中文摘要

本研究旨在設計和實現一種基於針孔陣列與智慧型手機的可攜式低成本共焦顯微鏡系統。反射式共焦顯微鏡體積龐大且成本較高昂，而高亮度 LED 與智慧型手機的普及和技術進步為我們提供了一個創新且經濟實惠的解決方案。利用針孔陣列技術，本系統能夠在沒有機械掃描裝置的情況下實現掃描和濾波功能，從而達到三維表面成像的效果。該系統通過智慧型手機進行即時成像，更容易觀測樣品感興趣的位置及無線傳輸數據，有效降低了成本和系統的複雜性。

研究結果顯示，這種新型可攜式共焦顯微鏡在教學、醫療和工業檢測等領域具有廣泛的應用潛力。其低成本和可攜性使其特別適合在資源有限的環境中使用，並有助於推廣先進的顯微成像技術。通過本研究，我們展示了如何將前沿的光學技術與現代手機相結合，為共焦顯微鏡的應用開闢了新的可能性。

關鍵字：針孔陣列、共焦顯微鏡、智慧型手機共焦顯微鏡、低成本、可攜式。

Master thesis

Portable Low-Cost Confocal Microscope Based on Pinhole Array and Smartphone

Presenter: Xuan-Ran, Wang**(王昡然)**

Collaborator:

Thesis Advisor: Prof. Ming-Che Chan 詹明哲

Thesis Advisor: Prof. Zu-Po Yang 楊斯博

ω *Photonic-Diagnosis LAB, NYCU, Taiwan*

Introduction

Advantage

- **Optical sectioning**.
- High resolution.
- Blocking defocused.
- Scattered light.
- Depth imaging.

Disadvantage

- **Bulky system**.
- **High cost**.

