インライン全数検査を目指す
非接触光表面形状計測

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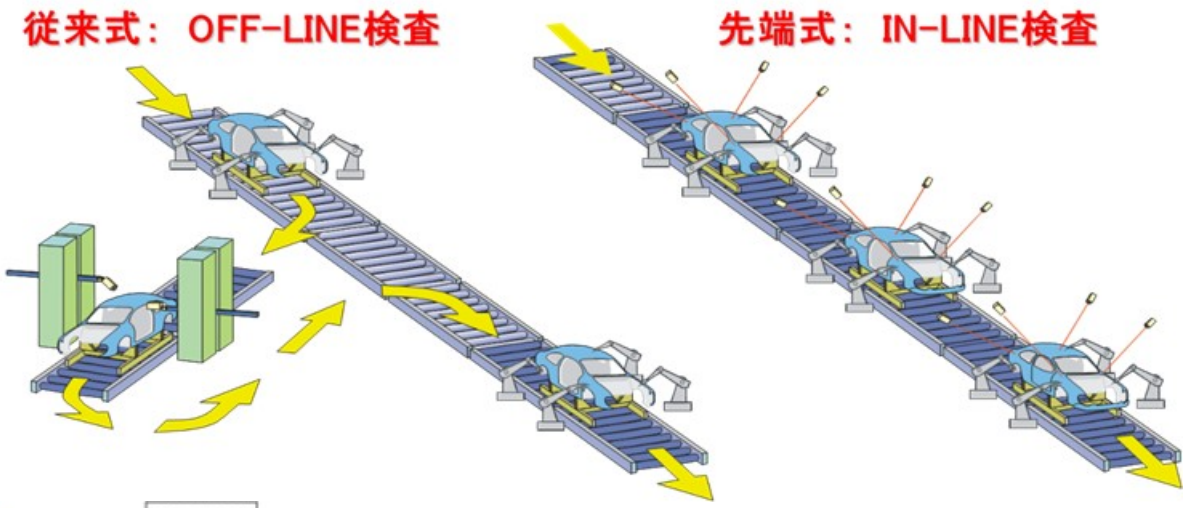
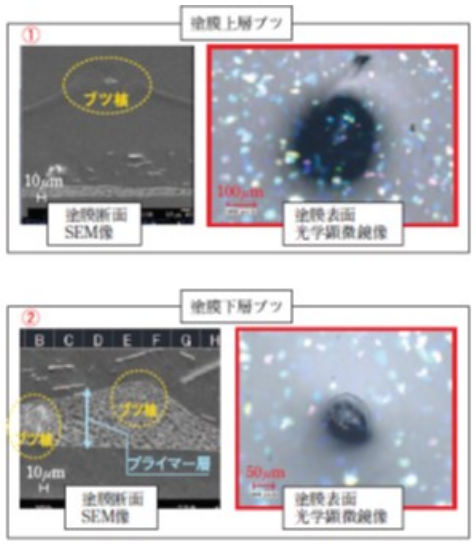
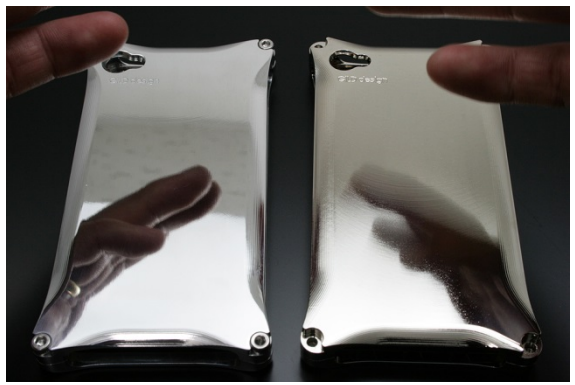
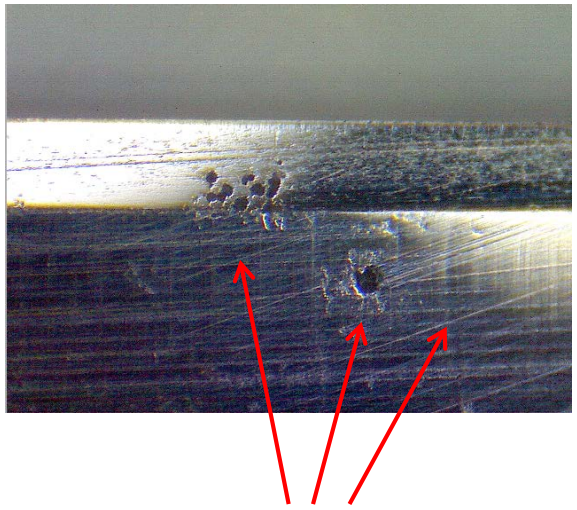
表面の形状検査（広い範囲を高速に）







光学顕微鏡



キズの有無は分かるが
出っ張りか凹みか、
深さも不明…

光学干渉計

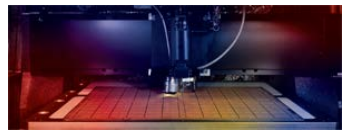
波の強め合い、弱め合い

光学干渉計を使うと

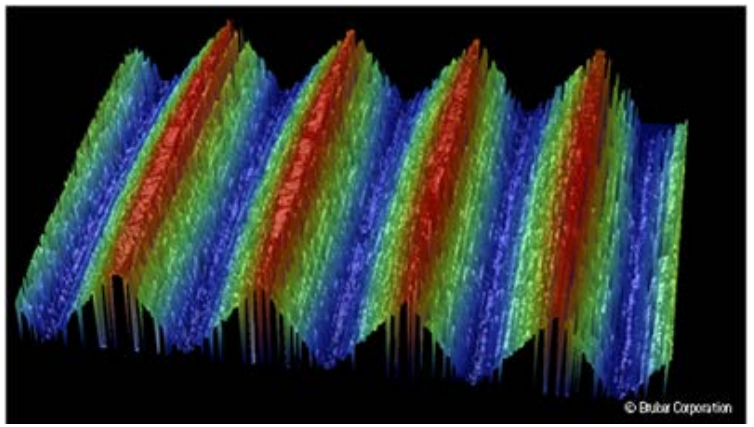
奥行方向の形状もわかる。

つまり、

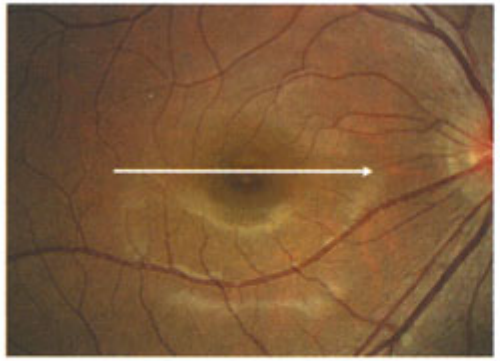
表面の3次元構造を測れる!!



