Roberval Laboratory

3D-vision method for robust inline inspection by combining complementary shape measurement principles

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Supervisors : Erwan Dupont, Hani Al Hajjar, Frédéric Lamarque

Outline

Research background

In the field of optical metrology

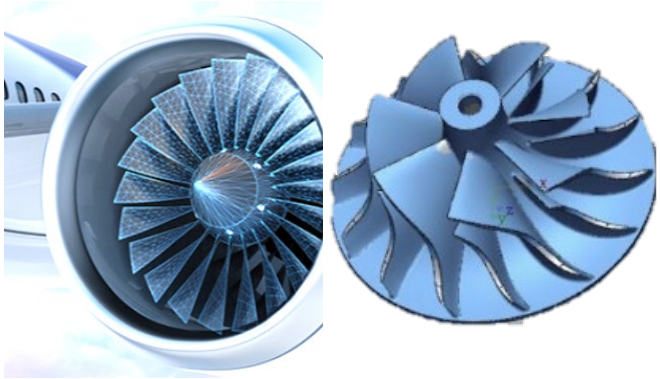
1. Introduction
2. n°1: Proposed Adapted SFF method
3. n°2: Proposed All-in-focus 3D measurement method
4. n°3: Proposed Specular-SFF method
5. n°4: Research on Frequency Domain Filter in FTP

1. Introduction

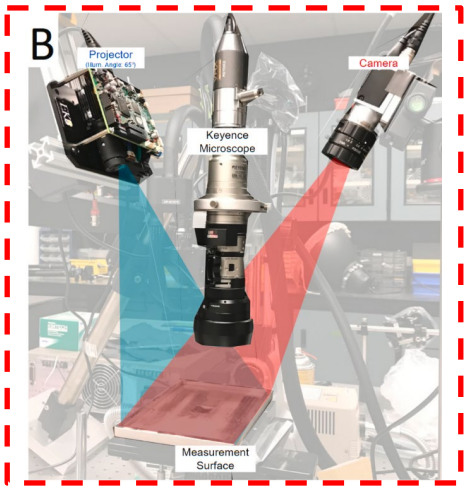
Applications of optical metrology

Reverse engineering
(CREAFROM Co.)

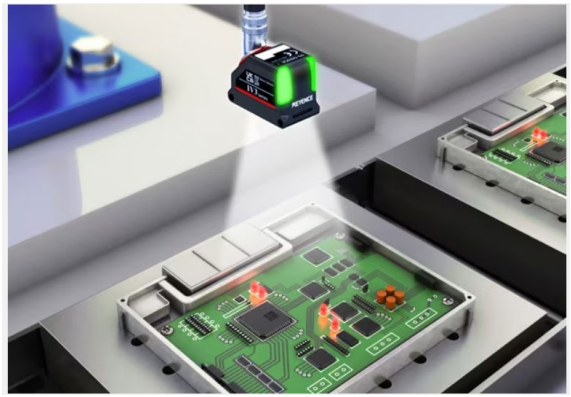
3D intraoral scanning
(Dental Wings Co.)



Aircraft rotor inspection
(Shining 3D Co.)



Additive manufacturing
(O'Dowd et al.)



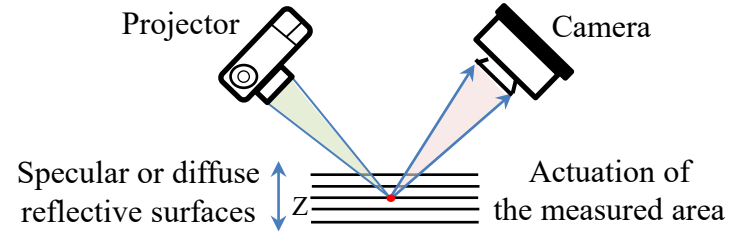
Electronic devices inspection
(KEYENCE Co.)

Education: Prehistoric sculpture reconstruction
(Shining 3D Co.)

1. Introduction

SLP : Structured light profilometry
SFF : Shape from focus
PMD: Phase measurement profilometry
FTP: Fourier transform profilometry
AIF : All-in-focus
DOF: Depth of field

A device combining active stereo vision and a z-axis actuator



3D with FTP
-Phase measurement
-Structured light
-No actuation
-Fourier transform
-Diffuse surfaces

3D with SFF
-Focus measurement
-Actuation
-Diffuse surfaces

Enlarge the DOF
Provide textures

3D with SLP
-Phase measurement
-Structured light
-No actuation
-Diffuse surfaces

Phase information

PMD
-Slope measurement
-Structured light
-Reflective surfaces

SFF: actuation and focused measurement

SLP: calibration data of camera/projector

PMD: calibration data for specular surface

SFF: focus measurement

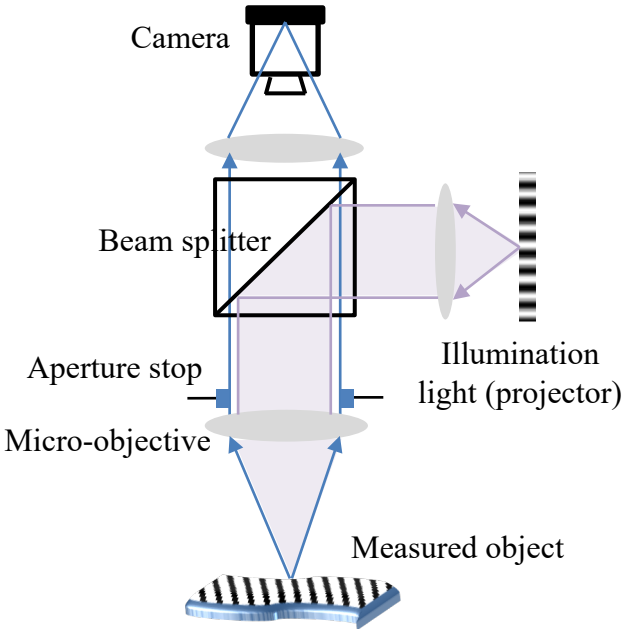
SLP: depth maps measurement

Two progress by combining SLP and SFF
1. Applied SFF to SLP context (Adapted SFF method)
2. Generated an all-in-focus 3D point cloud (AIF method)

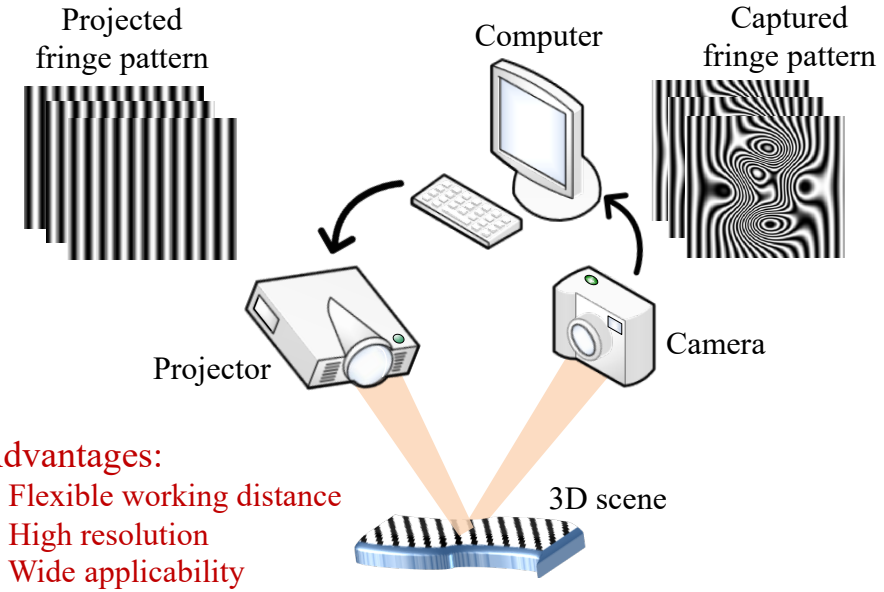
3D with specular-SFF(Combine SLP, SFF and PMD)
1. Focused point measurement
2. Structured light
3. Actuation
4. Diffuse and specular Reflective surfaces