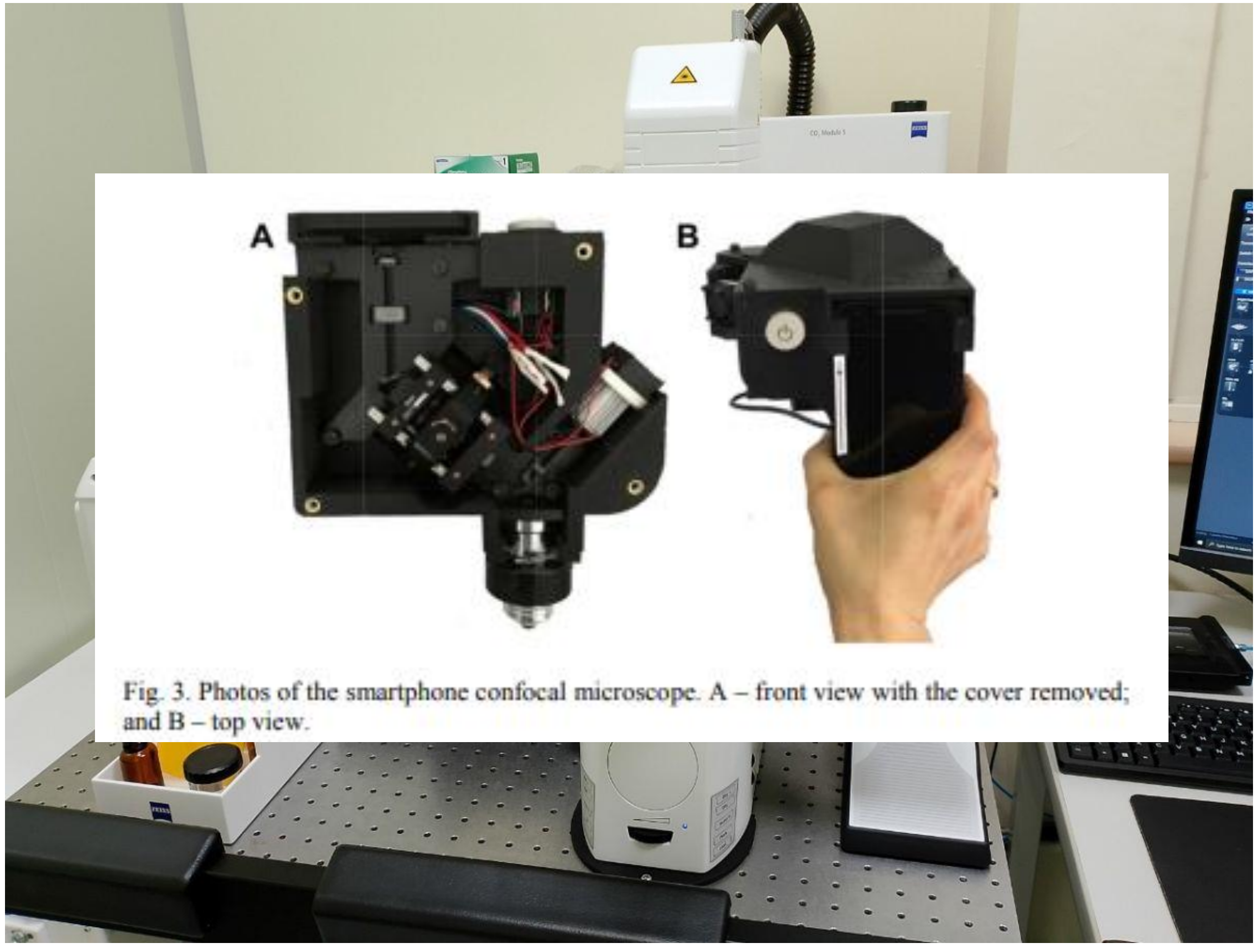


Fig. 3. Photos of the smartphone confocal microscope. A – front view with the cover removed; and B – top view.

US350,000=NTD10,000,000

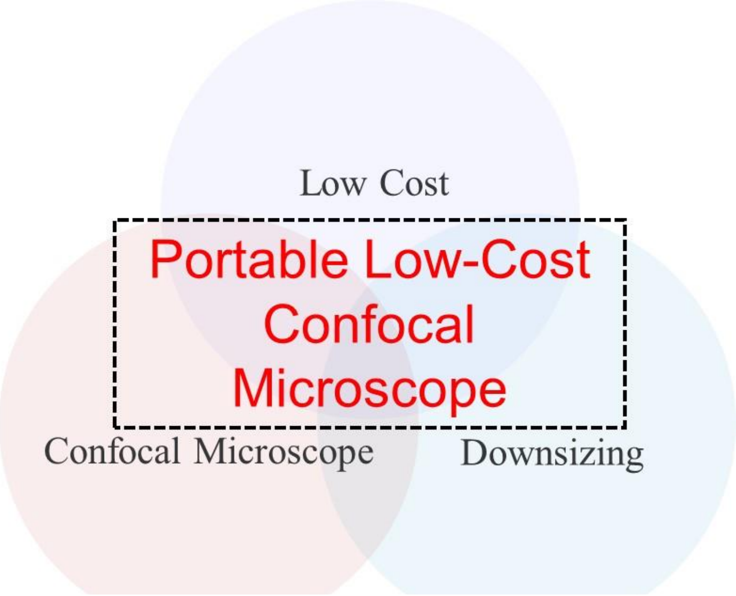
Conclusion

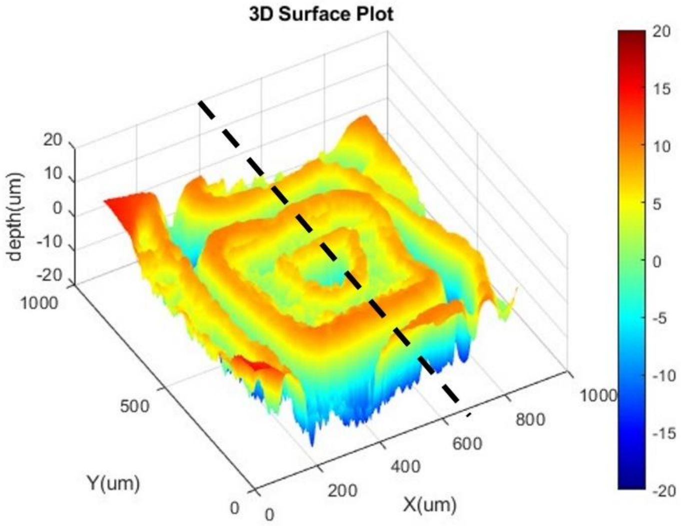
limitation

The cost is approximately NTD 60,000 .

