Dielectric Metasurface Concentrators

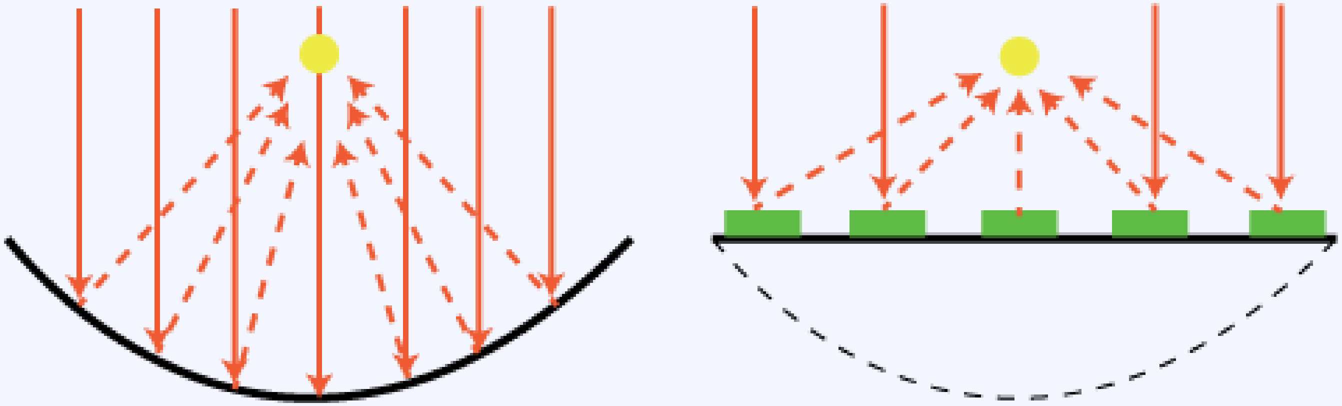
BOUBACAR KANTÉ

DEPARTMENT OF ELECTRICAL ENGINEERING
AND COMPUTER SCIENCES, UC BERKRLEY
BKANTE@BERKELEY.EDU

JULIUS YELLOWHAIR

SANDIA NATIONAL LABORATORIES

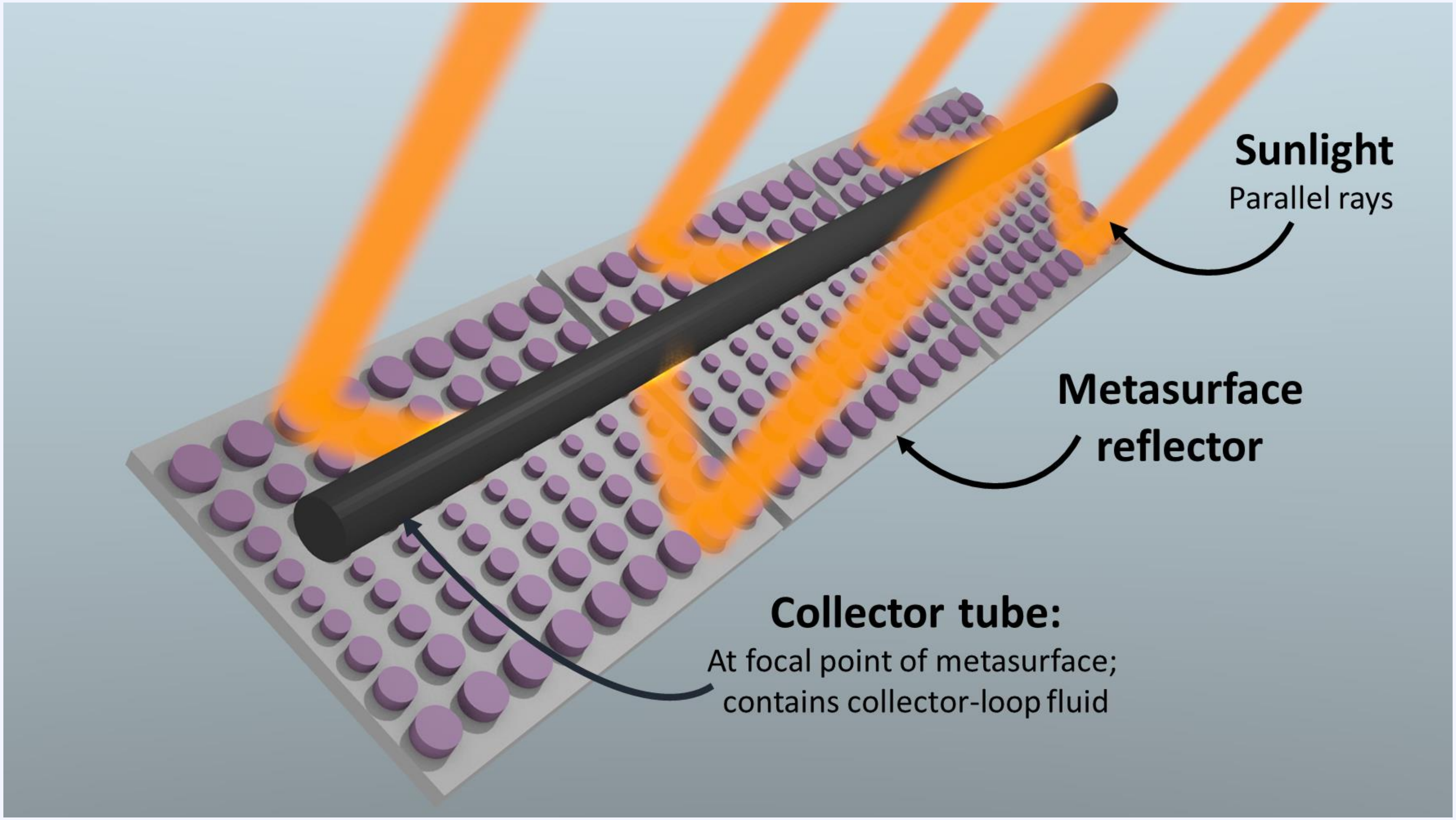
Planar structured interface collector



Parabolic in space → Parabolic in phase

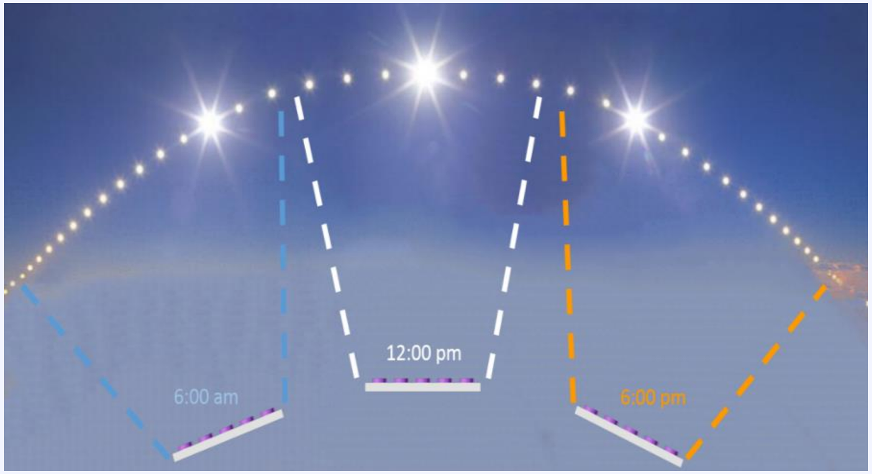
$$\Phi(x) = k_0\left(\sqrt{x^2 + f^2} - f\right)$$

Dielectric Metasurface Trough Collector



Reduce needed area, Wider acceptance angle, Reduced tracking.