1. Summary of research background

Measurement configuration and fringe pattern

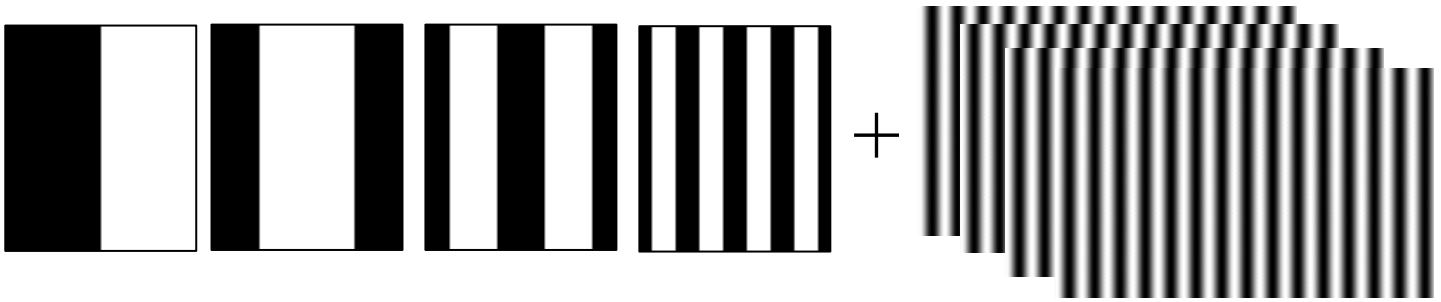


Coaxial configuration



Advantages:
1. Flexible working distance
2. High resolution
3. Wide applicability

Triangulation configuration



Hybrid methods

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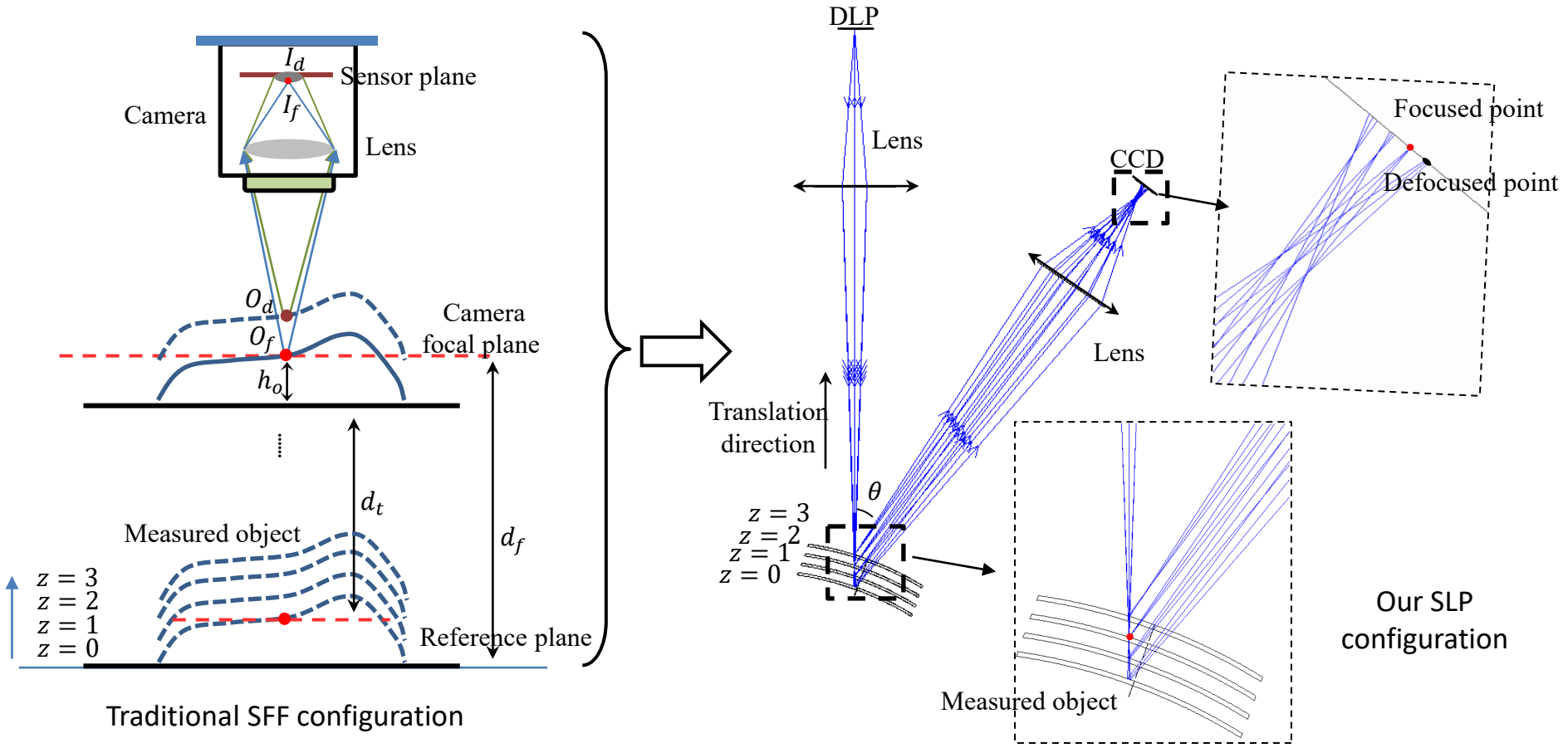
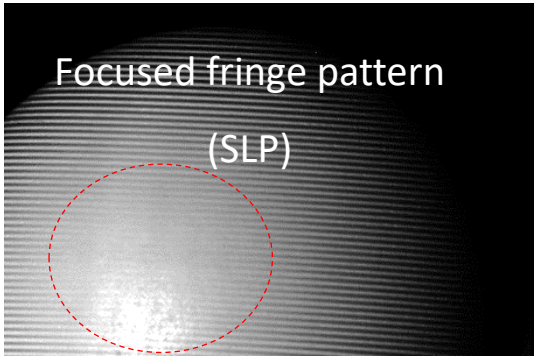
nº1: Proposed Adapted SFF method