- Without ambient light
- Image need to be aligned
- Two smartphone

Components	NTD
Lens*4	2870
DMLP567	6000
FGL495	1300
EBS1	1150
Optomechanical components	22000
Smartphone*2	10600
Objective lens	14420
Total	58340





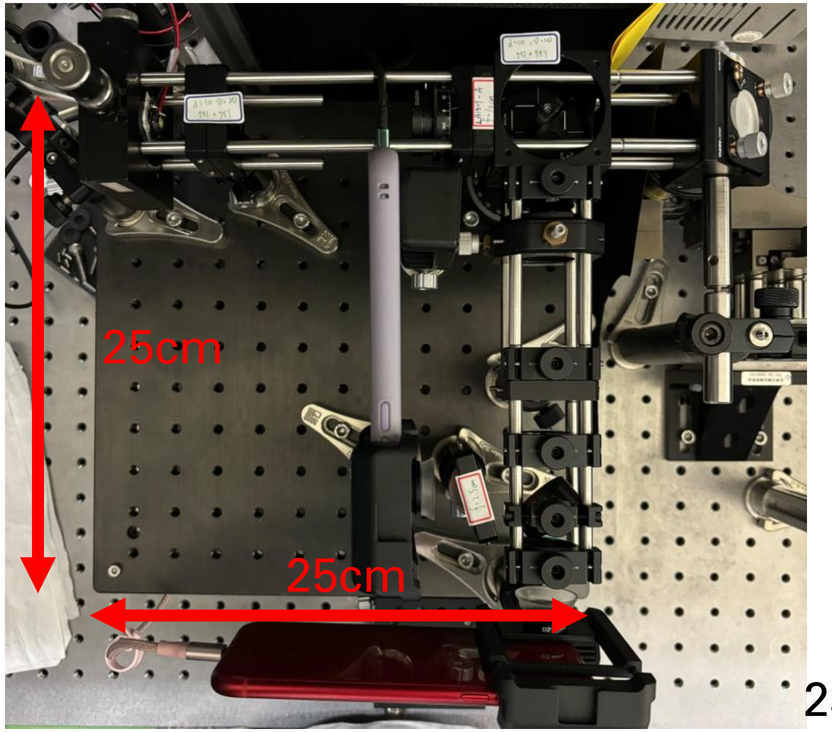
Resolution

Horizontal Resolution of 20X is 2.19 um.

Theoretical Resolution of 20X is 1.99 um.

