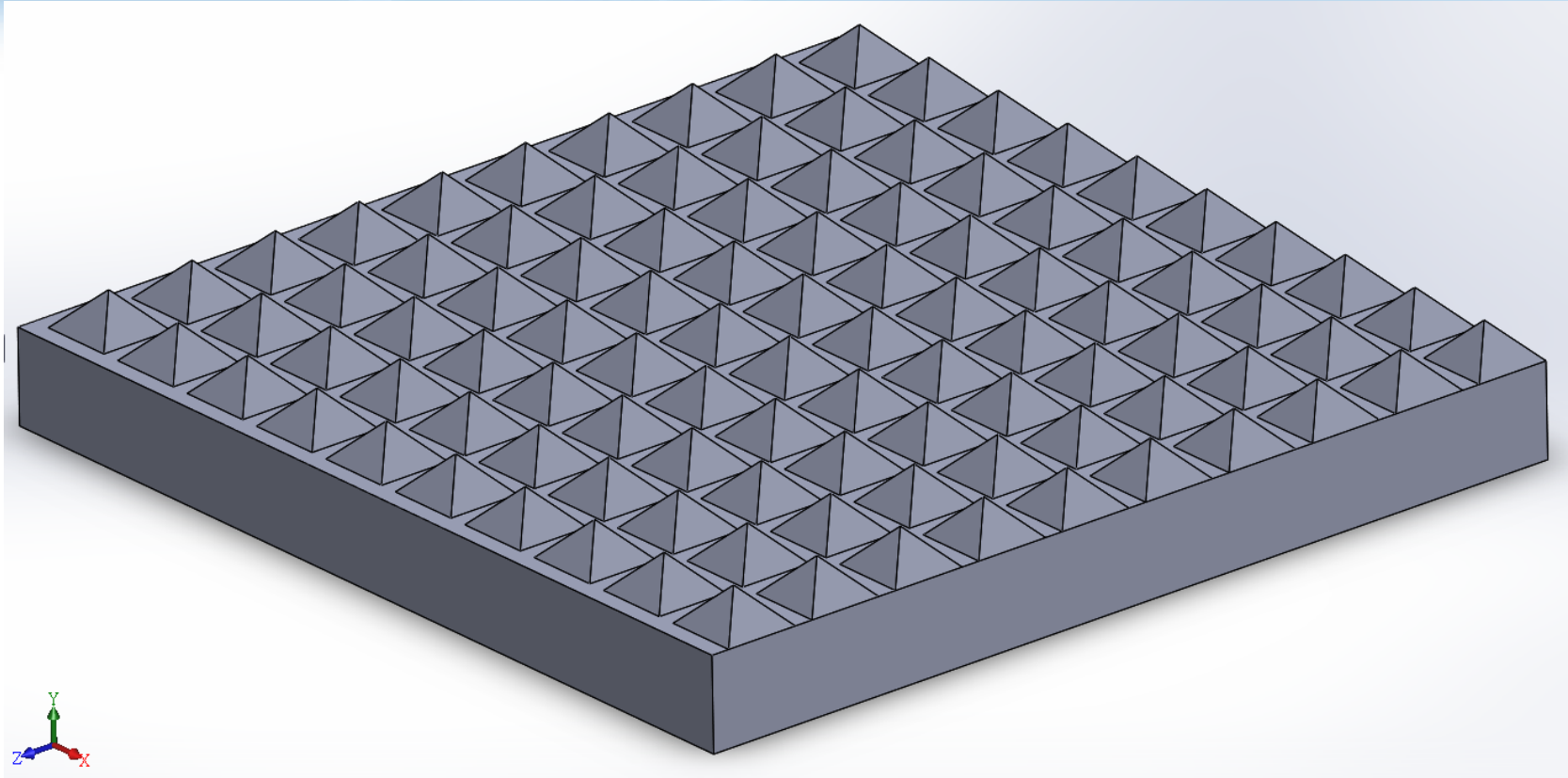
Research and Development of Micro Additive Manufacturing System Using Direct Light Projector

Jeng-Ywan Jeng

2014.08.18

Objective

- Very high resolution in a relative large area
- Y1: 10mmX10mm working area in 2um/pixel resolution, total 5,000X5,000 pixels.
- Y2: 50mmX50mm working area in 0.5um/pixel resolution, total 100,000X100,000 pixels


Y
Z
X

Technologies

- Hardware of Micro Lithography using DLP
- Software of Slicing and Mask Image Correction
- High Resolution Resin
- Bio-Application


Sub1
Hardware
Sub2
Software
Sub3
Material
Sub4
Application
Micro Additive Manufacturing System

Thanks For Your Attention!