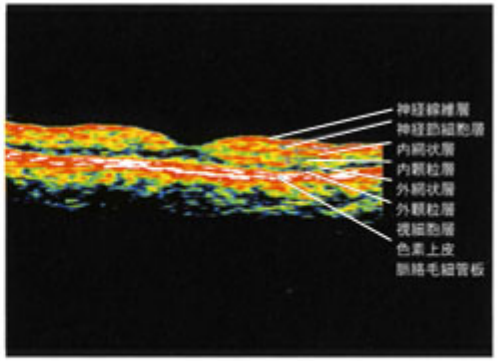
3D Industrial Optical Microscopy
3D Surface Metrology



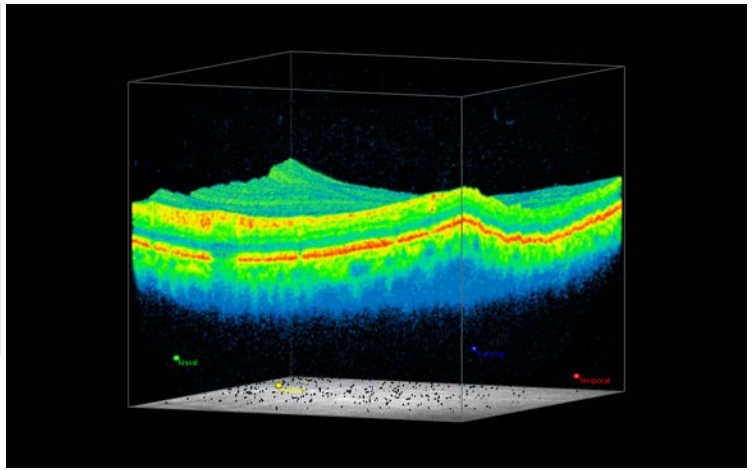
光コヒーレンストモグラフィー（OCT）

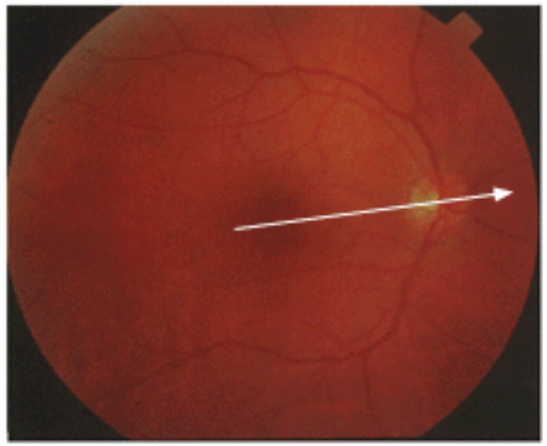


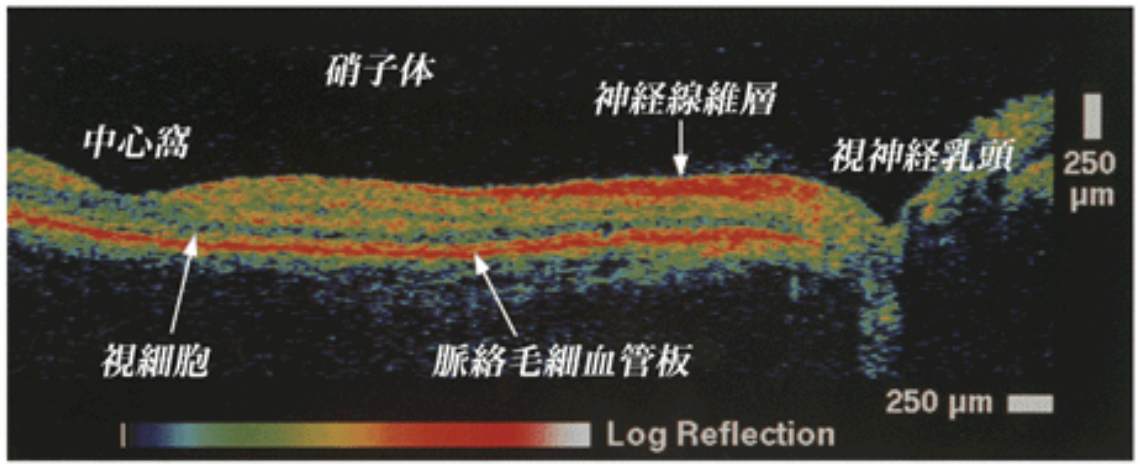
正常眼の黄斑部
矢印は 2.83mm（標準設定）の走査線と方向を示す.



黄斑部の OCT 像
神経線維層，内・外網状層，網膜色素上皮＋ Bruch 膜＋脈絡毛細管板が高反射層となる.