Motivation

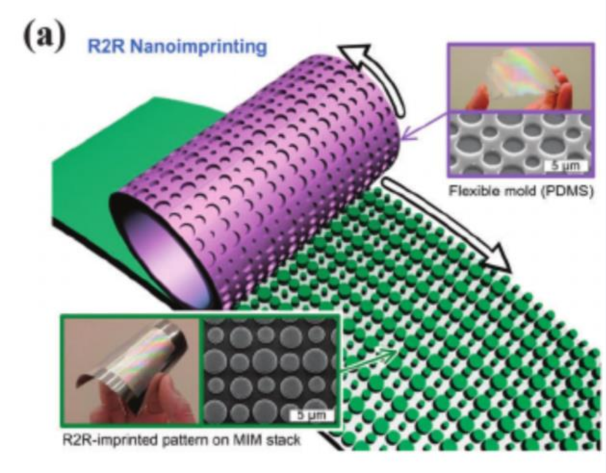


- Wider acceptance angle

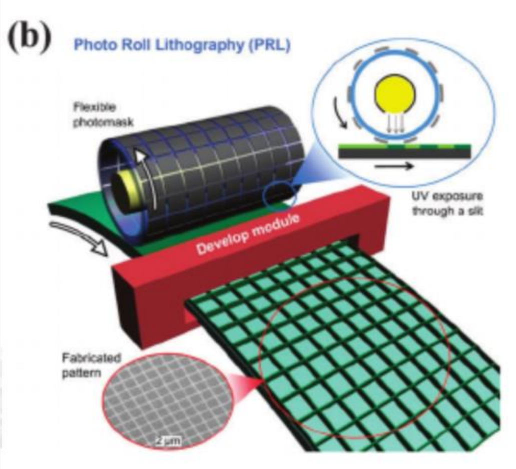
- May not need to be moved as much

relax tracking system.

Long term vision:



Nanoimprint



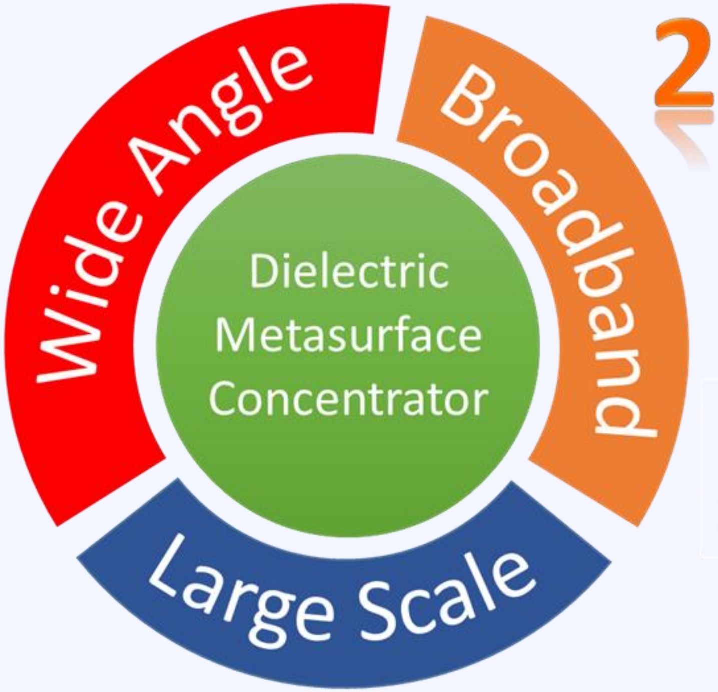
Roll-to-roll fabrication

J. Mater. Chem. C, 2016,**4**, 5133-5153

Challenges

1

- Φ≈2π
- θ≥40°
- Optimization
- Experiments



Wide Angle

Broadband

Large Scale

Dielectric Metasurface Concentrator

2

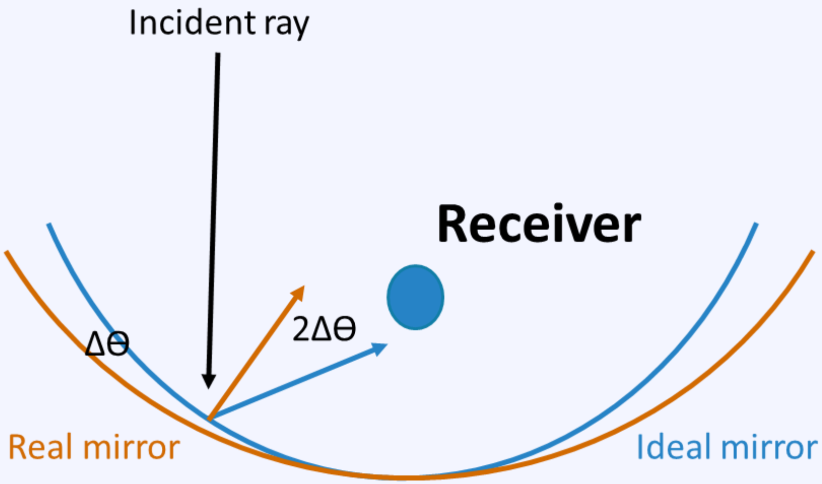
- Frequency-dependent
- BW≥15%
- BW≥15% and θ≥40°
- Experiments