國立臺灣科技大學
National Taiwan University of Science and Technology

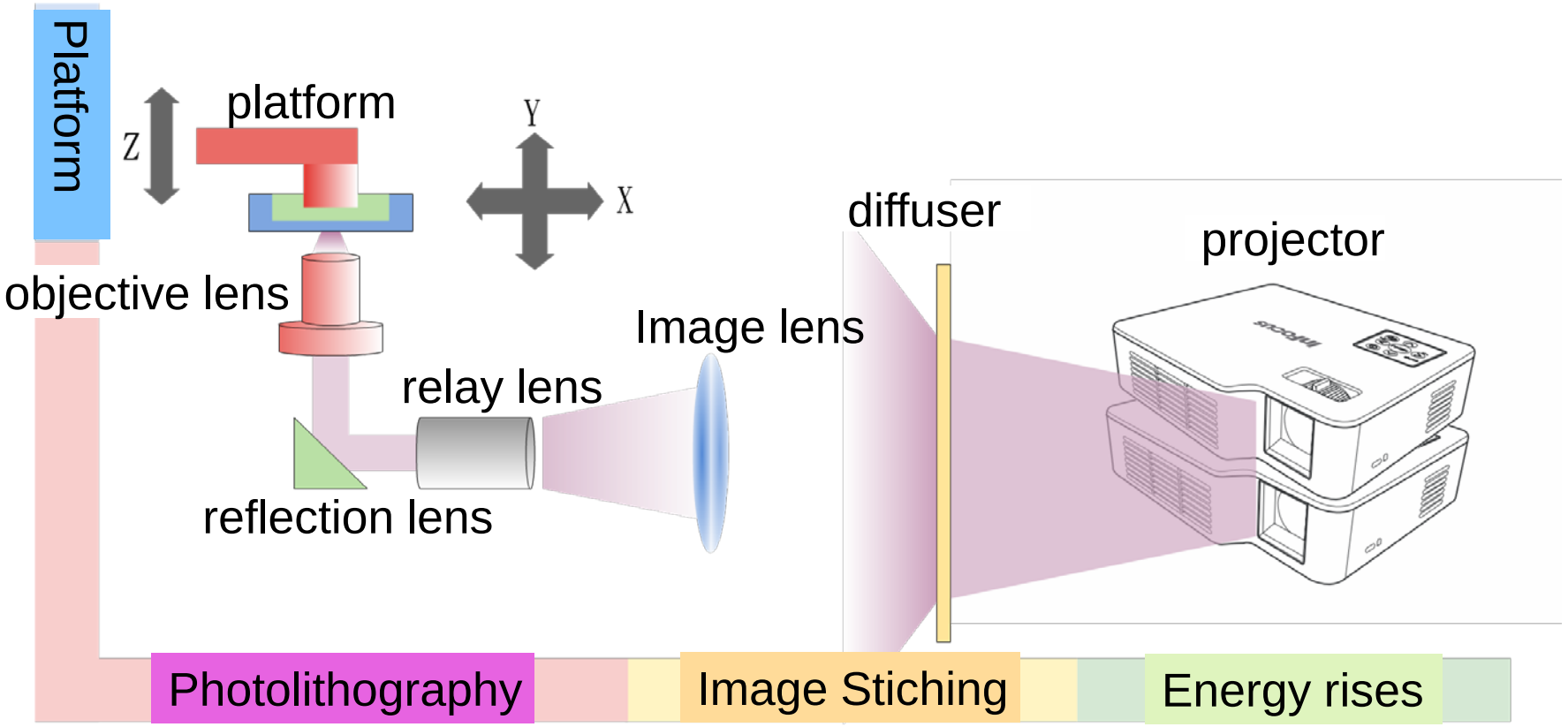
sub-project I

Hardware Development of Micro Additive Manufacturing System

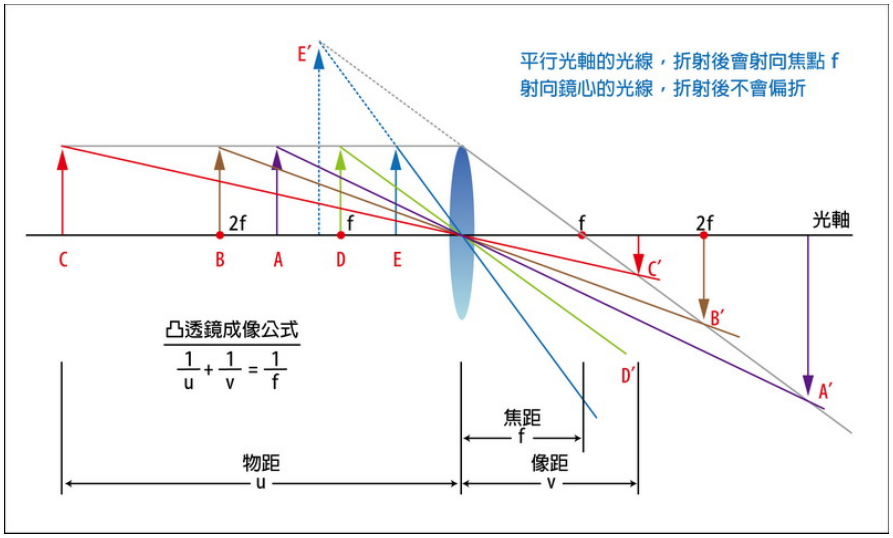
- Jeng-Ywan Jeng

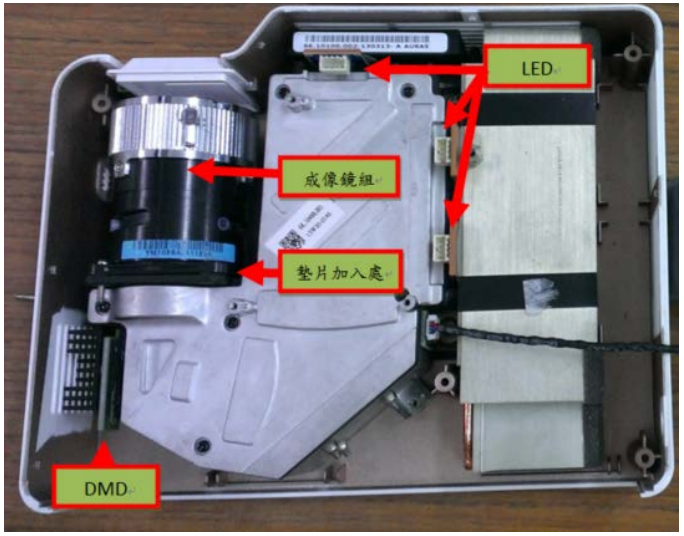
- 2014/8/18

System diagram



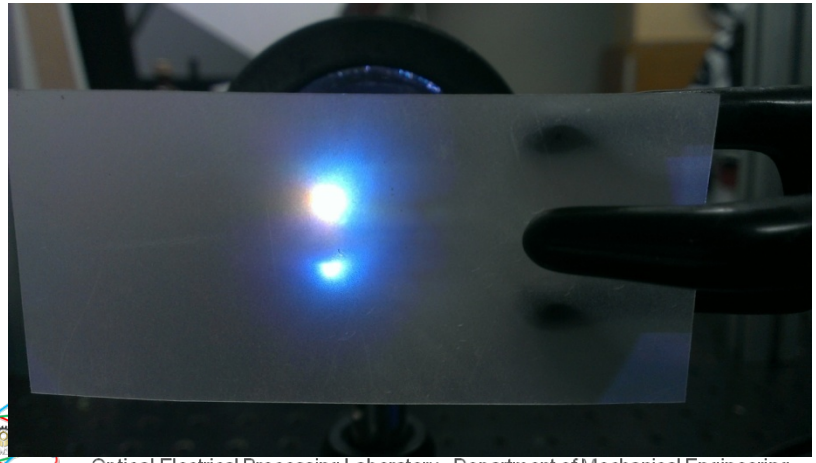
Energy rises

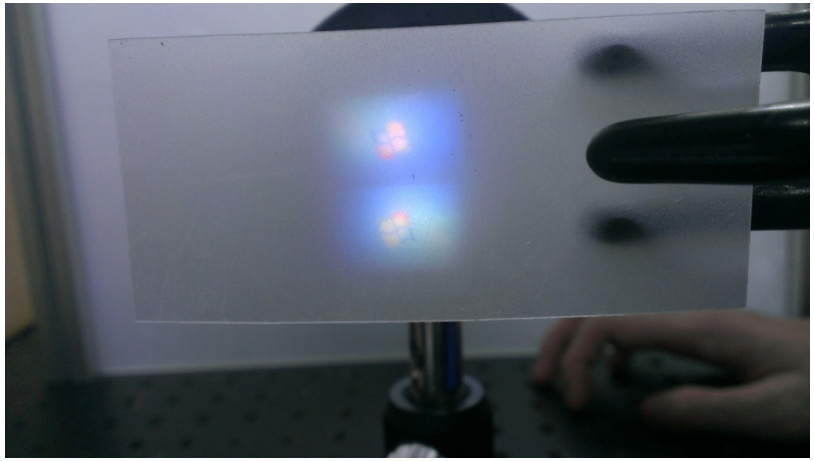




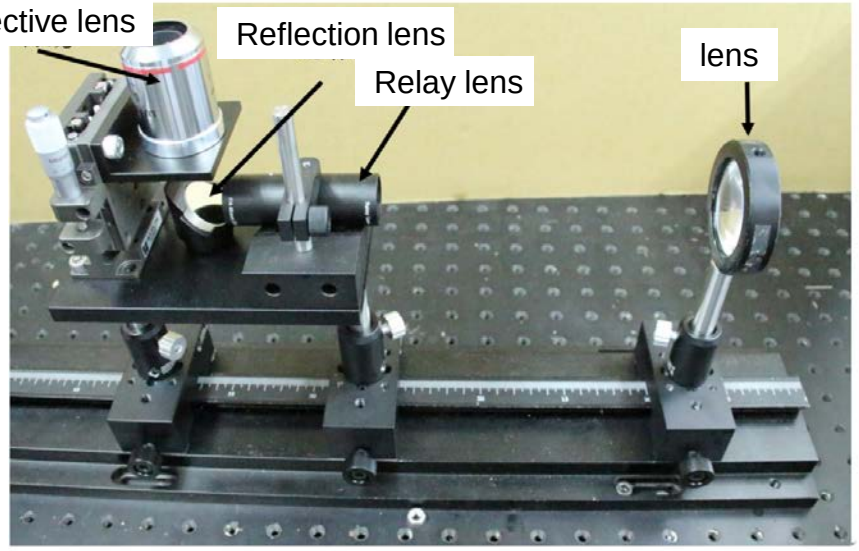
		
1 spacer	2 spacer	3 spacer

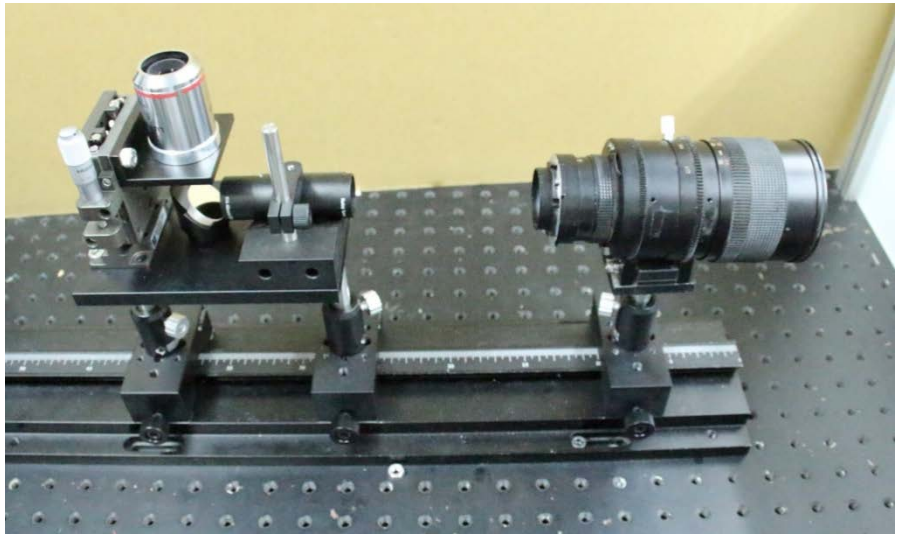
Image stitching

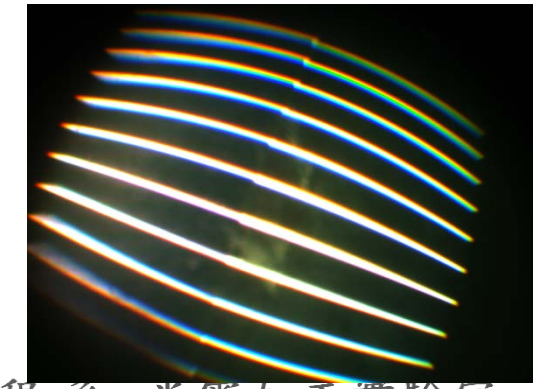


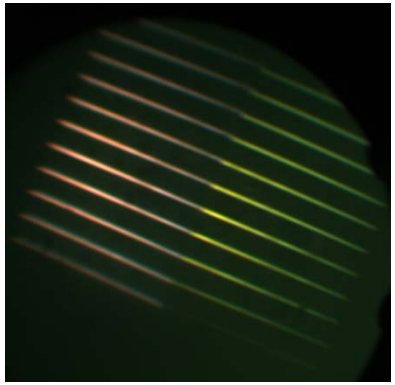


Lithography image

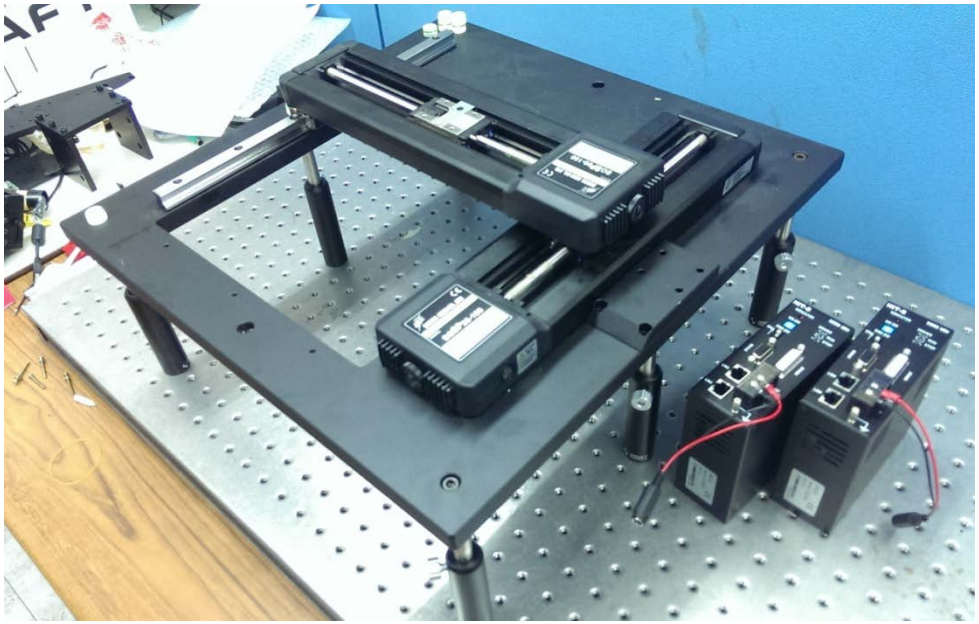




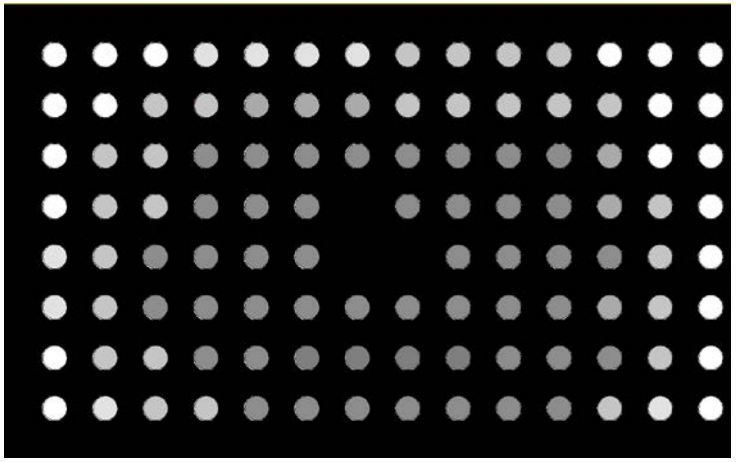




Big area exposure system



Light uniformity improved results



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240	192	192	144	144	144	144	144	144	144	144	168	192	240
216	192	192	144	144	144	144	144	144	144	144	144	192	240
216	192	144	144	144	144	144	144	144	144	144	168	192	240
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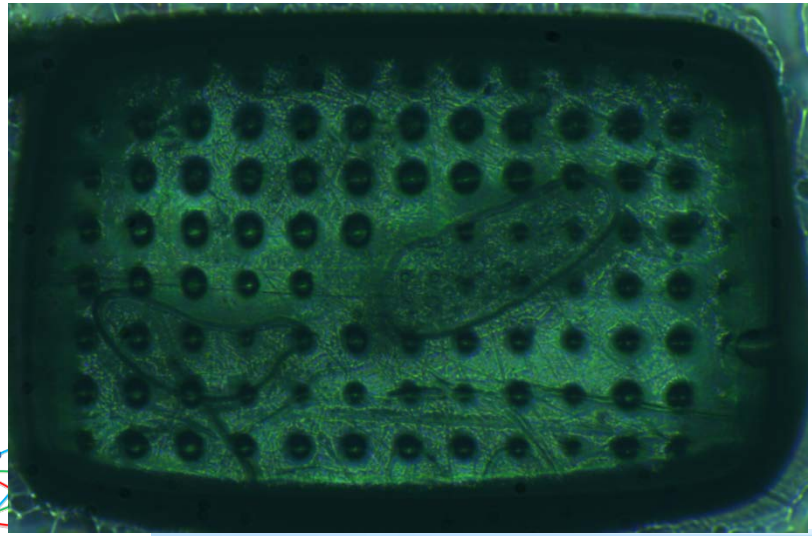
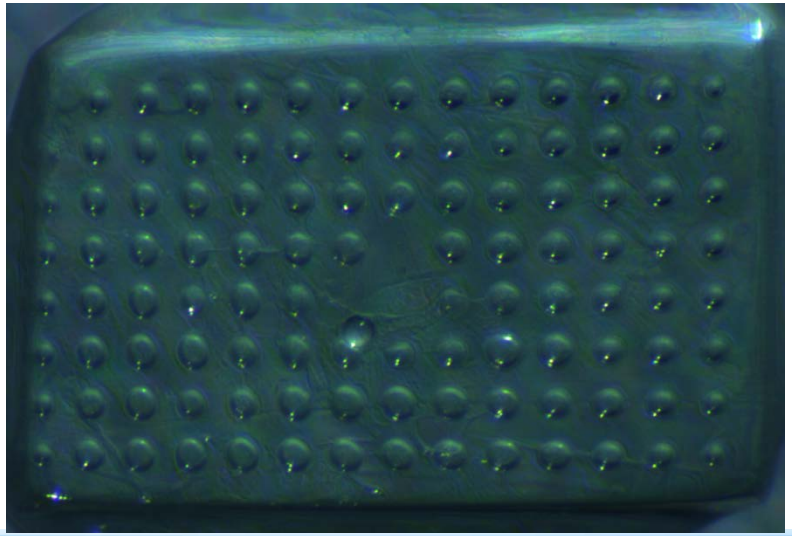
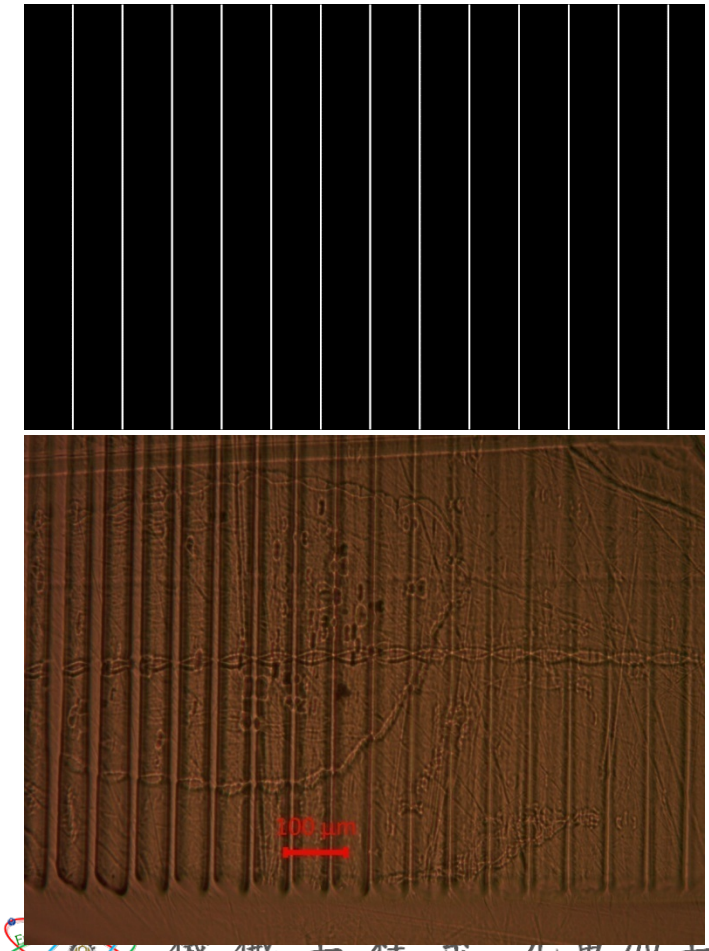
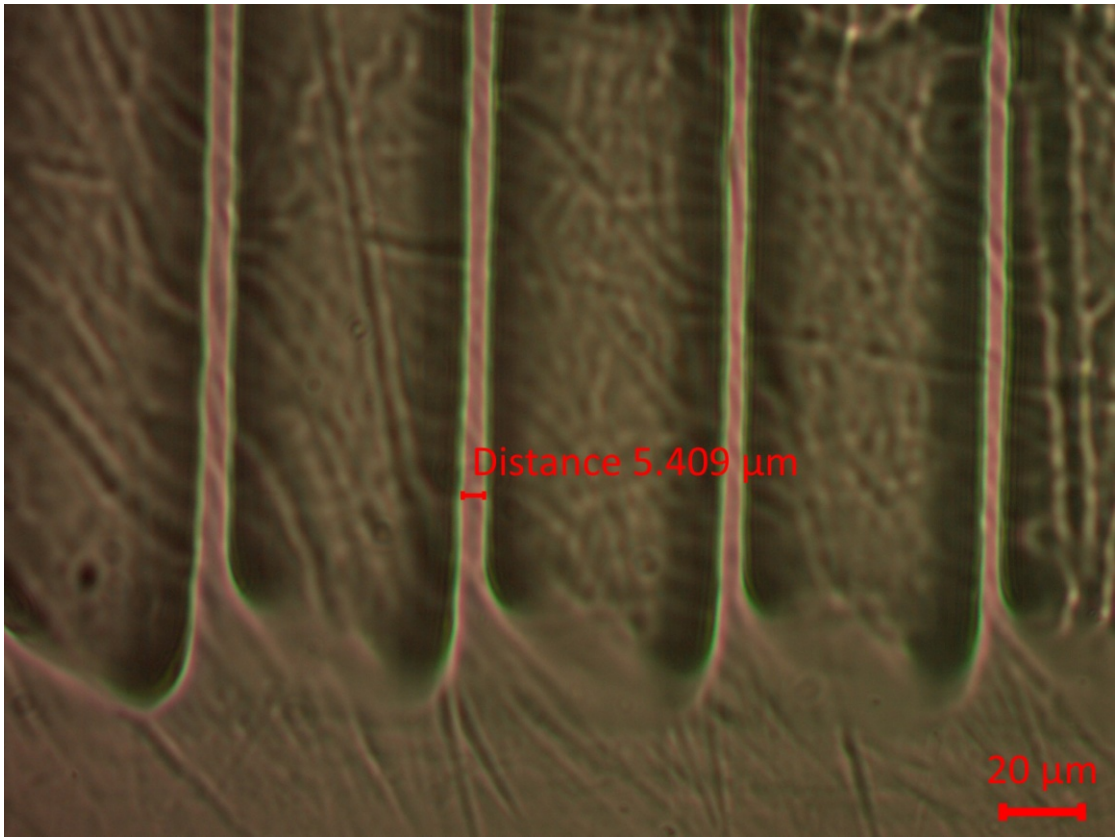


