ME290R: Topics in Manufacturing

Fall 2017

Nanoscale manipulation of materials

Lecture 13.2: Emerging X-ray and Optically-based Lithography Techniques II

November 20, 2017

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Three-dimensional photopolymerized microstructures for *in vitro* stem cell studies

July 11, 2014

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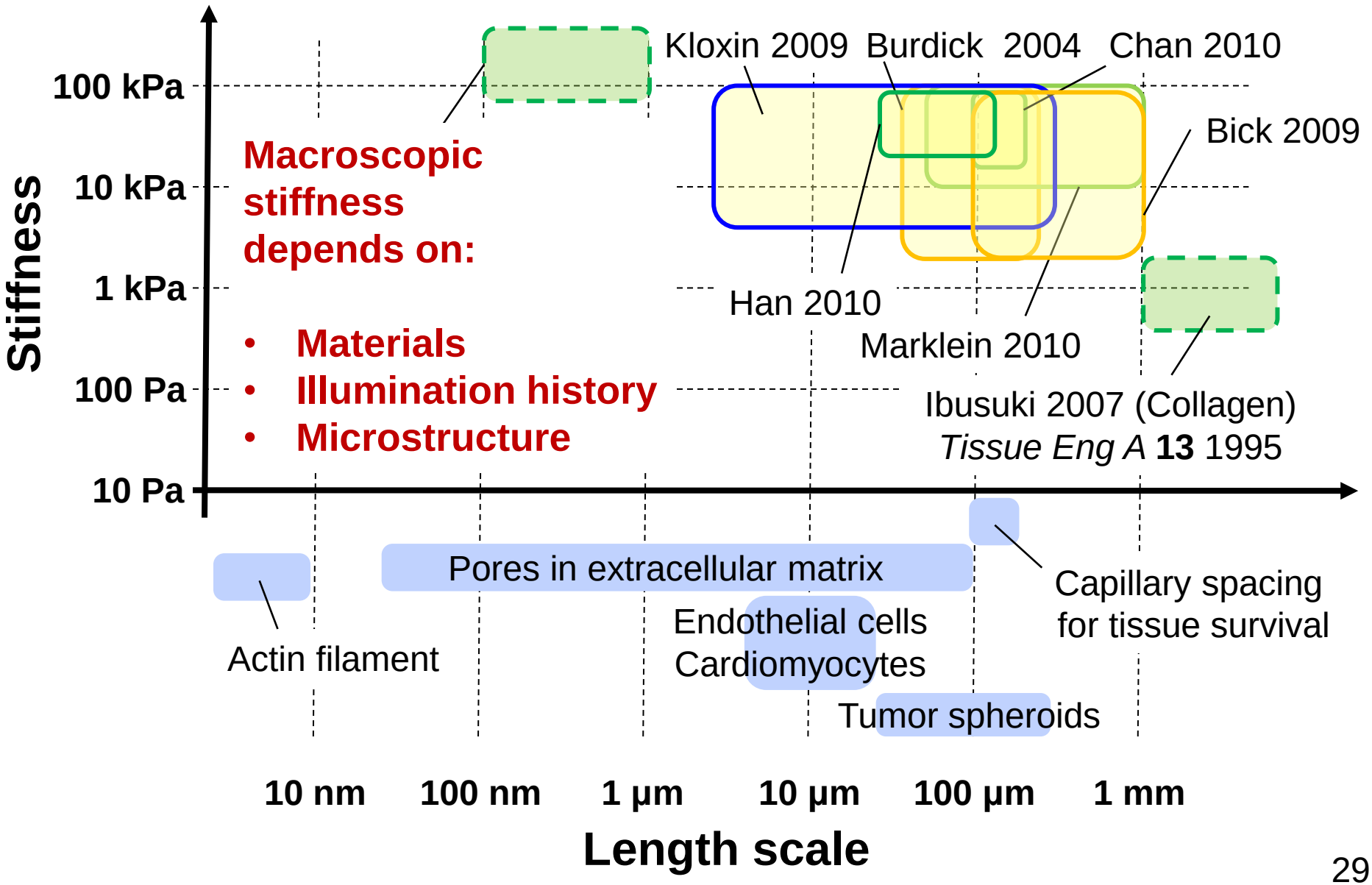
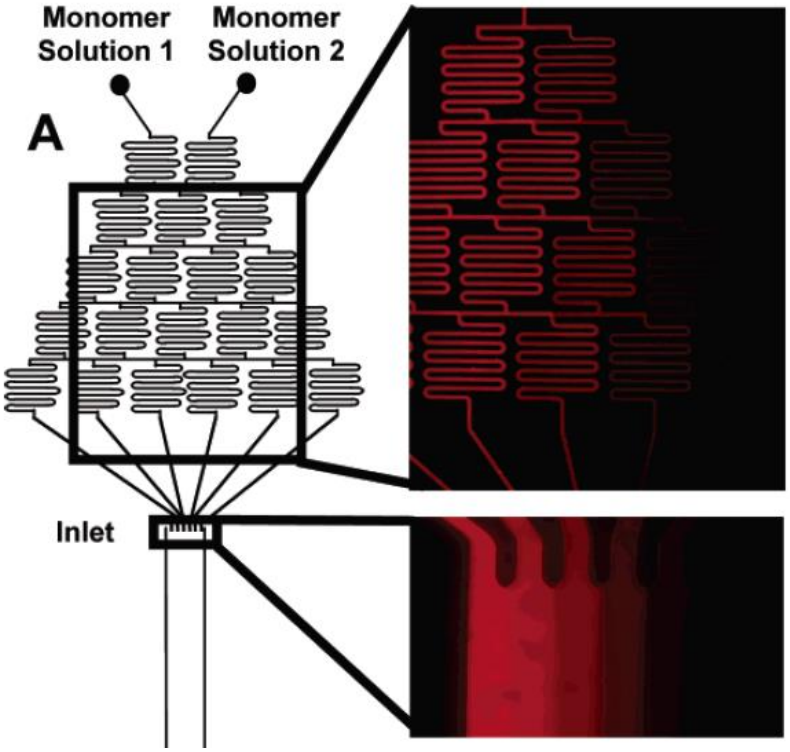
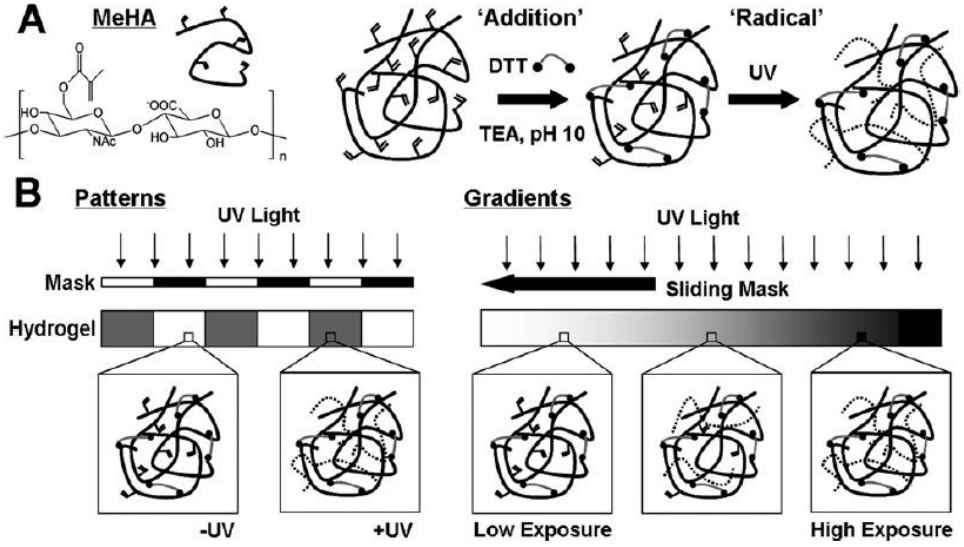
Relevant extra-cellular matrix length-scales and stiffnesses span several orders of magnitude