Applying SFF to SLP measurement configurations

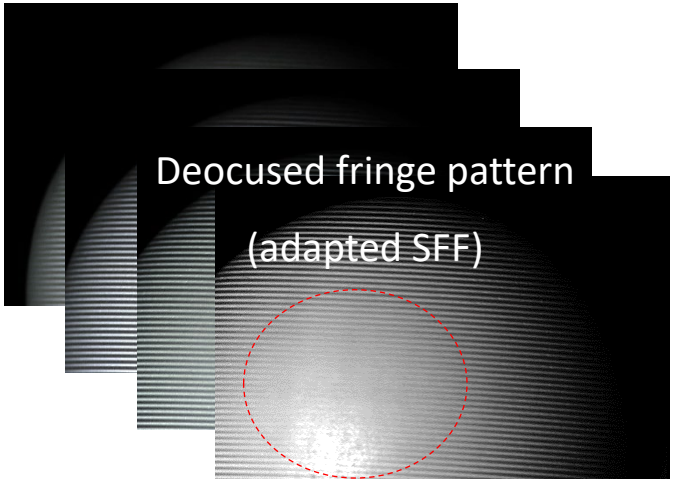


nº1: Proposed Adapted SFF method

Diameter: 20mm

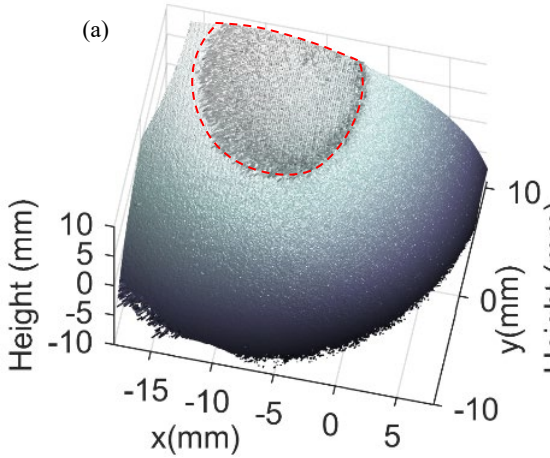


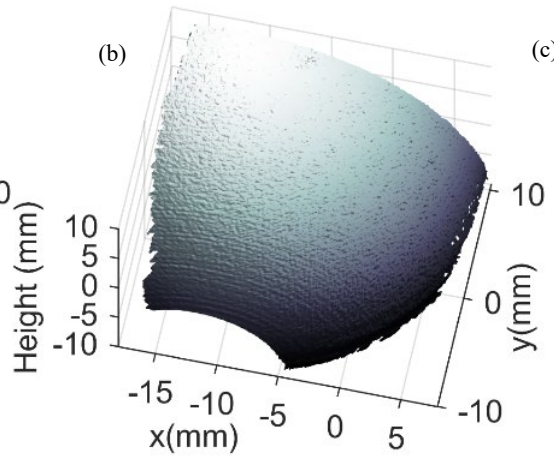
Blurred area



3D reconstruction using SLP

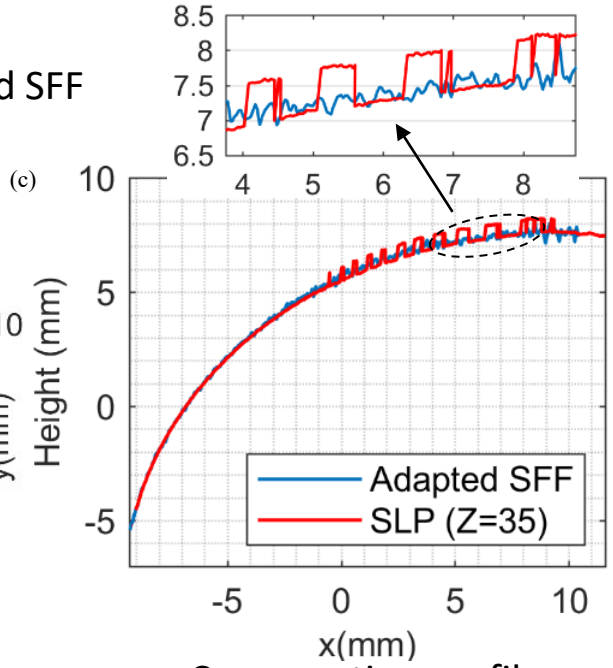
3D reconstruction using adapted SFF





Estimated radius: 20.3768 mm

Relative error: 1.89%



Cross-section profiles

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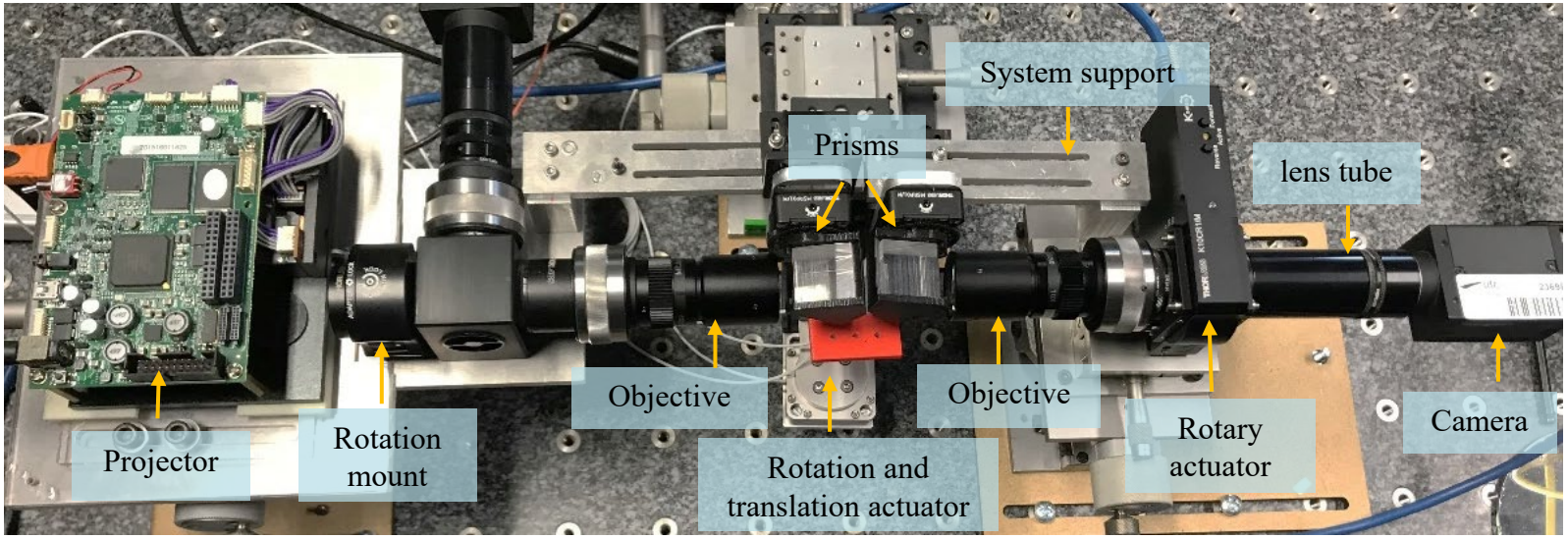
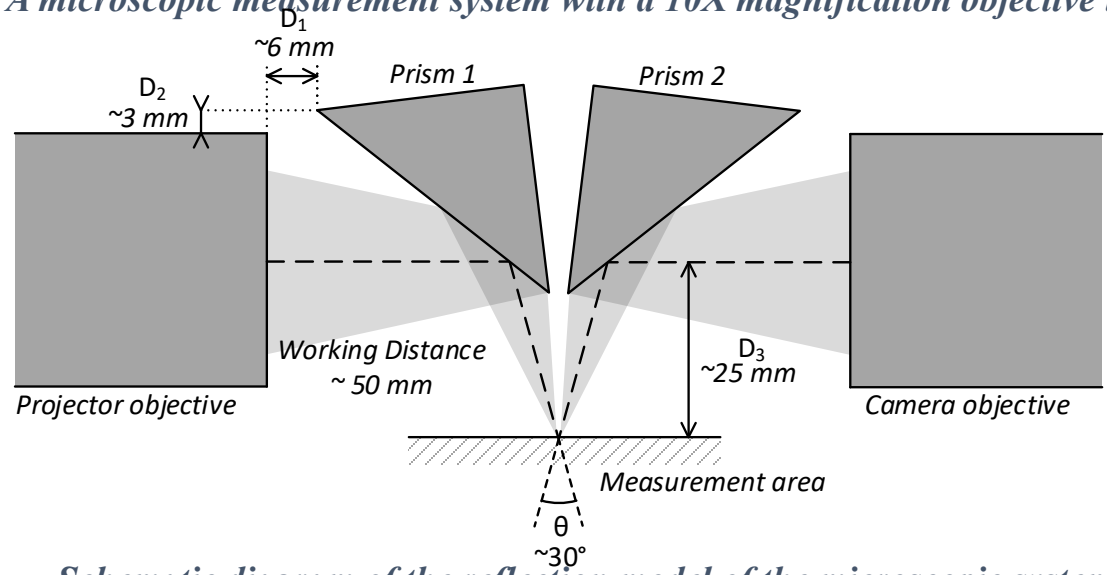
nº2: Proposed All-in-focus 3D measurement method