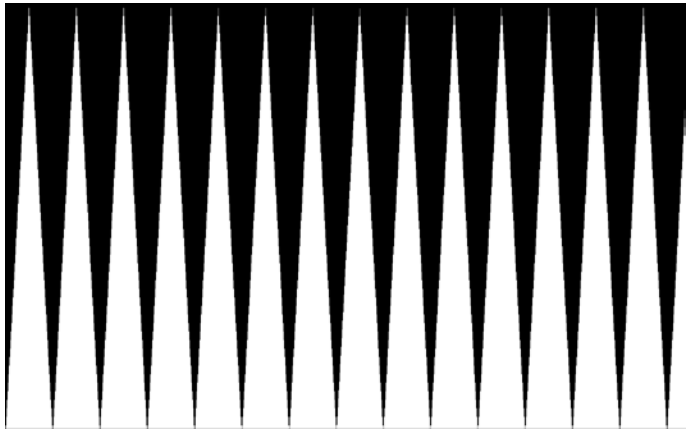


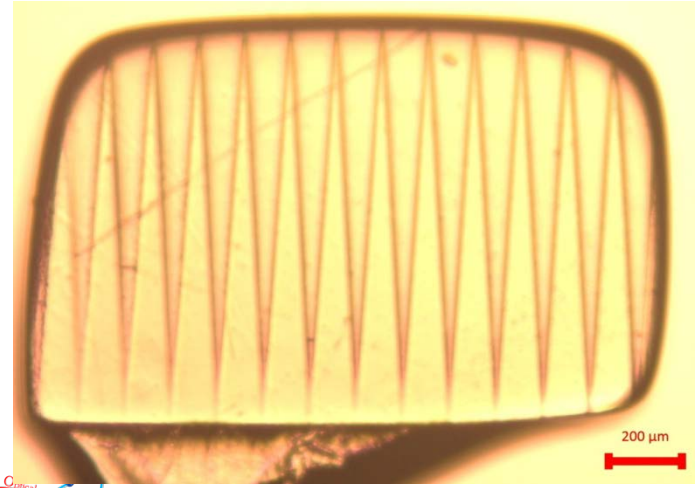
Resolution test 1

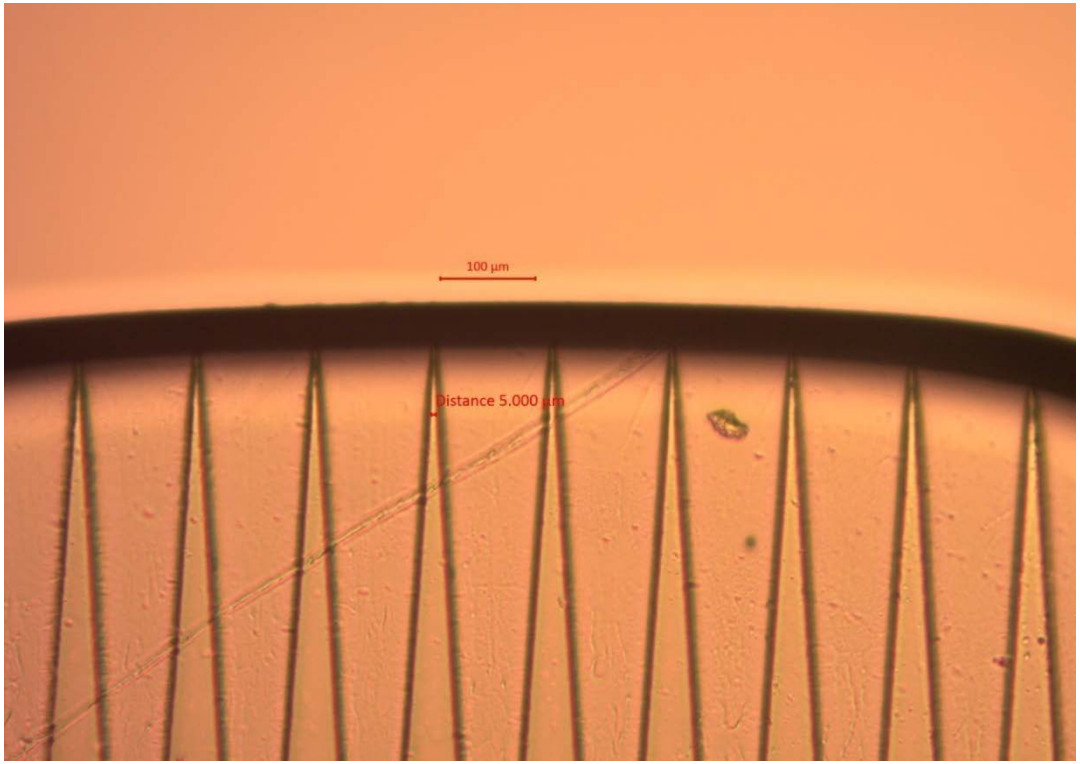




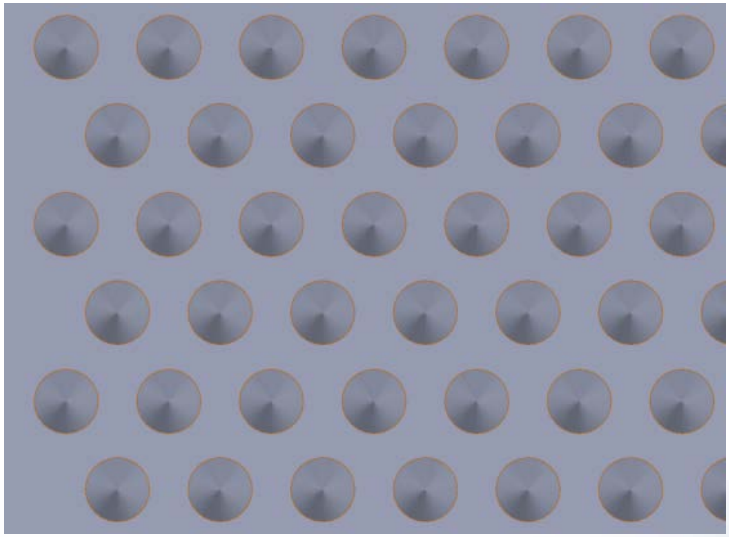
Resolution test 2

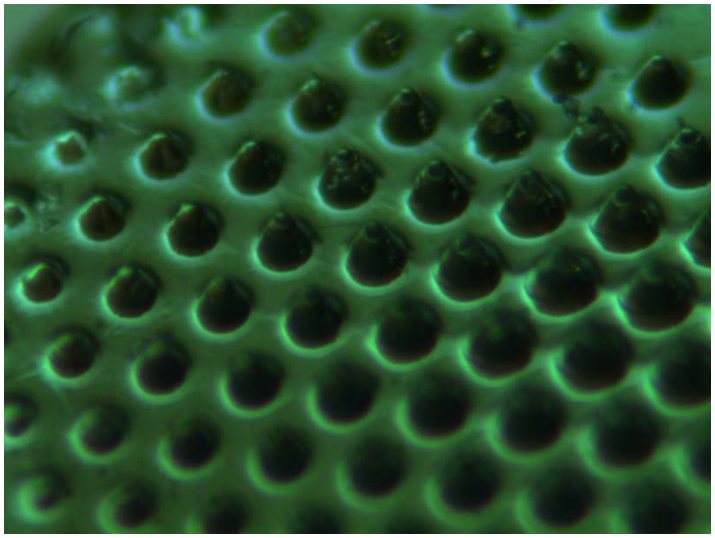


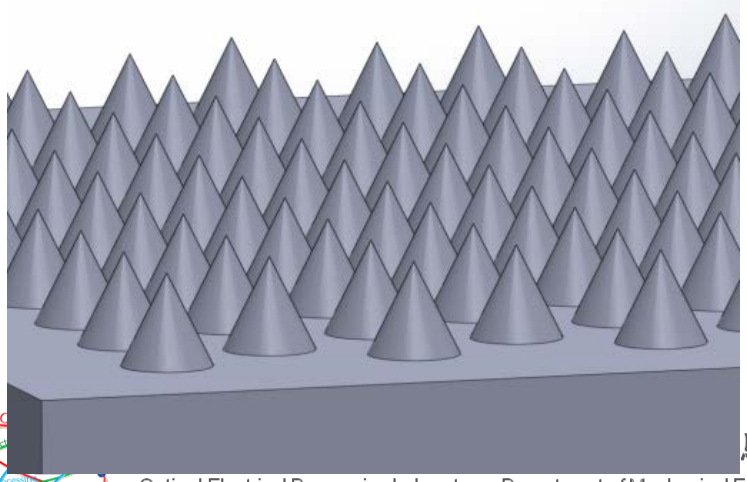


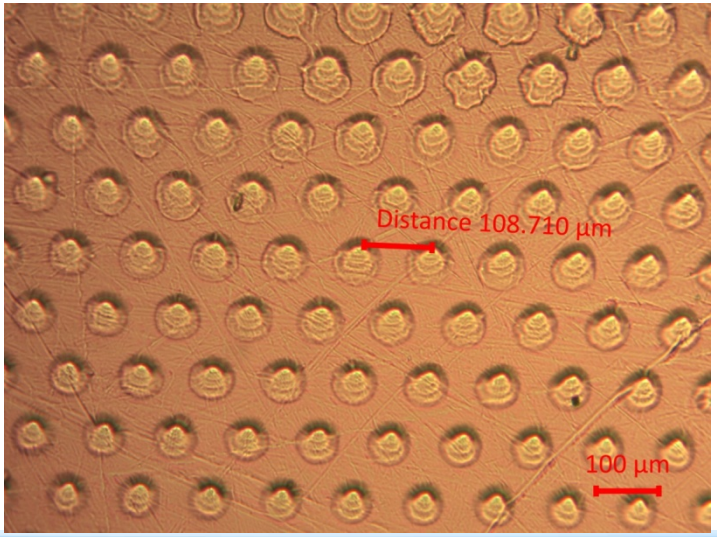


Micro-structure manufacturing










Thank You!

TAIPEI TECH 國立臺北科技大學

sub-project II

Software Development of Micro projection type RP

Jia-Chang Wang

2014/8/18

3D技術特色實驗室
3D Technology Featured LAB

Outlines

- Introduction
- Image Distortion Correction
- Uniform Energy Distribution
- Photo Mask Generation (Slicing)
- Multi-Image Stitching
- Conclusions

Introduction - Objective

- The objective of the software design is because of the physical resolution limitation.
- If the resulting 3D structures are placed on a 10mmX10mm area and in resolution of 2μm/pixel, it need 5,000X5,000 resolution of projection image. (Y1)
- If the resulting 3D structures are placed on a 50mmX50mm area and in resolution of 0.5 μm/pixel, it need 100,000X100,000 resolution of projection image.(Y2)
- The dynamic mask generator is based on DLP engine and the resolution is limited. The stepping technique is necessary to this ultra-high resolution application.
- In order to reduce the need of stepping times, it is necessary to combine many projecting images into one.

Introduction - Needs

- 4 images into 1
  - Image Distortion
  - Energy Distribution
  - Slicing in different region
  - Stitching

Part 1

IMAGE DISTORTION CORRECTION

- Due to the limitation of optical design, there is always a distortion of image from a projector
- In order to combine many projected small images into a large image to gain a higher resolution, the tilt angle is necessary and causing more distortion.

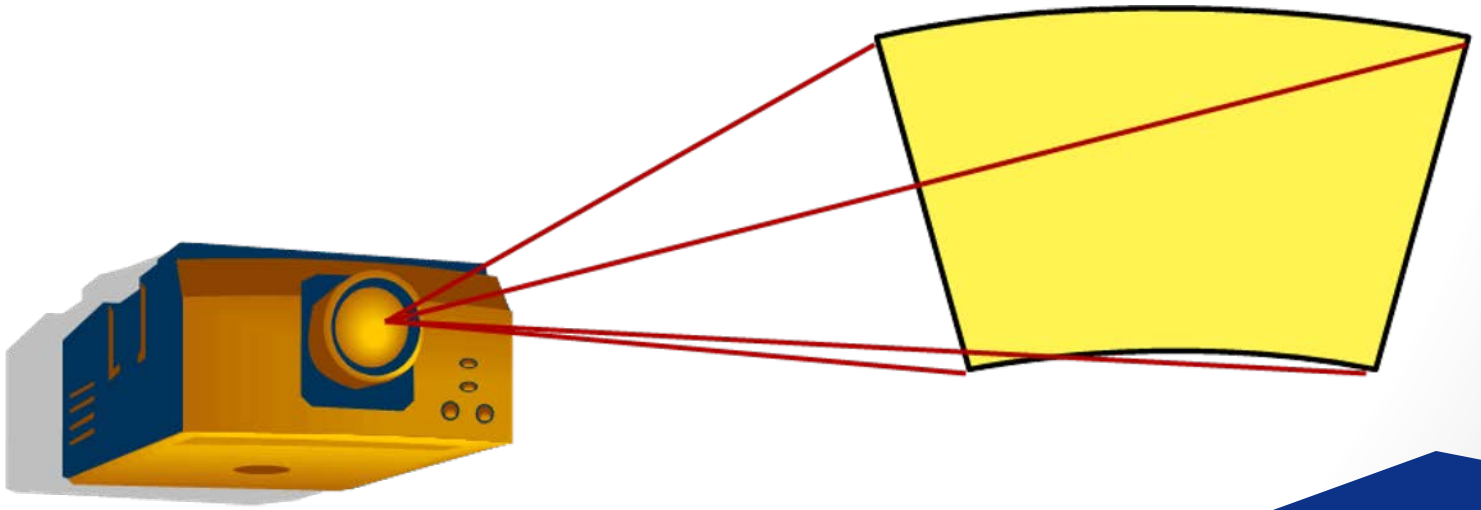
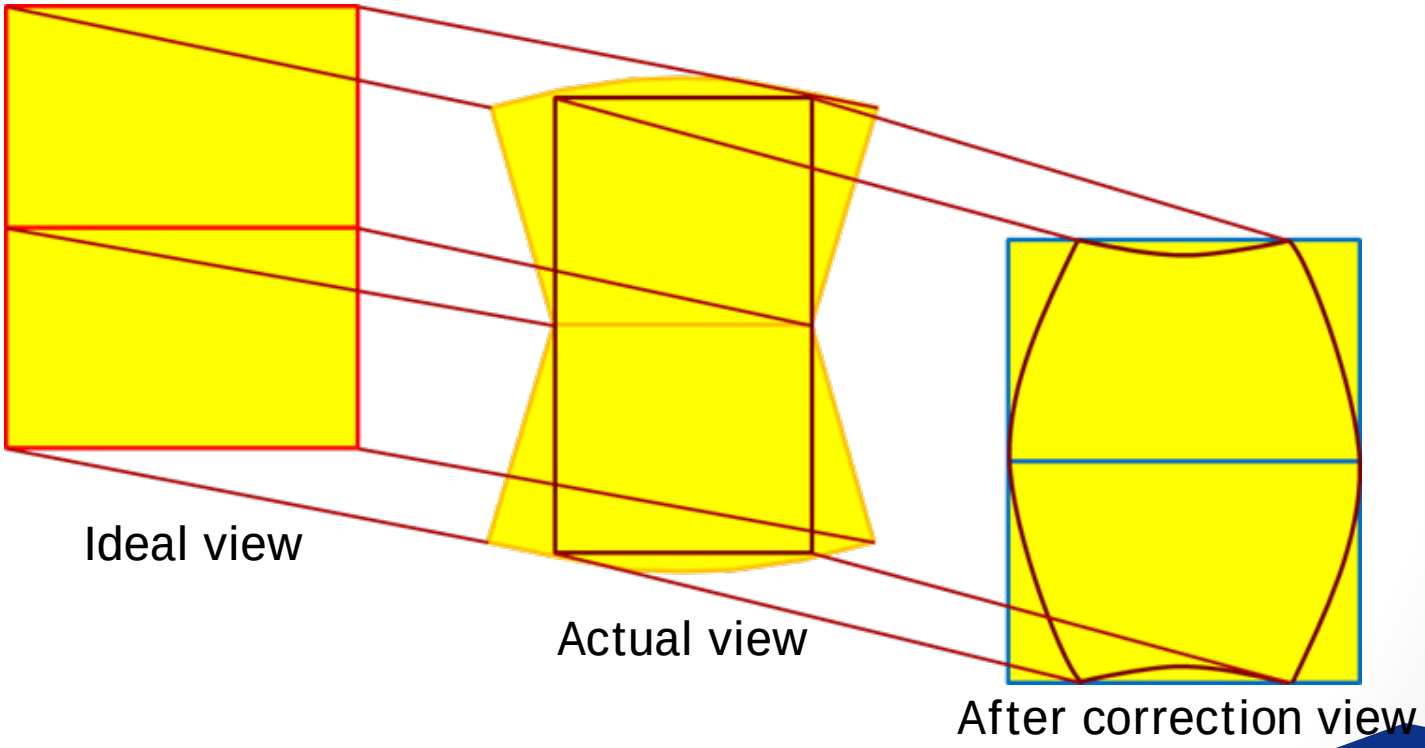


Image Distortion Correction

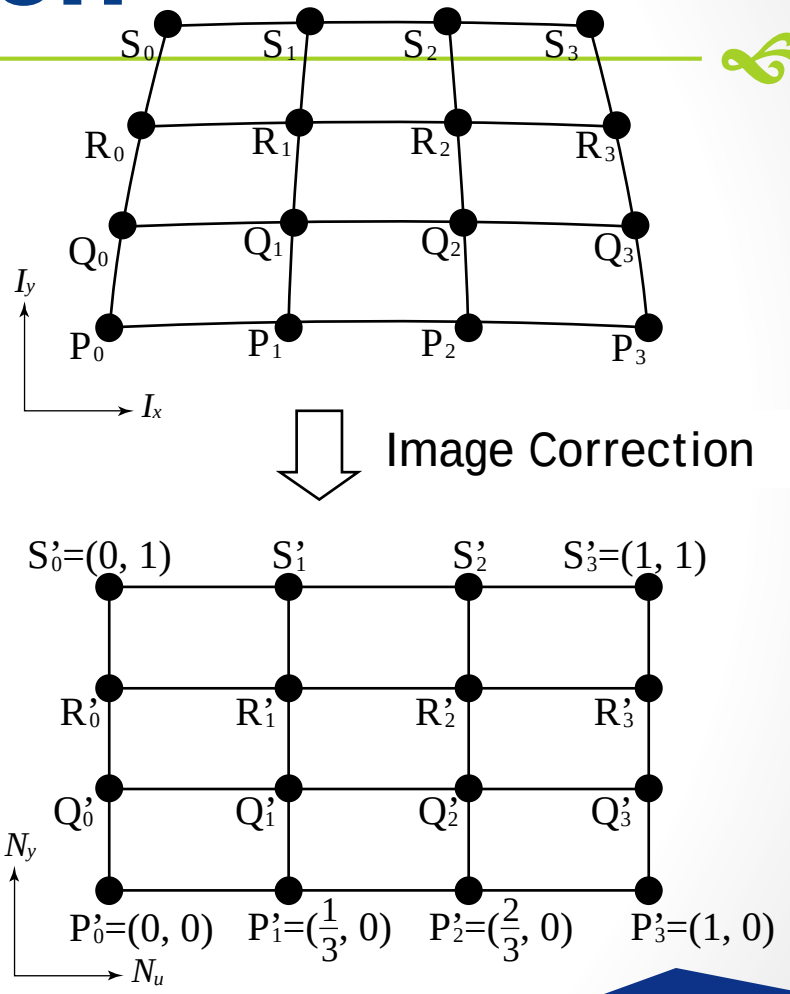
- By OpenGL based software to polynomial surface fitting.
- Real-time computing and projecting.

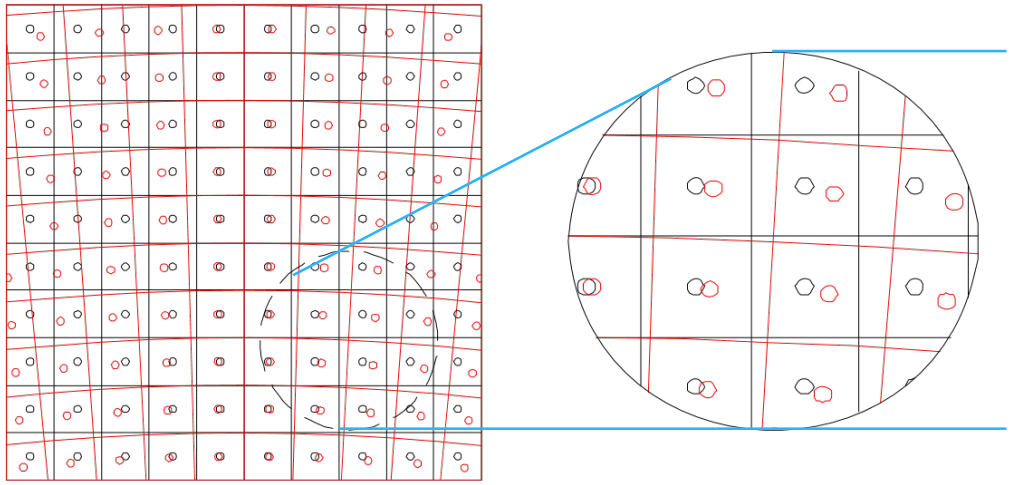


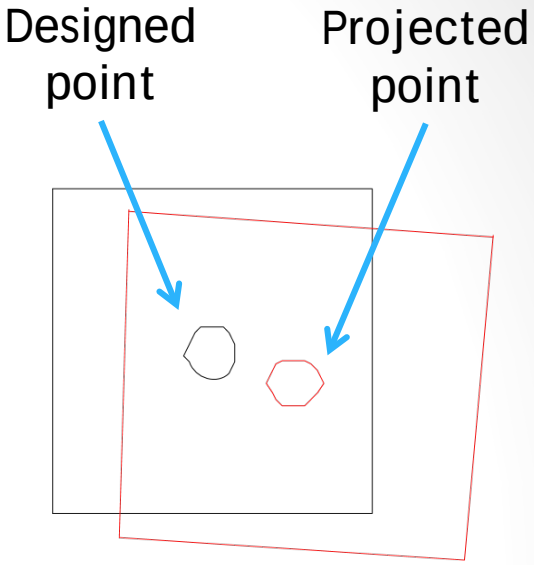
Formula equation

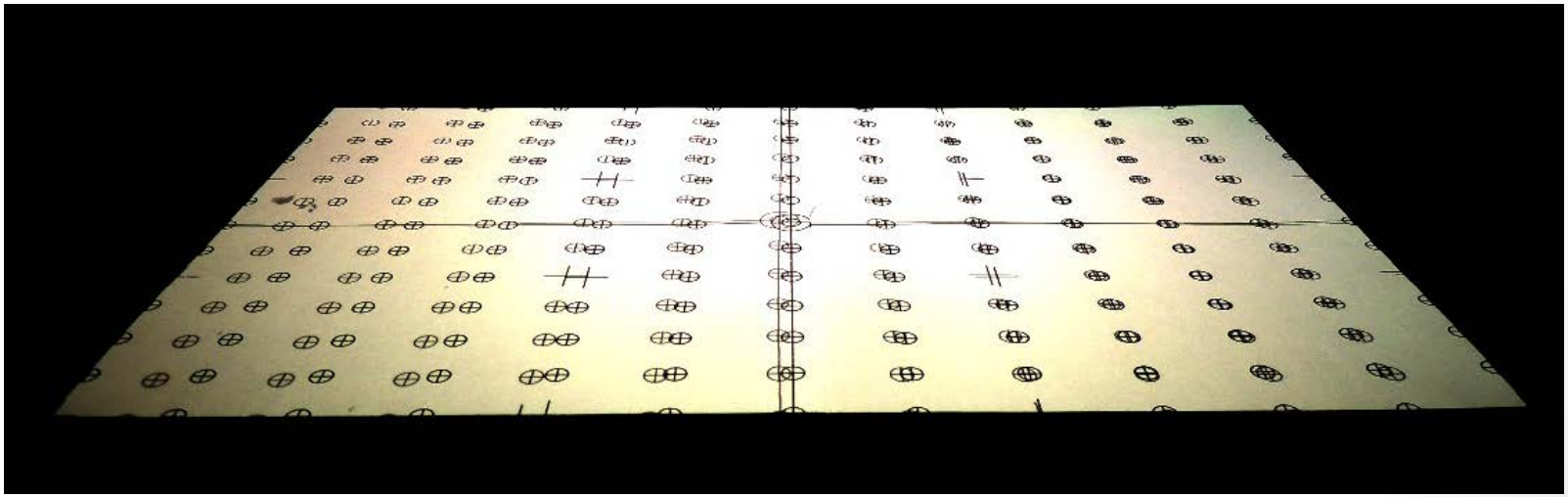
- A 4X4 check board has been designed for surface distortion monitoring.
- The deformation equation has been designed

