



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

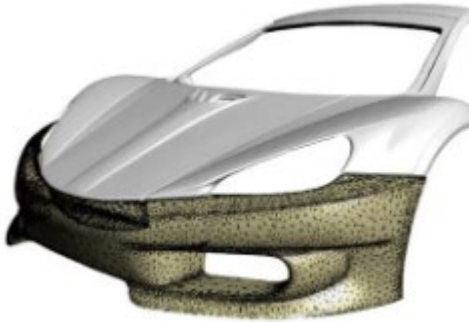
## Research background

*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

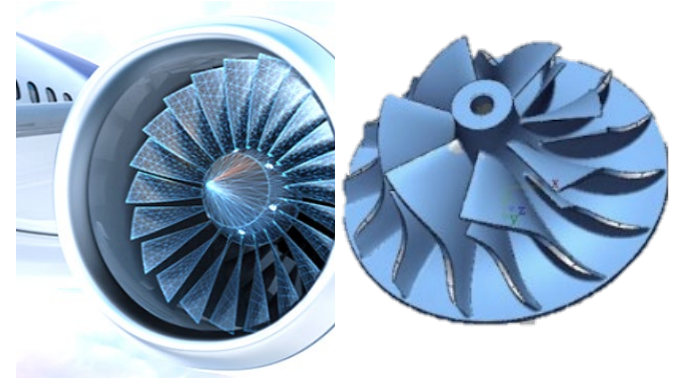
## Applications of optical metrology



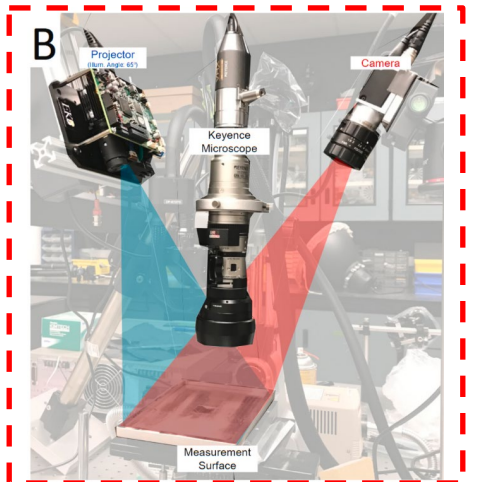
Reverse engineering  
(CREAFROM Co.)



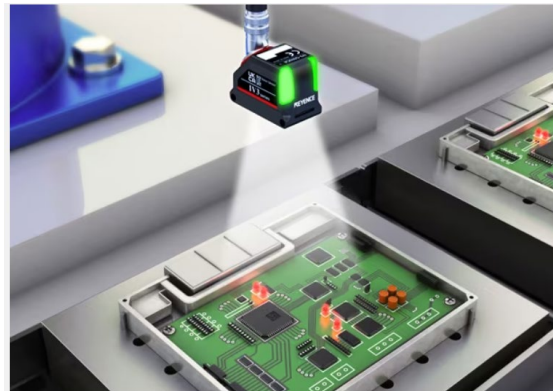
3D intraoral scanning  
(Dental Wings Co.)



Aircraft rotor inspection  
(Shining 3D Co.)



Additive manufacturing  
(O'Dowd et al.)



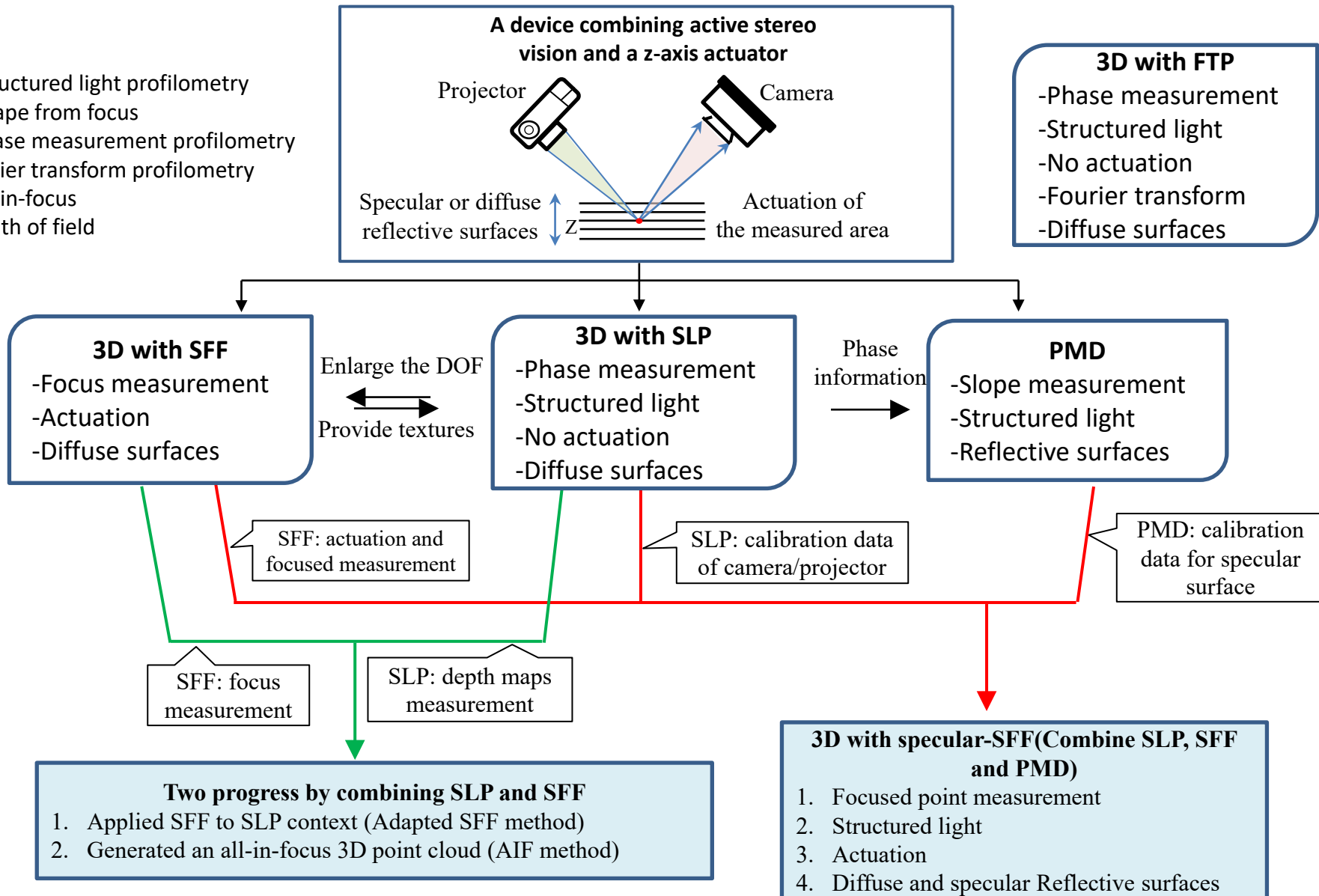
Electronic devices inspection  
(KEYENCE Co.)