3

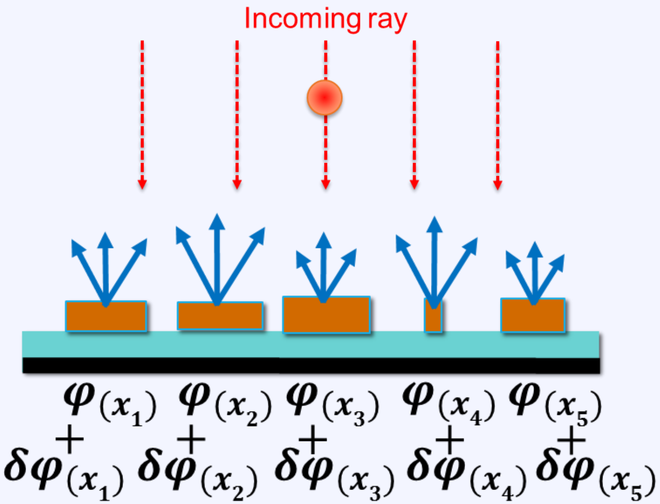
- From mm to m
- Lifetime extension
- Integration
- Experiments

From parabolic trough to metasurface concentrator

Geometric optics concentrator



Metasurface concentrator



Phase errors due to fabrication imperfections

Slope error: $\Delta\theta$

$$\textit{Slope error}: \frac{1}{k_0}\frac{d\delta\varphi}{dx}$$

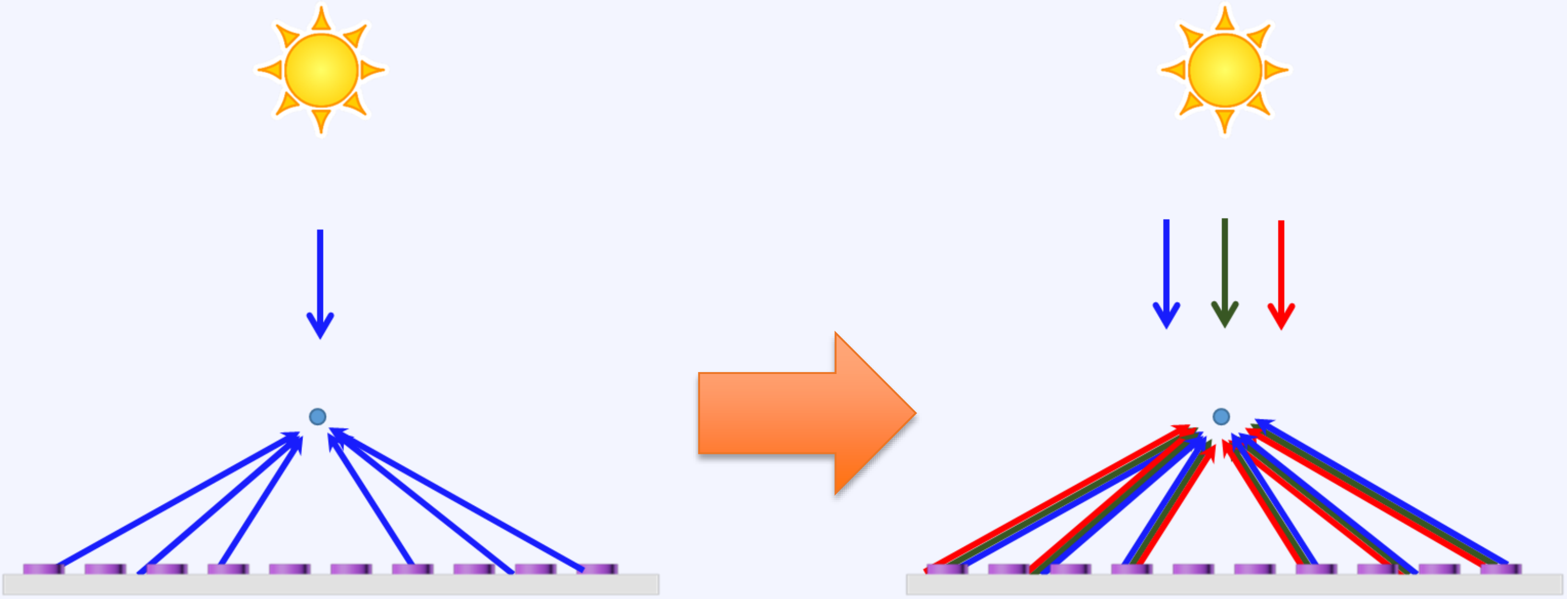
(a unitless phase gradient error)

Intercept factor $$\gamma = \frac{\#\ of\ rays\ intercepts\ the\ receiver}{total\ \#\ of\ rays}$$