$$I(x, y) = f\{N(u, v)\}$$





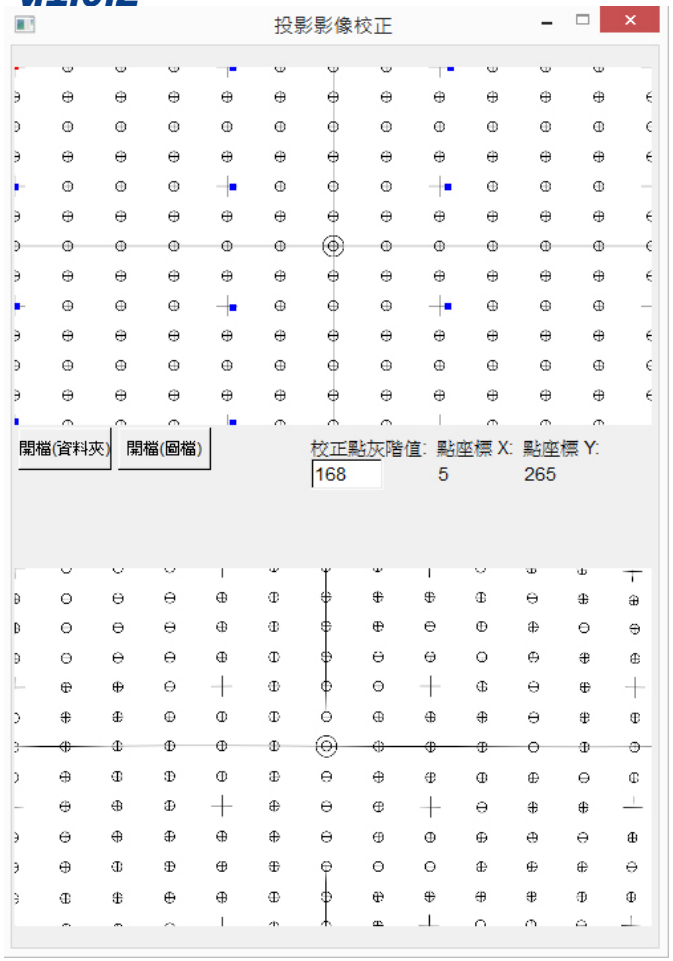




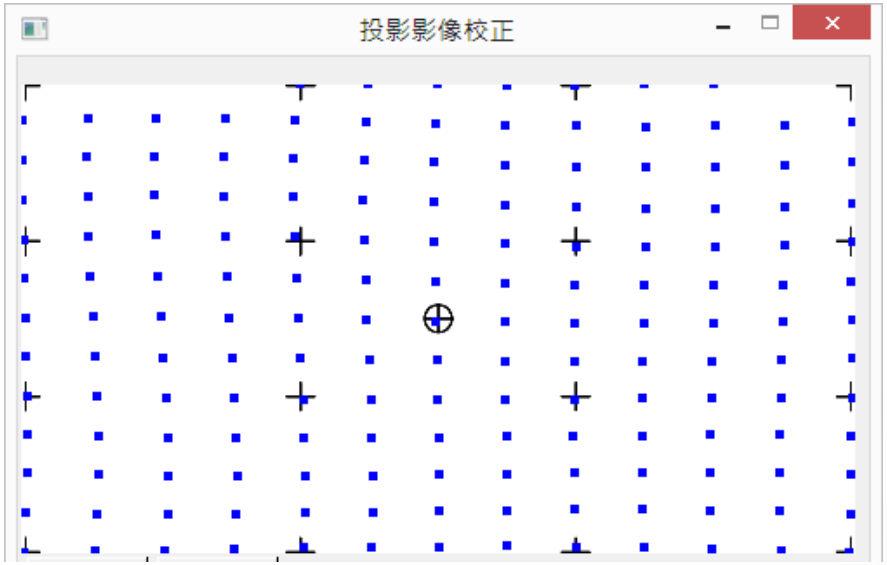
Before correction, each point get wrong position

Control Software Screen Shot

v.1.0.2

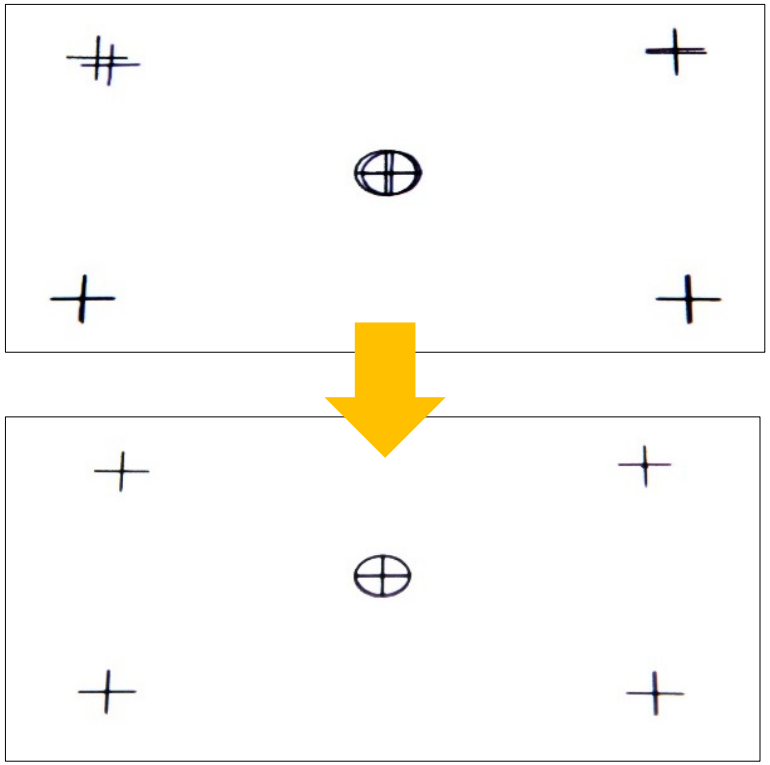


Correction of Initial

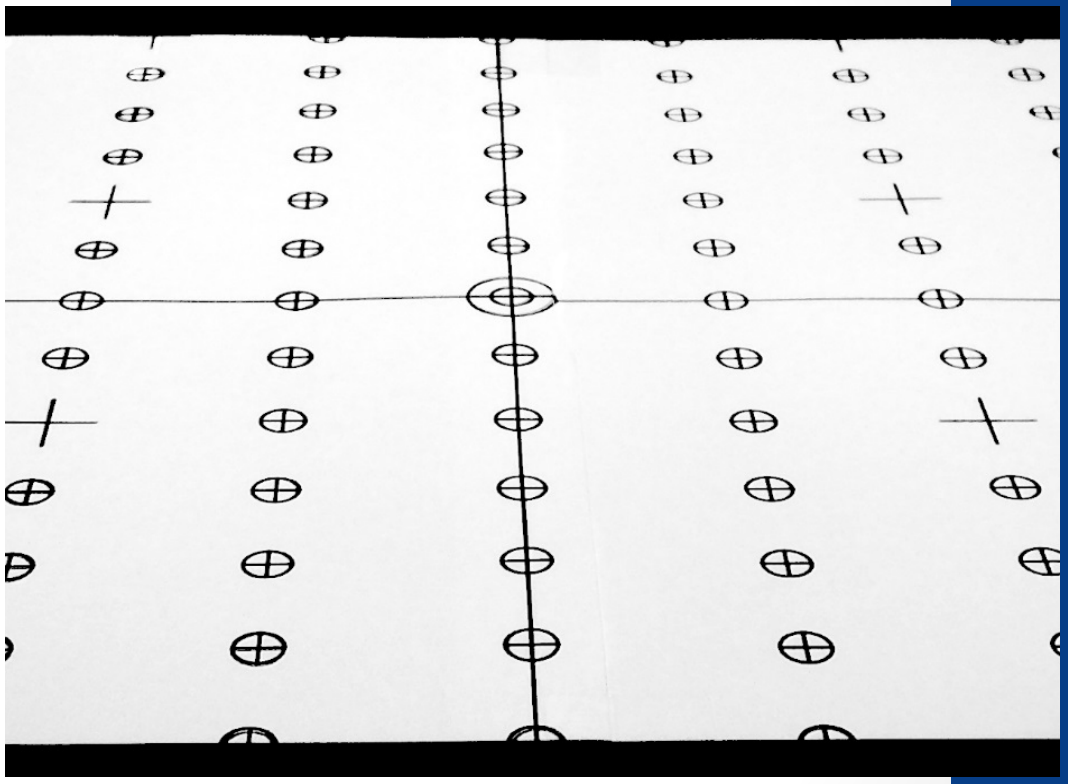


Click MMB into fine tuning mode, open 13×13 control point (part view)

Before Image Correction



After Image Correction



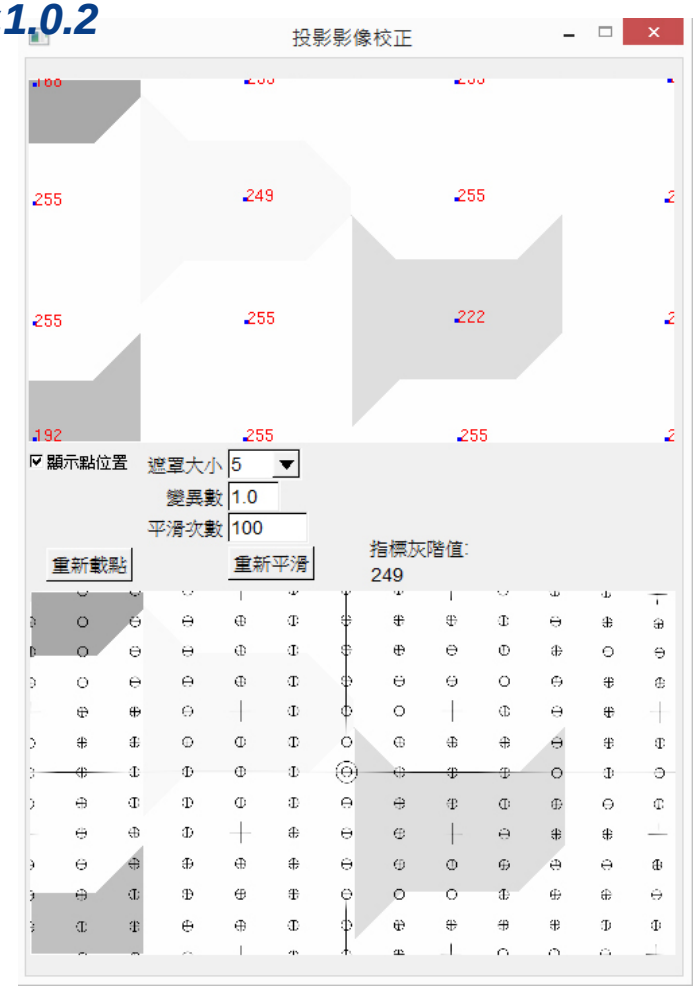
Part 2

UNIFORM ENERGY DISTRIBUTION

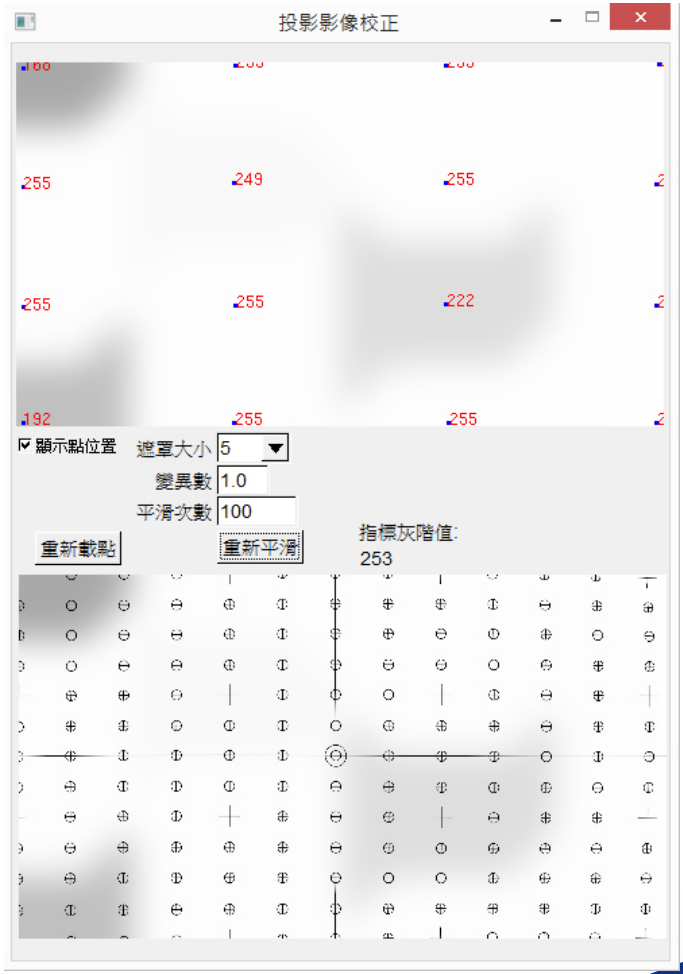
- The image energy uniformity is also a key issue in photo-polymerization to bring a designed thickness everywhere has been exposed.
- The image processing algorithm to solve the physical non-uniform energy distribution problem in necessary.