Existing approaches to introducing artificial ECM structure are either 2-D or serial

- **2-D**
  - **Microfluidic creation of stiffness gradients**
  - **Photopolymerization using transparency masks**



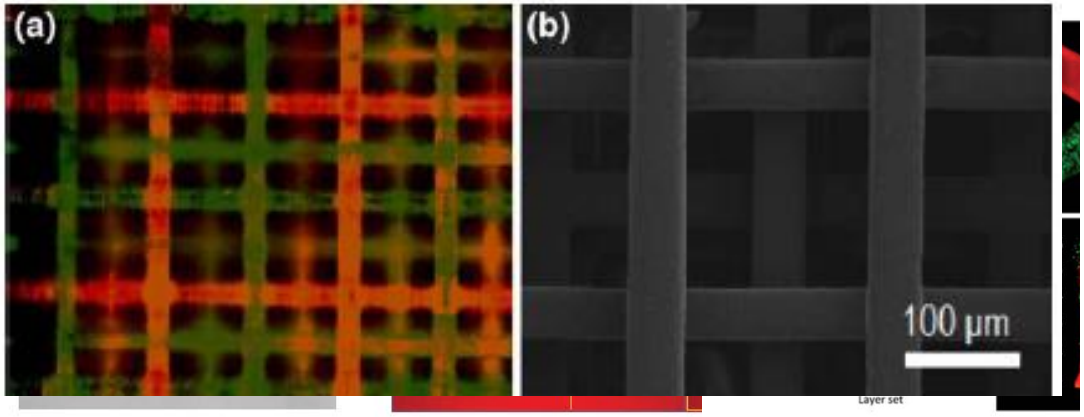


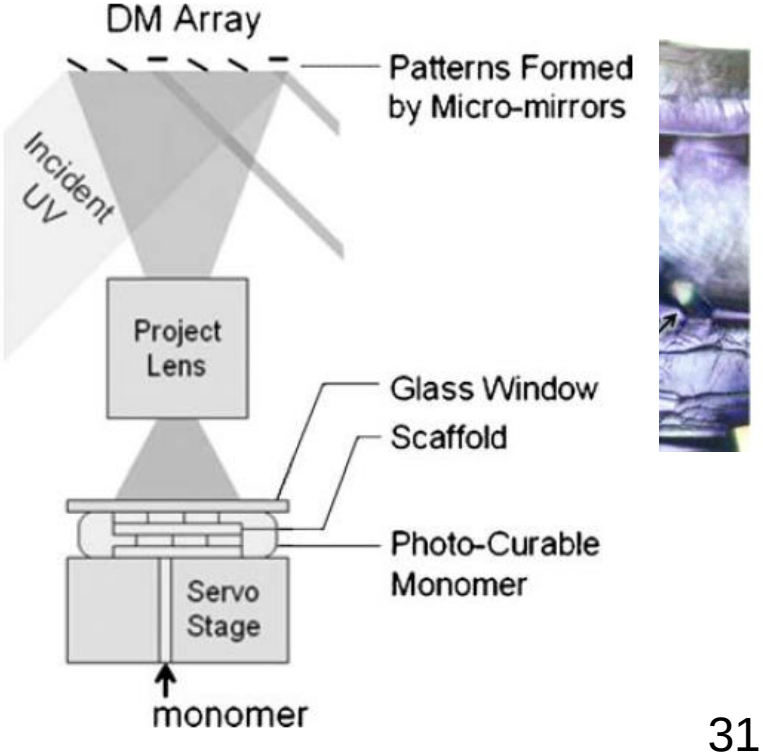
Burdick et al., *Langmuir* **20** 5153 (2004)

Marklein, *Soft Matter* **6** 136 (2010)

Existing approaches to introducing artificial ECM structure are either 2-D or serial