Intercept factor $$\gamma = \frac{Energy\ incident\ on\ the\ receiver\ (\textbf{with}\ phase\ noise)}{Energy\ incident\ on\ the\ receiver\ (\textbf{without}\ phase\ noise)}$$

$$\gamma > 0.9$$

Broadband Metasurfaces



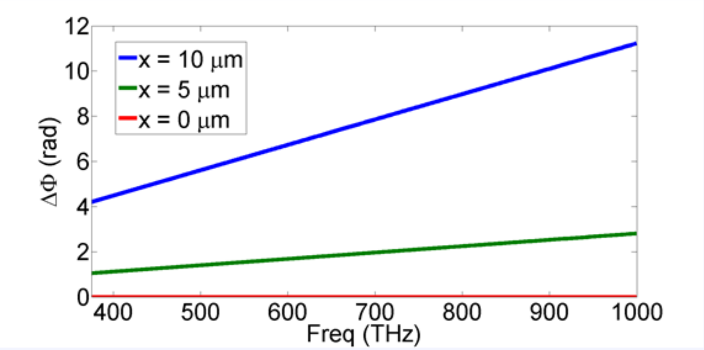
Single Frequency

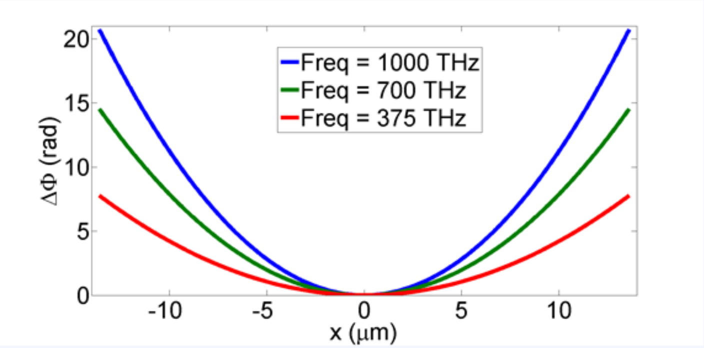
Broadband

Hsu, B. Kanté *et al.* Opt. Letters , 1520 (2017)

Requirement and challenges for broadband metasurface concentrator

$$\Delta\Phi = \frac{2\pi\nu}{c}\left(\sqrt{x^2 + f^2} - f\right)$$





1. Linear phase shift with frequency (ν).

Solution:

- **Propagating mode with constant effective refractive index.**

2. Control slopes of the phase shift.

Solution:

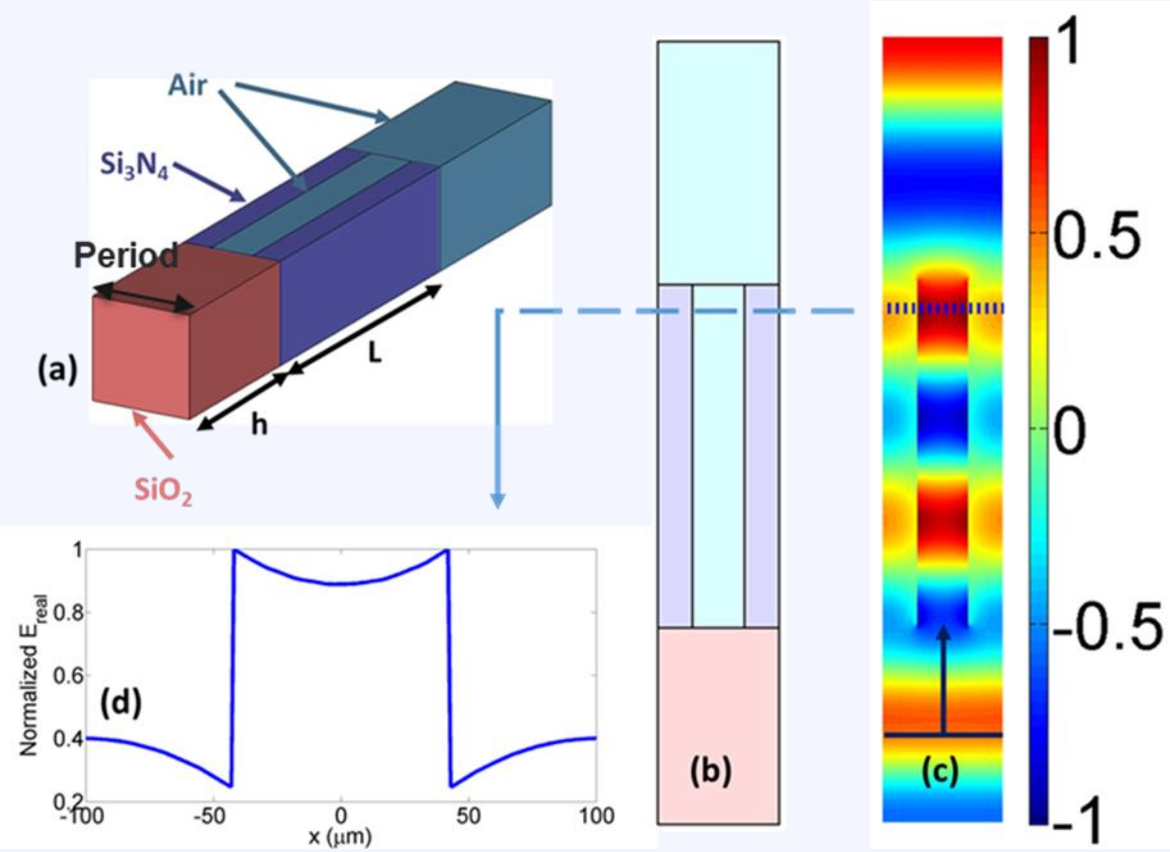
- **Propagating length or effective index.**

3. Zero phase shift intercept.
(Constant phase-intercept).

Solution:

- **Propagating length or effective index.**

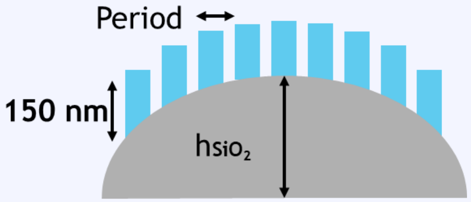
Proposed design for metasurface: Slot waveguide