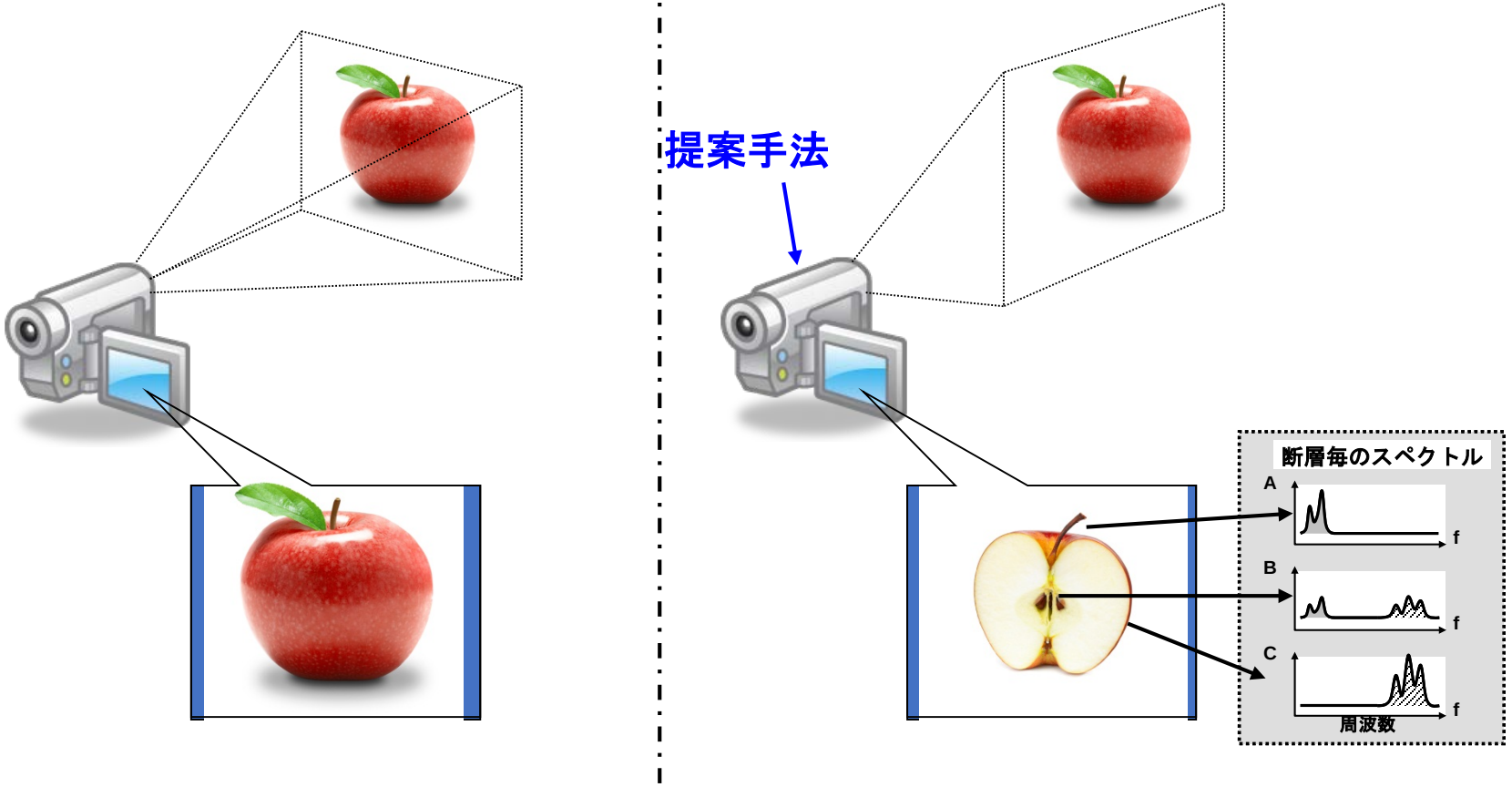




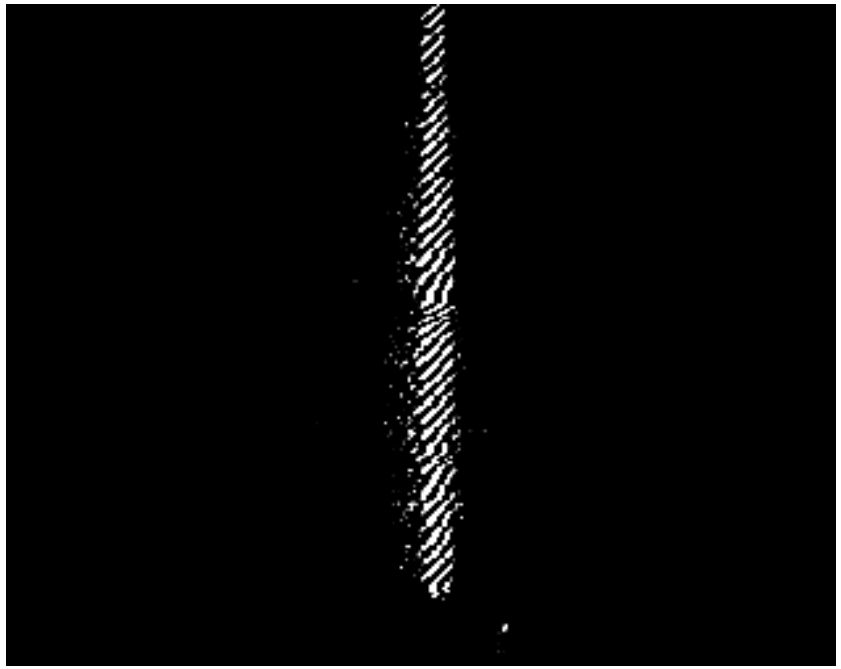
奥行方向の２次元断層画像を取得

デジタルカメラ

提案手法



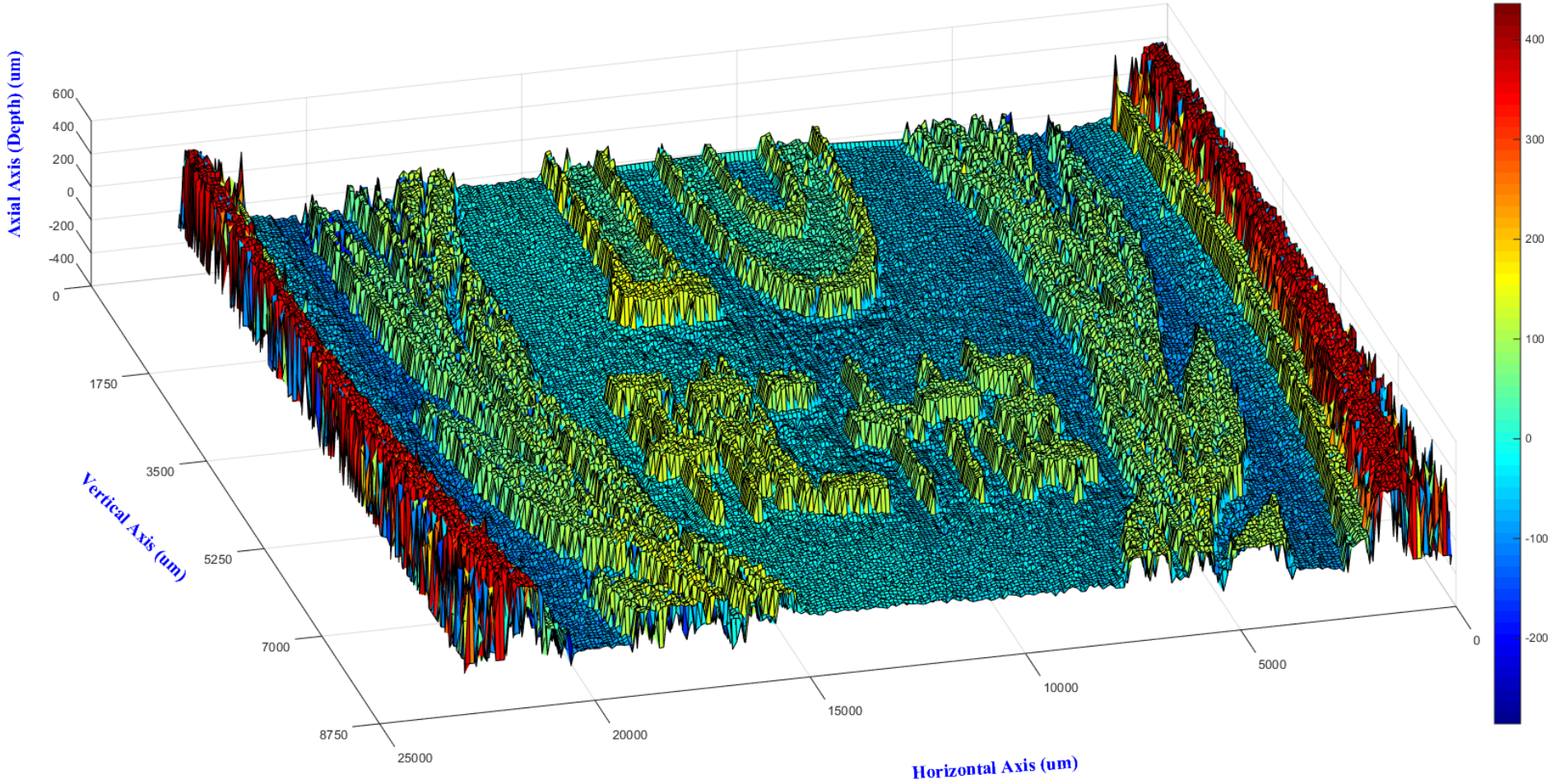
適用例　～十円玉表面形状計測～



Fringes continuously appeared on CCD

Sample is moved in lateral direction with 100 μm per step

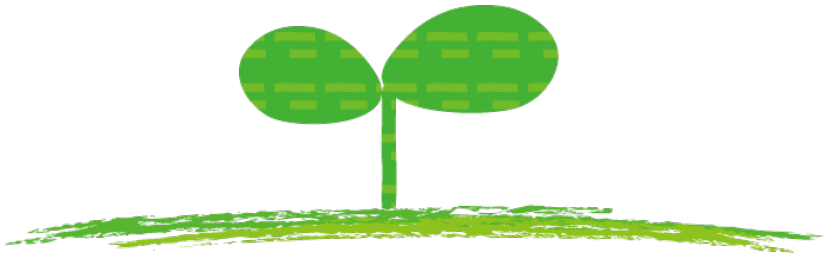
適用例　～十円玉表面形状計測～



3D reconstruction image

「インライン検査の要求と必要な仕様」

シングルショット2次元計測

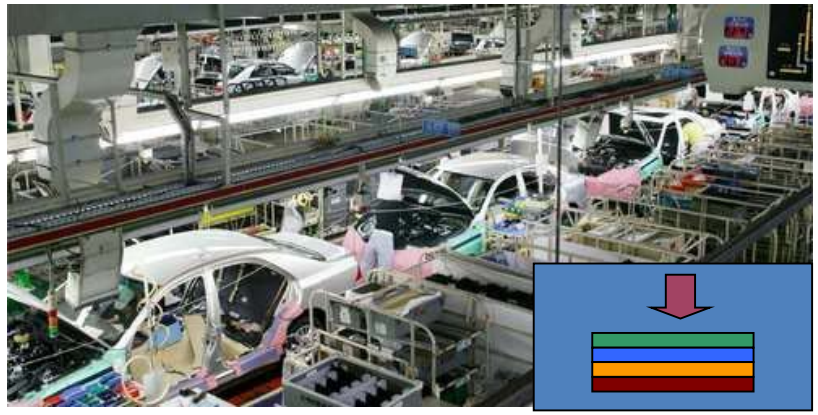


Introductions

- Low-coherence interferometry
  - Non-destructive
  - High resolution: 1 μm

→ Many reports on:
biology, chemistry, industry…

- Spec. for interferometer → Inline inspection of surface profilometry

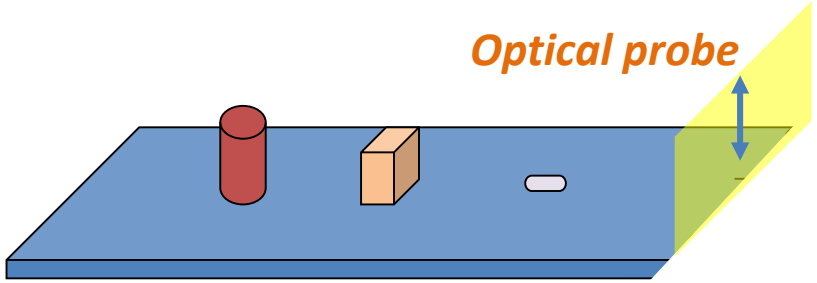


Products flow continuously…

Data volume→ 1 PB/hour

- ✓ *Capturing*
- ✓ *Processing*
- ✓ *Analysis*

} ***simultaneously with flowing products***



Specifications required for inspection

Details for the inline inspection of surface profilometry:

*In-axis(**z**):*
- Measurement range: > 100 mm
- Resolution: ~ 1 μm

} **10^5 samples** (z)