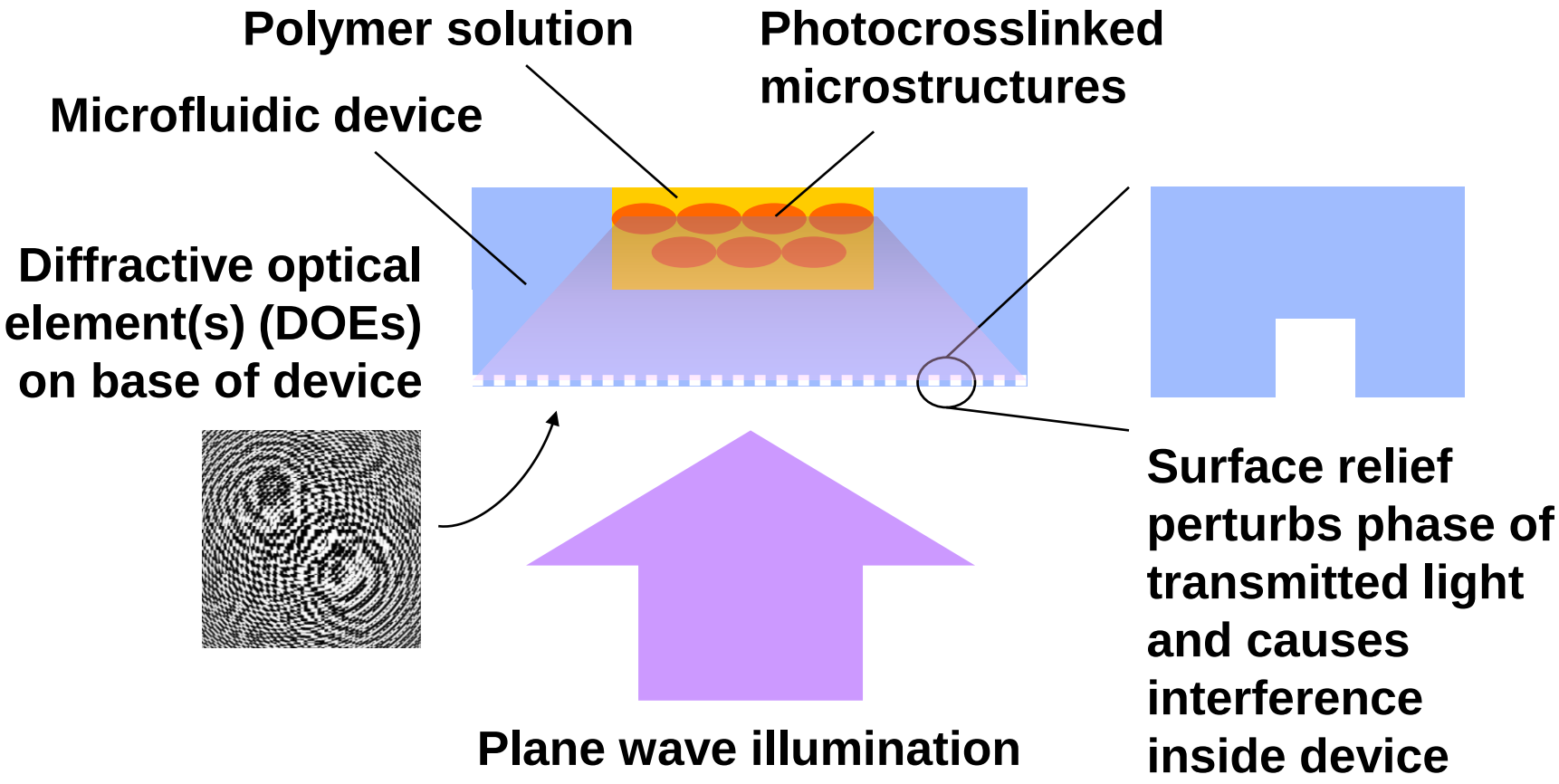
- **3-D**
  - **Two-photon laser-scanning lithography**
  - **Layer-by-layer cell encapsulation using stereolithography**
  - **Layer-by-layer hydrogel microfluidic network construction**
  - **Dispenser printing**
  - **Attempts to parallelize using digital micromirror devices**