- **Mode confined in air**
  Less dispersion

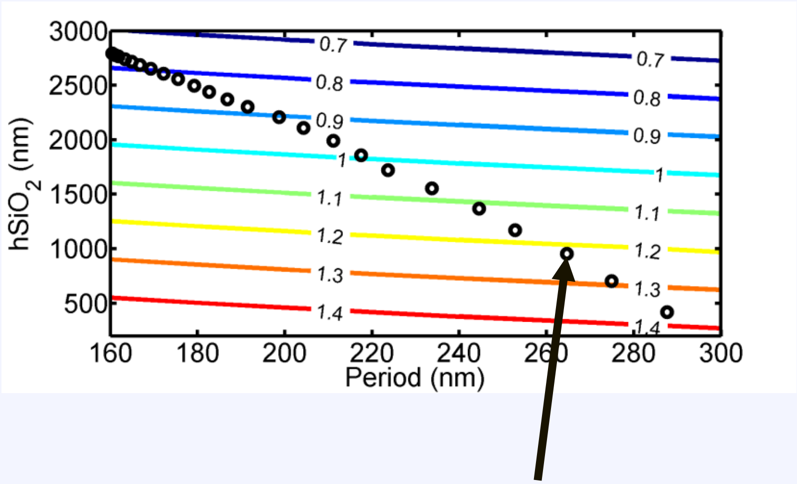
- **Linear polarization**
  Higher efficiency.

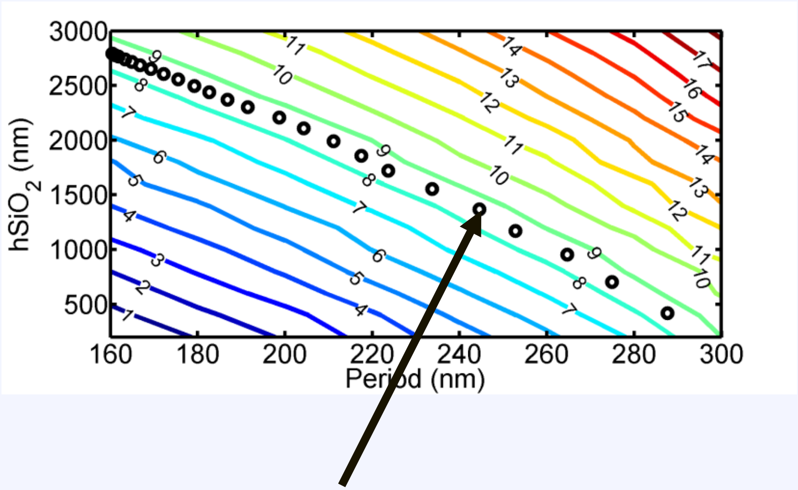
Slope and phase shift intercept



Slope

Phase Intercept



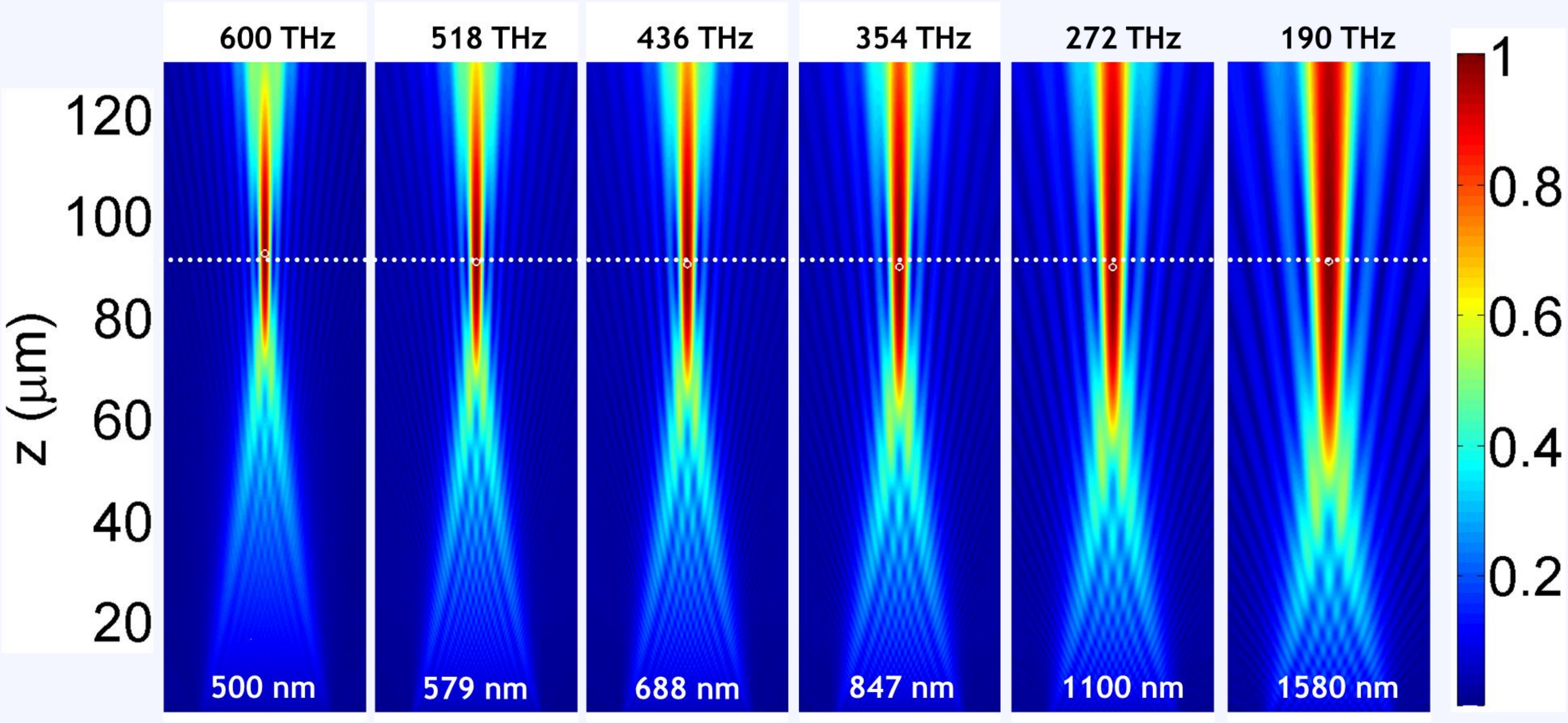


Different Slopes

Constant Phase Intercept

Bandwidth [500nm-1580 nm] (100%)