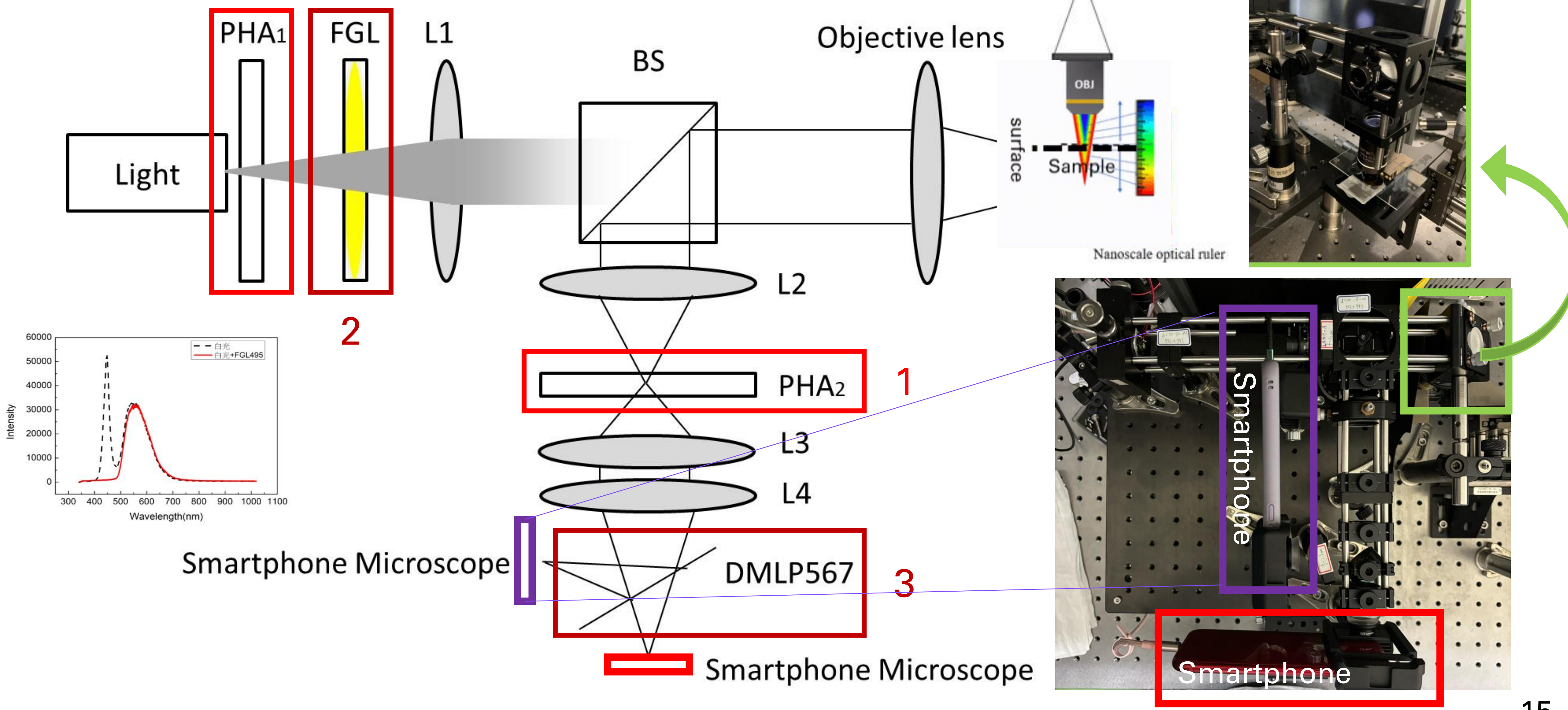
Vertical sensitivity of 20X is 0.5 um.

Portable Confocal Microscope



Confocal microscopy theory

Pinhole array confocal microscope



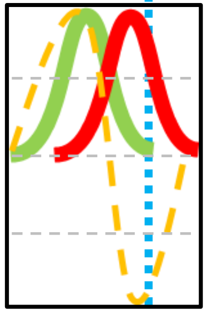
Master thesis Outline

- Introduction & Conclusion
- Theory
- Experimental process
- Results

Experimental process

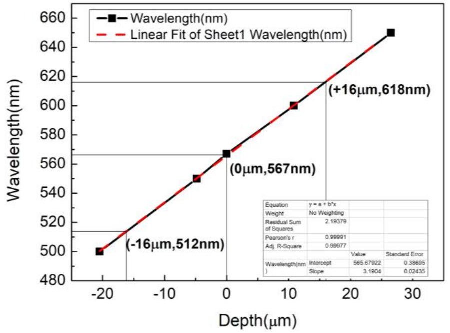
Part1:Image process

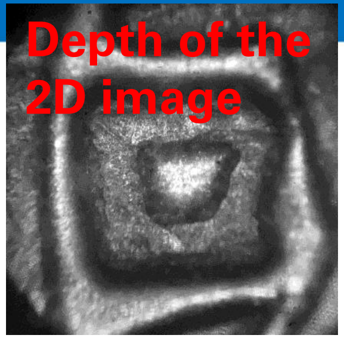
Obtain a 2D image stack. → **Align the transmission and reflection image stacks.** → **Select the region where the pinhole is clear, plot the z-axis curve to obtain the 1D longitudinal response curve.** → **Normalize each image stack, then subtract them to obtain the slope of the linear region.**

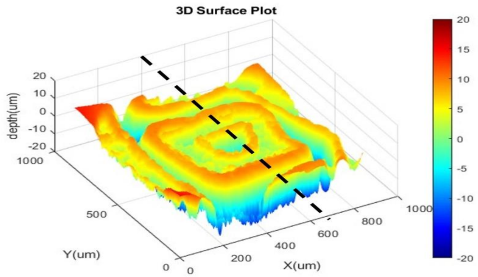


Part2:

→ **Establish a calibration curve.** → Divide the image's light intensity by the slope of the linear region to convert it into depth information. → Use MATLAB for 3D rendering to visualize the data and calculation results for analysis and interpretation.