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

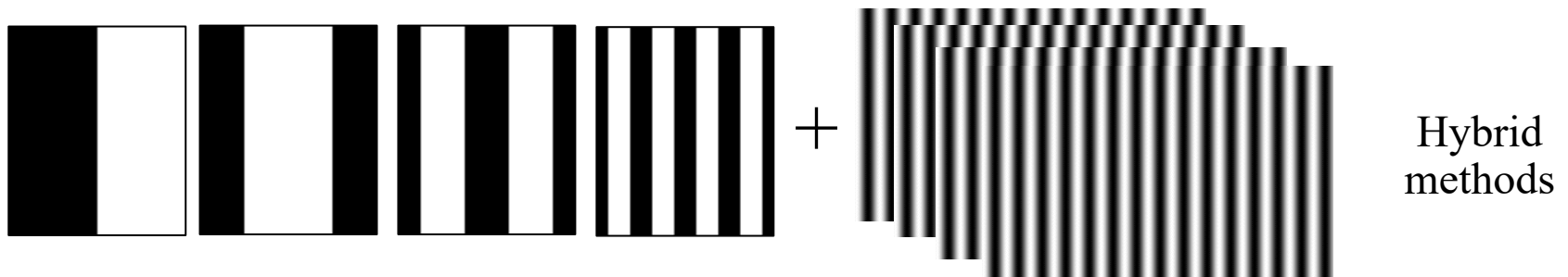
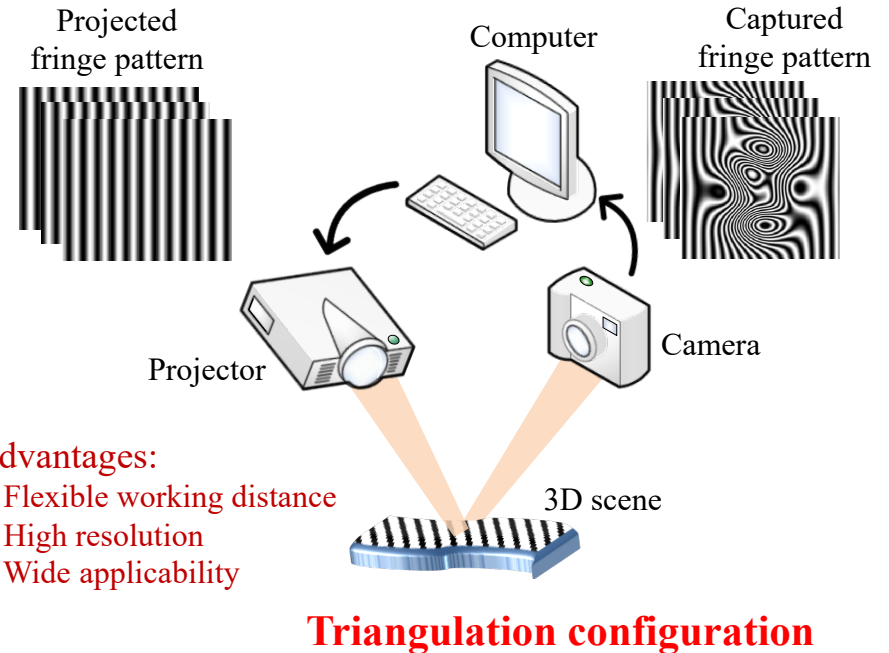
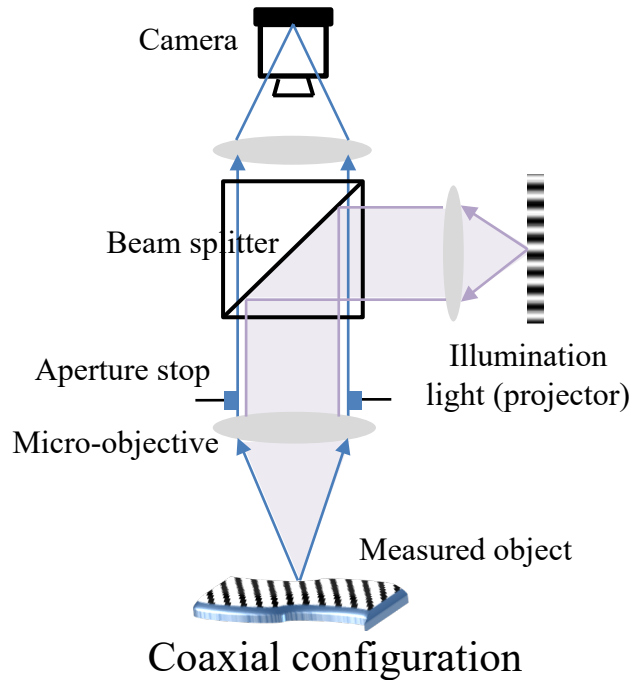
# 1. Introduction

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



# 1. Summary of research background

## Measurement configuration and fringe pattern



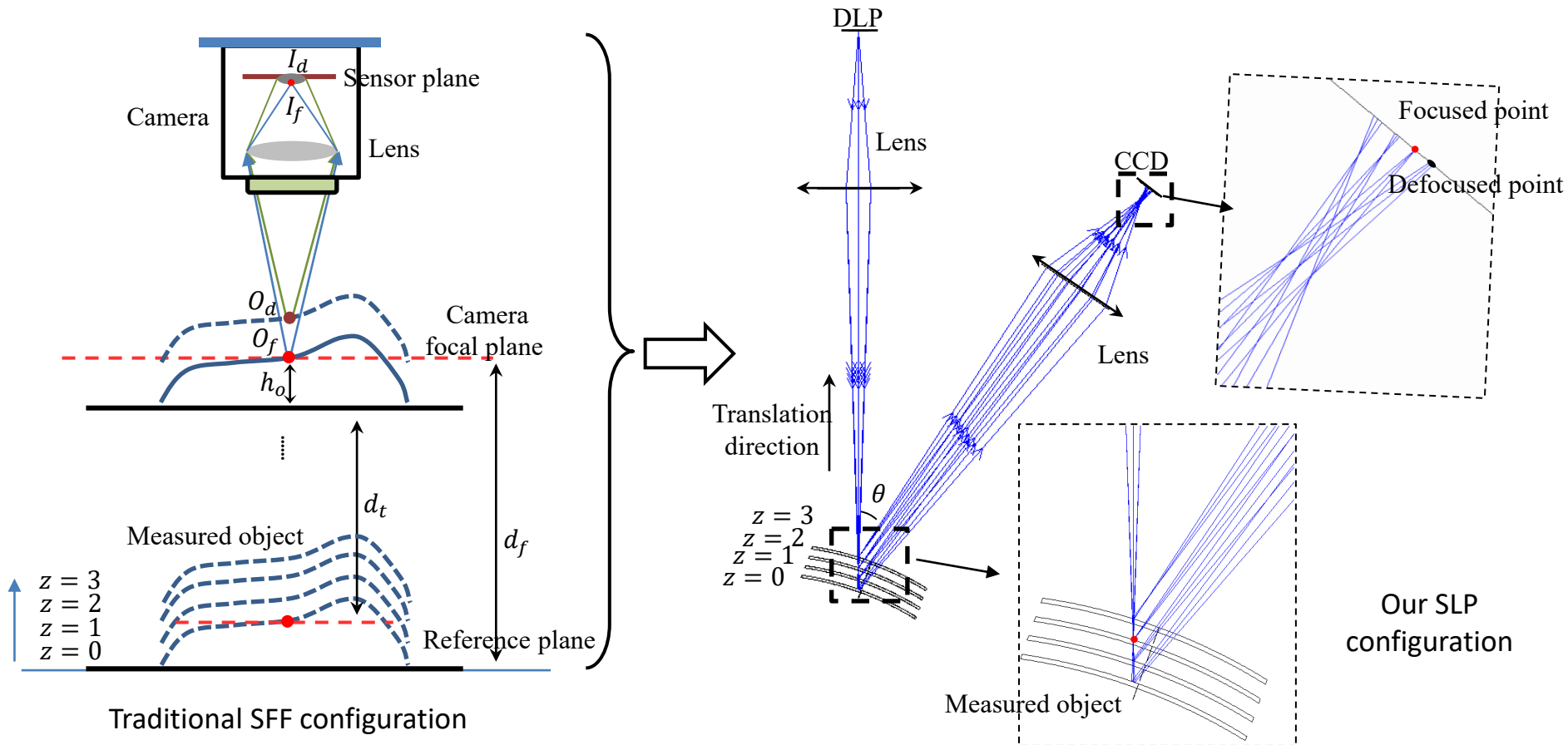
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# n°1: Proposed Adapted SFF method