Control Software Screen Shot

v.1.0.2

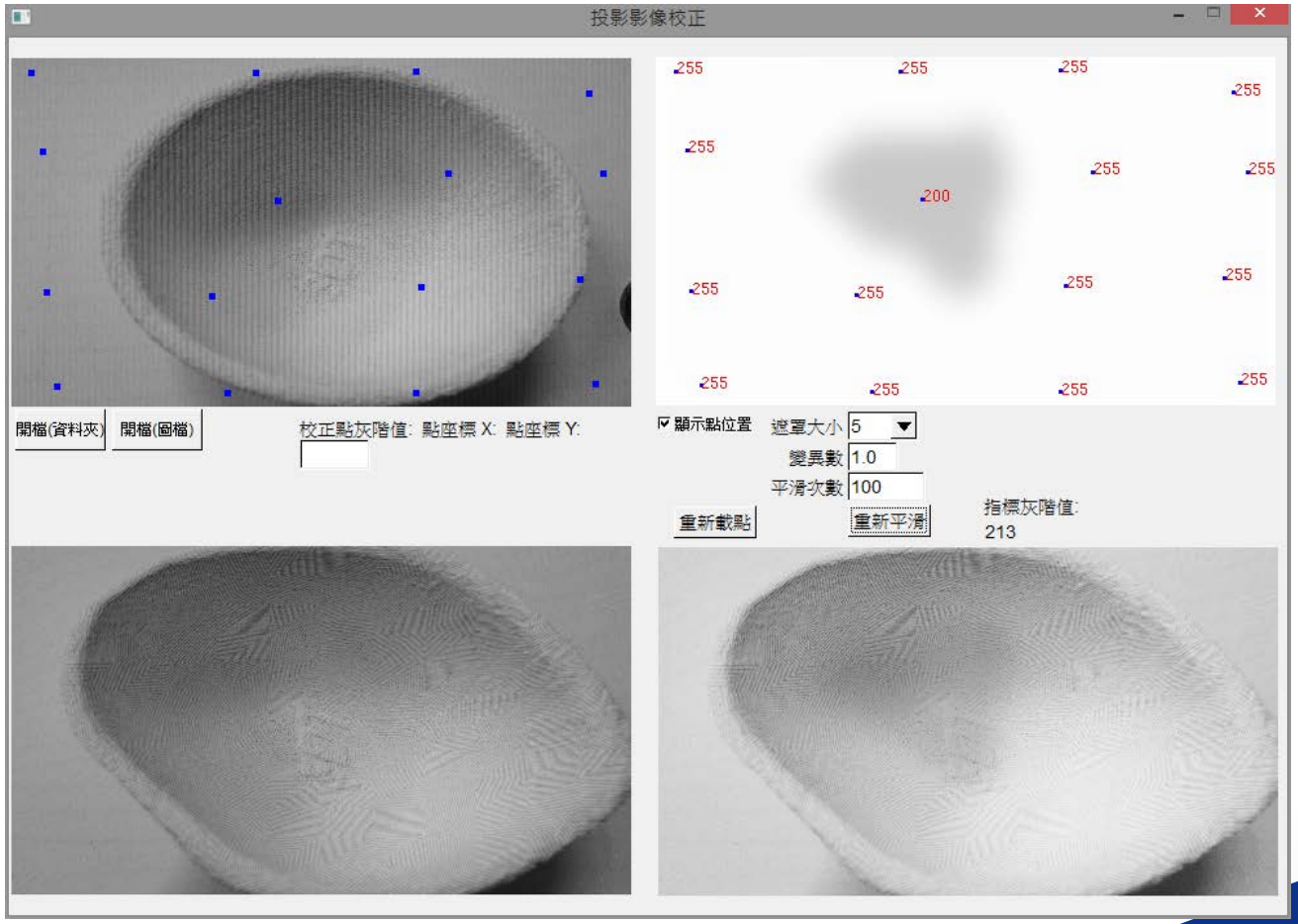


▲before grayscale compensation



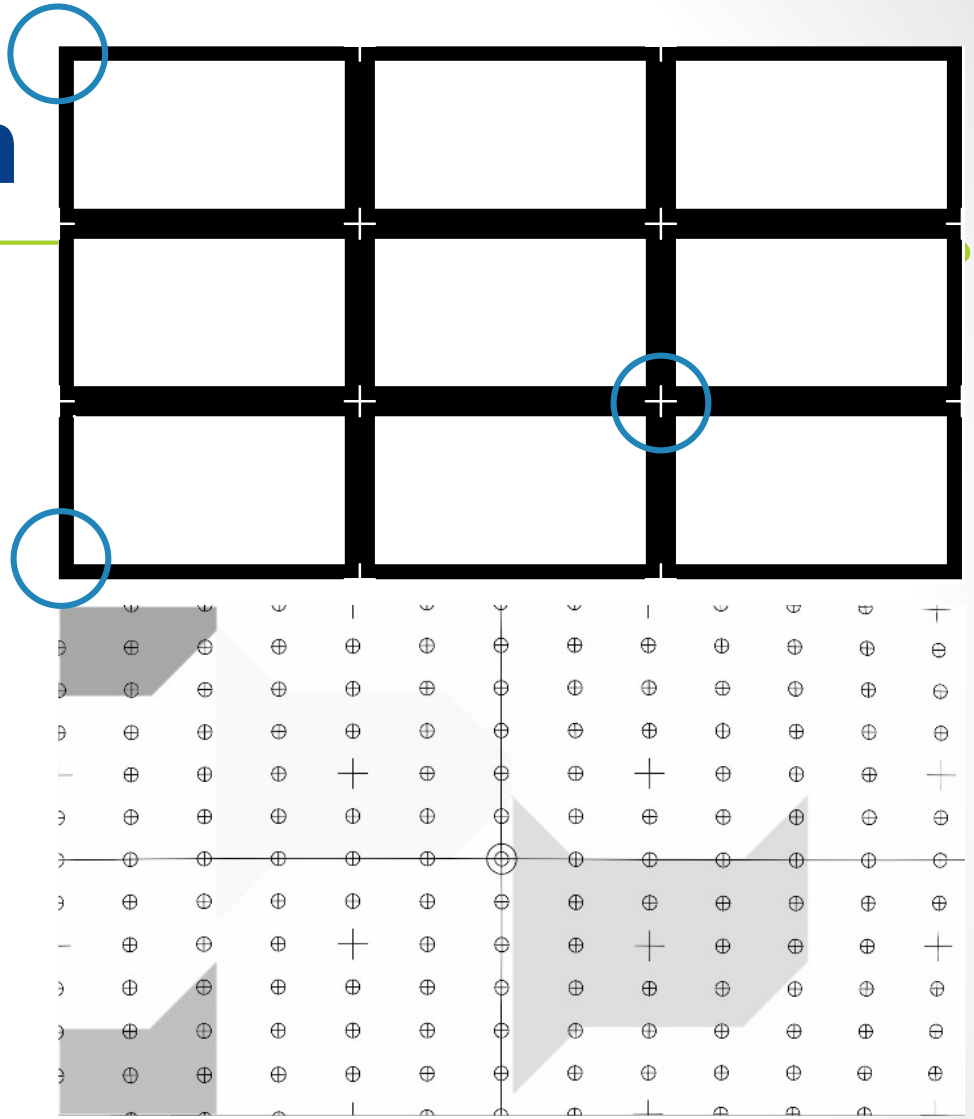
▲after grayscale compensation

Control Software Screen Shot



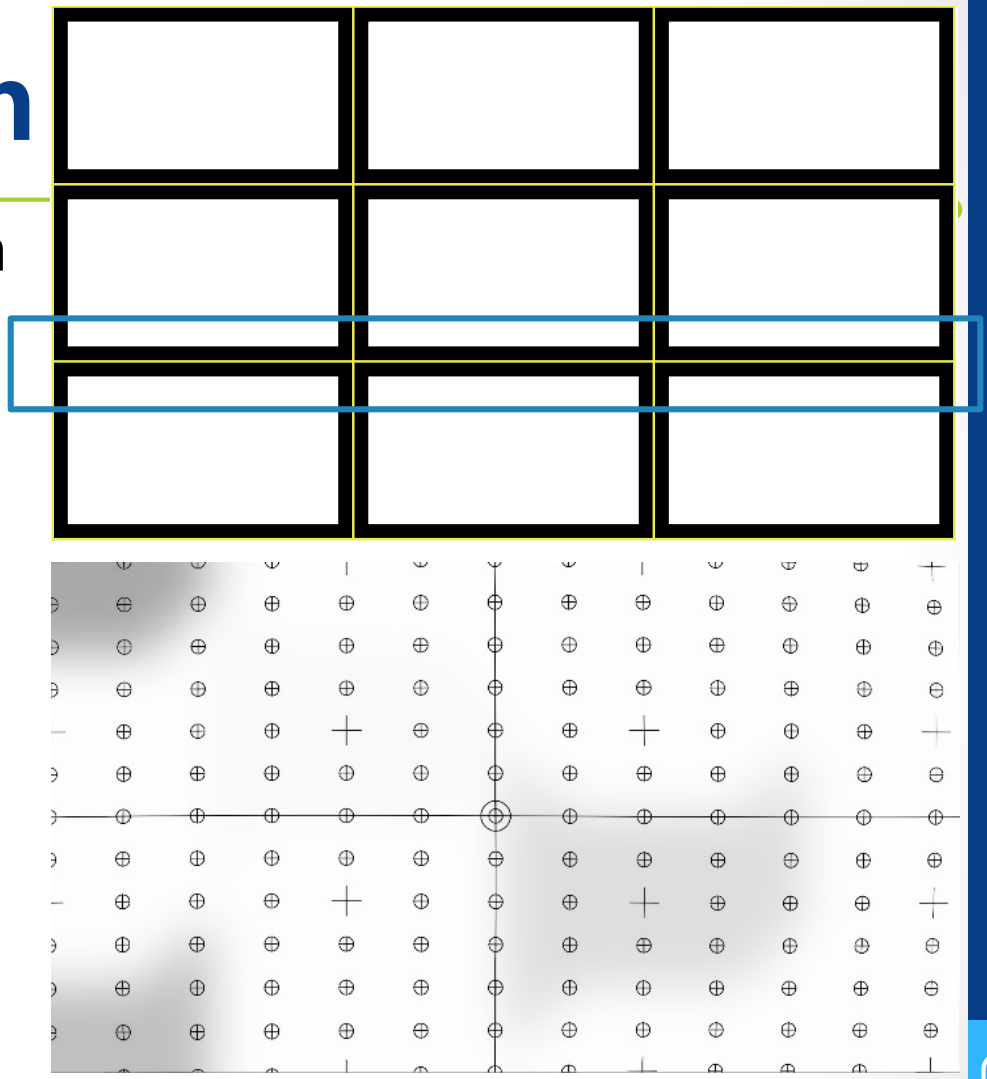
1st Distribution

- 4X4 point energy testing by building up a long exposure one layer sample.
- Measuring the thickness of these 16 points.
- Adjusting the gray level of these 16 points.
- Repeat the process until the thickness is similar to each other.



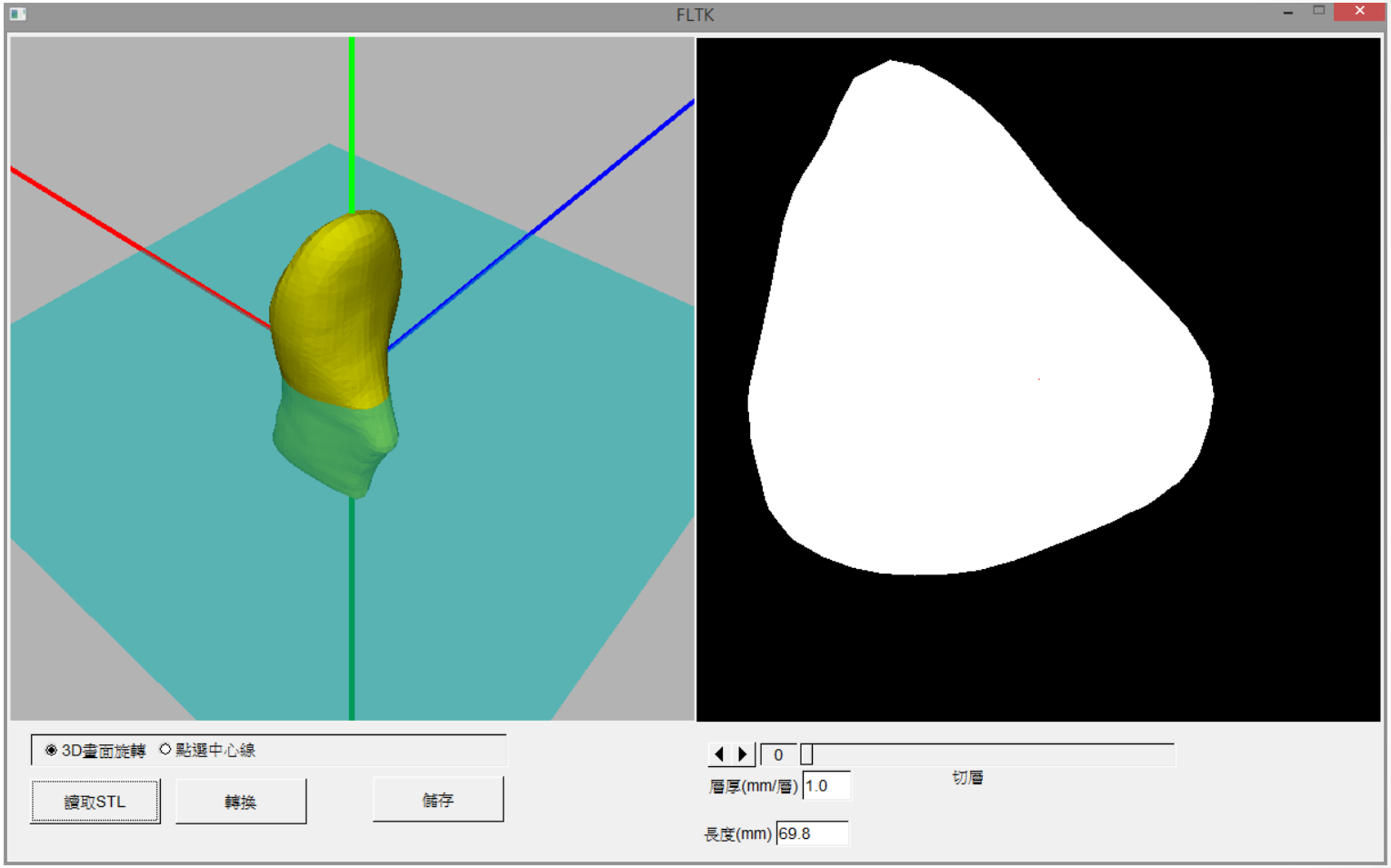
2ed Distribution

- Applying energy smooth operation to generate 2D energy distribution map from the 4X4 gray lever points.



Part III

PHOTO MASK GENERATION

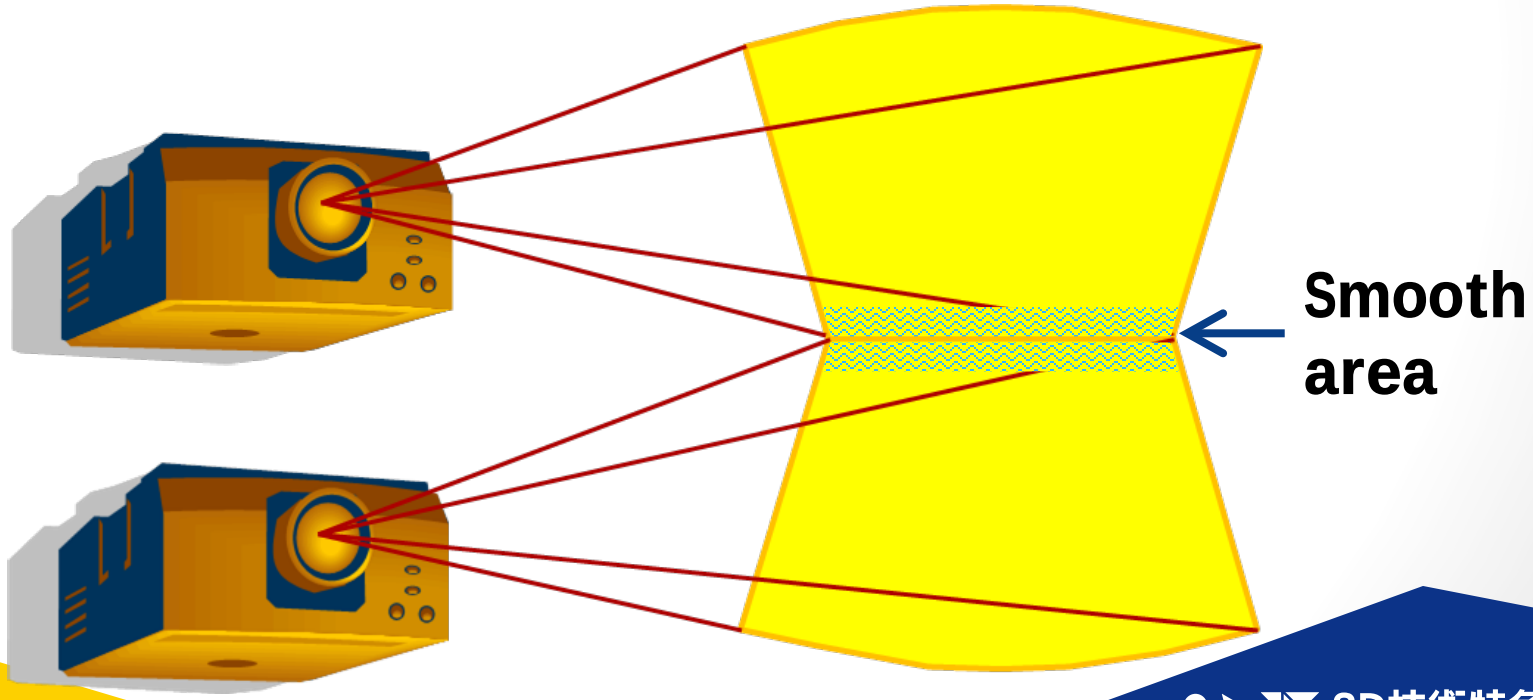


Real-time slicing using Frame Buffer Object(FBO)

Part IV

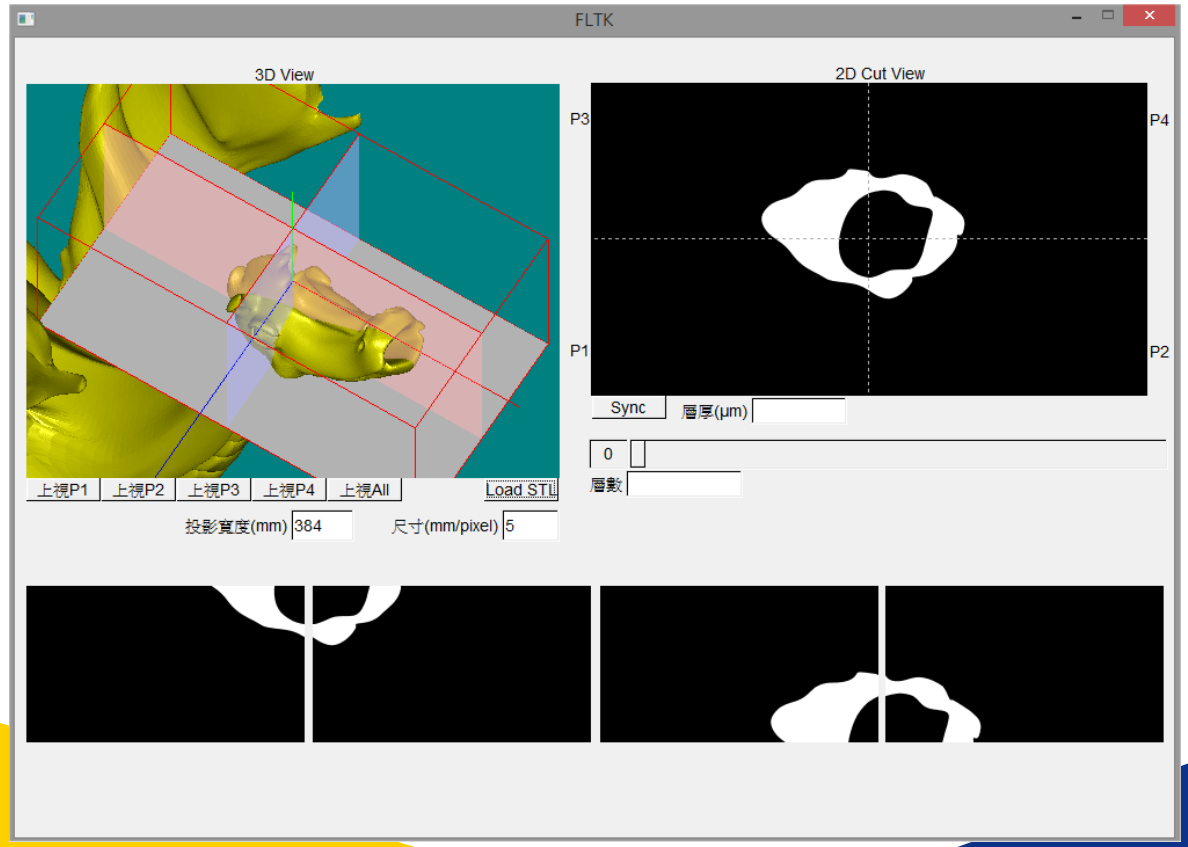
MULTI-IMAGE STITCHING

- Many image processing approach to stitch images is using smooth calculation to bring a smooth image changes. In out research, the true stitch is required.