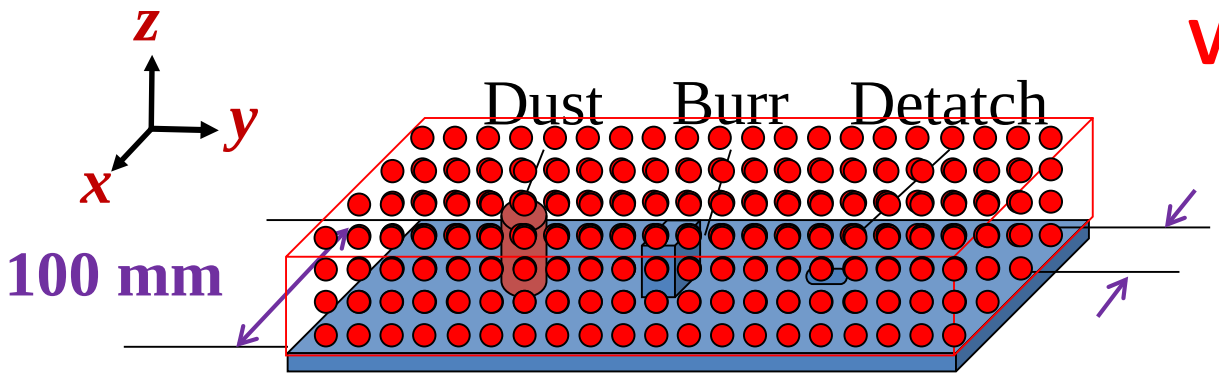
*Lateral(**x**):*
- Measurement range: > 10 mm
- Resolution: 100 μm

} **10^3 samples** (x)

*Lateral(**y**):*
- Measurement range: > 100 mm
- Resolution: 100 μm
- Conveyance speed: 100 mm/sec

} **10^3 samples/sec** (y)

Volume sampling rate:
10^{11} samples/sec
CONTINUOUSLY



Data acquisition speed vs. volume sampling rate

- Data acquisition speed of optical sensing device < 10 GHz
  (*throughput of detector, A/D converter, …*)

  ➡ Max: 10^9 *samples/sec* (pay 10 bit for gray scale)

Gap

To achieve the volume sampling rate at 10^{11} *…*

(1) Optical frequency comb (OFC) interferometry

➡ Range expansion: **× 10^2 times** (effectively)

(2) 2-D single-shot imaging

➡ Sampling rate: **10^9 samples/sec**

} **10^{11}**

Additional information

- Recent camera captures *continuously*
  1,000 pix × 1,000 pix × 1,000 frames/sec × 12 bit (gray scale) = 10^9 sampling points/sec × 12 bit.

- FD-OCT captures 2D information by single-shot.
  2D Fourier-analysis takes slower than 1k fps.