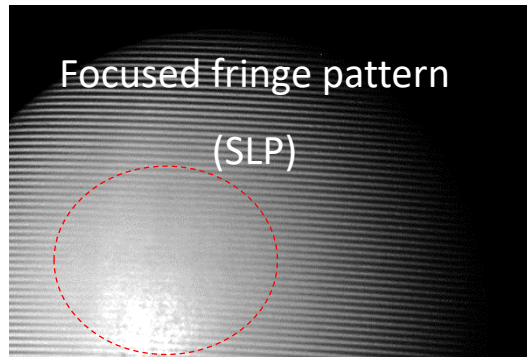
## Applying SFF to SLP measurement configurations



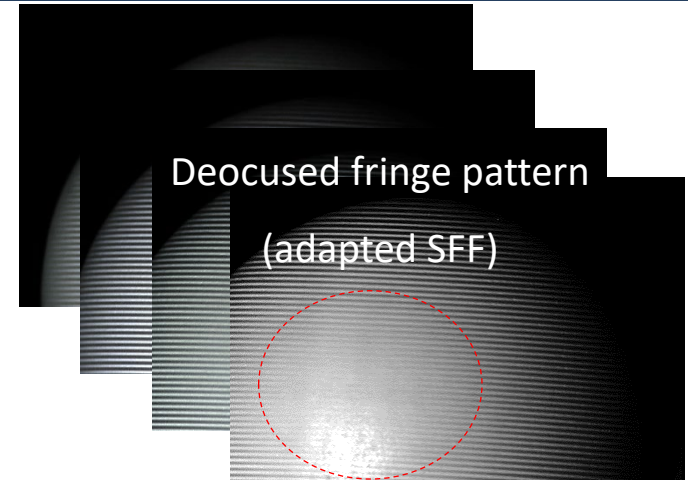


# n°1: Proposed Adapted SFF method

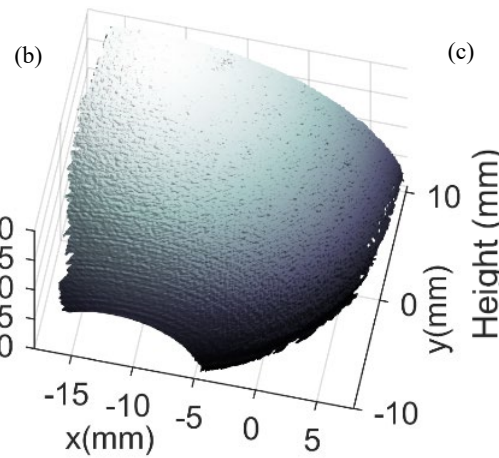
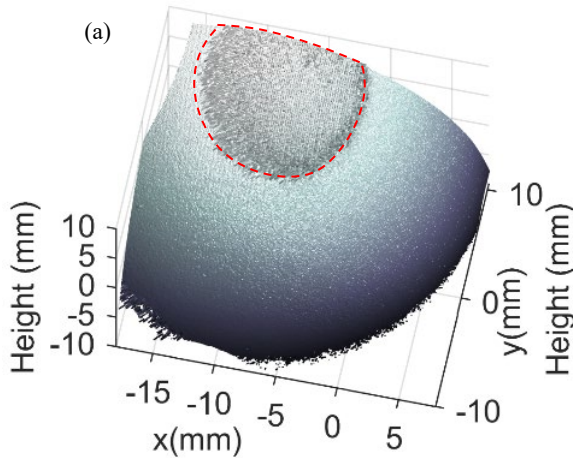
Diameter: 20mm