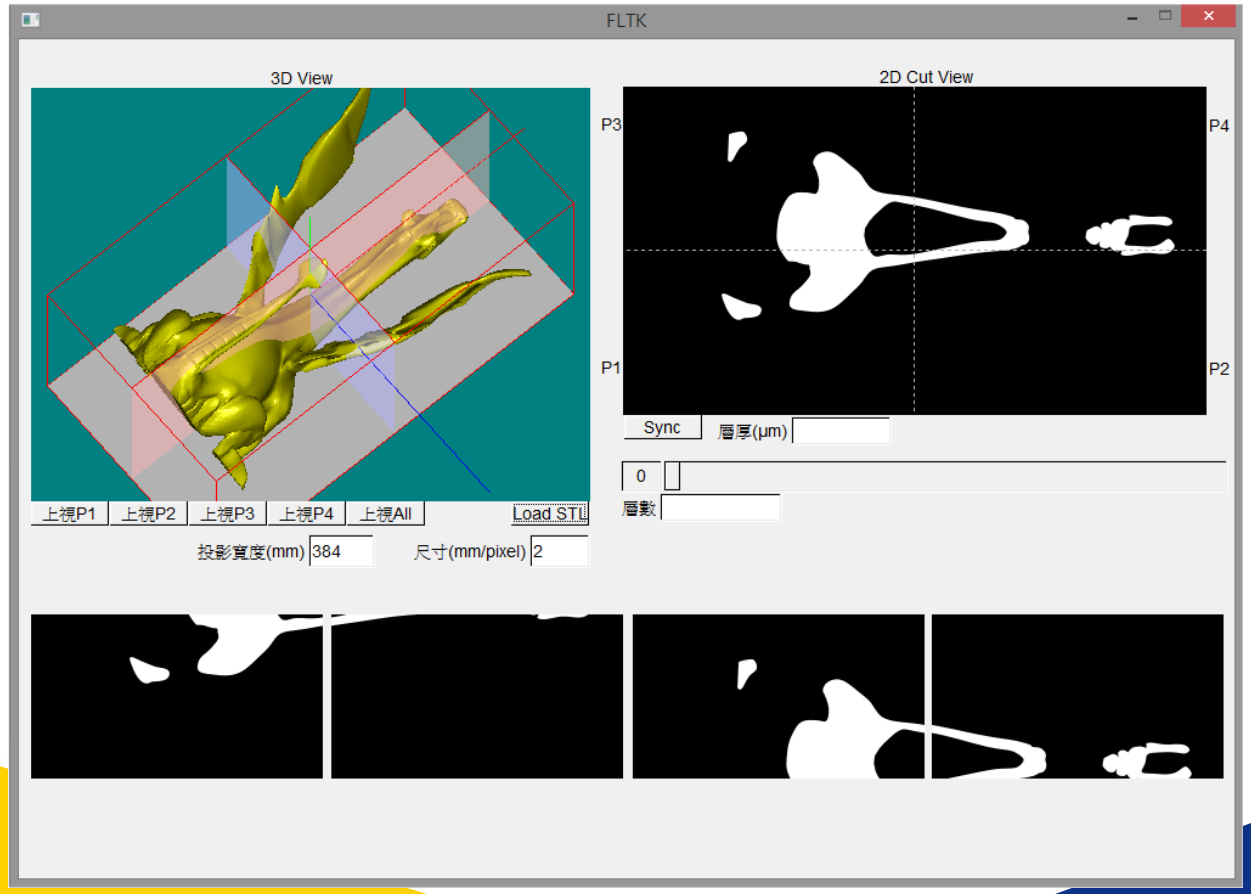
Multi-Image Stitching

- Large working area need many images to stitch together
- For time consuming consideration, 4 images should be stitched into a large image to have a good resolution.



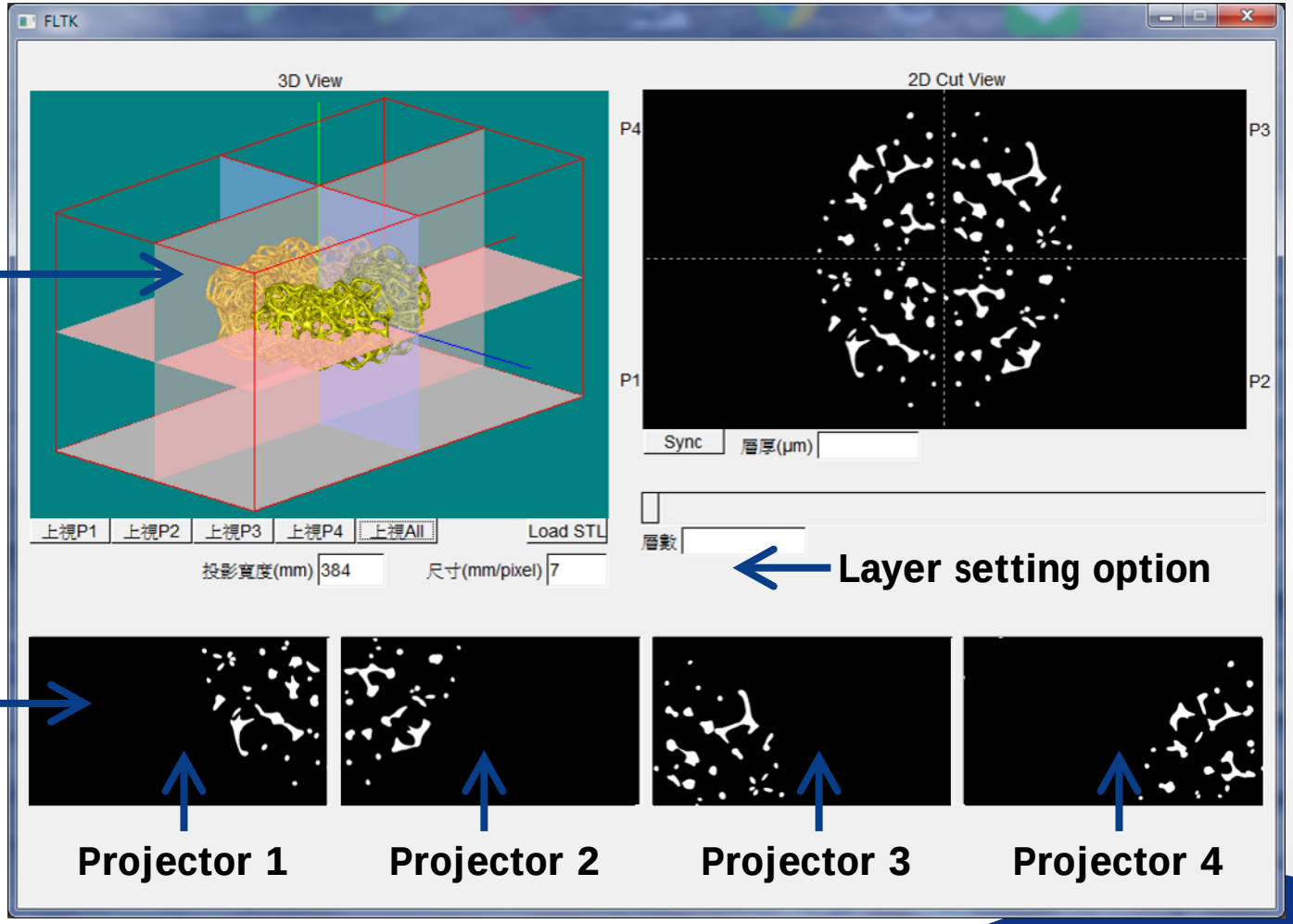
Multi-Image Stitching

- Large working area, 4 images stitched into a large image to be a portion of the large working area.



Multi-Image Stitching

Rotate STL model to check each layer's position



CONCLUSIONS

Conclusions

- The functions of slicing, image distortion, uniform energy correction, multi-image stitching have been developed in this project.

Future Work

- The all-in-one program with accepted user interface is under development.
- System integration to work with sub-project 1 is necessary.

Sub-Project III
Visible Photoinitiator –Based On Thioxanthone for Free Radical Polymerization

Student :鄭育承(Cheng-Yu, Cheng)
Advisor : 蘇威年(Wei-Nien, Wsu)
National Taiwan University of Science and Technology

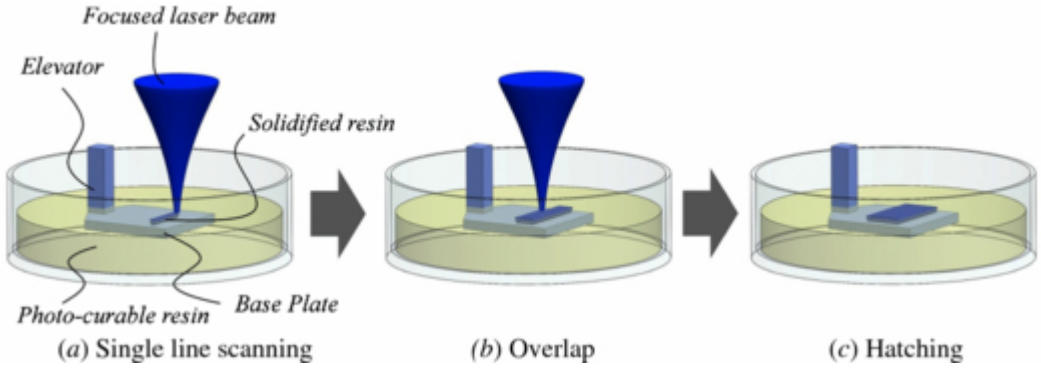
3DP-Resin

- **Photocuring Resin-**

Using UV / visible light source to cure the resin.

- **Technique-**

Stereolithography,SLA



- **Advantages-**

- Strong
- Fast curing (between a few seconds)
- Small shrinkage and clean.

Introduction

UV/Visible Light

- UV Resin disadvantage-Patent issues, expansive, unfriendly for environment.
- Photoinitiators for visible light have found particular interest because of their use in many targeted applications such as dental materials, photoresists, laser-induced 3D curing.
- The necessity for such interest lies in the fact that there is no single photoinitiator which fulfills the particular requirements of all industrial applications.
- **Visible light advantages-**
  - Light transmittance
  - Safety
  - Cheaper

Photoinitiator

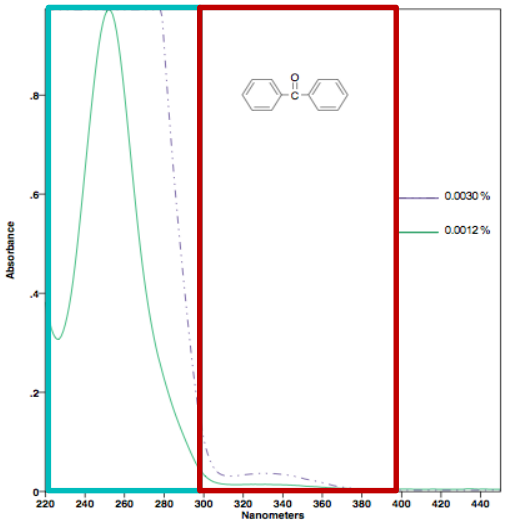
Photoinitiators are classified into two general categories

1. **α-cleavage (Type I) -** Reactive species are formed by direct fragmentation in Type I photoinitiators.
2. **hydrogen abstraction–type (Type II) -** The triplet states of Type II photoinitiators readily react with a coinitiator to yield the initiating radicals.

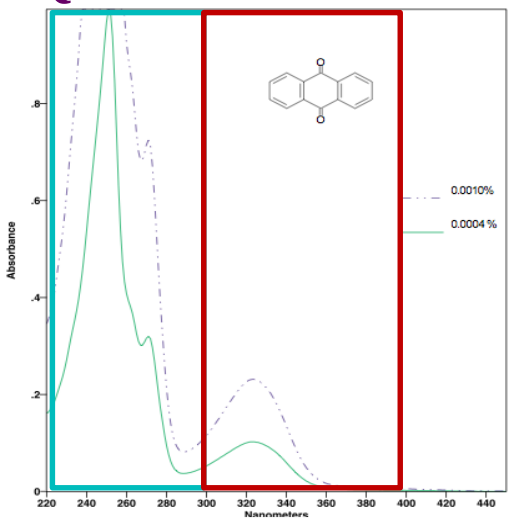
Despite acting more slowly as a result of bimolecular radical generation process, Type II photoinitiators possess better optical absorption properties in the ultraviolet-visible (UV-vis) spectral region.

Current PI-TypeII

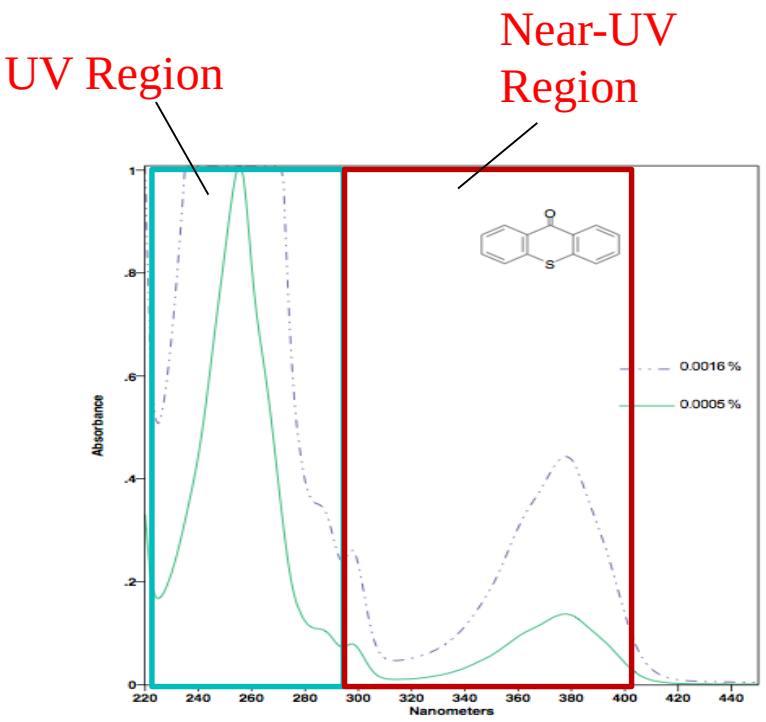
- **Benzophenone-**slow cure rate, toxic



- **Quinone-**Poor solubility



- **Thioxanthone-**Optical properties

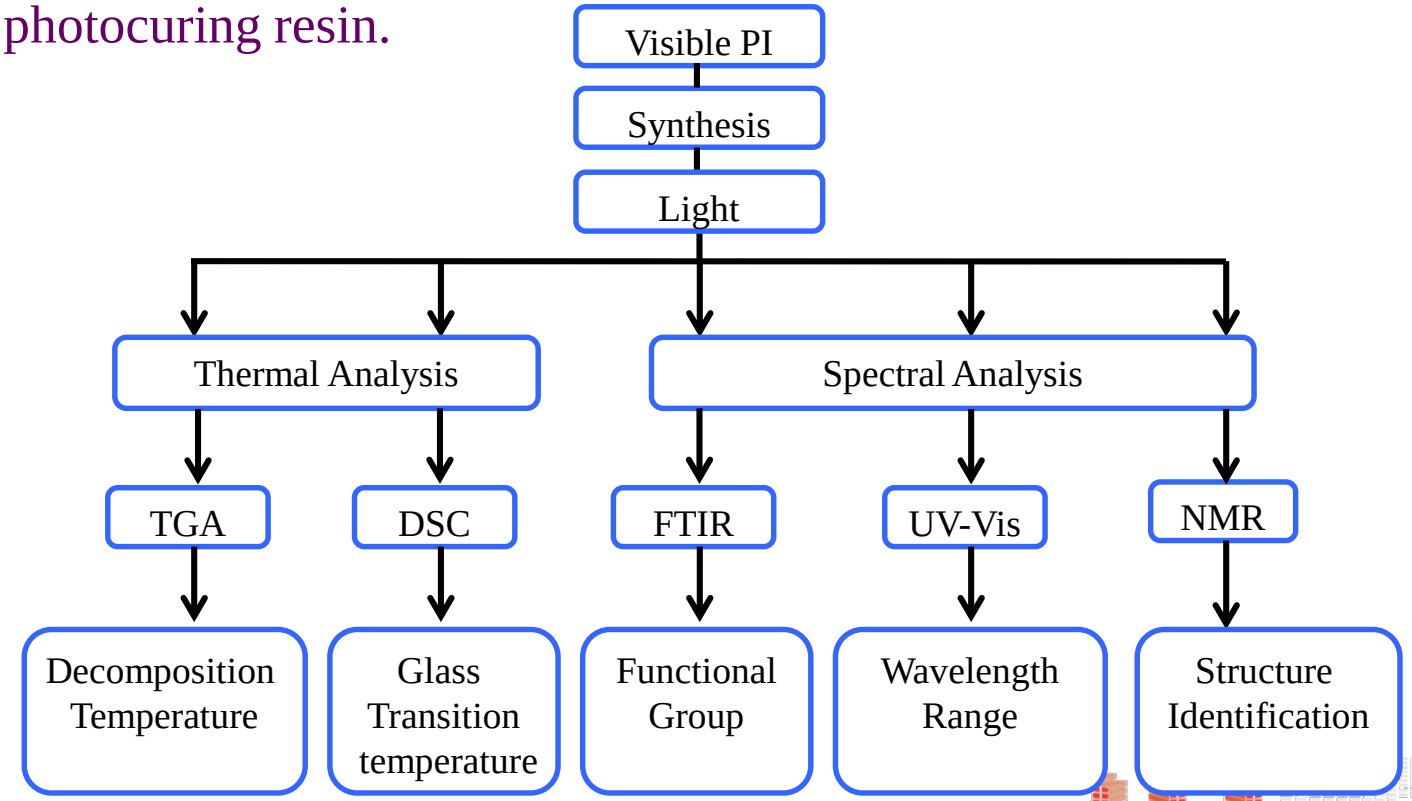


Target-

- Extend wavelength
- Control the absorption position-Enhanced Signal

Approach Work

1. To confirm the experimental approach.
2. Change the other chromophore with high yield & Extend wavelength & Control the absorption position- Enhanced Signal.
3. Add PI into acrylate (oligomer & monomer) & Analysis photocuring resin.



Thanks for your attention.