Kloxin *et al*., Science 324 **59** (2009)
Chan *et al.*, *Lab Chip* **10** 2062 (2010)
Bick *et al.*, *NE Bioeng. Conf.* 2009
Han *et al.*, *Biomed Microdevices* (2010)

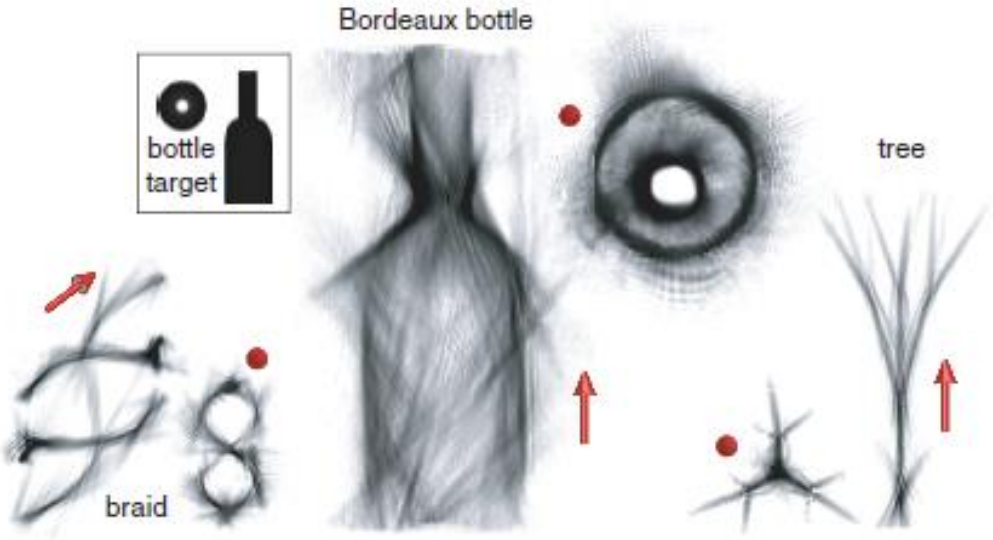
3D Holographic Lithography: static 2D diffractive pattern on a substrate directs 3D photopatterning



- Minimal external optics
- Microstructures could be created on demand in a few seconds
- Adds little to cost of device
- Potential for large-area patterning

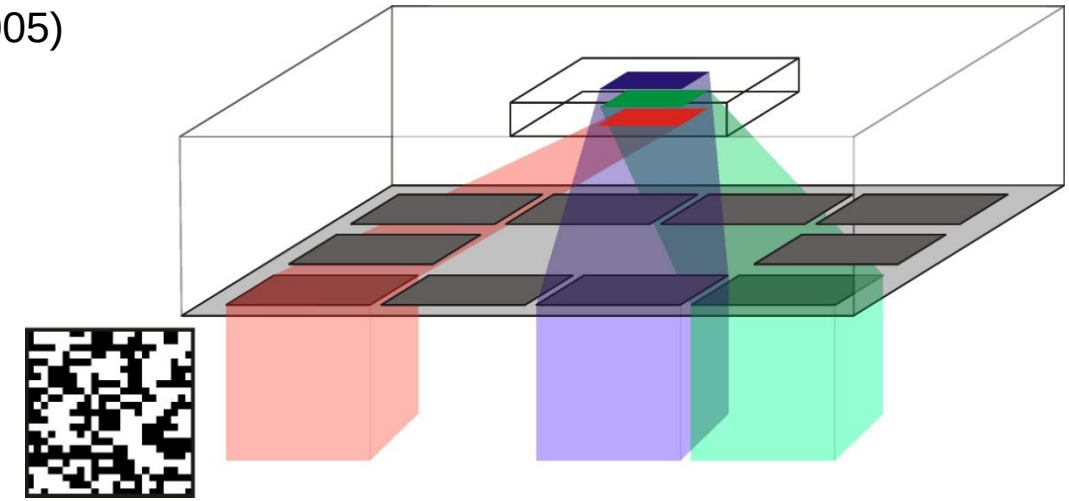
Can a diffractive element be designed to pattern *any* given 3D structure in one step?