➡ Difficult simultaneous processing for the continuous measurement

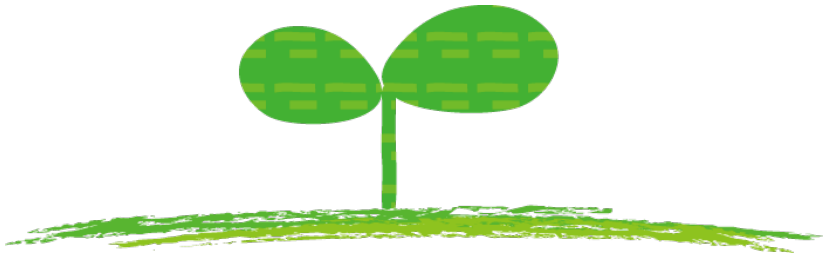
2次元画像一括取得の利点2/2

2次元画像一括取得：

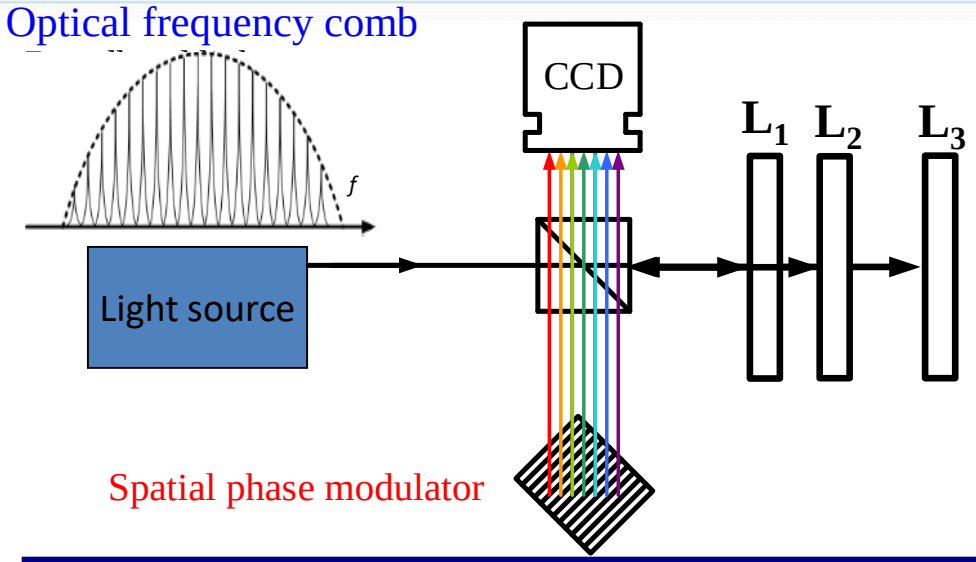
① 1次元の高速走査不要

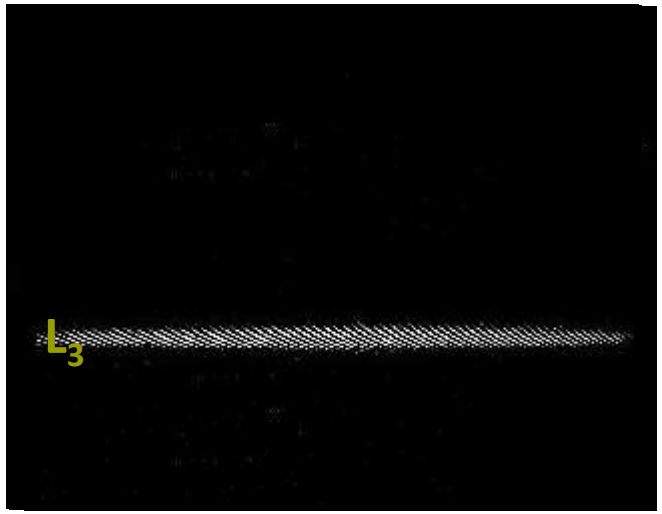
② 振動に強い

光コム干渉計
と
空間分解スペクトル計測の原理



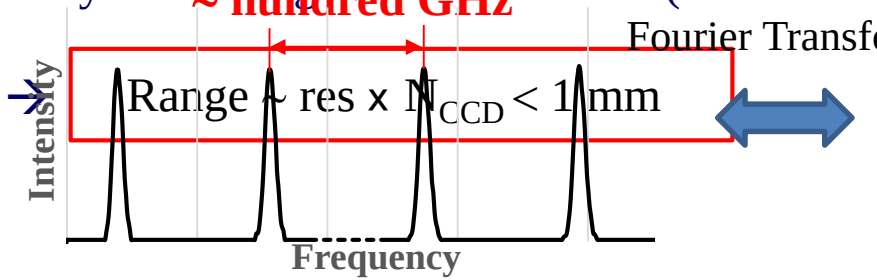
Principle: single-shot 2-D imaging & range expansion





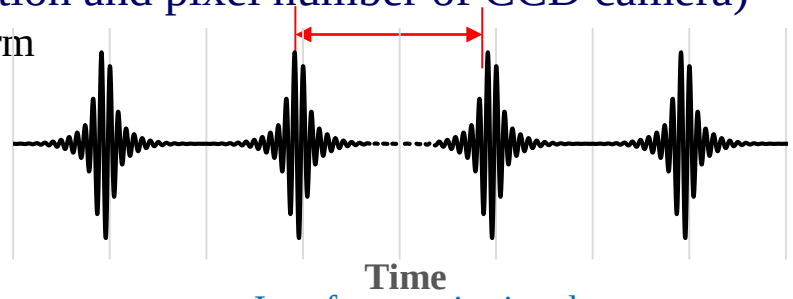
Using **optical frequency comb**[1] can be expanded measurement range

- Dynamic range of CCD camera (axial resolution and pixel number of CCD camera)