Sub-project IV
Research on Biomedical Application

TAIWAN TECH

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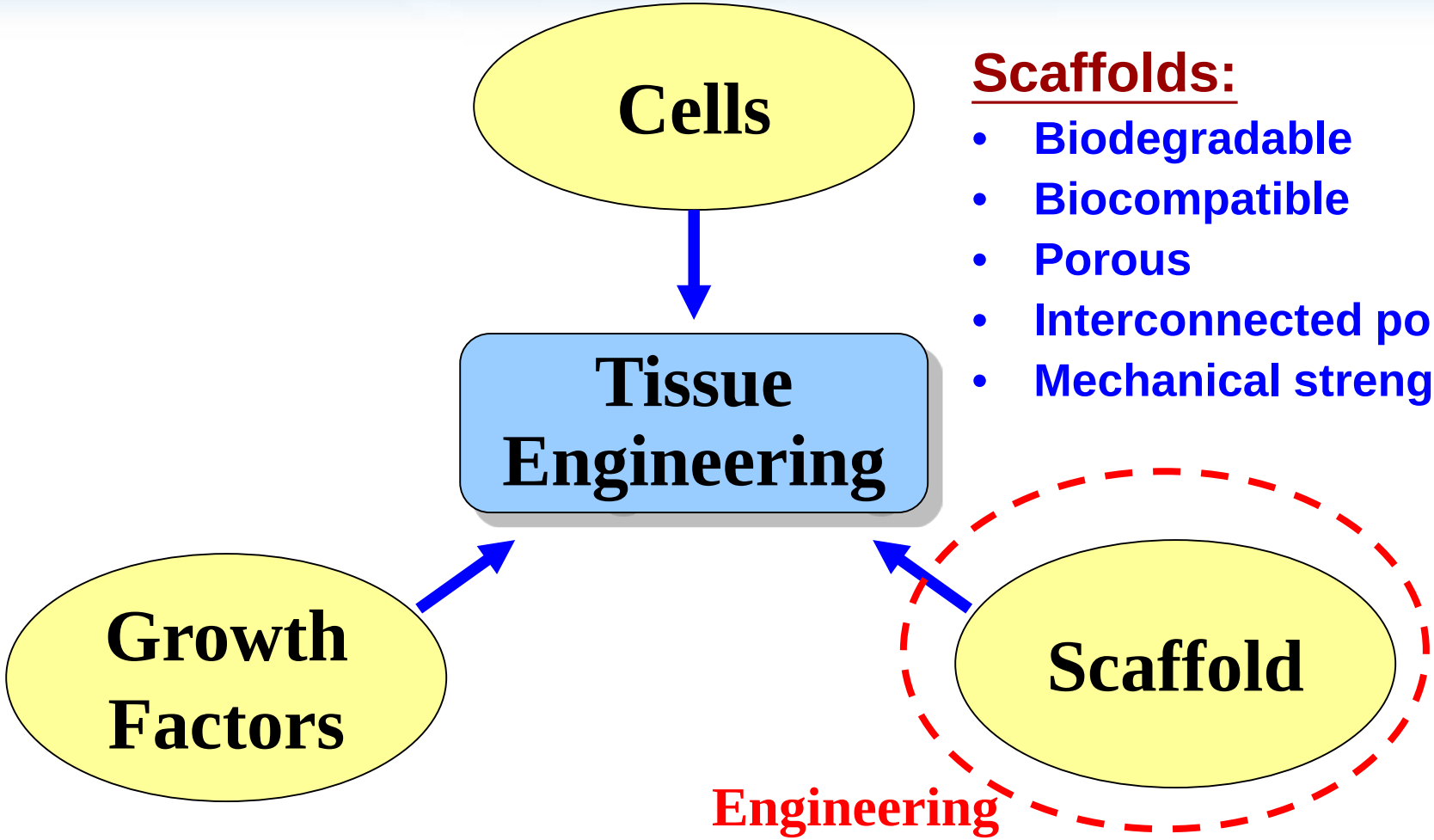
2014.08.18

Outlines

- Introduction
- Scaffold Material System
- AM System for Scaffold Fabrication
- Flow of Micro-pattern Transferring on to Scaffold
- Micro-pattern transferring to PDMS Film
- Micro-pattern Transferring from PDMS to Biomaterial
- Conclusions

Tissue Engineering



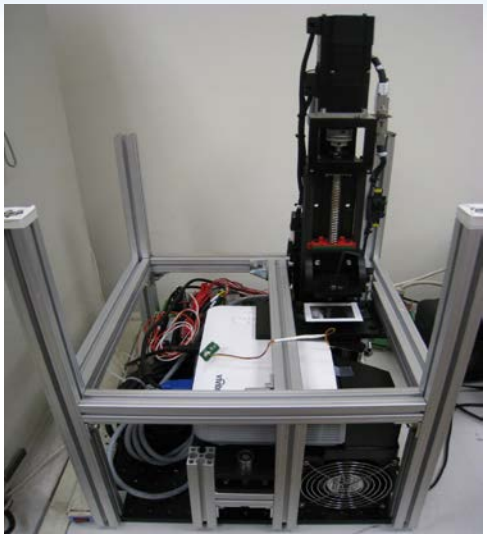
Scaffolds:

- Biodegradable
- Biocompatible
- Porous
- Interconnected pores
- Mechanical strength

AM for Scaffold Fabrication

- AM can build parts w/o restrictions in geometry and micro-architecture

→ provide a great opportunity to fabricate 3D tissue engineering scaffolds with controlled pore-size.



Our previous works:

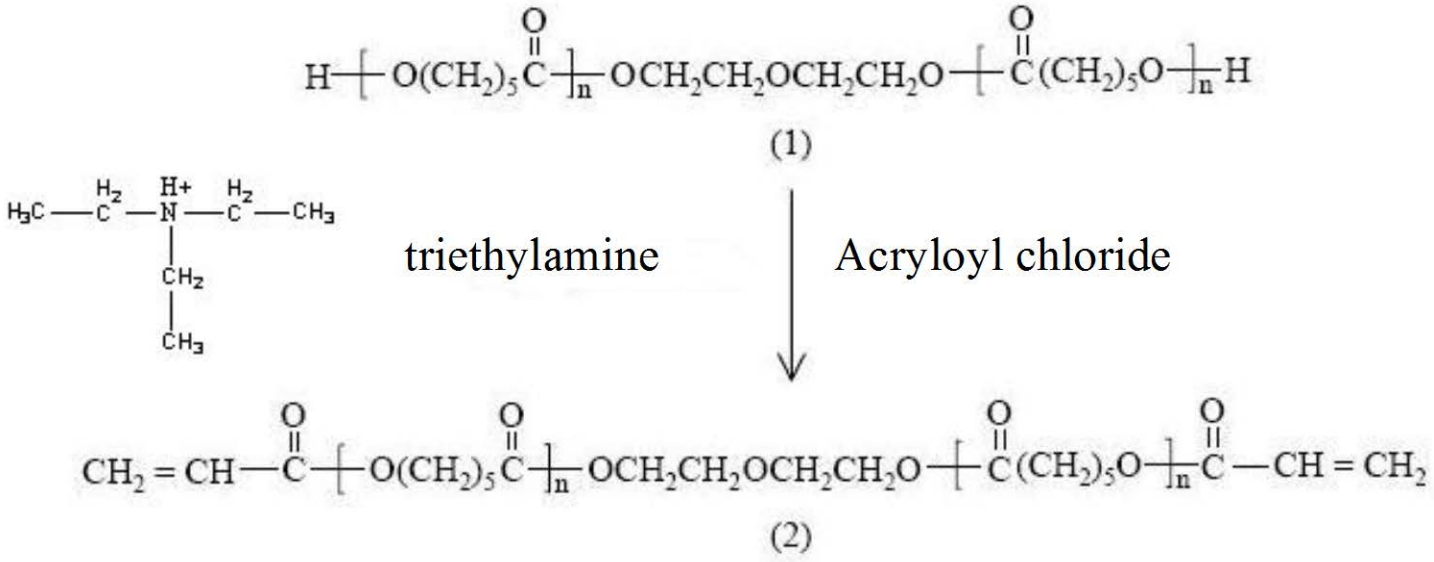
- ***Cure PLGA by UV***
- ***Cure PCL-PEG-PCL by visible light***
- ***Cure PCL-DA/PEG-DA by visible light***

→ ***Smallest pore size ~ 50 mm***

- Adding micro-pattern on the scaffold surface for better cells attachment?
- Will use micro-patterns generated from this integrated project!

Synthesis of Polymerizable PCL

- Photo-curable biodegradable materials are not commercially available
- PCL diol → polymerizable PCL (PCL-DA)
- Synthesized by ourselves



Material System

Previous

PCL-DA

+

Crosslinking agent: PEG-DA

+

Photo-initiator: TPO

+

Acetone

Cannot transfer micro-pattern to scaffold material successfully!

Preliminary Test

PEG-DA

+

Photo-initiator: TPO

+

Dispersant

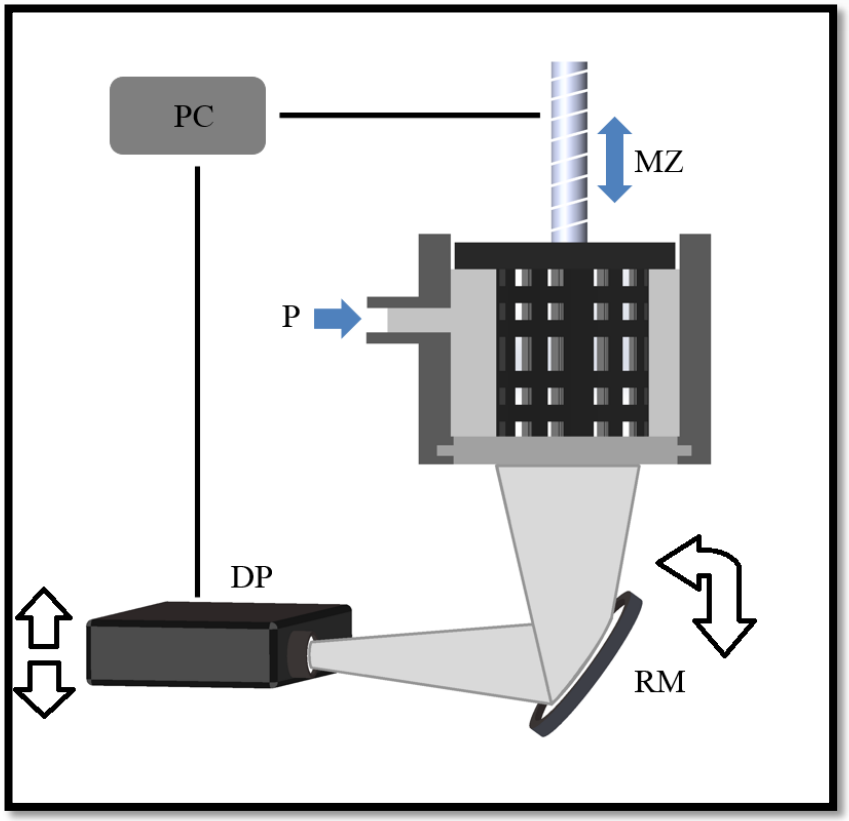
Remove acentone

→ Improve material resolution!

AM System for Scaffold Fabrication

- Use DLP projector directly
- PDMS thin film with micro-pattern is attached to the bottom of material tank

→ During the curing process layer by layer, the micro-pattern on the PDMS should transfer to the surface of the biomaterial

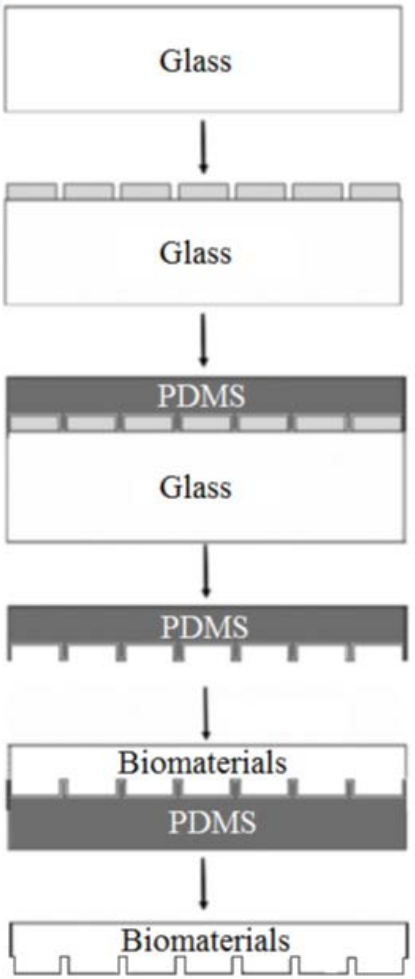


Flow of Micro-pattern Transferring on to Scaffold

- For testing the transferring results, micro-pattern was generated by photo-resist on glass substrate.
- Pattern transfers to PDMS film
- PDMS film attaches to the bottom of the material tank
- Photo-curing biomaterial

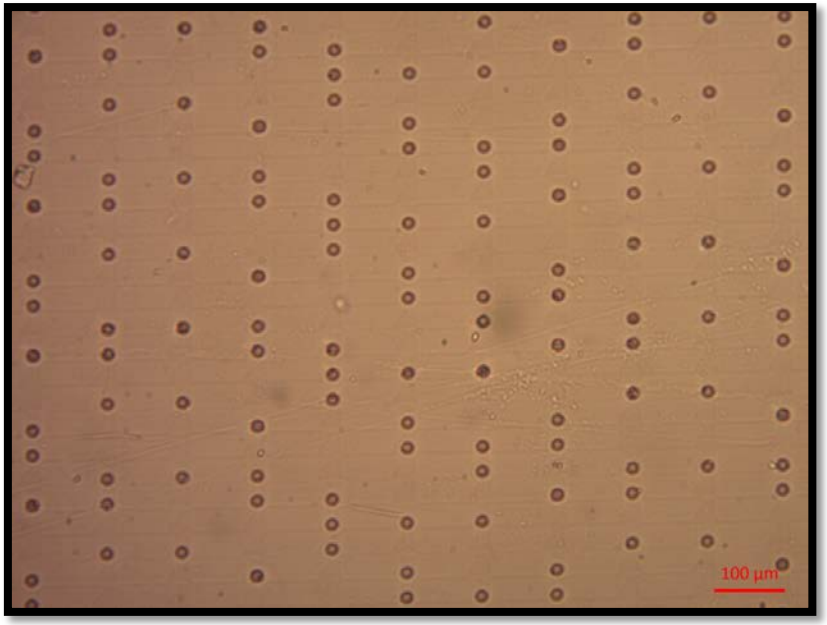
Issues

- PDMS composition
- Temp. control of PDMS curing
- Temp. control of biomaterial curing process
- Pattern design