Experimental process

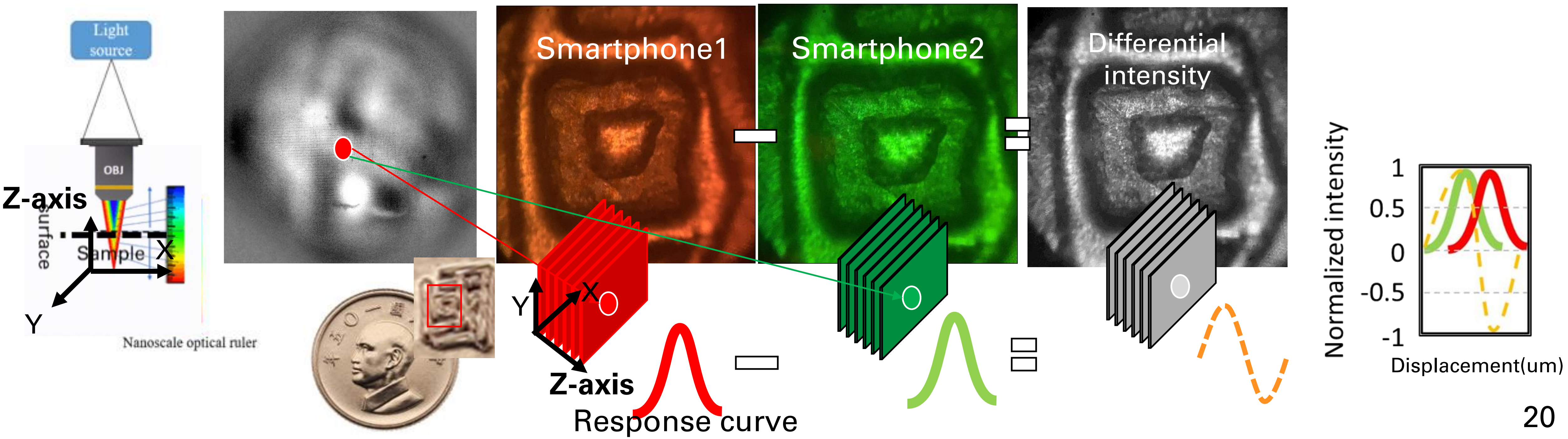
Part1

Obtain a 2D image stack.

Align the transmission and reflection image stacks.

Select the region where the pinhole is clear, plot the z-axis curve to obtain the 1D longitudinal response curve.

Normalize each image stack, then subtract them to obtain the slope of the linear region.



Experimental process

Part2

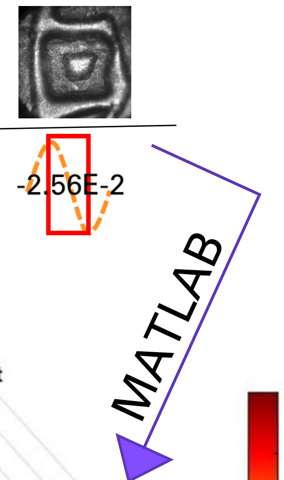
Establish a calibration curve.

