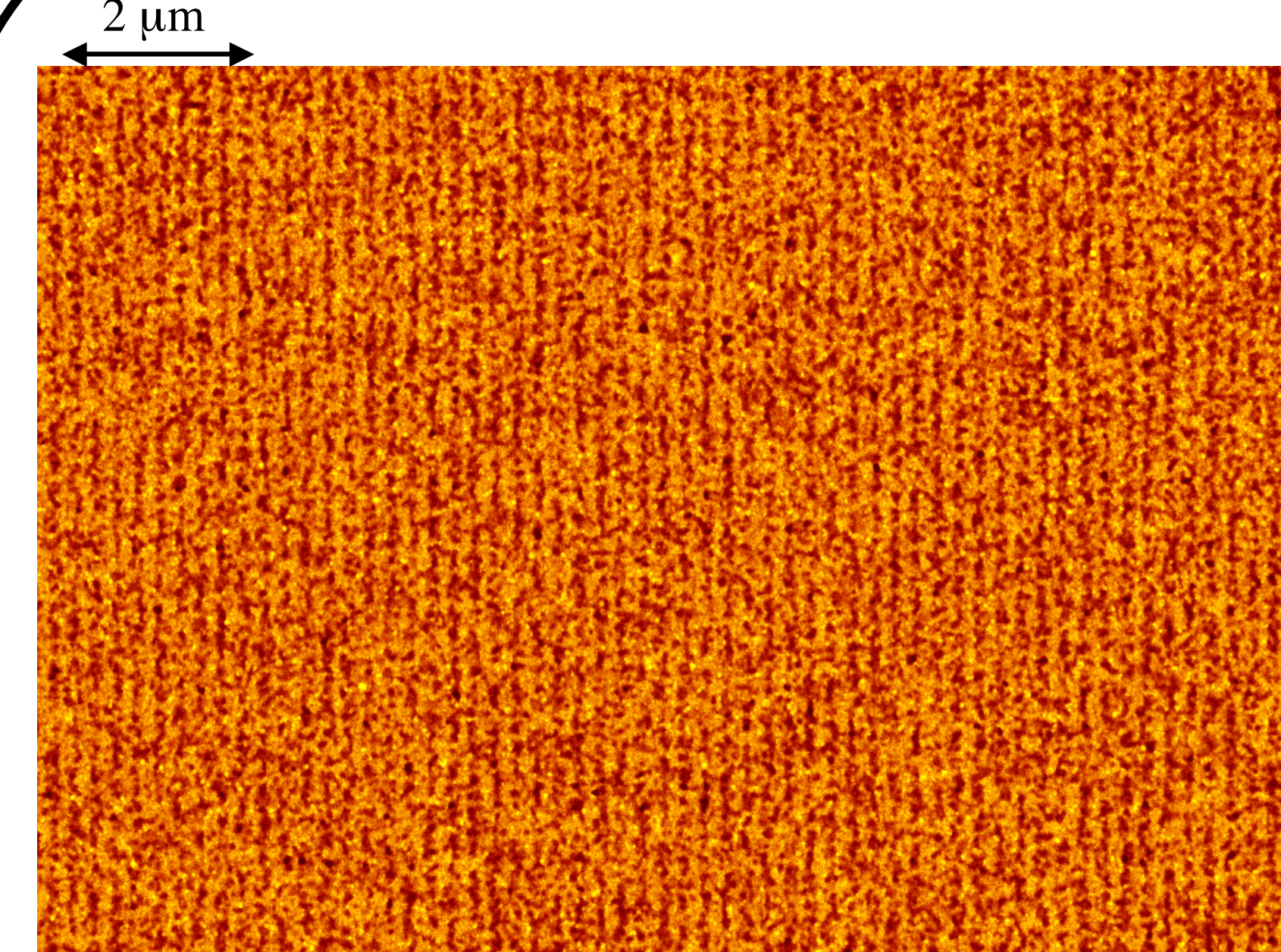
PHYSICAL MASK:



1083 nm OPTICAL MASK:



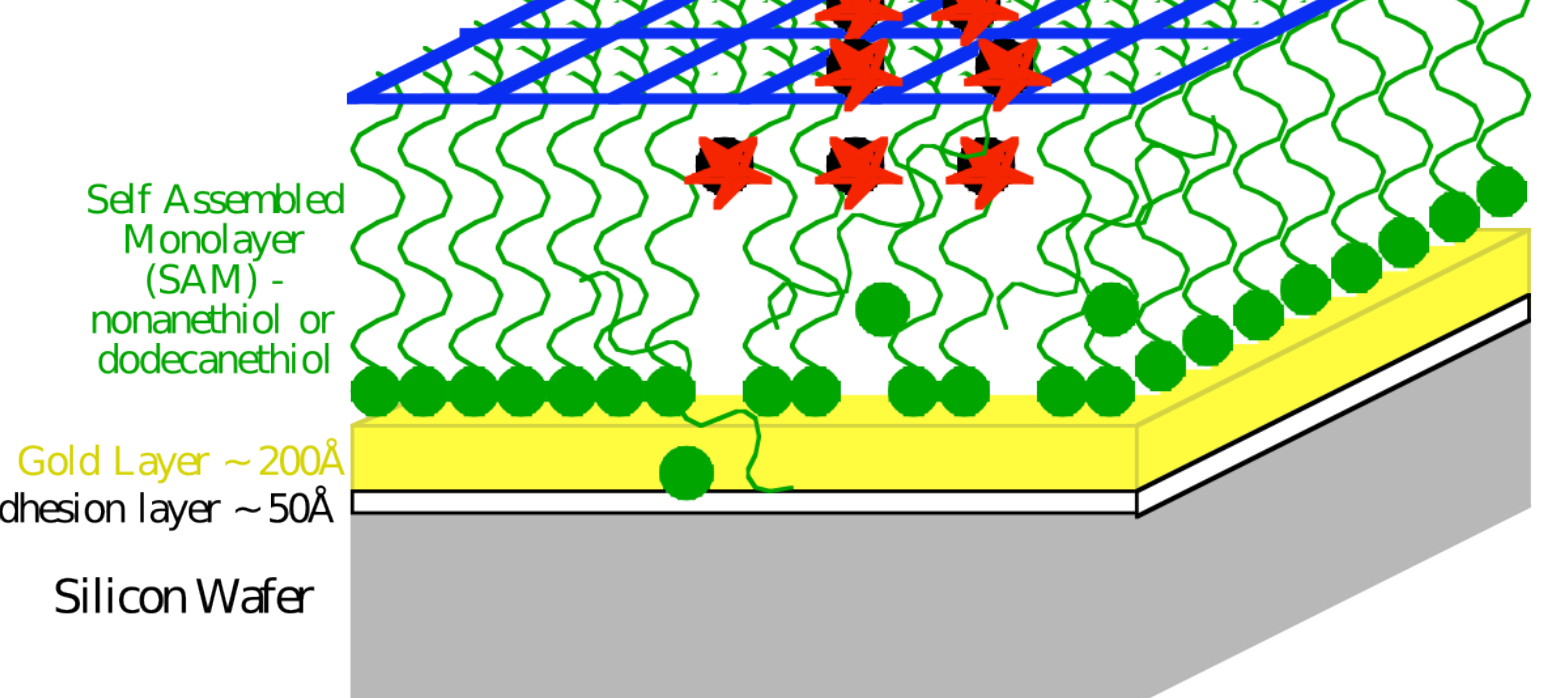
389 nm OPTICAL MASK:



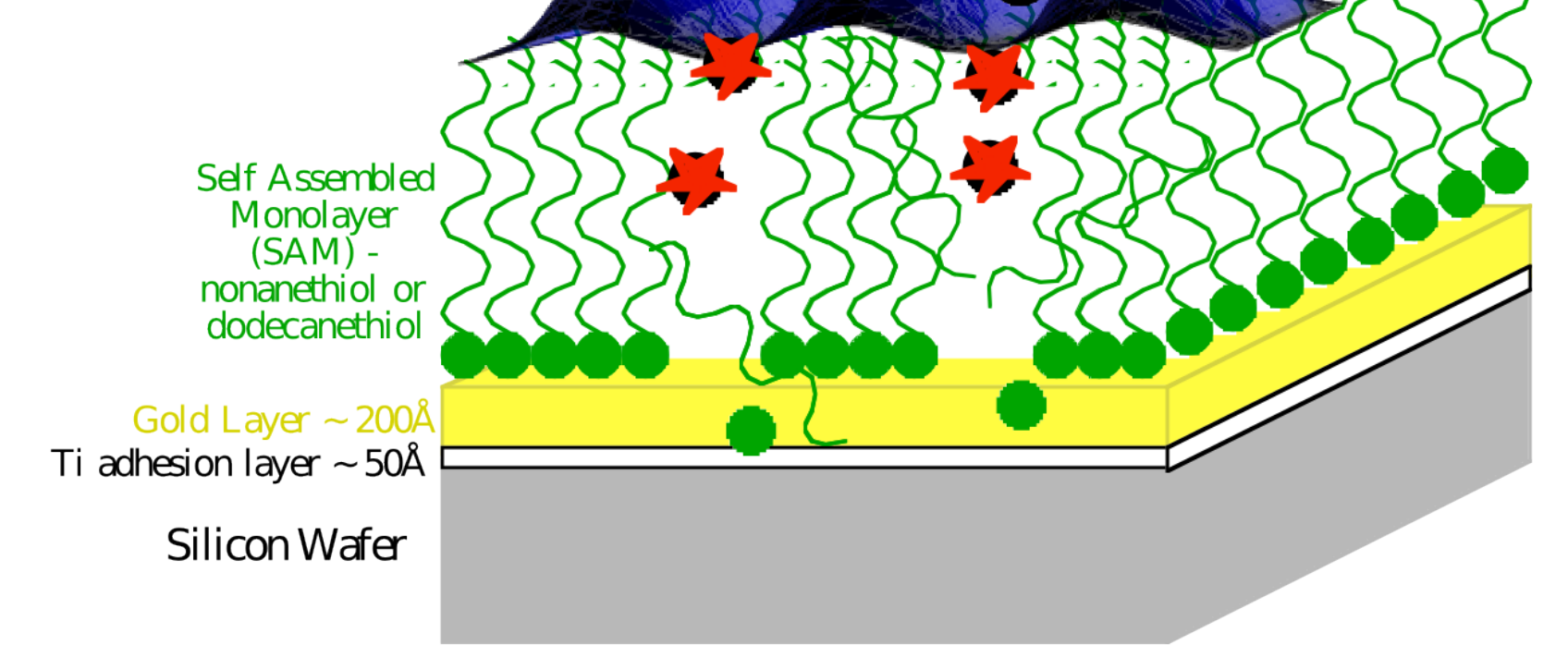
LITHOGRAPHY PROCESS

He^* has 20 eV of internal energy which destroys the alkanethiol molecules of the SAM on impact.

Physical Mask



Optical Mask



References:

- J. Kawanaka et. al. Appl. Phys. B **56** 21-24 (1993)
- C. Allred, et. al. J. Appl. Phys. **107**, 033116 (2010)

Further Reading:

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 D. Meschede, H. Metcalf, J. Phys D: Appl Phys. **36** R17 (2003)

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