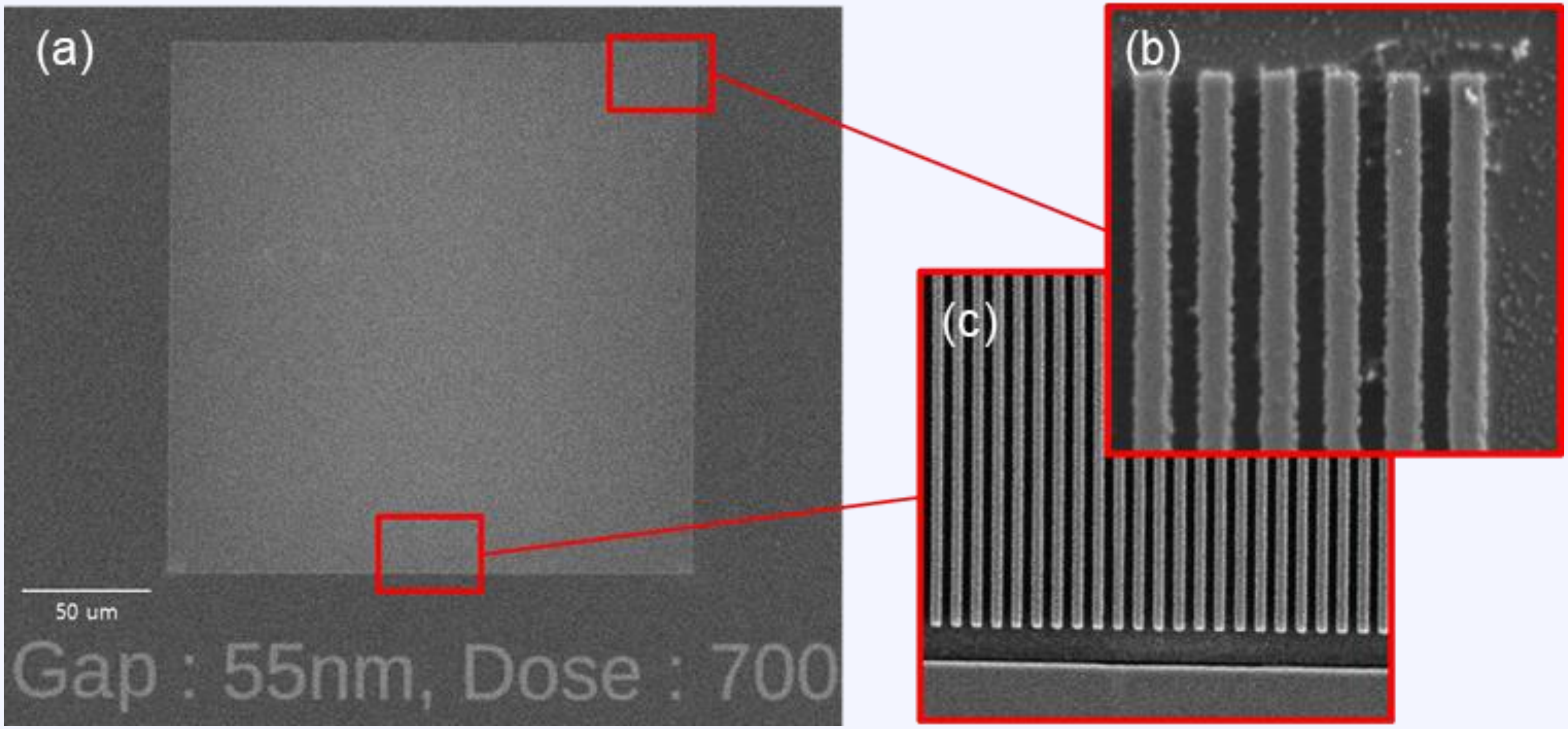
Simulation Results (E-field)