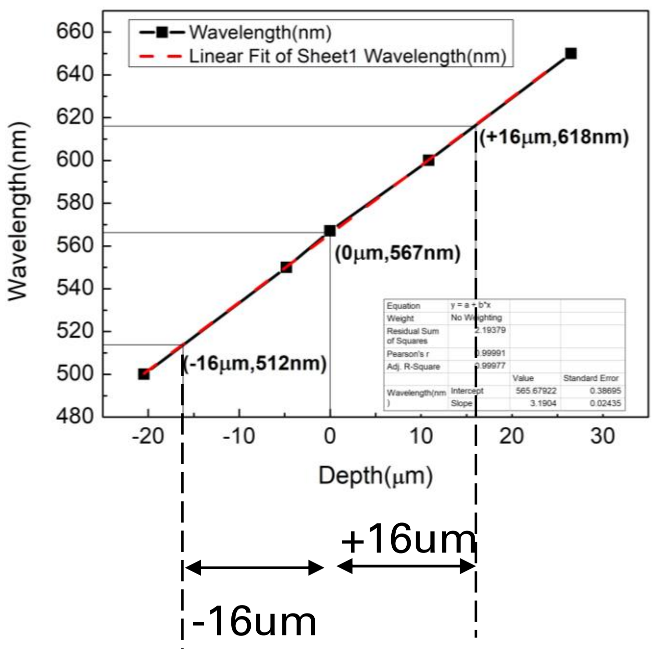
Divide the image's light intensity by the slope of the linear region to convert it into depth information.

Use MATLAB for 3D rendering to visualize the data and calculation results for analysis and interpretation.

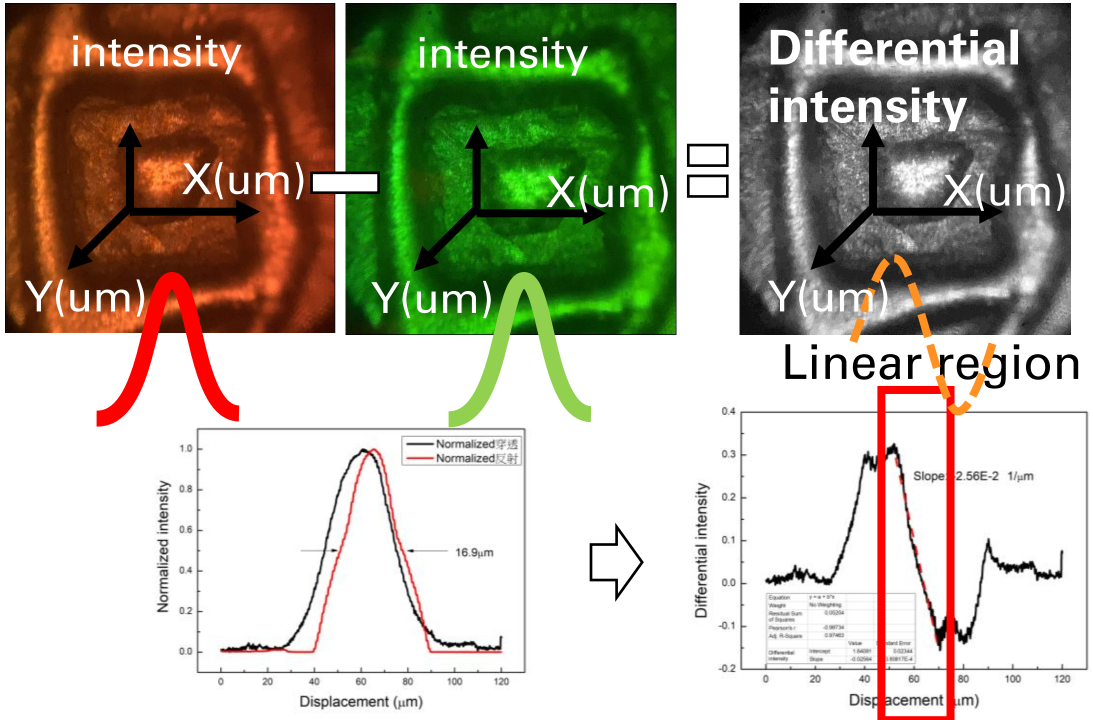
Depth of 2D image:

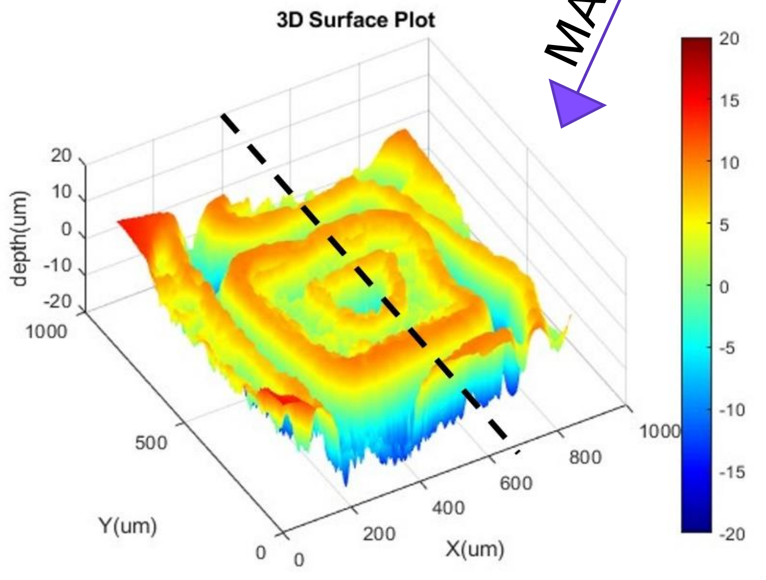
$$\frac{Differential\ intensity}{slope(\frac{Differential\ intensity}{depth})}$$





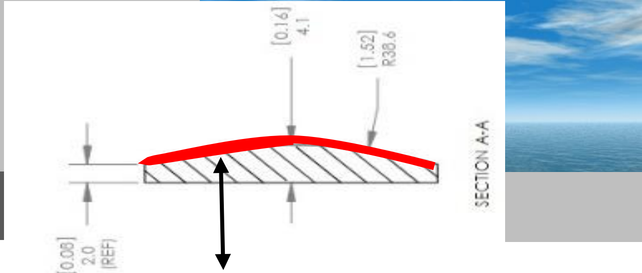
Valid range



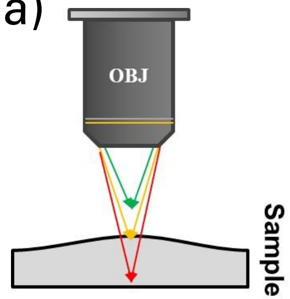


Slope:-2.56E-2
(differential intensity/depth)