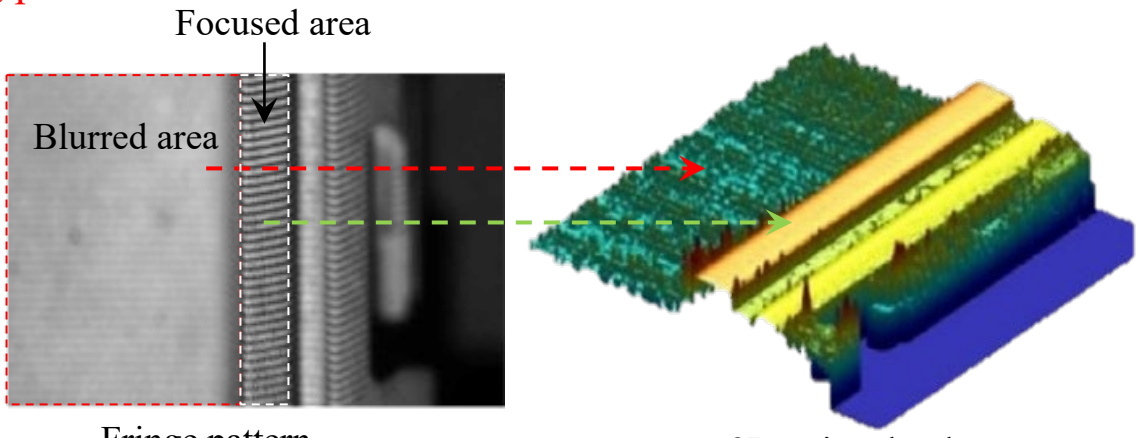
A microscopic measurement system with a 10X magnification objective lens



Schematic diagram of the reflection model of the microscopic system

nº2: Proposed All-in-focus 3D measurement method

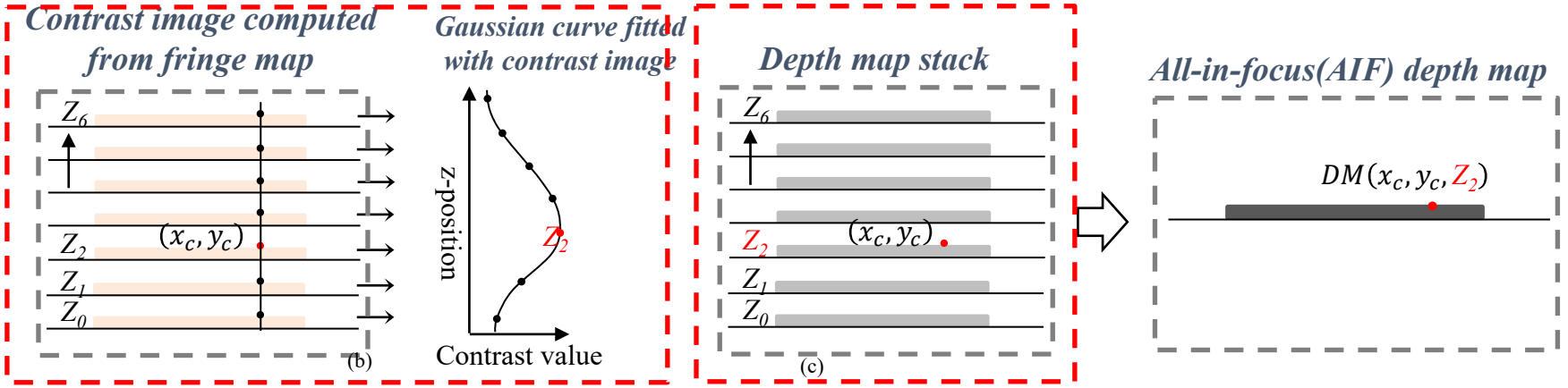
Existing problem:



*A reduced measurement range caused by **limited depth of field** (Y. Liu et al.)*

Solution to the problem:

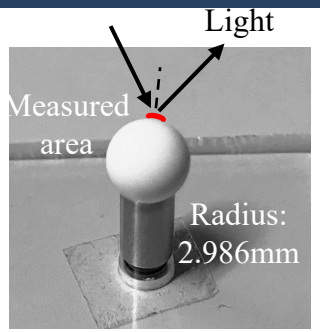
The reconstruction process of the AIF measurement method

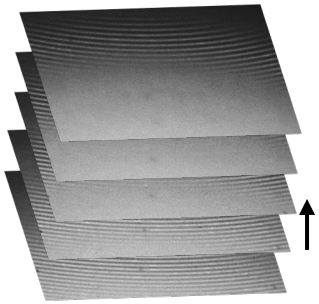


Focus detection techniques

nº2: Proposed All-in-focus 3D measurement method

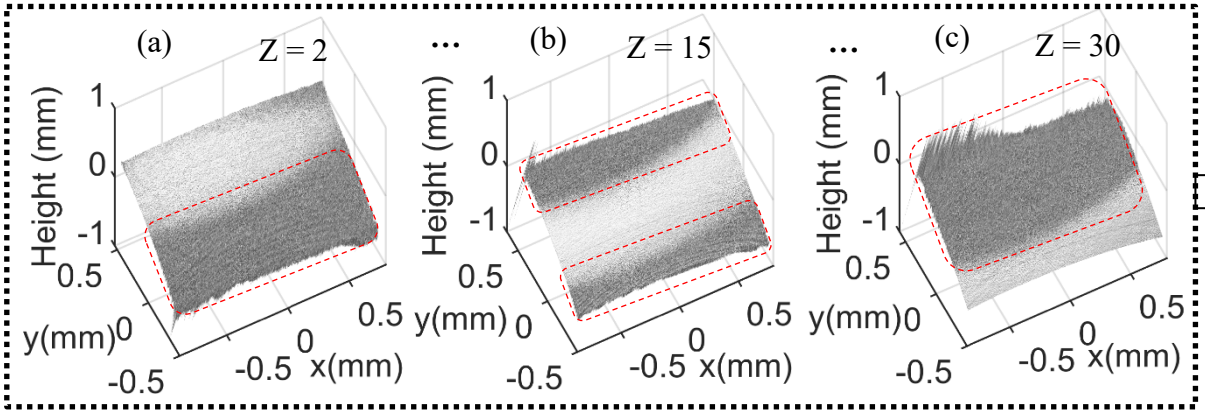
Experimental validation of the AIF measurement method