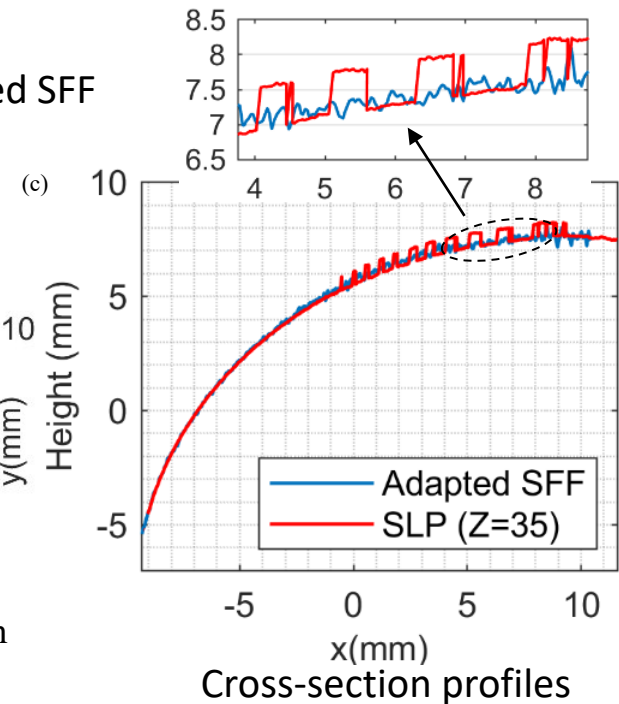
Blurred area



3D reconstruction using SLP    3D reconstruction using adapted SFF



Estimated radius: **20.3768** mm  
Relative error: **1.89%**



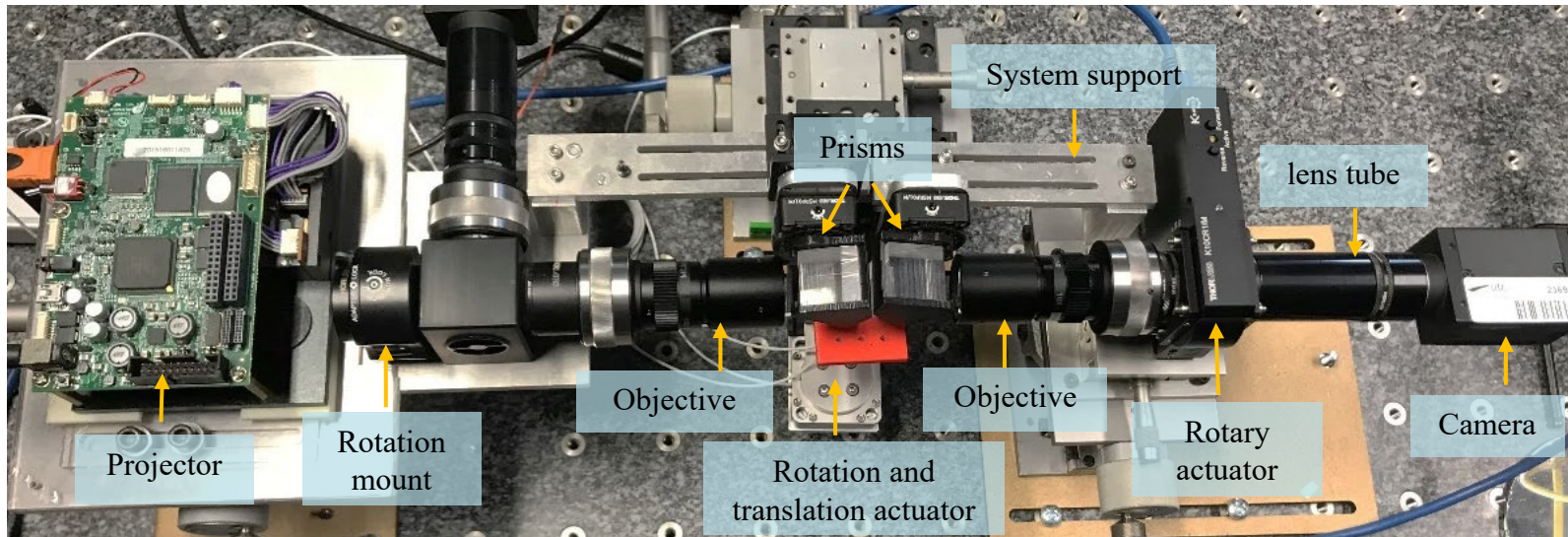


## Research background

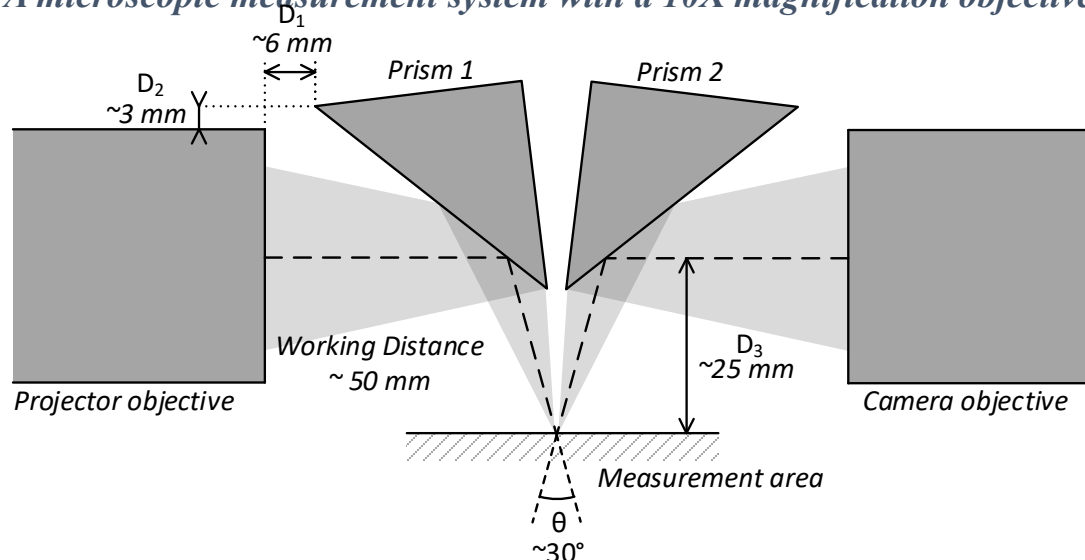
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## nº2: Proposed All-in-focus 3D measurement method



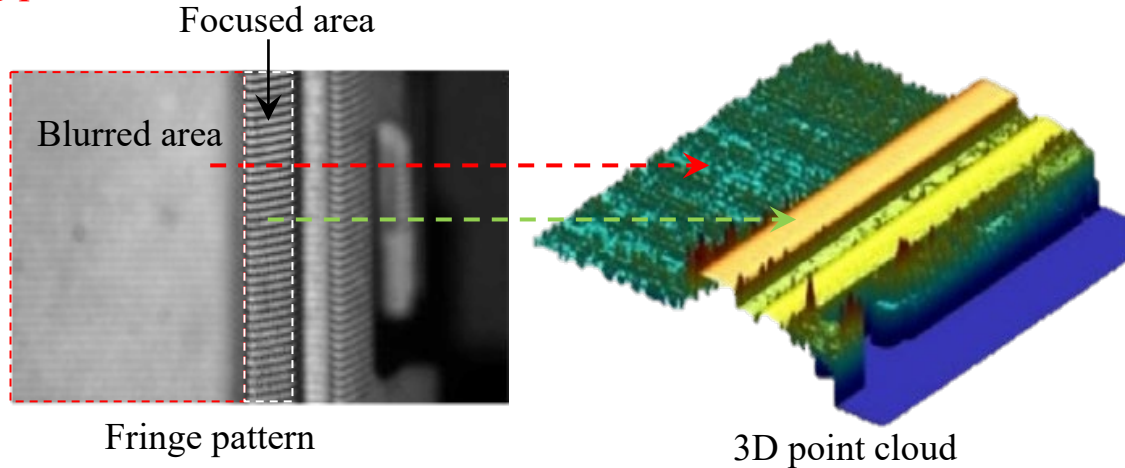
*A microscopic measurement system with a 10X magnification objective lens*



*Schematic diagram of the reflection model of the microscopic system*

## n°2: Proposed All-in-focus 3D measurement method

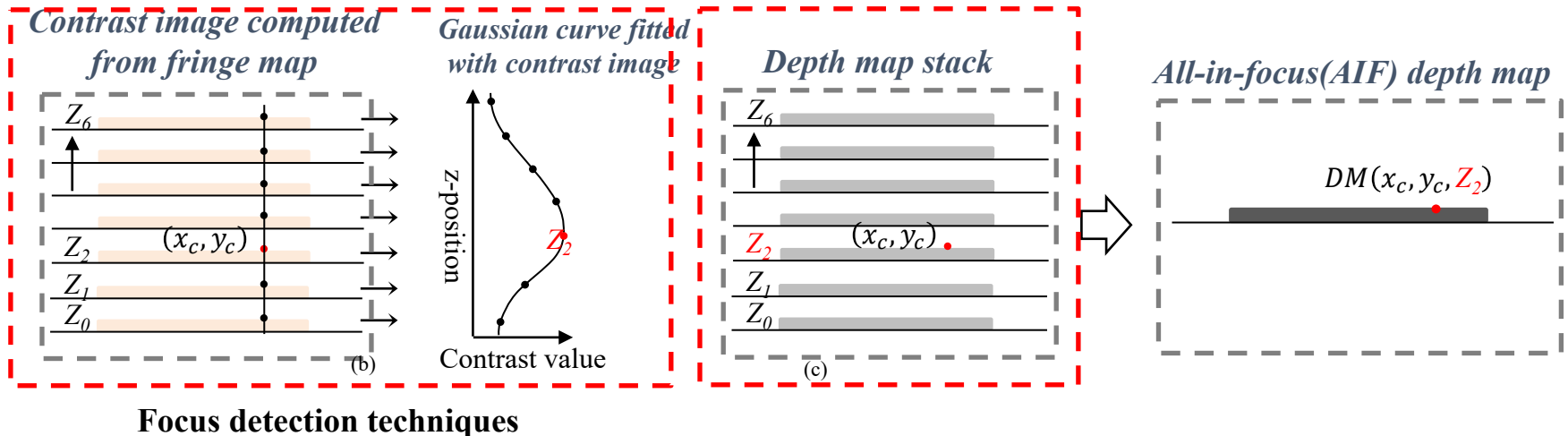
Existing problem:



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

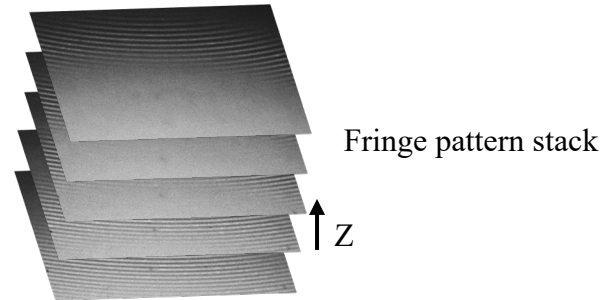
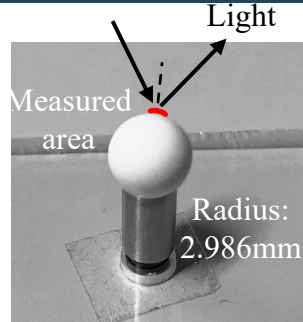
Solution to the problem:

*The reconstruction process of the AIF measurement method*

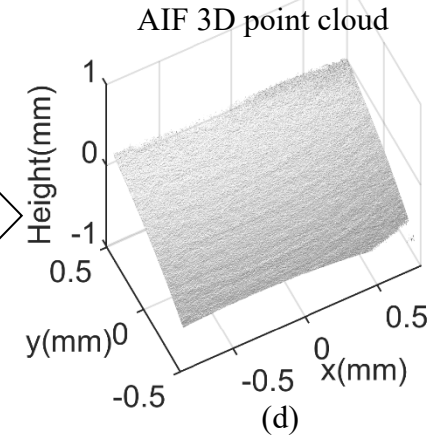
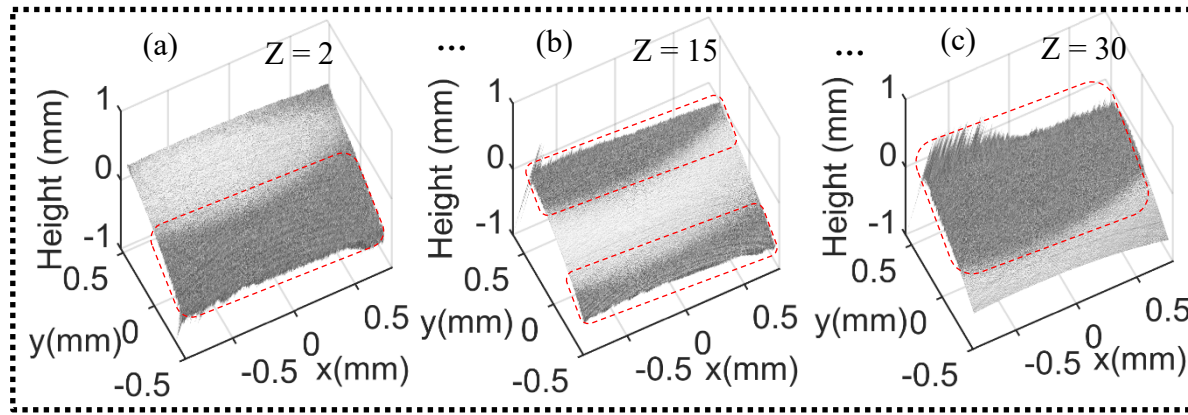


## n°2: Proposed All-in-focus 3D measurement method

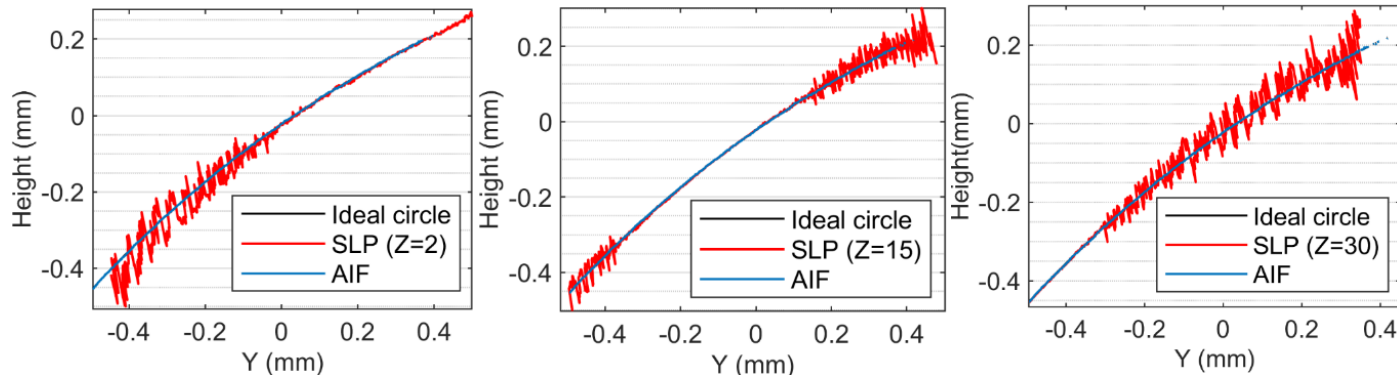
### Experimental validation of the AIF measurement method



### 3D point clouds

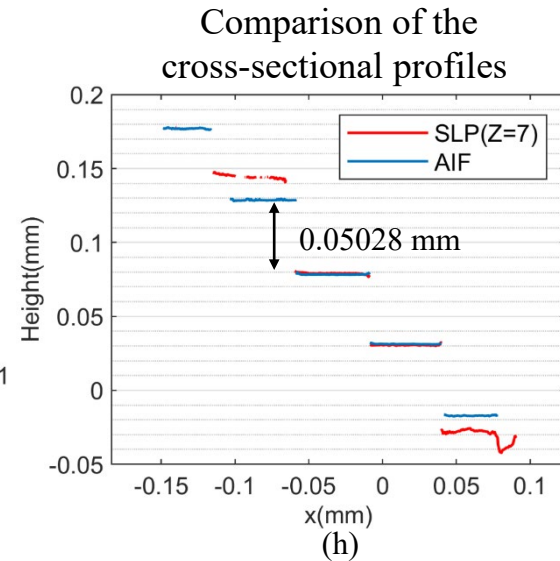
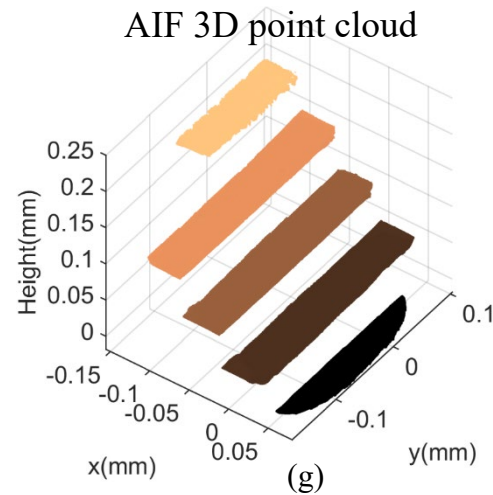
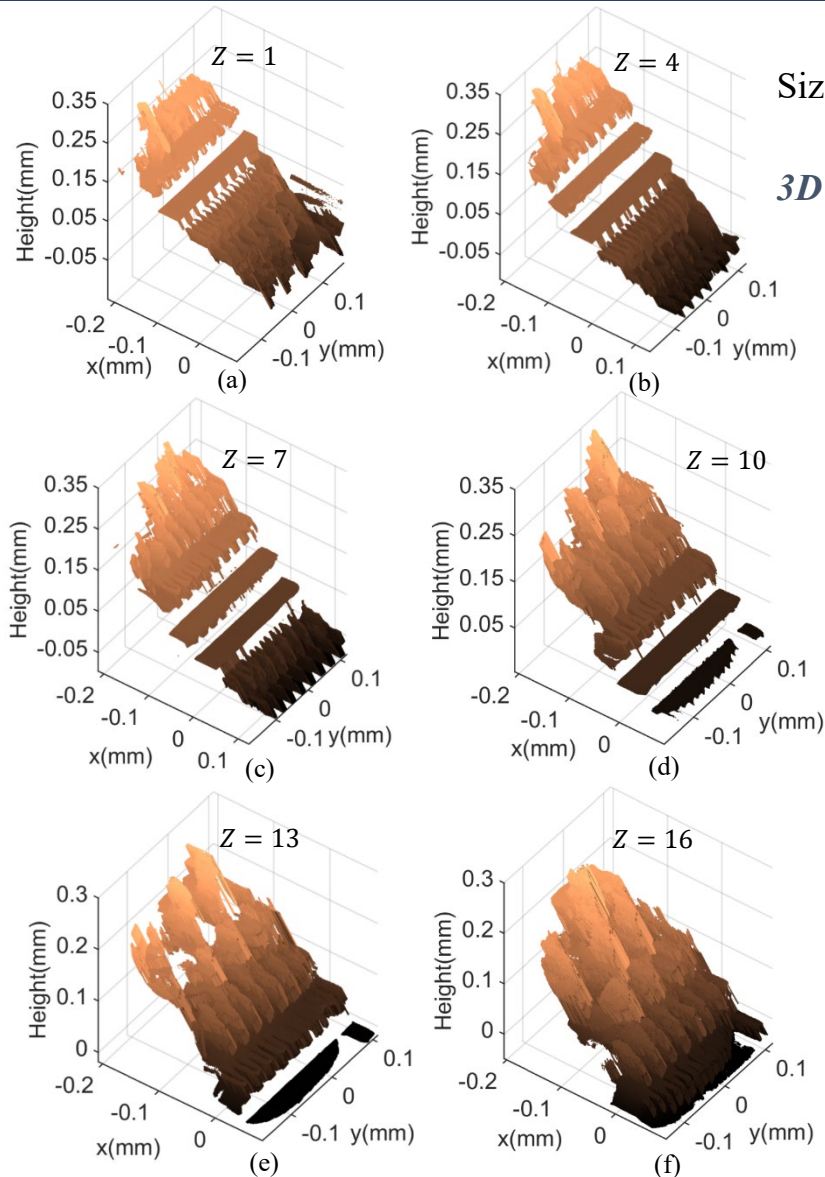