3-D Gerchberg Saxton algorithm?



Whyte *New J Phys* **7** 117 (2005)

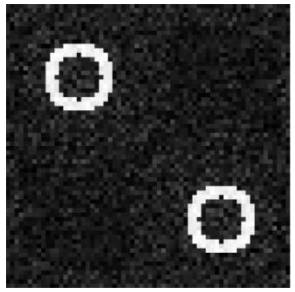
***Instead*: independent holographic 'tiles' map to different axial slices of the target volume**

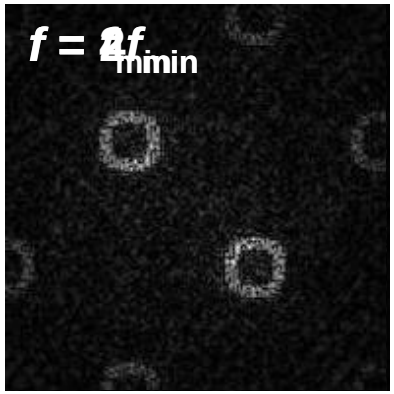


Hologram and lens are superimposed: focused image size depends on pixel size and focal length

Image size *S* is:

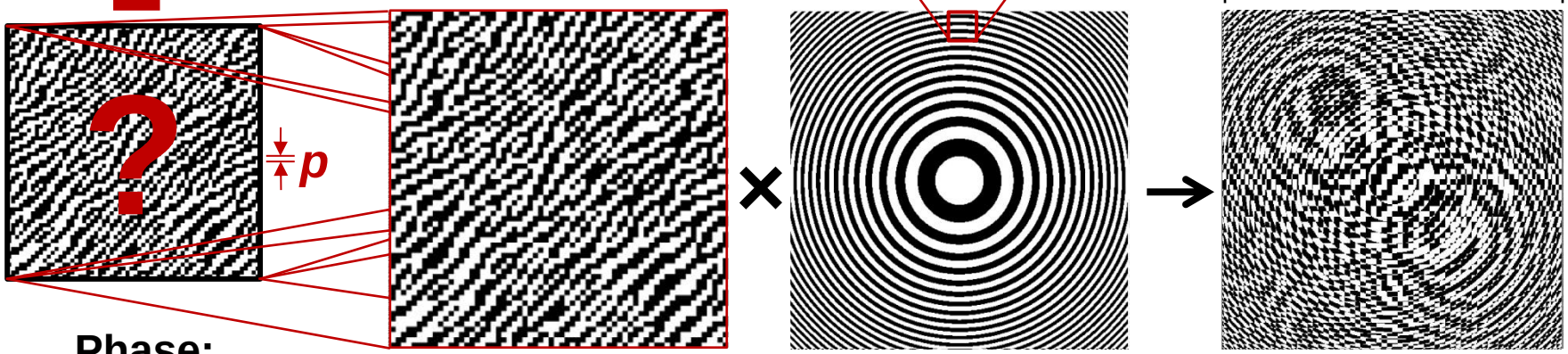
- **Inversely proportional to *p***
- **Proportional to *f***





$$f_{min} = \sqrt{2}D\sqrt{\left(\frac{d_{min}}{\lambda}\right)^2 - 0.25}$$

2D Fourier transform



Focal plane

Phase:
■ 0
□ π

Tiled hologram

Lens

Diffractive optical element (DOE)

D

The Gerchberg-Saxton algorithm iteratively extracts hologram phase from a target amplitude