Experimental results-Tunable lens

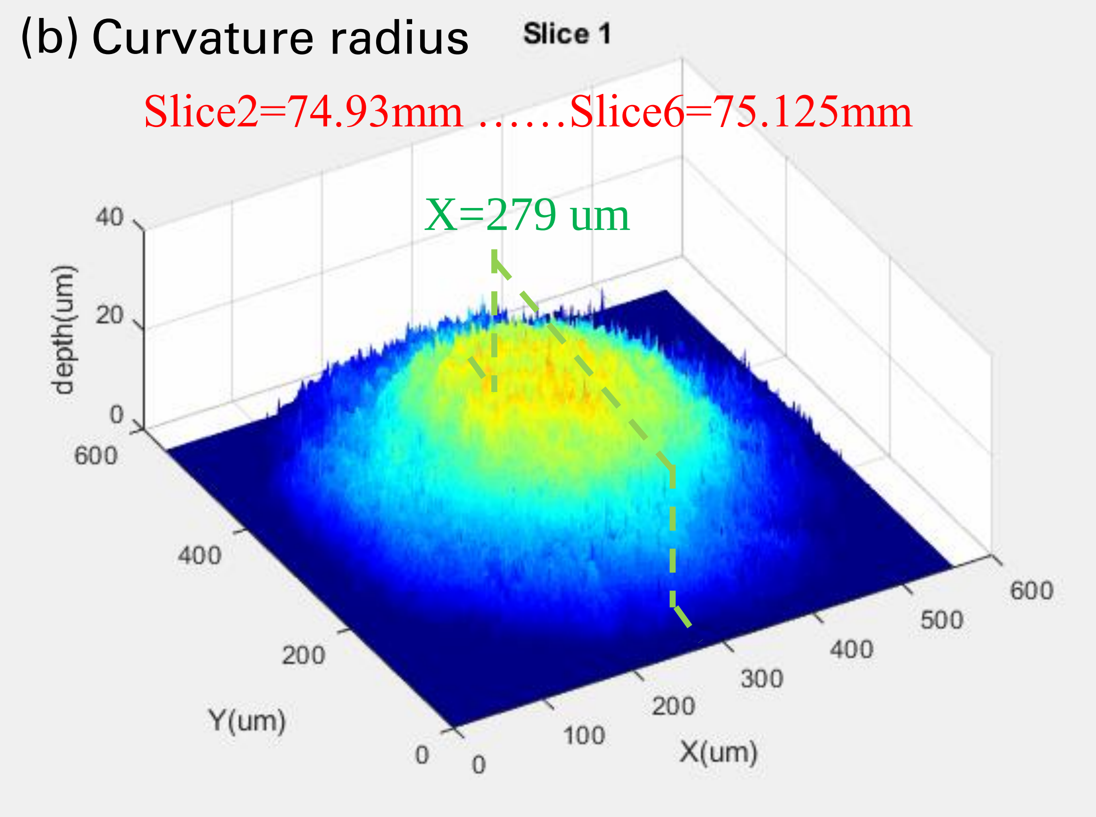


(a)



I(mA)	111.06	114.88	115.02	115.16	115.3	115.44	119.21
Focal length(mm)	76.49	75.125	75.07	75.02	74.978	74.93	73.65
Surface change(um)	-16.18um (2899.06)	-1.11um (2914.13)	-0.55um (2914.69)	0um (2915.24)	0.55um (2915.79)	1.1um (2916.34)	15.97um (2931.21)

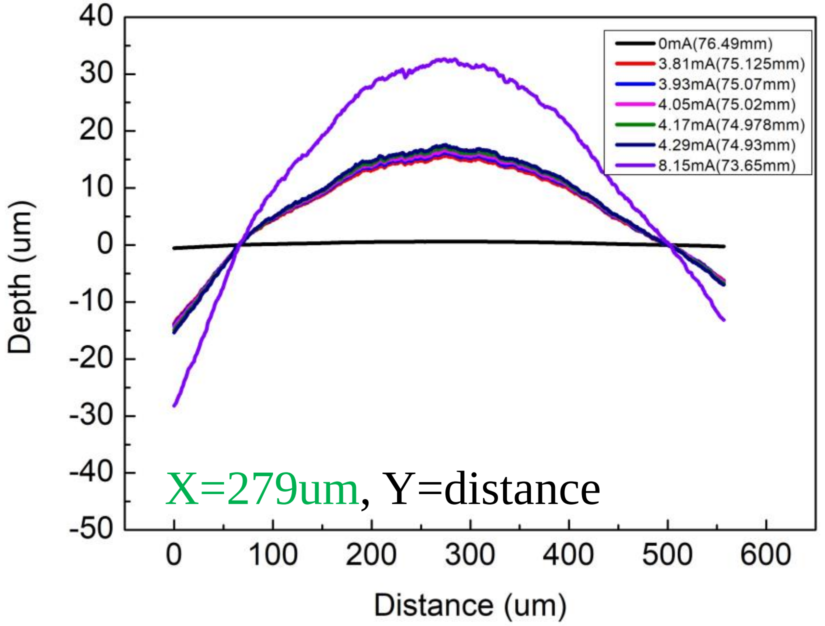
(b) Curvature radius



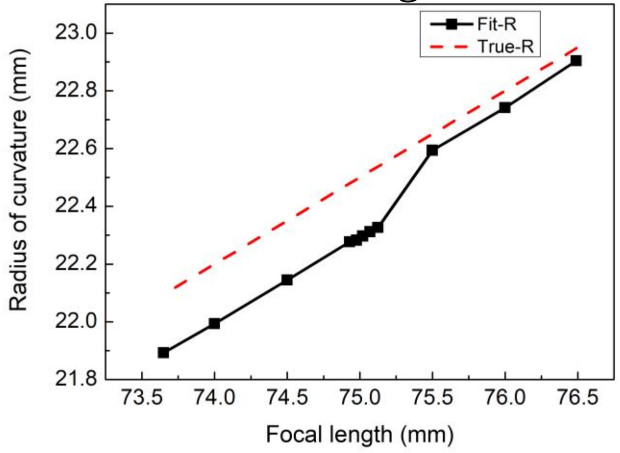
thick lens equation

$f = R/(n-1)$

(c) Curvature radius



Fitting



Residual