Optical power spectrum of frequency comb light source

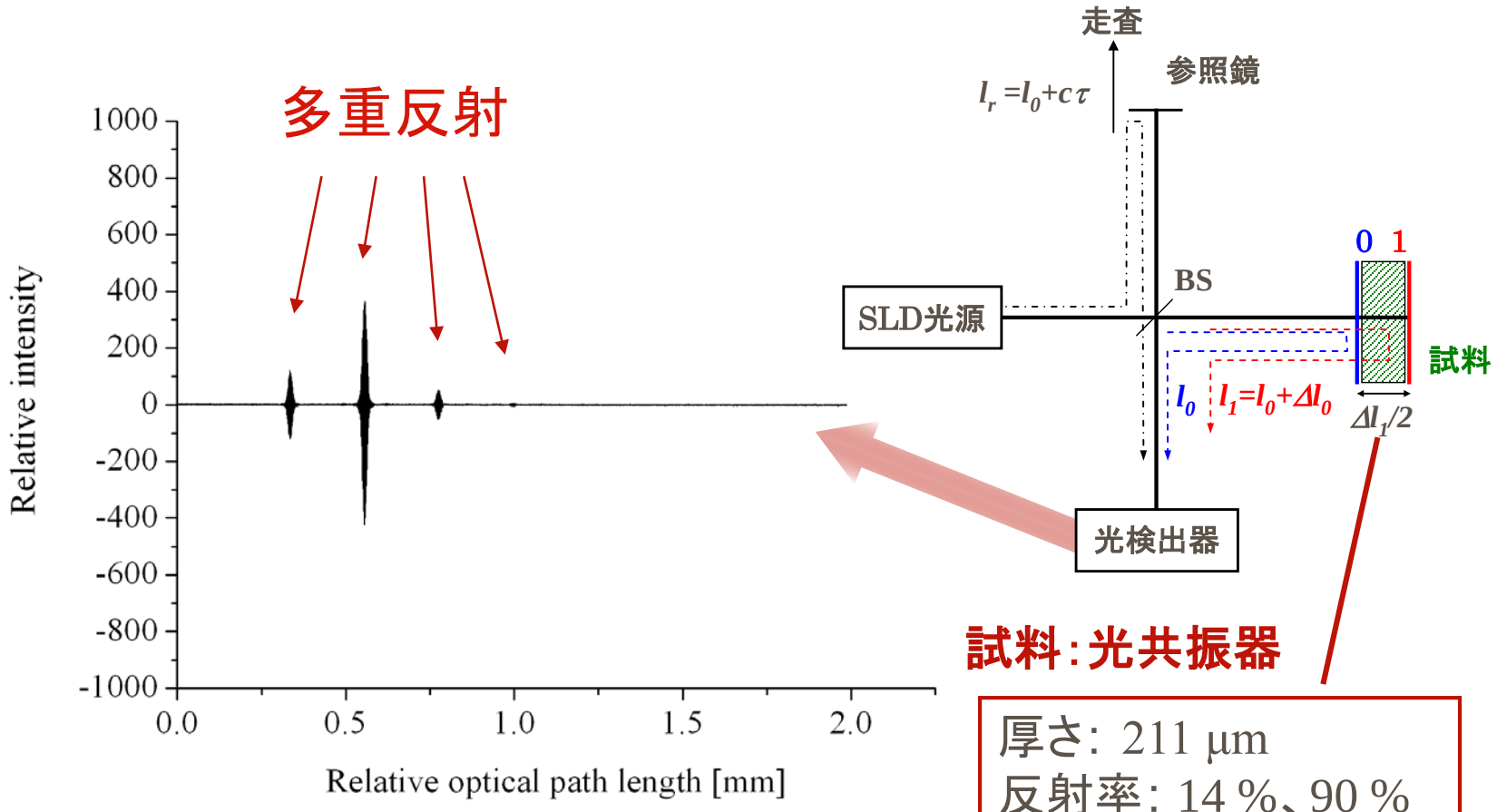
Fourier Transform



Interferometric signal

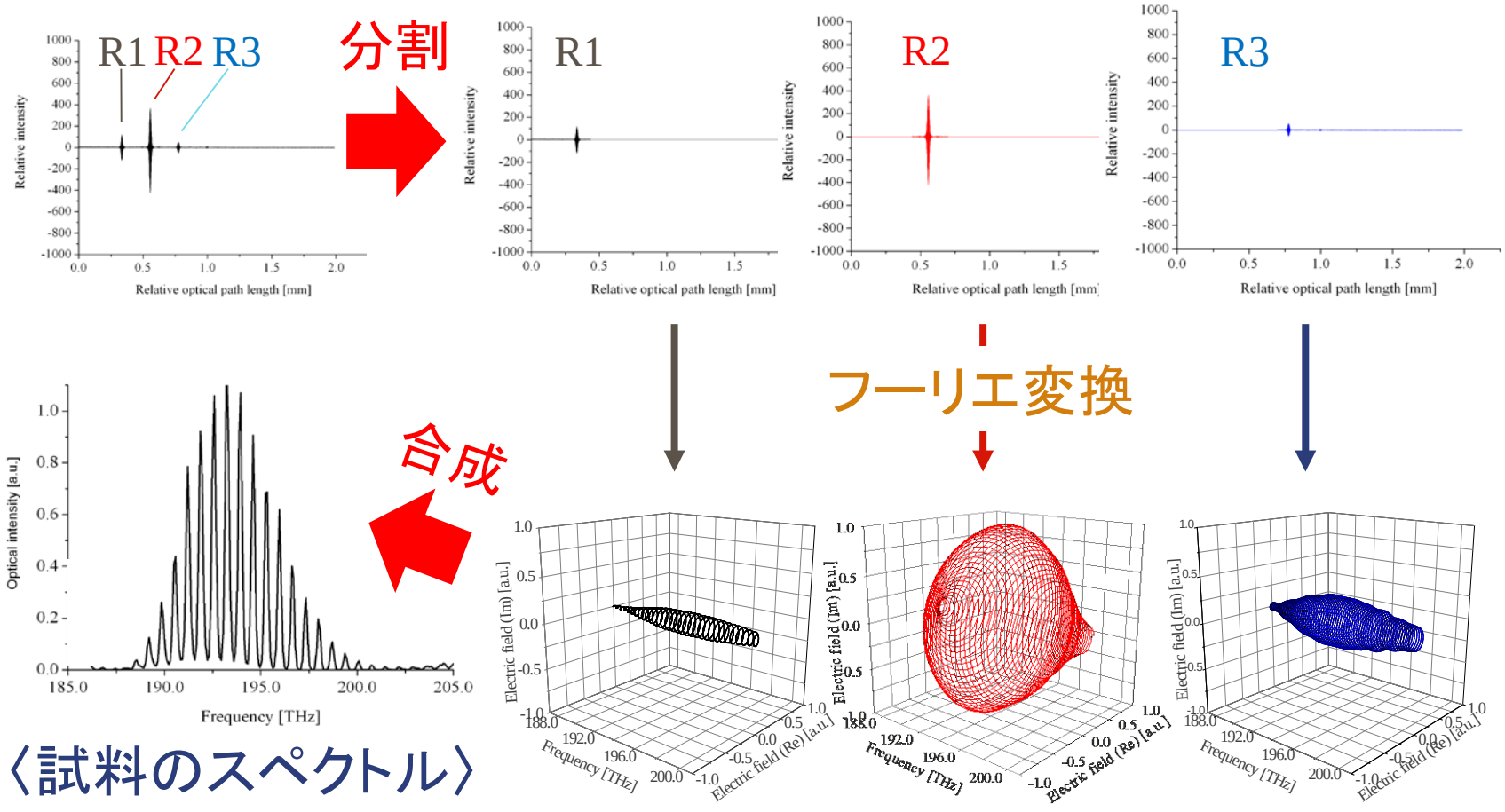
[1] S. Choi, M. Yamamoto, D. Moteki, T. Shioda, Y. Tanaka, and T. Kurokawa., Opt. Lett., **31**, 1976-1978 (2006).