### Cross-section profiles





## n°2: Proposed All-in-focus 3D measurement method



### Advantages:

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

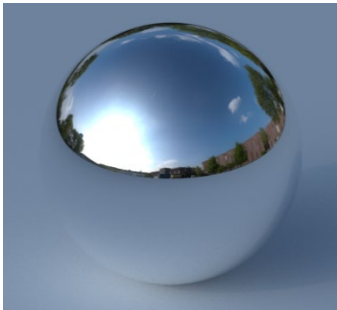
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## n°3: Proposed Specular-SFF method

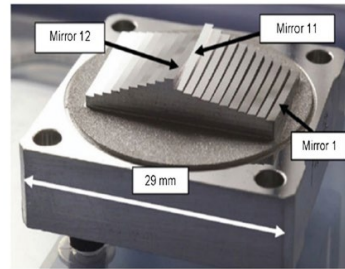
### High-reflective surfaces



Smooth sphere



Glasses



Reflective workpiece



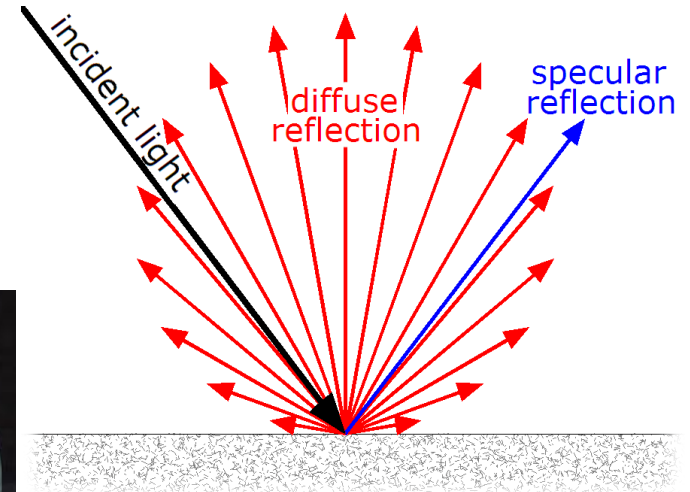
Steel kettle



Car door



Lens



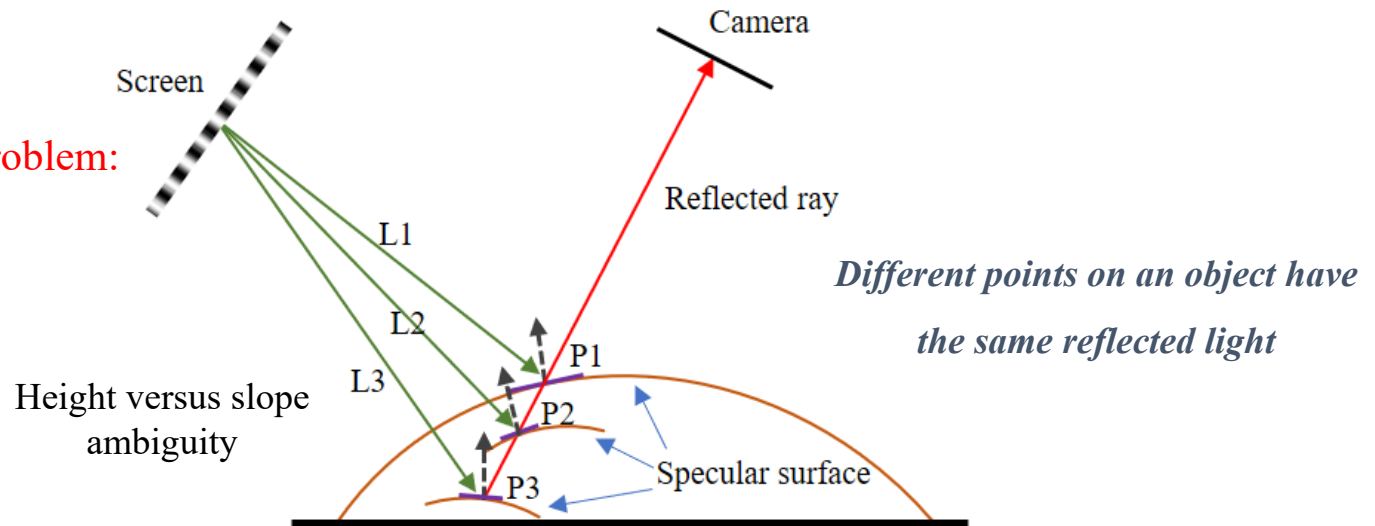
Schematic diagram of specular and diffuse reflections

*\*All images above are from Google Images*

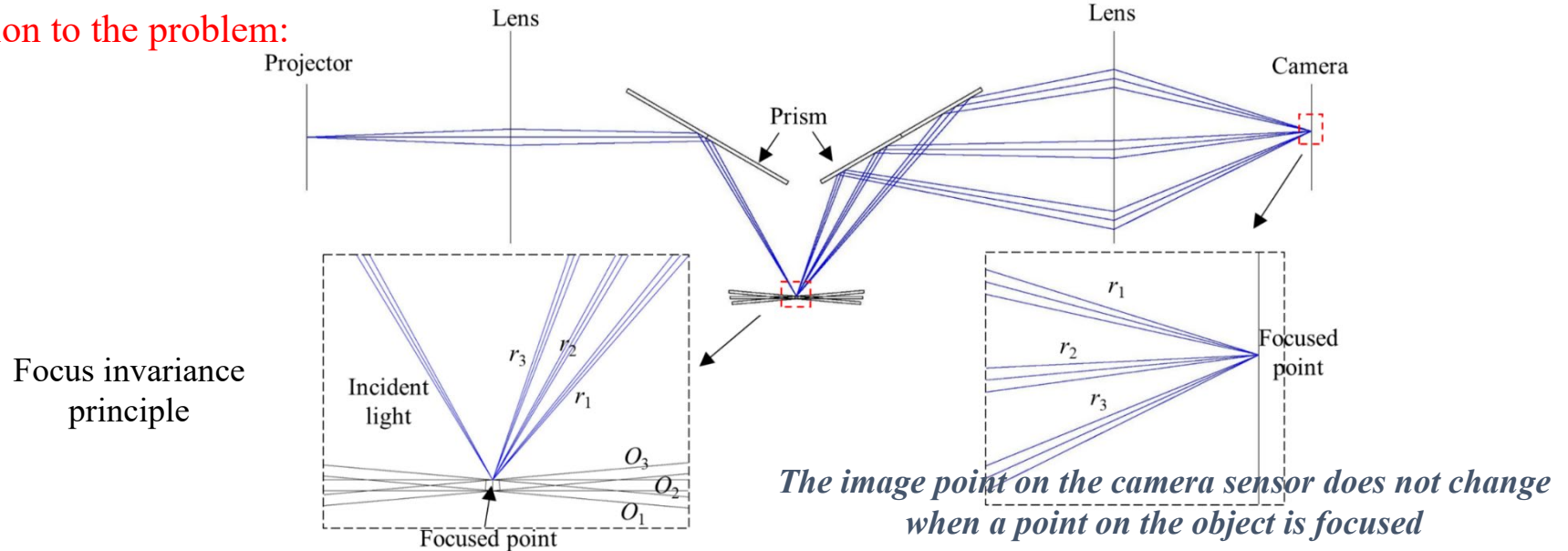


## n°3: Proposed Specular-SFF method

Existing problem:



Solution to the problem:



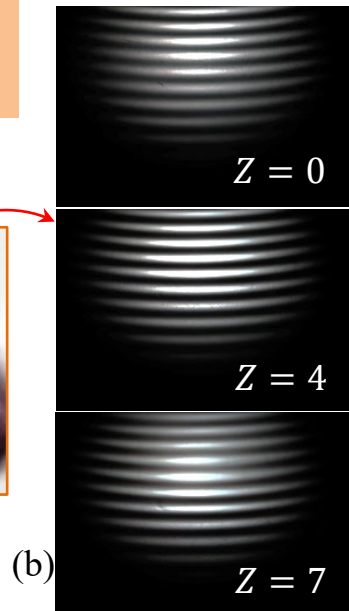
# n°3: Proposed Specular-SFF method

Experimental validation  
of the specular-SFF  
measurement method

$r = 1.0 \text{ mm}$

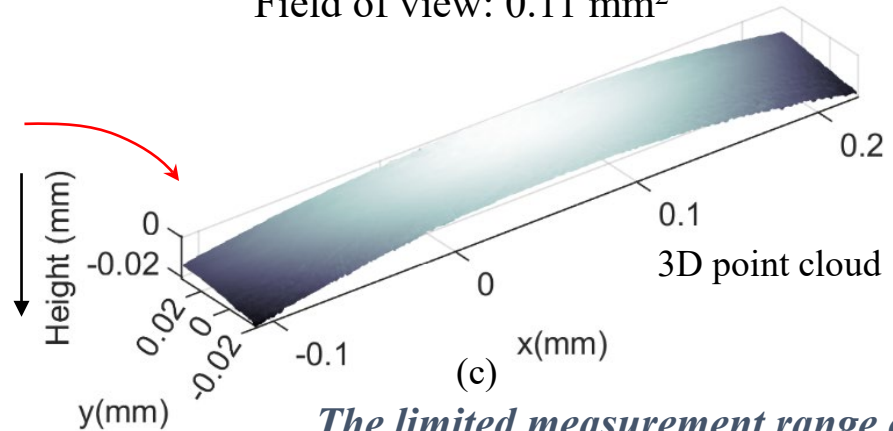


(a)



(b)

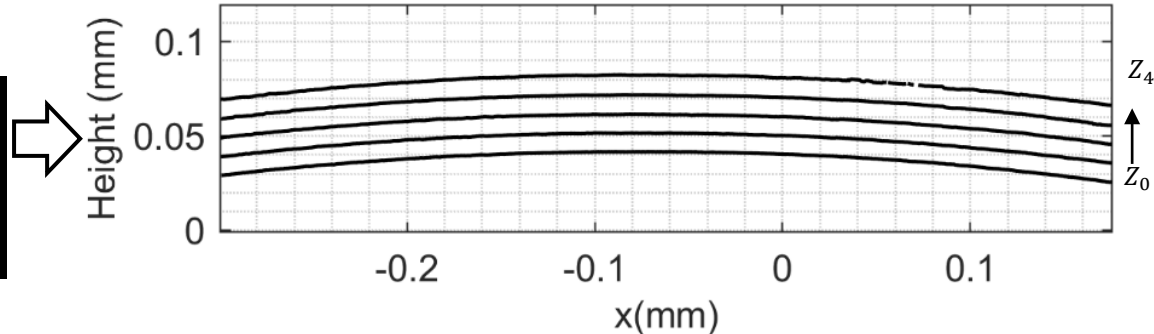
Measurement range :  $0.012 \text{ mm}^2$   
Field of view:  $0.11 \text{ mm}^2$



(c)

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

Out of focus



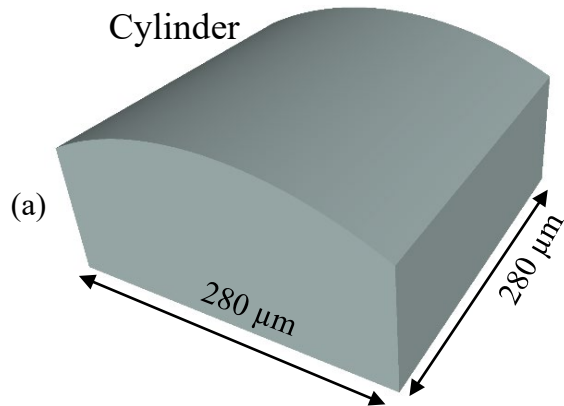
*The cross-sectional profiles of the 3D point cloud using the specular-SFF technique at different  
z-positions, with the entire z translation distance beyond the DOF of the system*

## n°3: Proposed Specular-SFF method

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

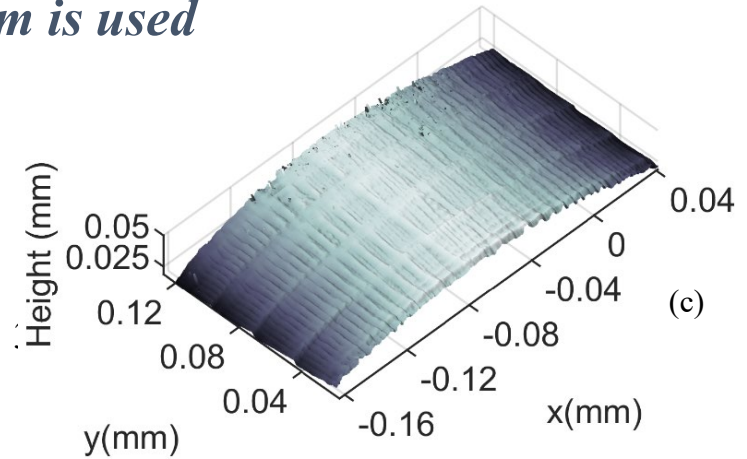
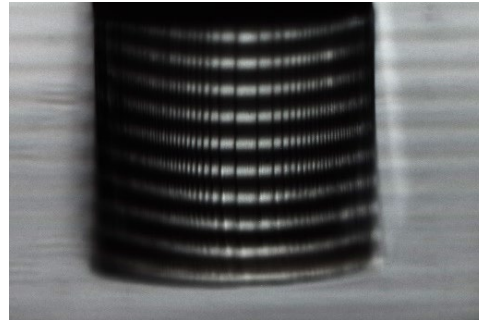
Radius: 300  $\mu\text{m}$