SunShot U.S. Department of Energy

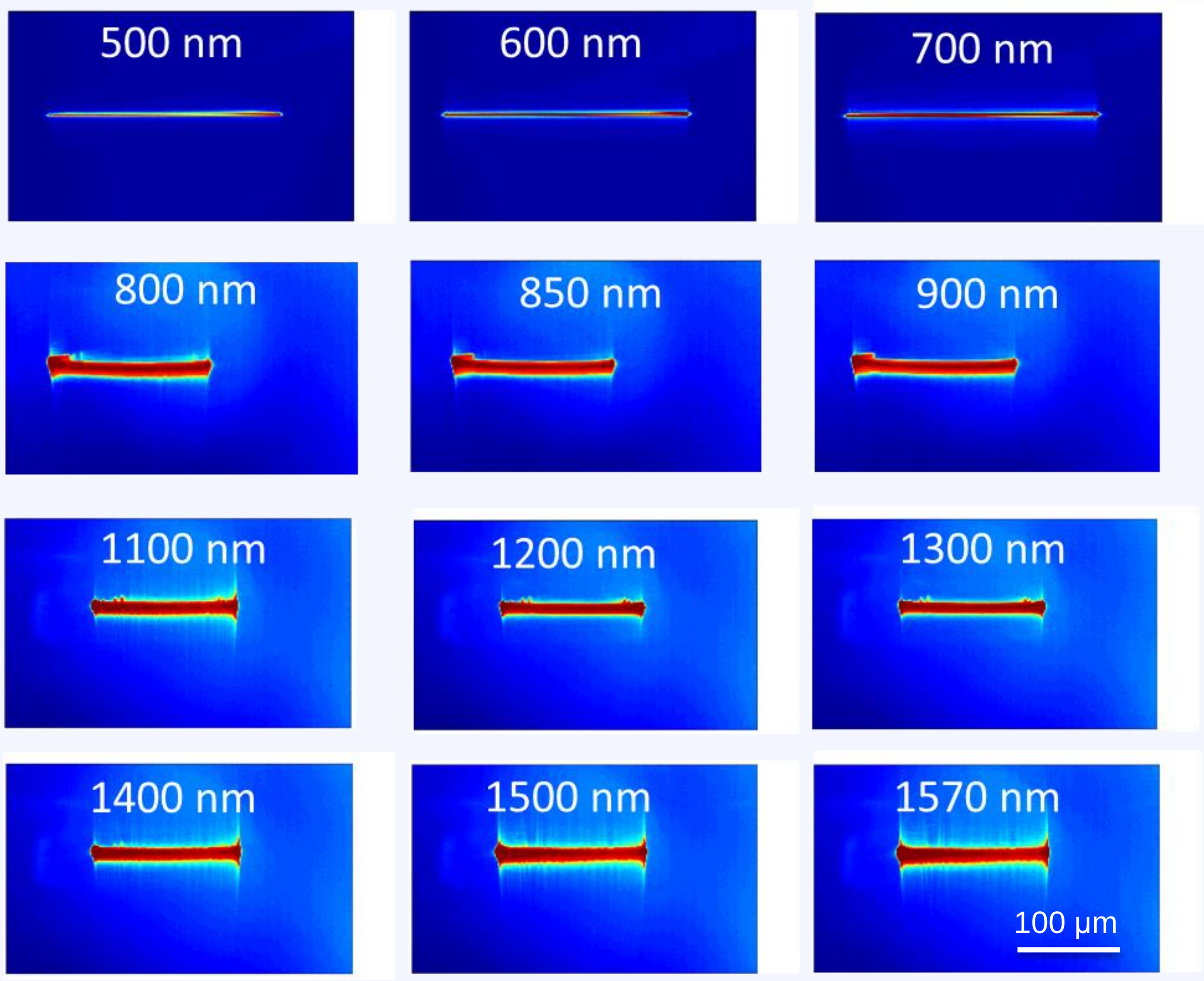
Patent and publication in preparation

Fabrication Results (SEM images)