光学系と干渉出力



相互相関：ウィーナー・キンチンの定理は成立しない

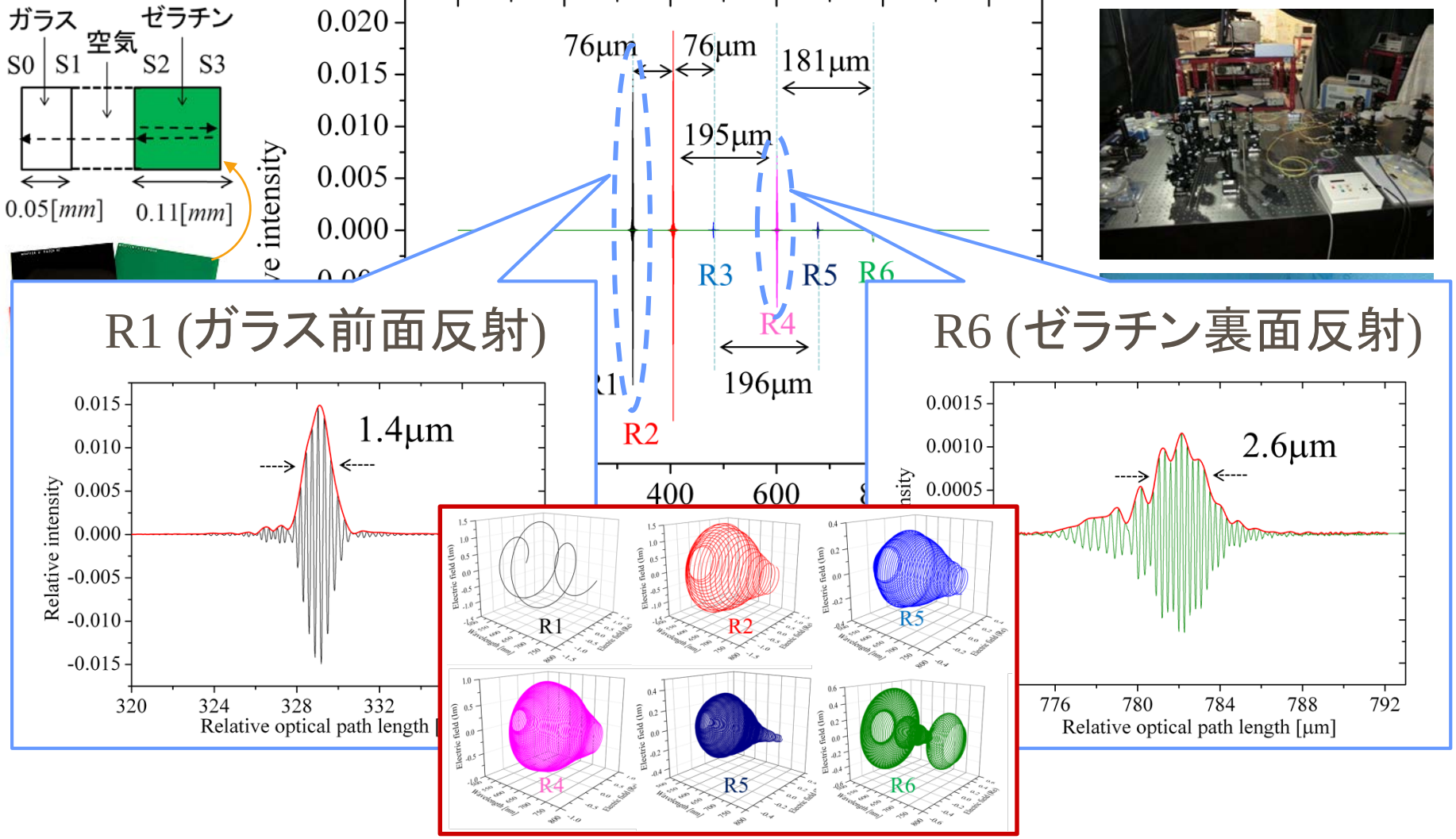
空間分解スペクトルの導出



〈試料のスペクトル〉

（複素）電界スペクトル

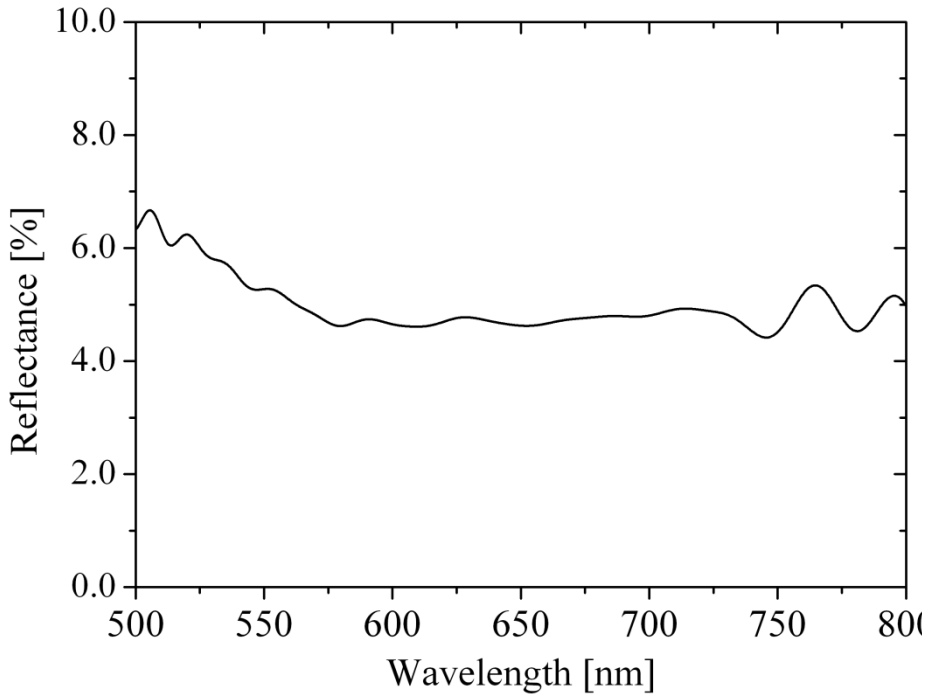
吸収試料の計測結果


ガラス
空気
ゼラチン
S0
S1
S2
S3
0.05[mm]
0.11[mm]
0.020
0.015
0.010
0.005
0.000
76μm
76μm
181μm
195μm
196μm
R1
R2
R3
R4
R5
R6
400
600
R1 (ガラス前面反射)
1.4μm
Relative intensity
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
320
324
328
332
Relative optical path length
R6 (ゼラチン裏面反射)
2.6μm
0.0015
0.0010
0.0005
776
780
784
788
792
Relative optical path length [μm]

ガラス反射率スペクトルと屈折率スペクトル

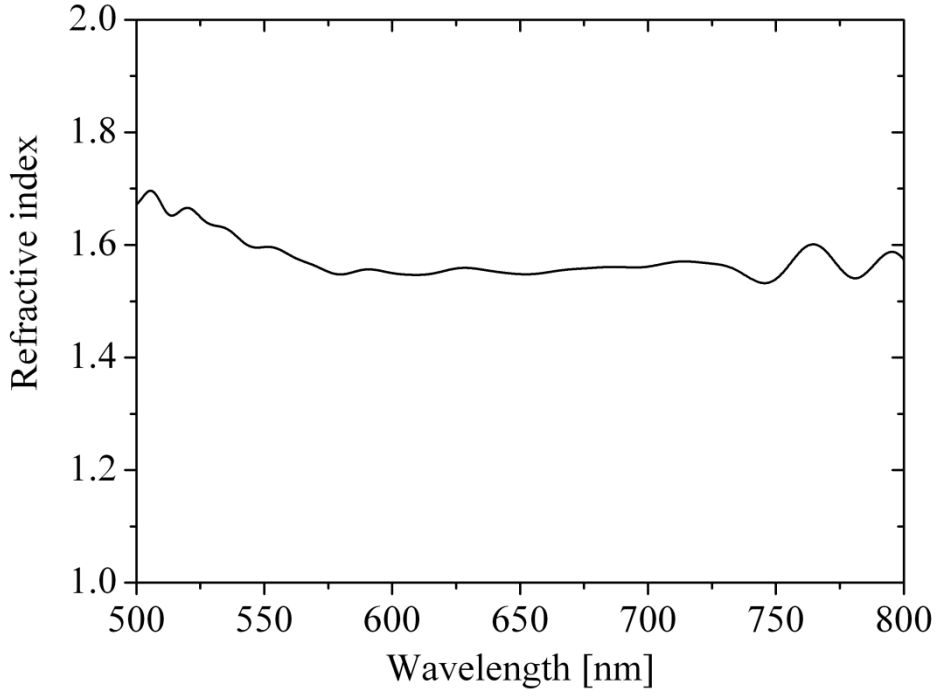
強度反射率スペクトル

➡ 4.85[%]