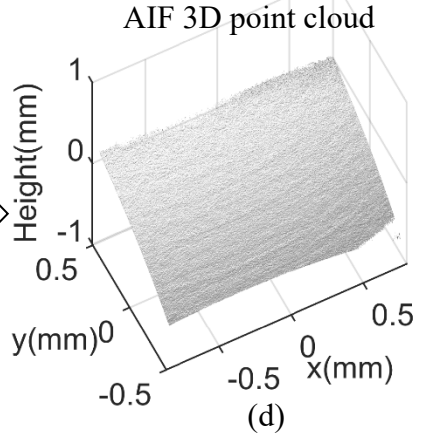




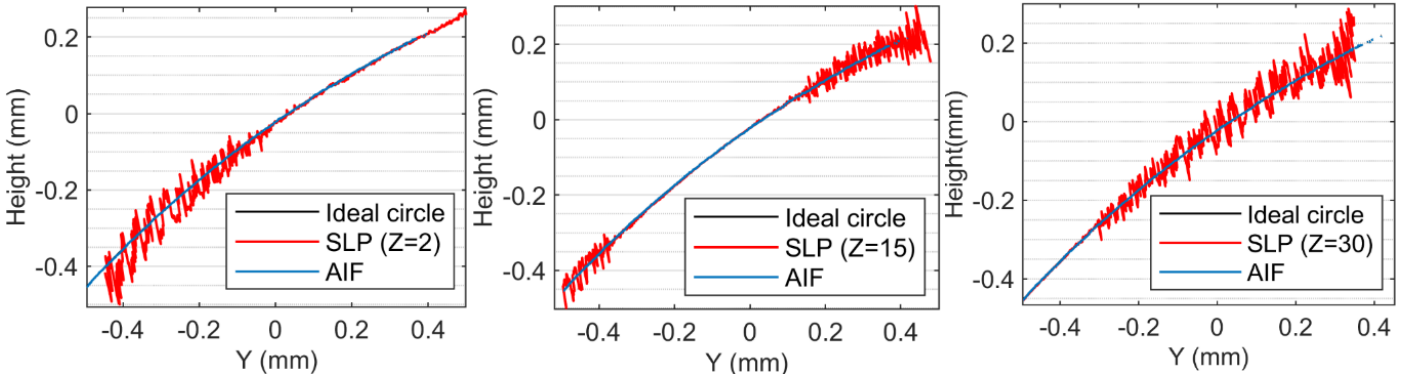
Fringe pattern stack

3D point clouds

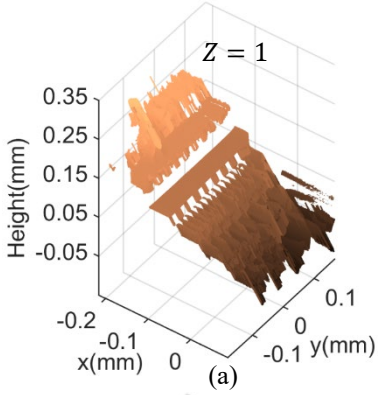


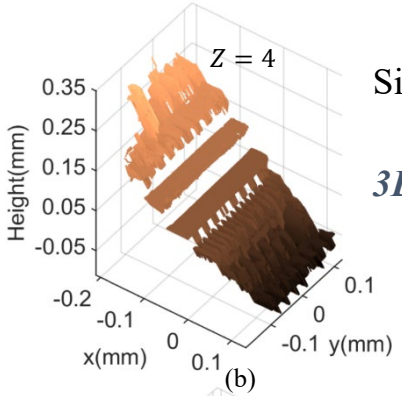


Cross-section profiles



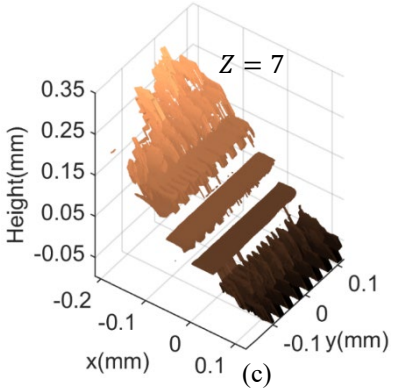
nº2: Proposed All-in-focus 3D measurement method

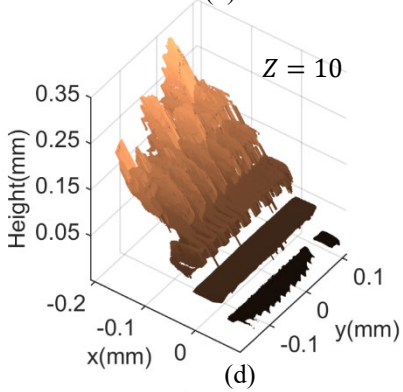




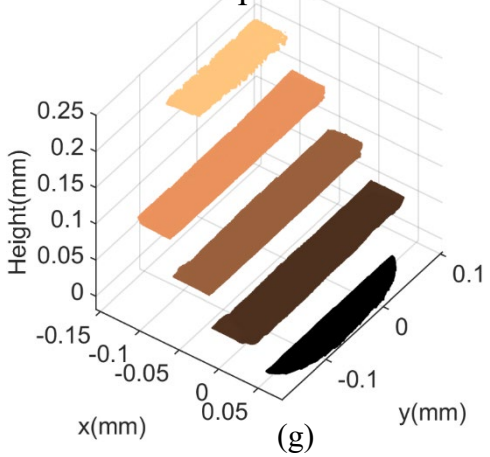
Step object
Size: 0.3mm x 0.3mm x 0.3mm

3D reconstructions used SLP at different z-position

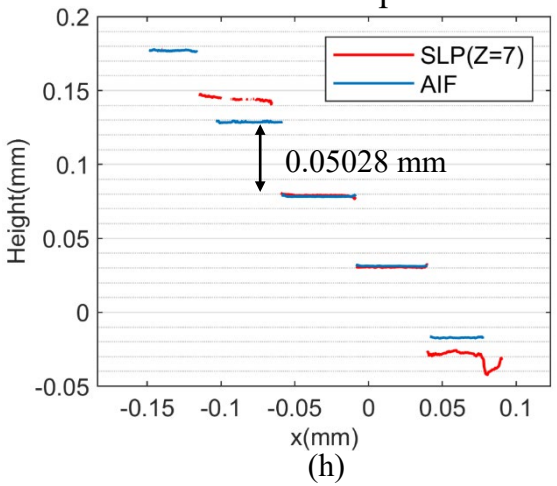


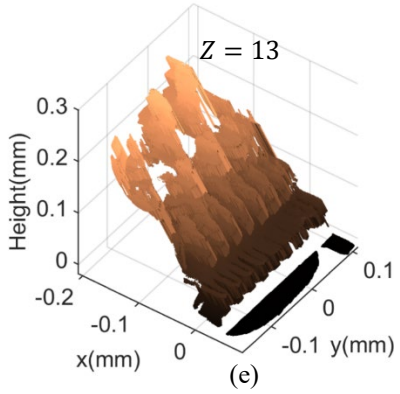


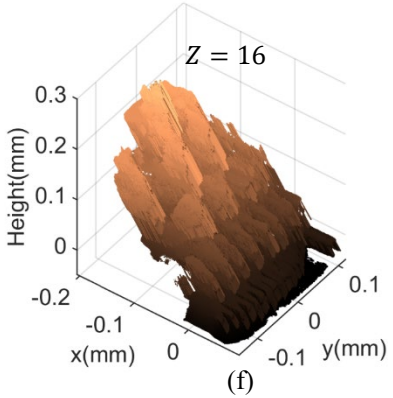
AIF 3D point cloud



Comparison of the cross-sectional profiles







Advantages:

1. Extend DOF of the system
2. High lateral resolution
3. Low cost
4. Simple principle and operation

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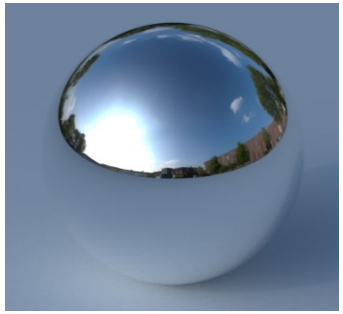
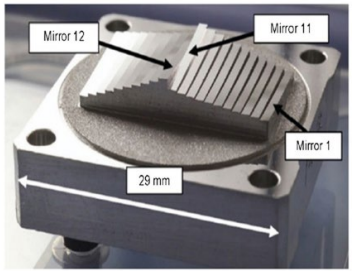
nº3: Proposed Specular-SFF method

High-reflective surfaces

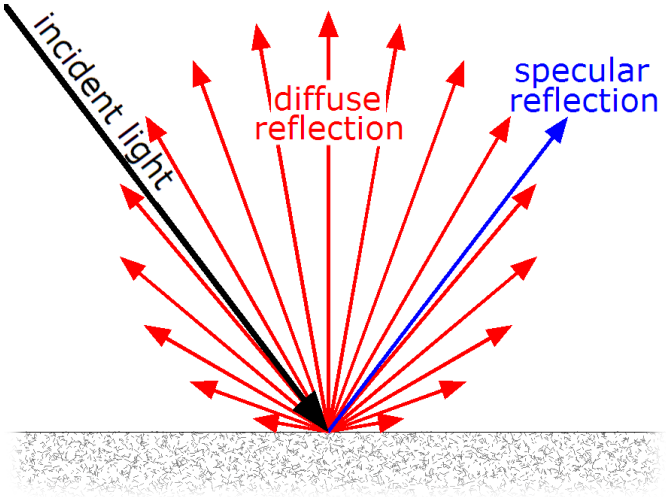


Smooth sphere

Glasses



Reflective workpiece



Schematic diagram of specular and diffuse reflections

Steel kettle

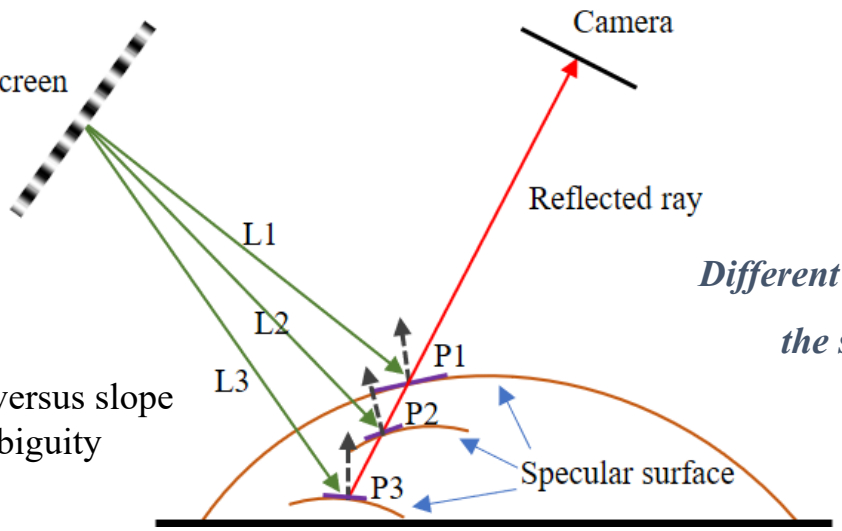
Car door

Lens

**All images above are from Google Images*

nº3: Proposed Specular-SFF method

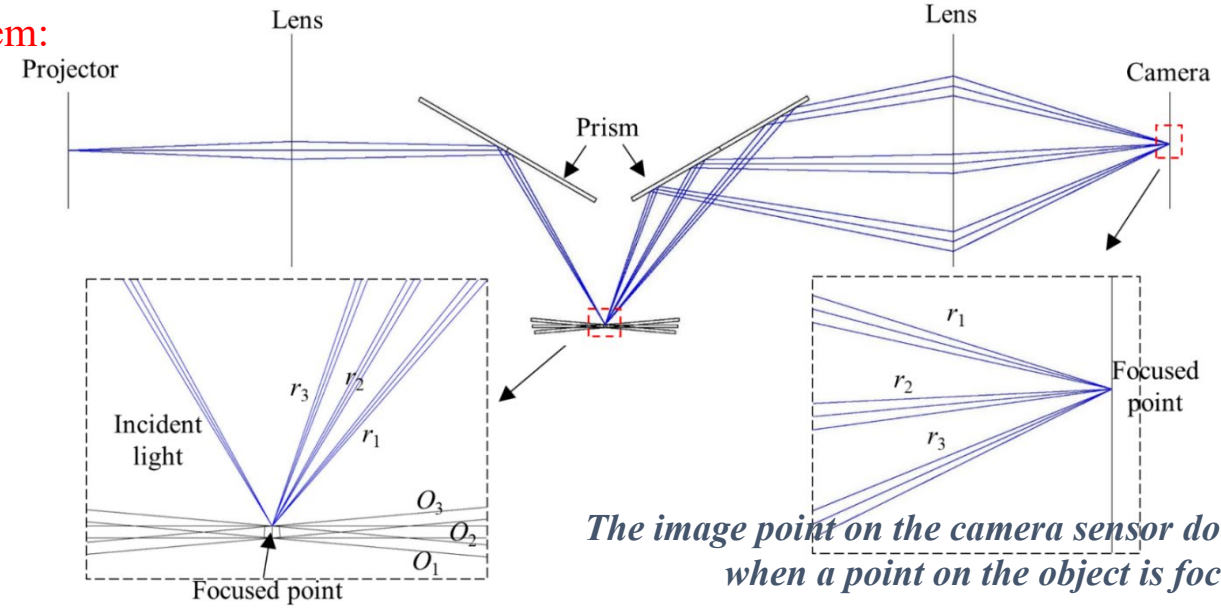
Existing problem:



Height versus slope ambiguity

Different points on an object have the same reflected light

Solution to the problem:

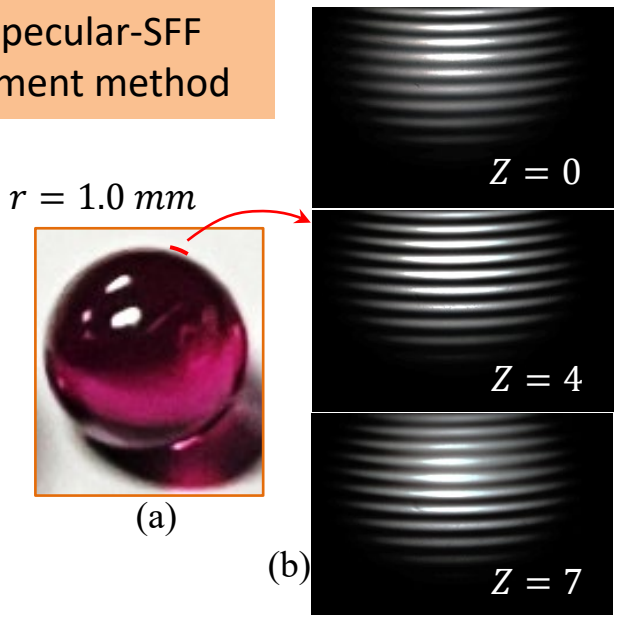


Focus invariance principle

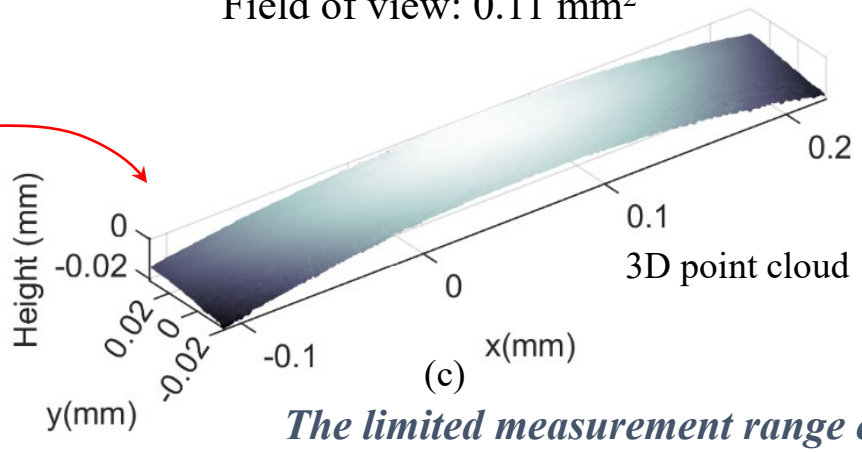
The image point on the camera sensor does not change when a point on the object is focused