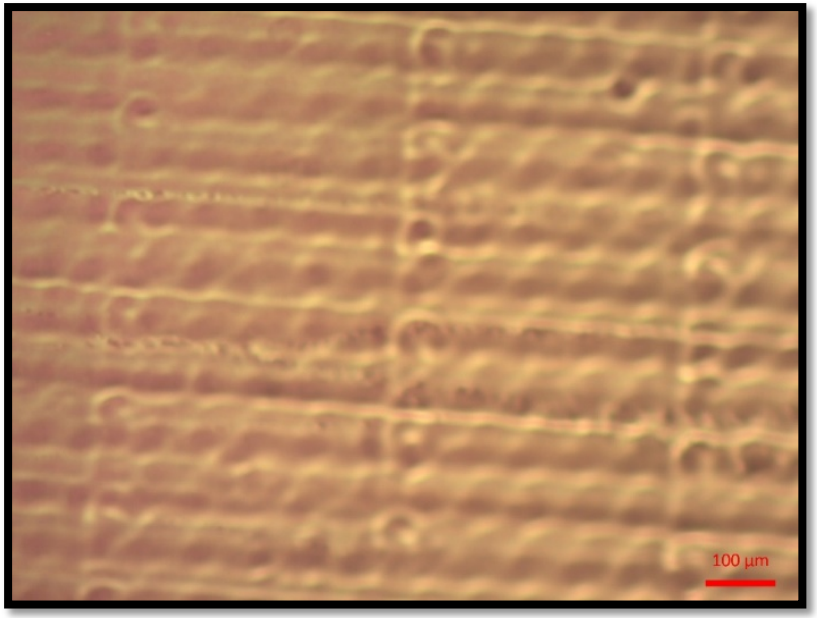


Micro-pattern Transferring to PDMS

Dot Pattern

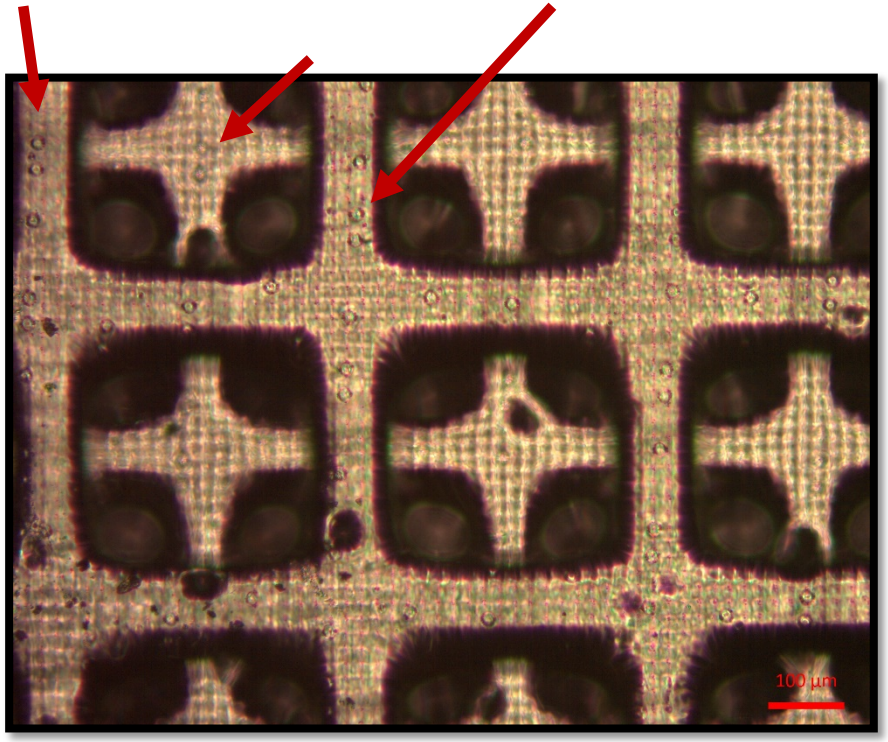


Rectangle Pattern

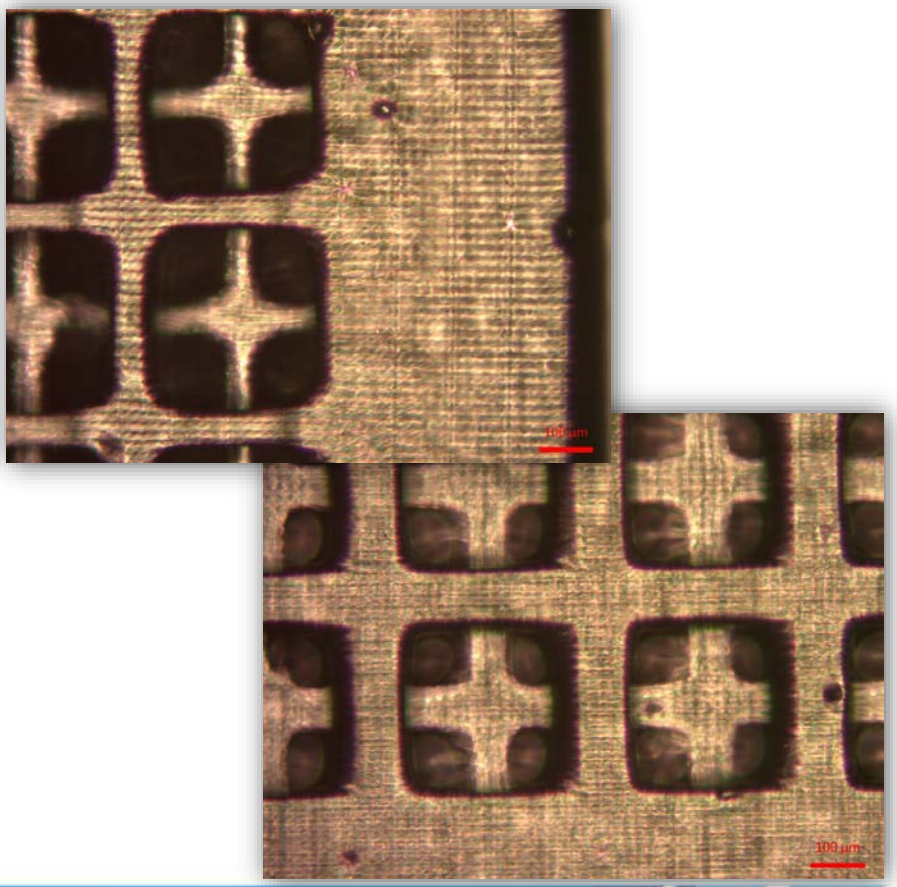


Micro-pattern Transferring to Biomaterial

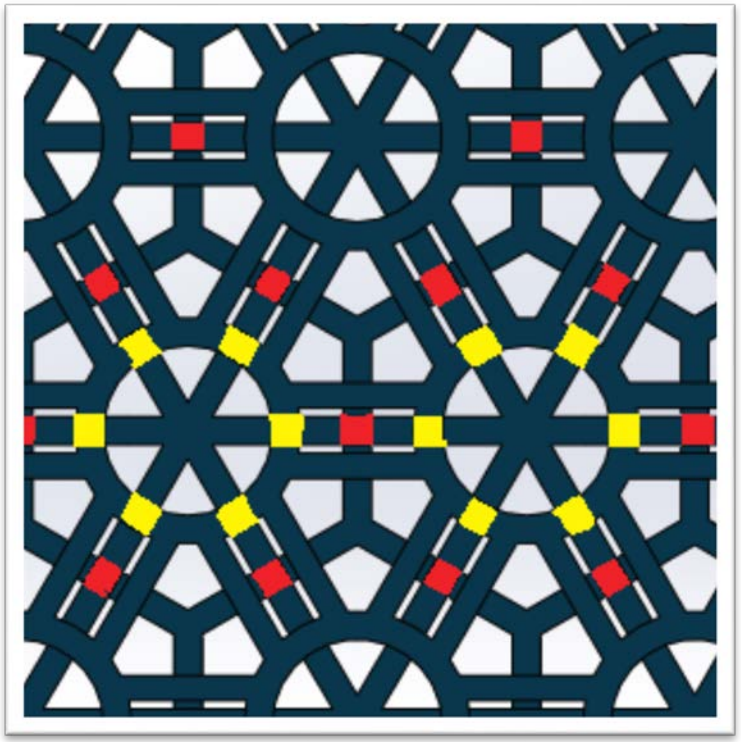
Dot Pattern

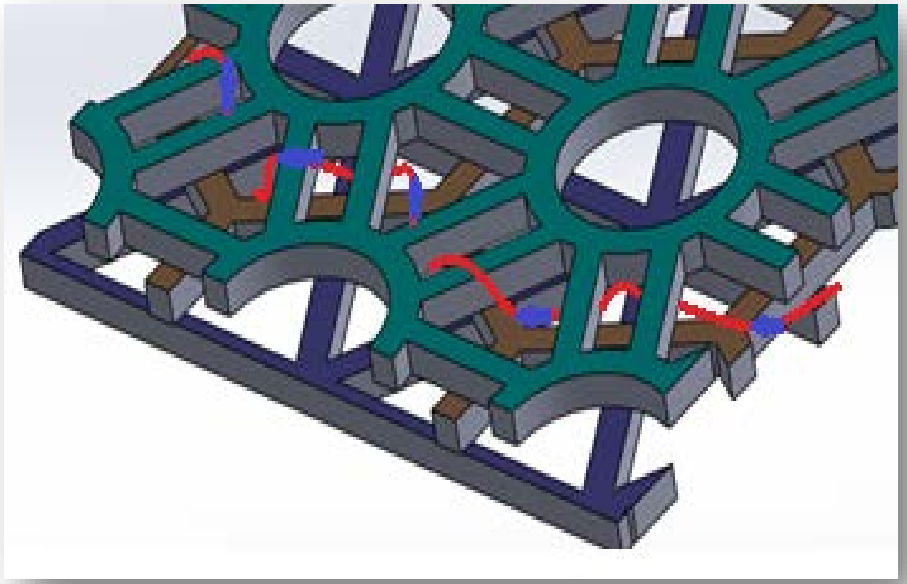


Rectangle Pattern



Multi-layer Testing



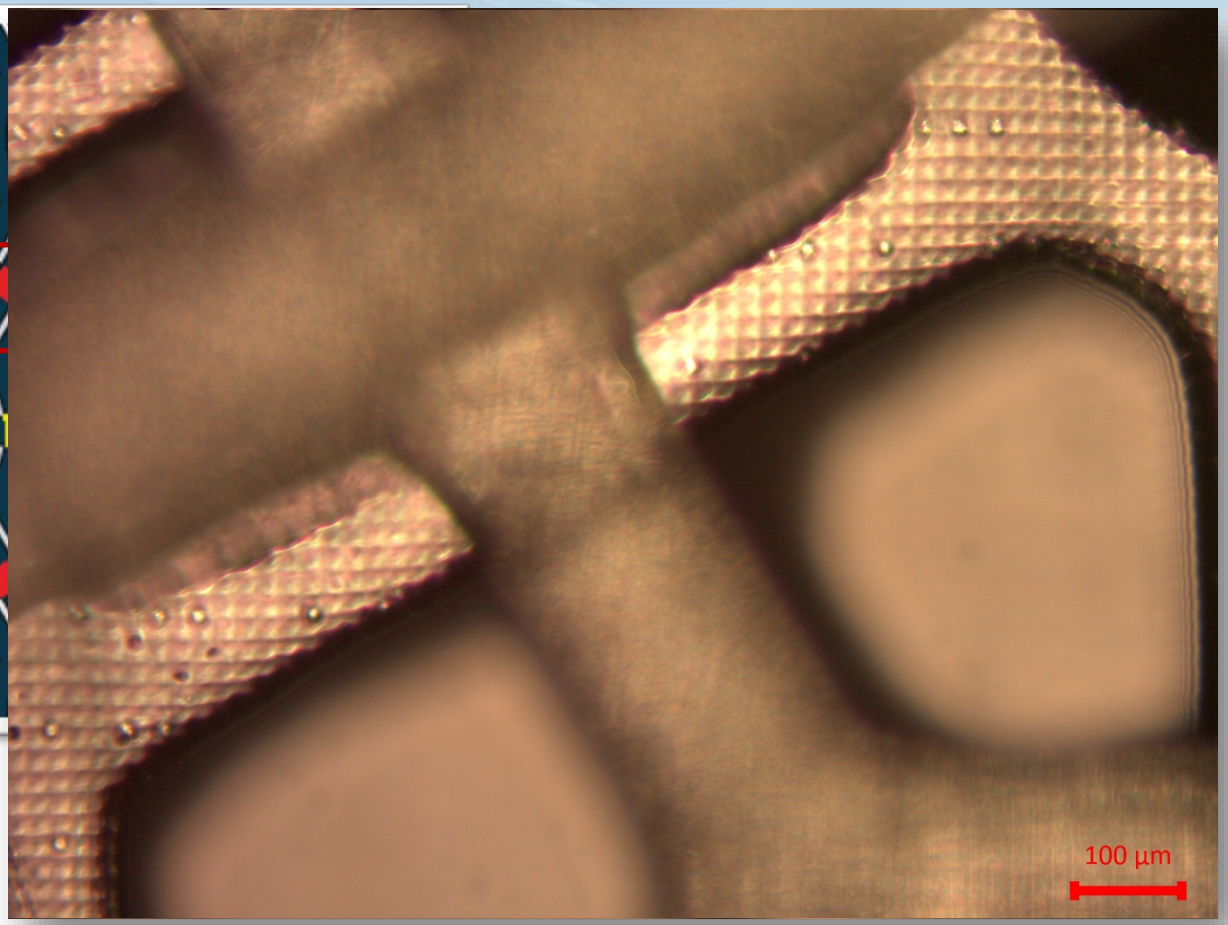


Layer thickness: 0.3 mm

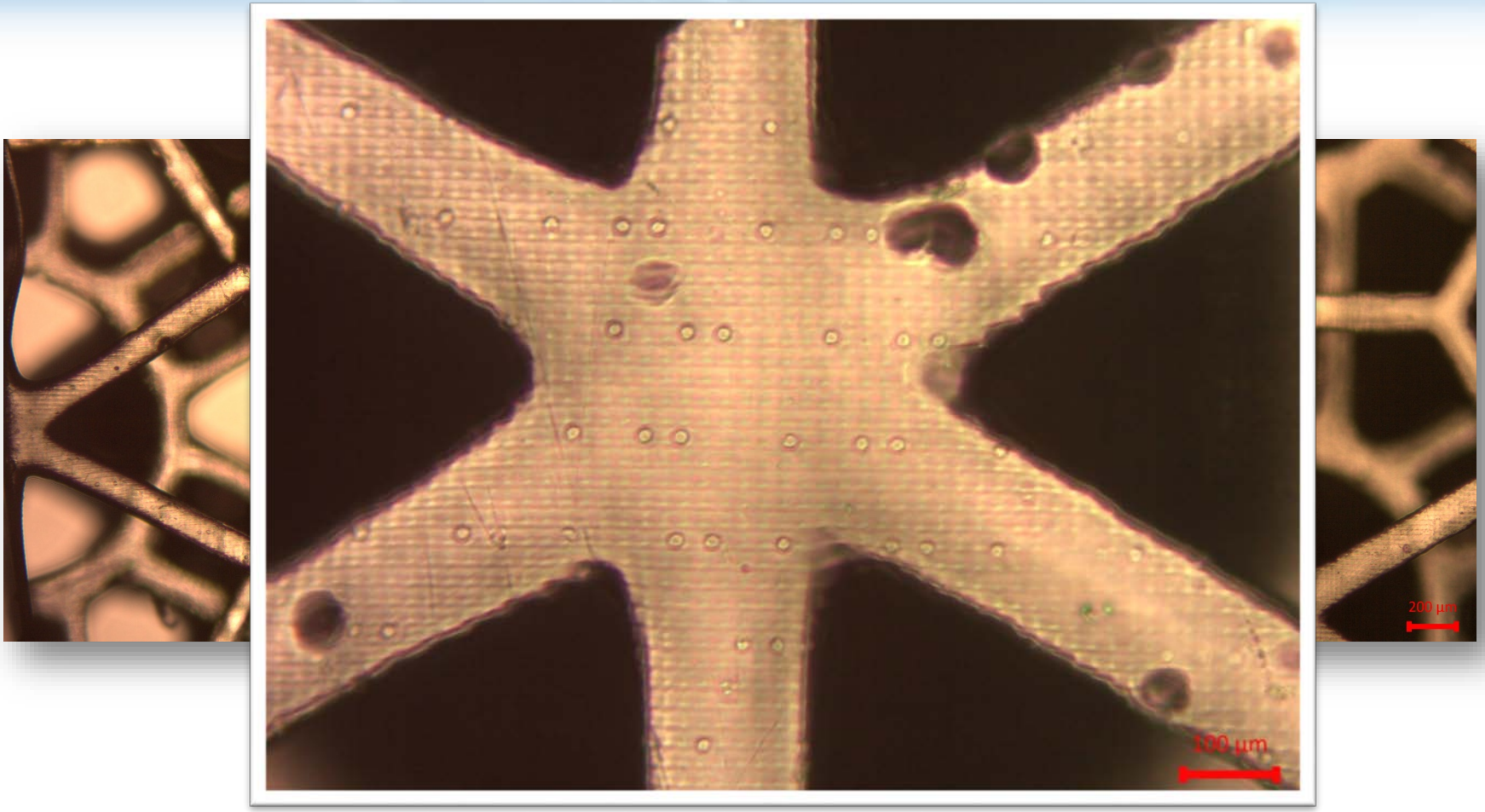
Curing time/layer: 10 sec

3 layers as a pattern cycle

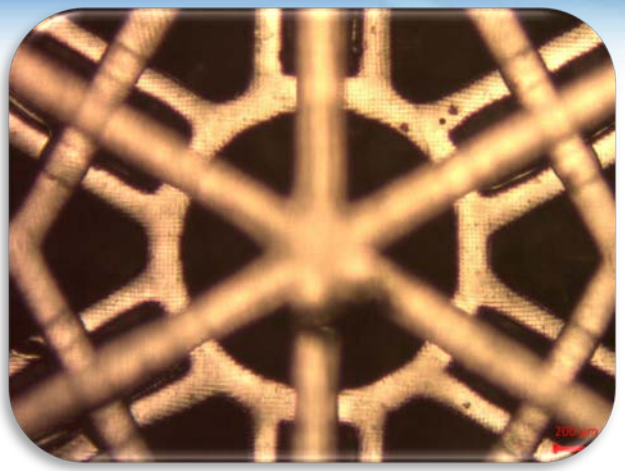
Results– 3 Layers

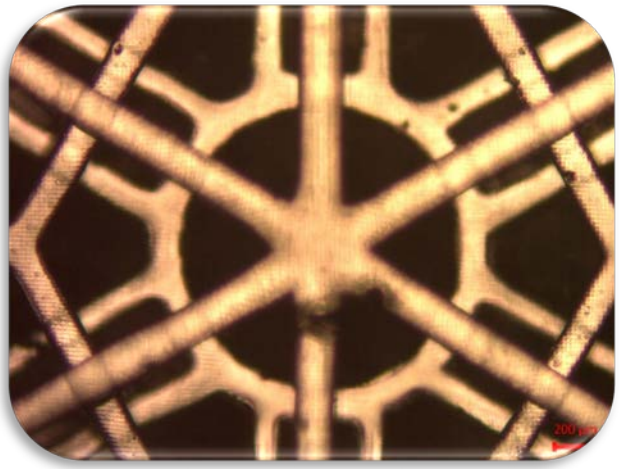


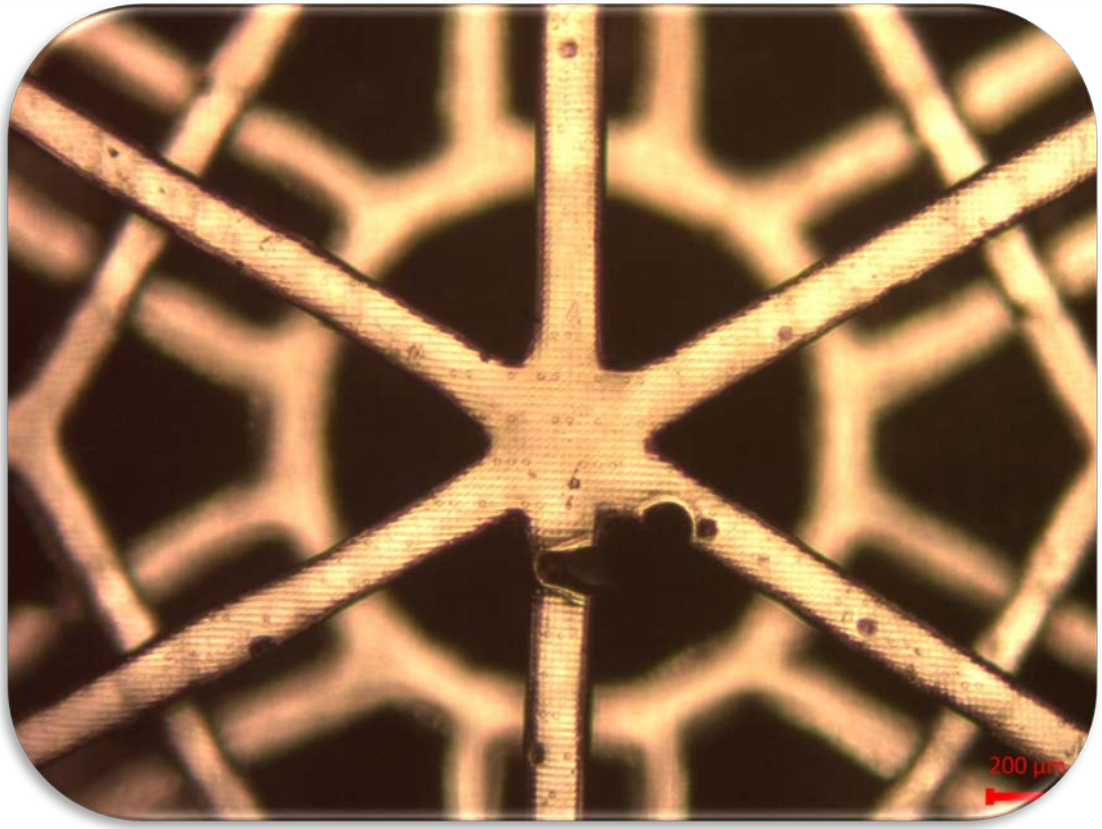
Results– 6 Layers



Results– 9 Layers







Conclusions

- Studying on applying micro-pattern into biomedical application – tissue engineering scaffold fabrication
- Micro-pattern transfers to PDMS and biomaterial are feasible!
- Two types of patterns were studied.

Future works:

- Design of different micro-patterns
- Adding PCL-DA into the material system w/o acetone
- Cell culturing tests to understand the effects of existence of micro-patterns
- Use the micro-patterns generated by this integrated project.


Thanks For Your Attention!