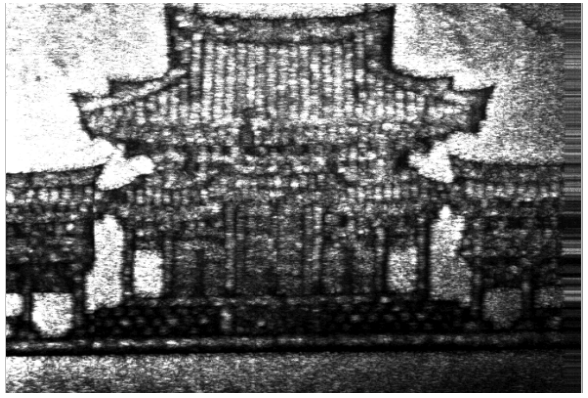


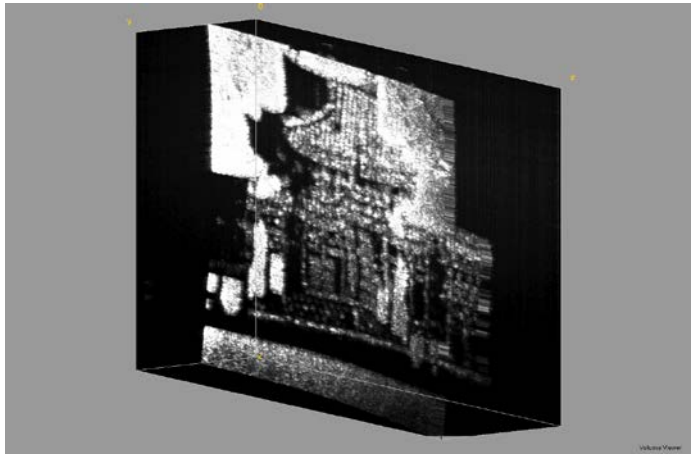
屈折率スペクトル

➡ 1.57

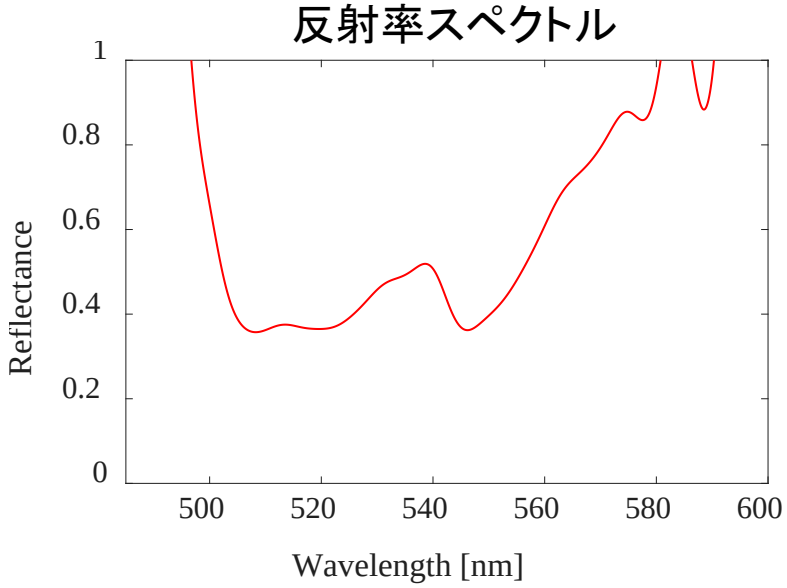


適用例　～十円玉表面形状計測～



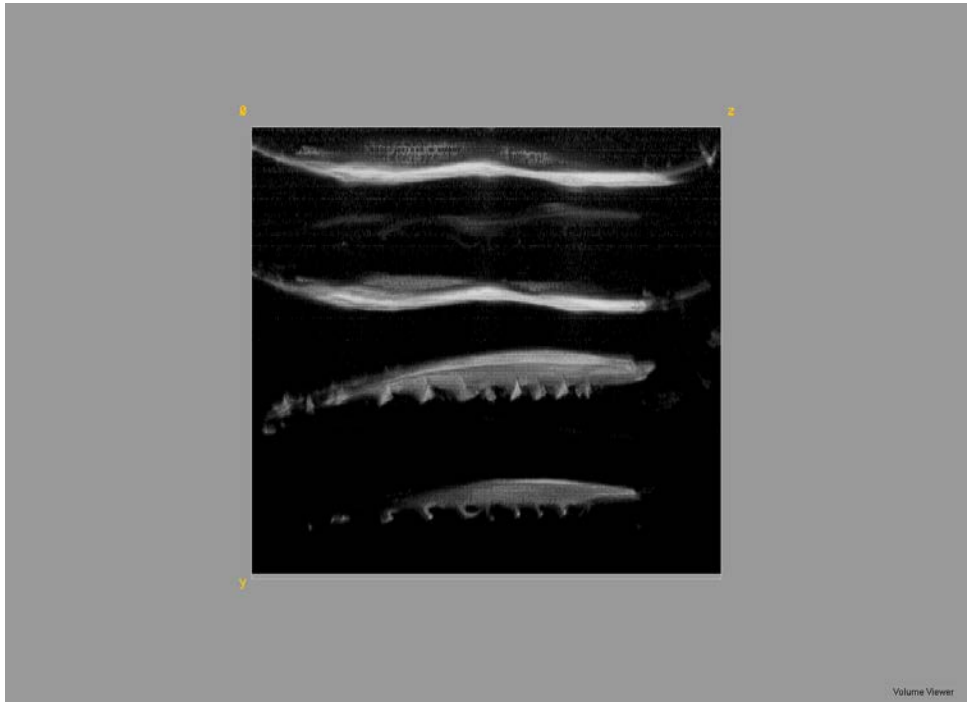


10 mm ＊7.0 mm ＊250 μm

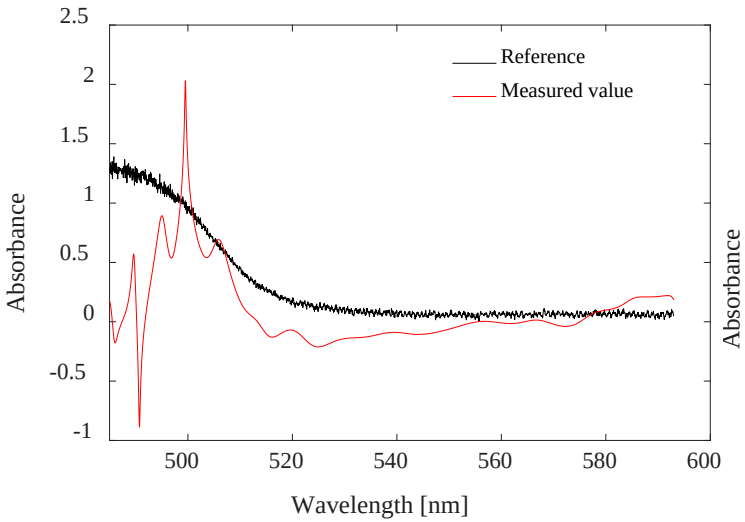


適用例　～ゼラチン多層膜の組成解析～

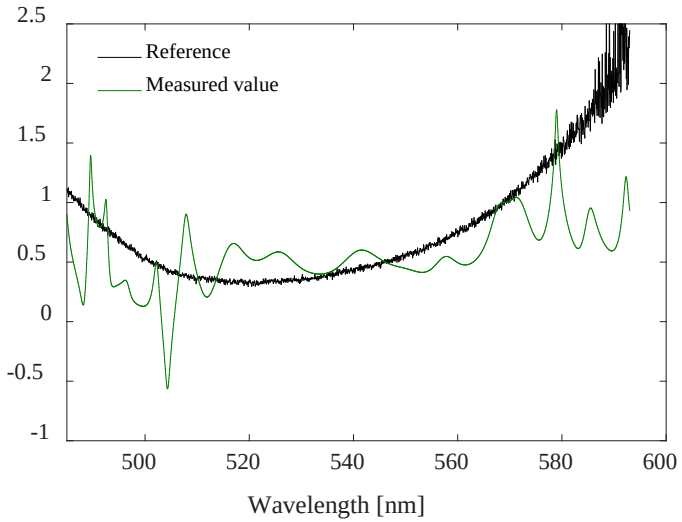
14 mm ＊14 mm ＊500 μm

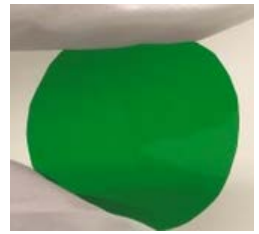


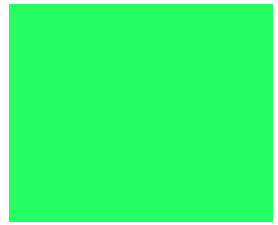
ゼラチン（イエロー）



ゼラチン（グリーン）







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