nº3: Proposed Specular-SFF method

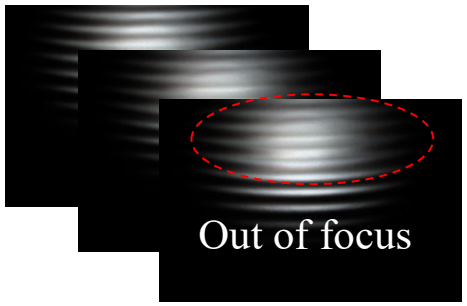
Experimental validation of the specular-SFF measurement method

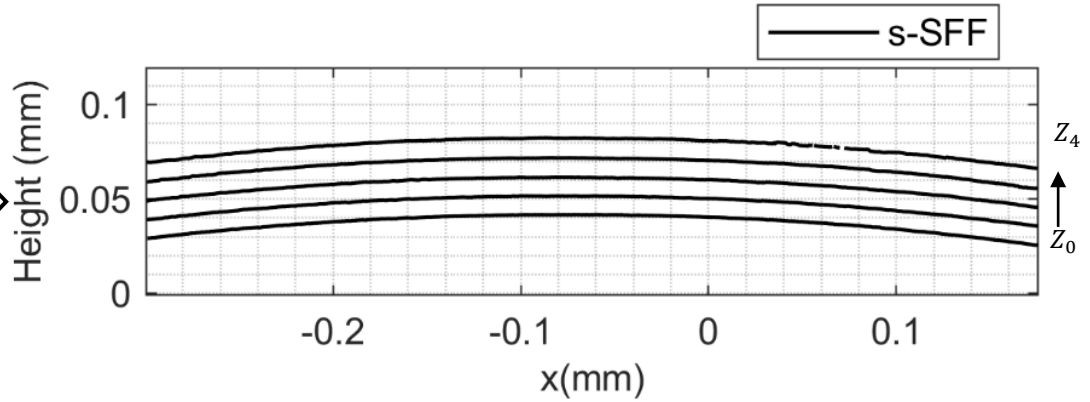


Measurement range :0.012 mm^2
Field of view: 0.11 mm^2



The limited measurement range caused by the presence of the solid angle.



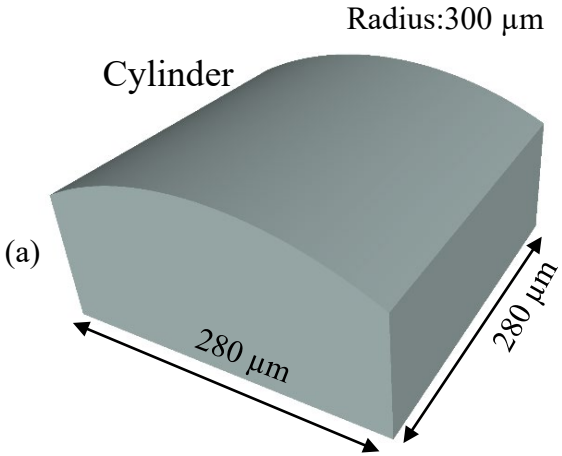


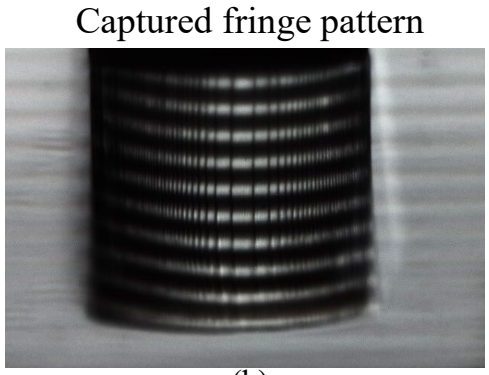
The cross-sectional profiles of the 3D point cloud using the specular-SFF technique at different z-positions, with the entire z translation distance beyond the DOF of the system

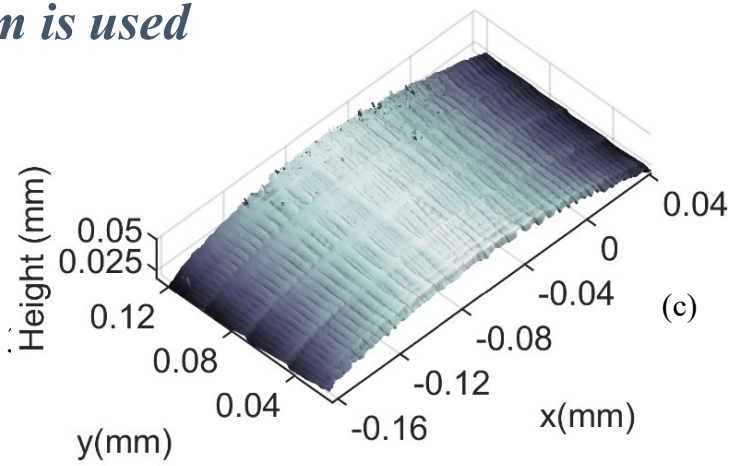
nº3: Proposed Specular-SFF method

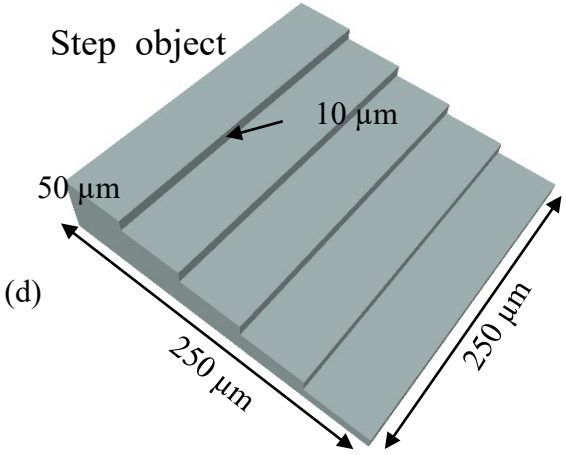
The measured object printed with **Nanoscribe ™ 3D printer**