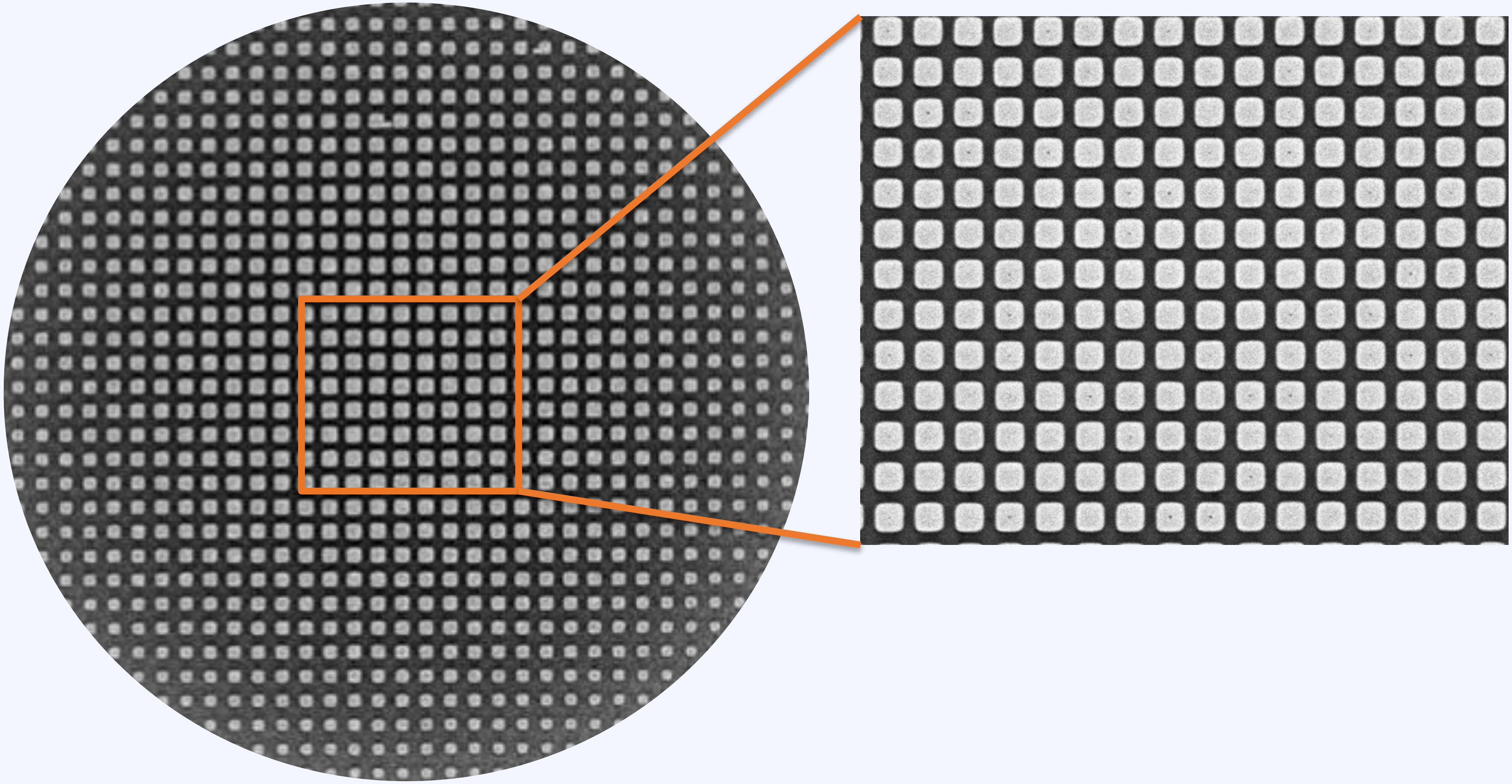
Patent and publication in preparation

Measurement Results



Patent and publication in preparation

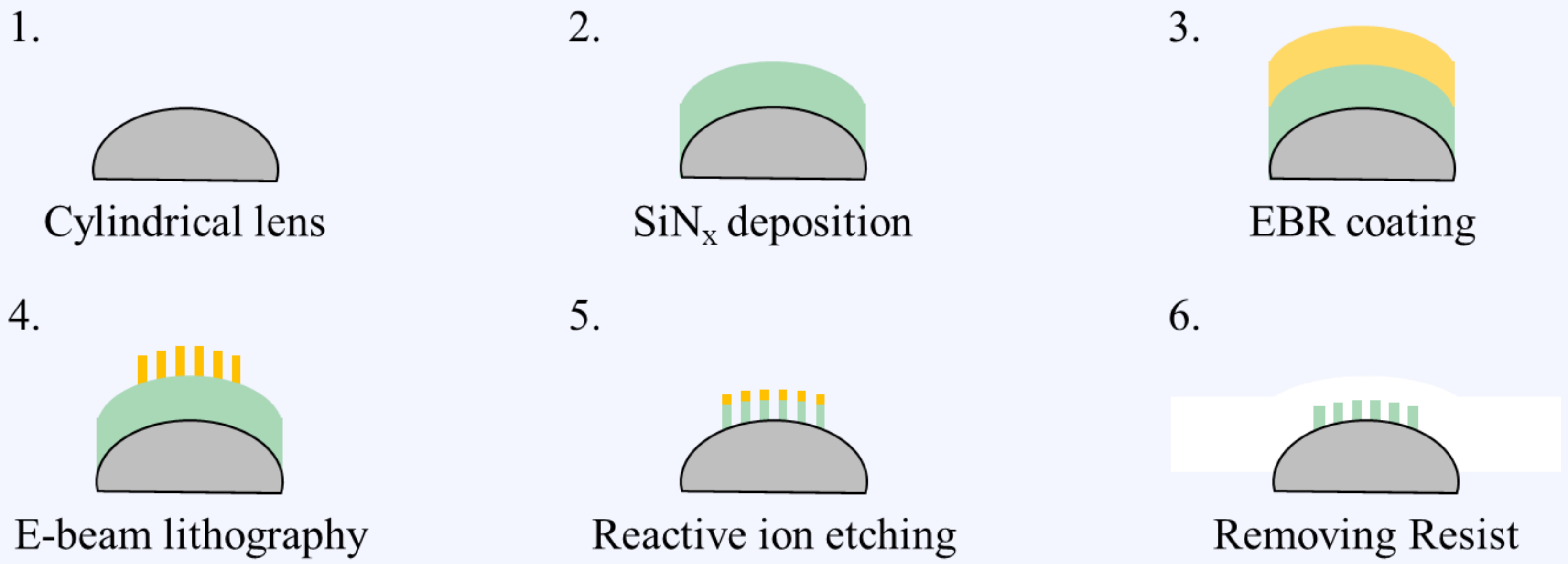
SEM image for polarization insensitive



Patent and publication in preparation

Thank you.

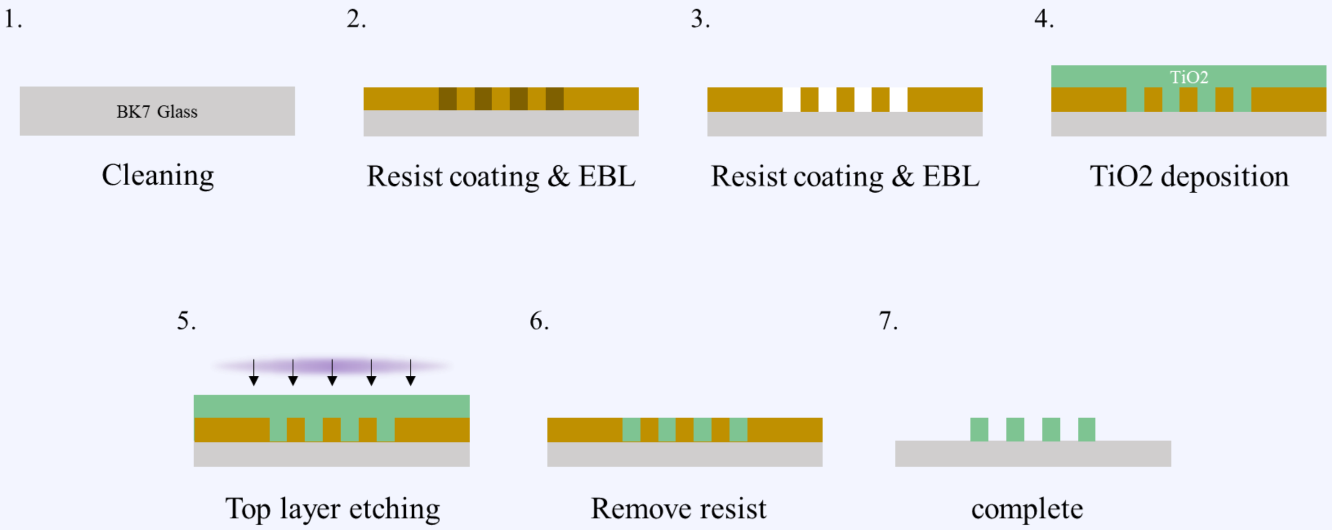
Fabrication flow chart



1. Cleaning (acetone, IPA, DI water)
2. SiNx deposition (150 nm) by the PECVD (350 C)
3. EBR coating for EBL(E-beam lithography) process (PMMA A2, 100 nm thickness)
4. EBL patterning (Vistec EBPG 5200)
5. RIE(Reactive ion etch) process for the SiNx etching
6. Remove residues of resist (by solvents or sulfuric acid and O2 plasma)

Fabrication flow chart

- lift-off, change the material SiNx to TiO_2 and thickness



1. Cleaning (Acetone, IPA, DI water)
2. EBR coating for EBL(E-beam lithography) process (PMMA C4 for 500 nm, A2 for 350 nm)
3. EBL patterning (Vistec EBPG 5200) to fabricate the resist etching mask
4. TiO2 deposition (500, 350 nm) by the ALD (TiCl4 + H2O precursor, 100 C)
5. RIE(Reactive ion etch) process to reveal the resist patterns
6. Remove residues of resist (by solvents and O2 plasma)