Cylinder

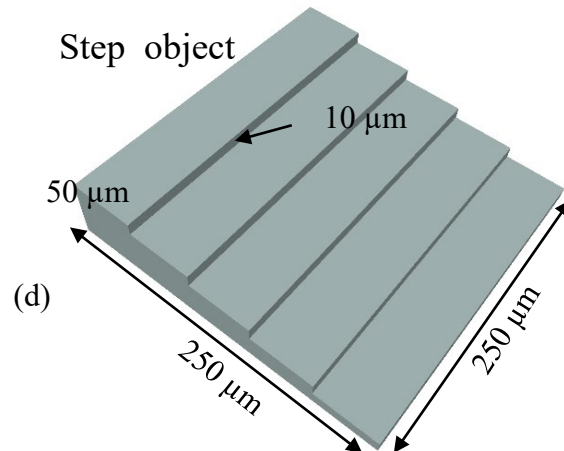


*A stitching algorithm is used*

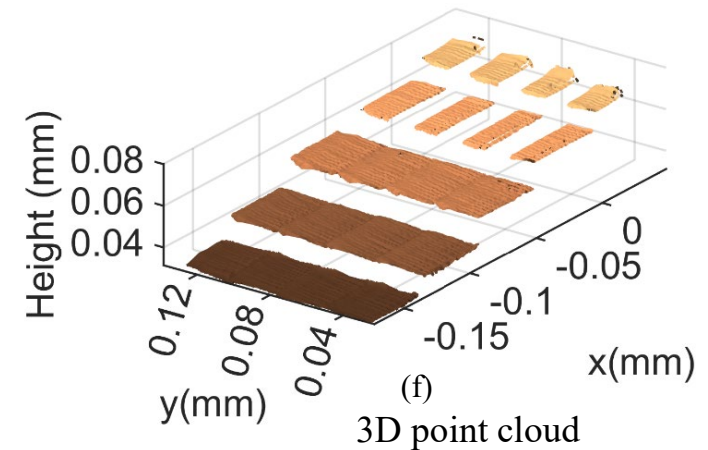
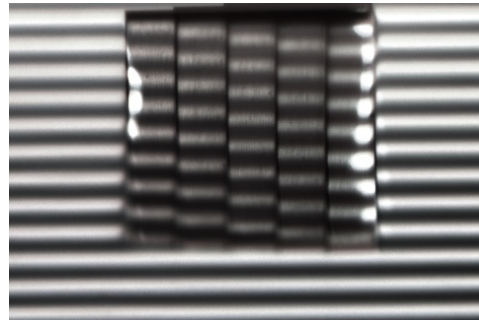
Captured fringe pattern



Step object



Captured fringe pattern

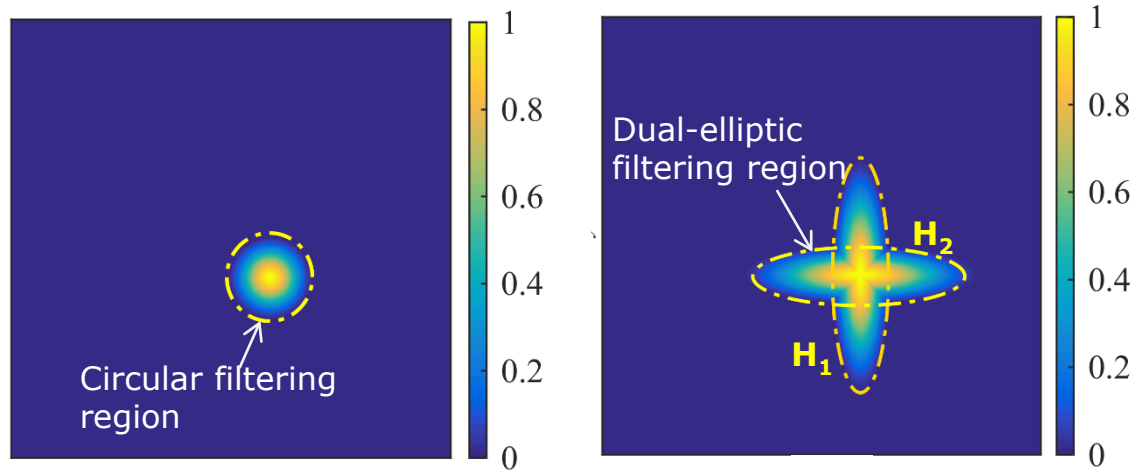


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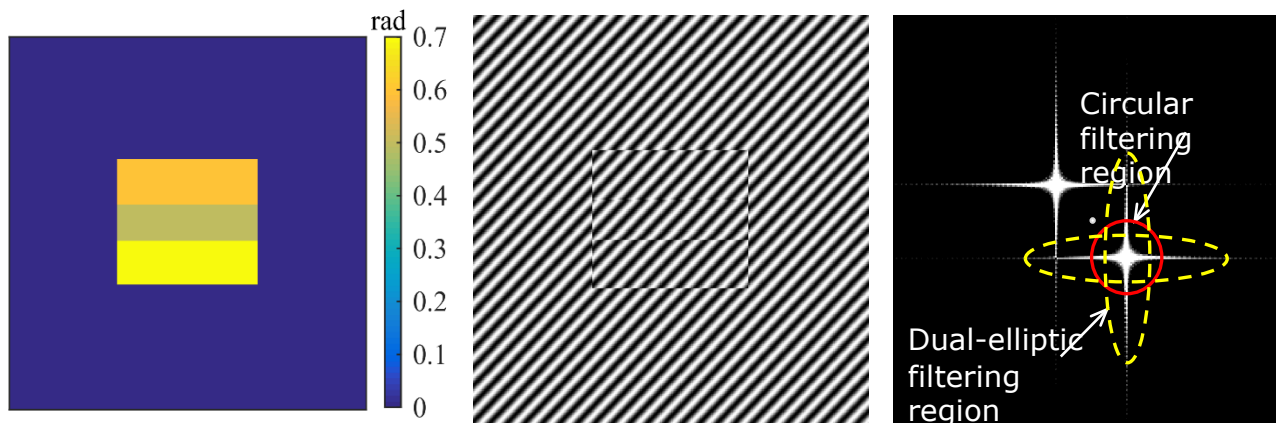
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## n°4: Research on Frequency Domain Filter in FTP

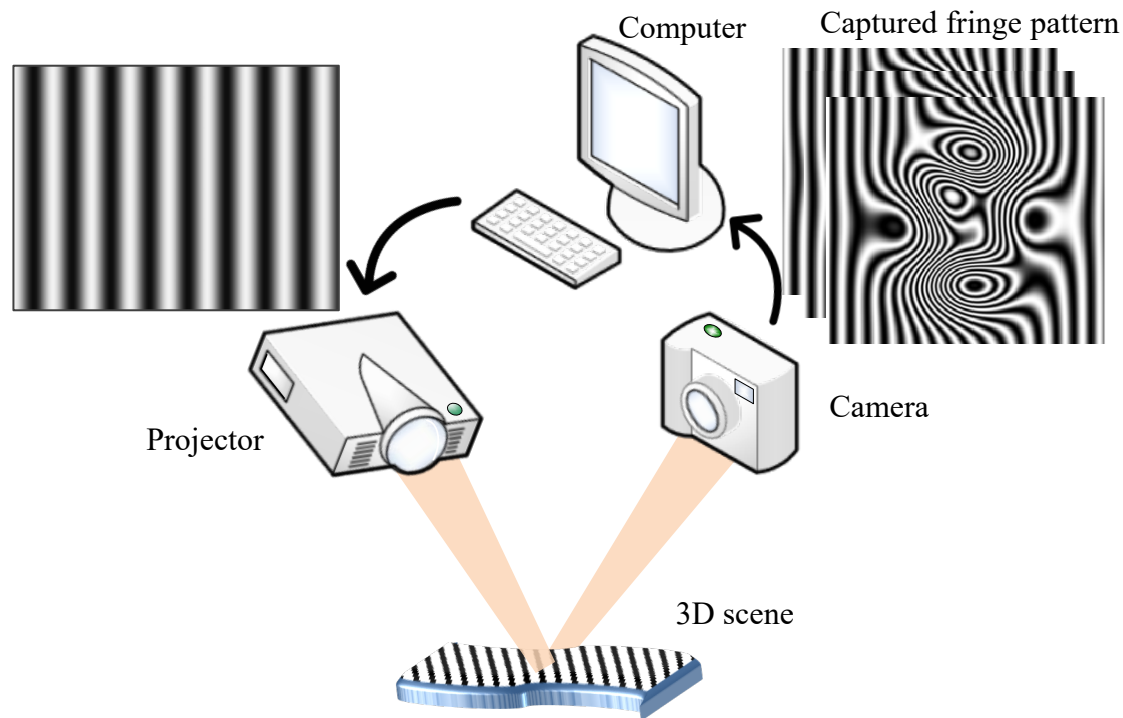


*Traditional Hanning filter compared to cross-shaped Hanning filter*



*Simulated step object    Deformed fringe pattern    Corresponding spectrogram*

# Thank you for your kind attention!



*Schematic diagram of the SLP configuration*