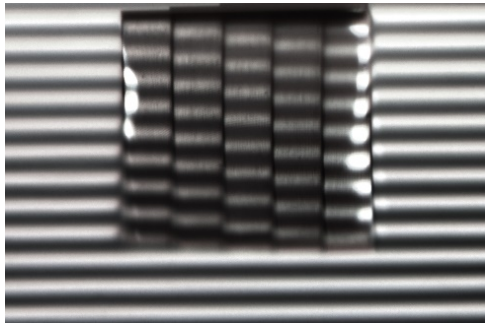
A stitching algorithm is used

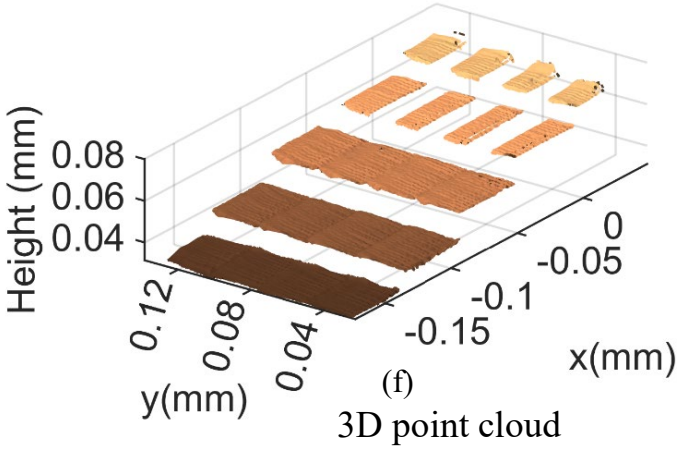












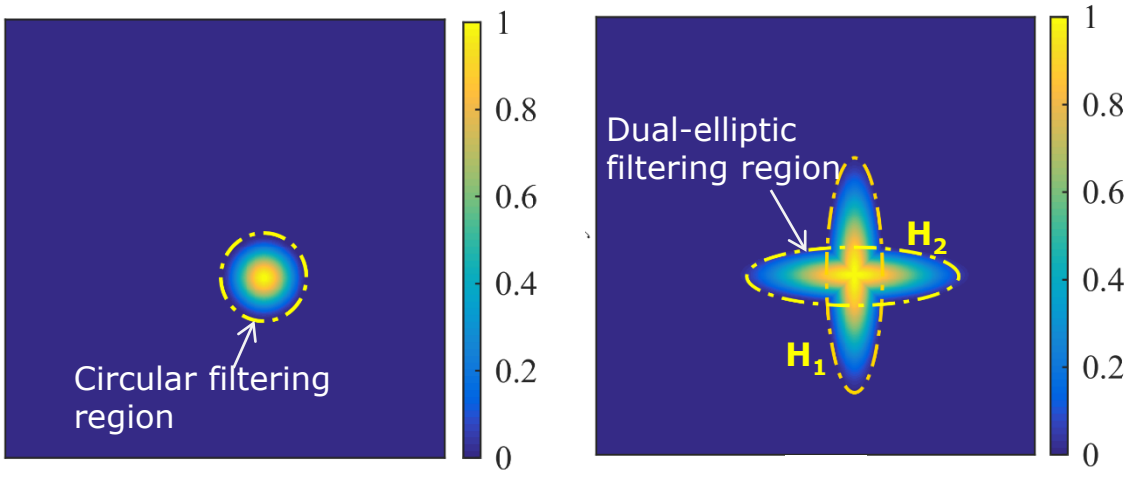
Outline

Research background

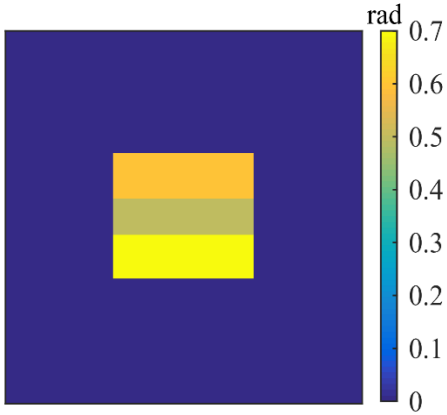
In the field of optical metrology

1. Introduction
2. n°1: Proposed Adapted SFF method
3. n°2: Proposed All-in-focus 3D measurement method
4. n°3: Proposed Specular-SFF method
5. n°4: Research on Frequency Domain Filter in FTP

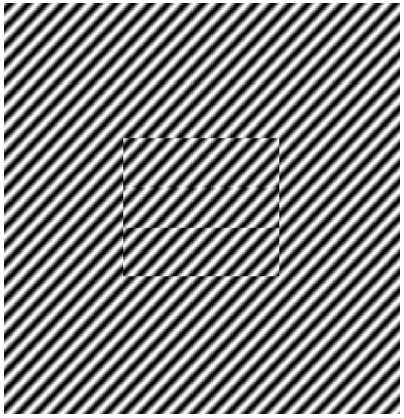
nº4: Research on Frequency Domain Filter in FTP



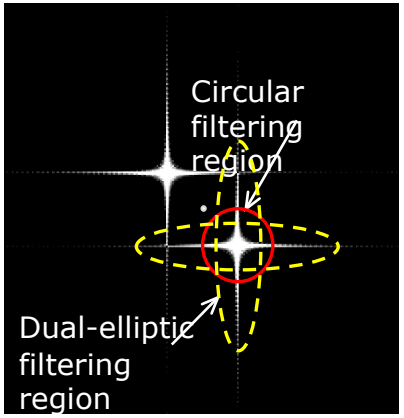
Traditional Hanning filter compared to cross-shaped Hanning filter



Simulated step object

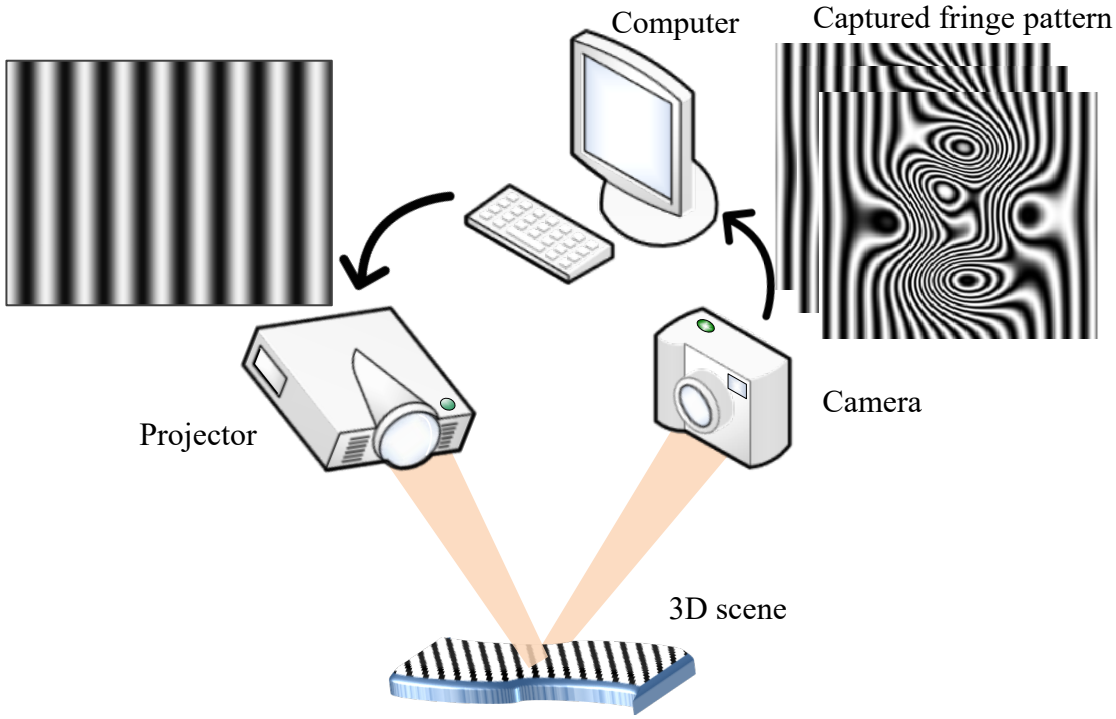


Deformed fringe pattern



Corresponding spectrogram

Thank you for your kind attention!



Schematic diagram of the SLP configuration