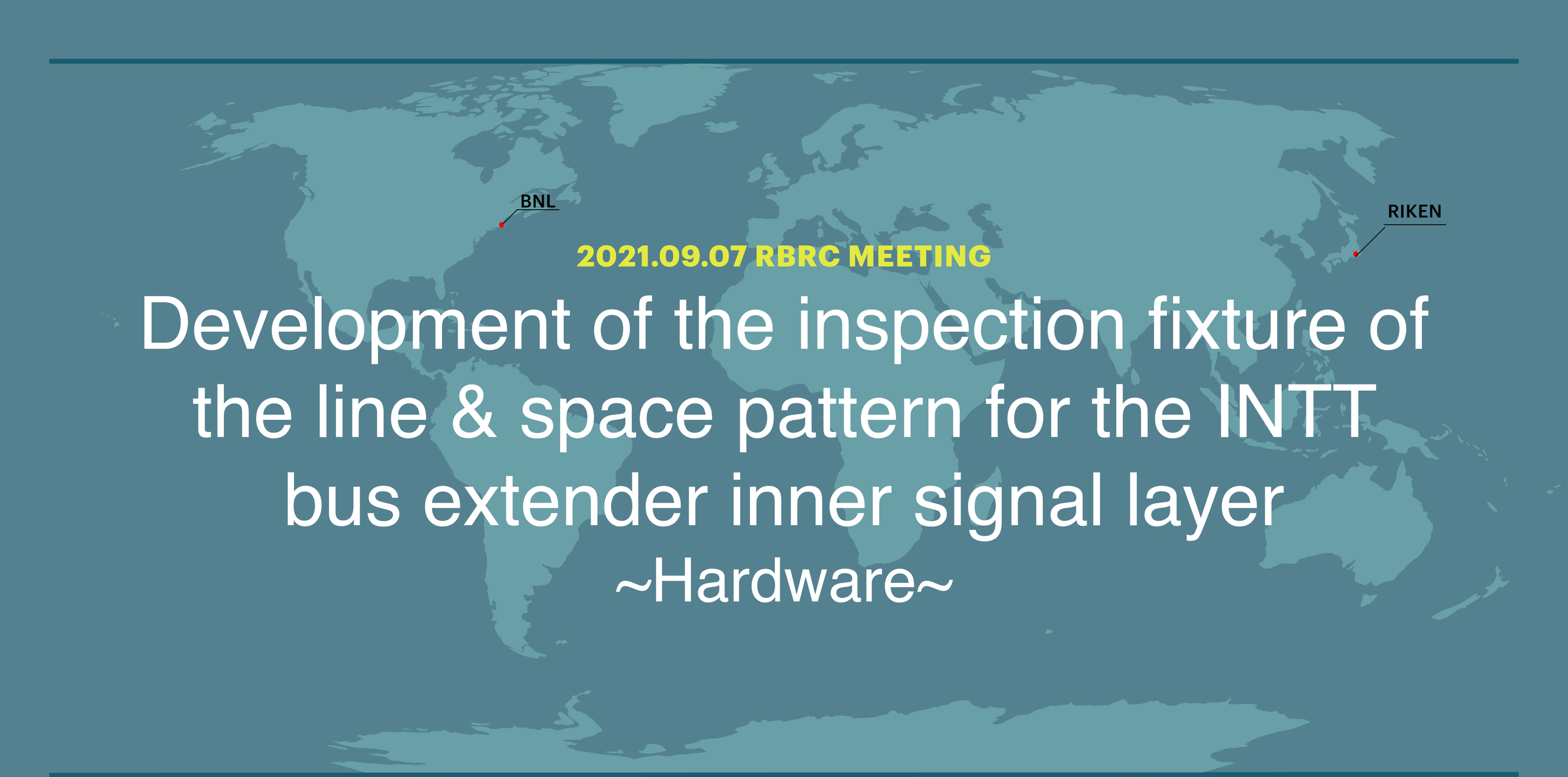


2021.09.07 RBRC MEETING

Development of the inspection fixture of the line & space pattern for the INTT bus extender inner signal layer
~Hardware~

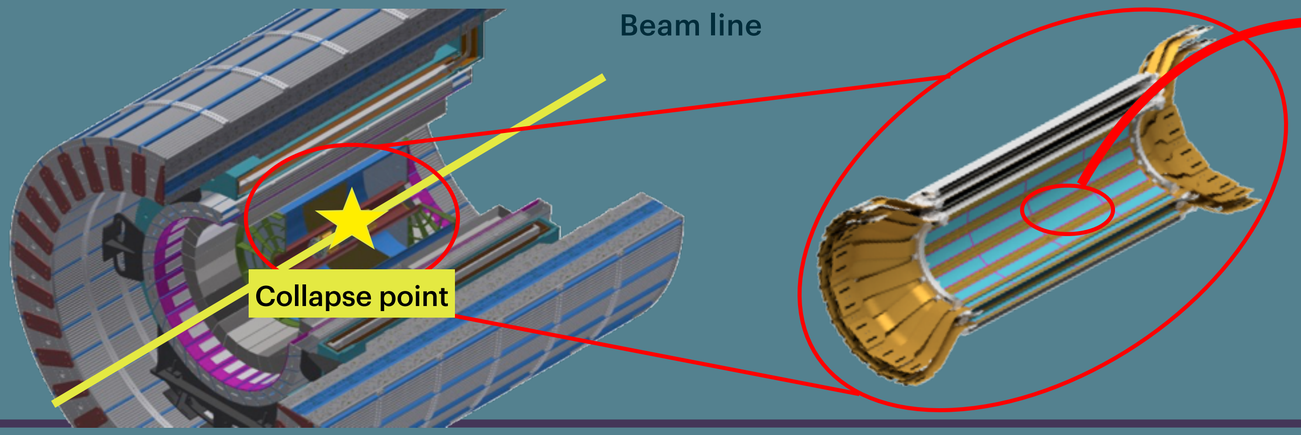
Rikkyo Univ. Nakamura Yusuke

INTRODUCTION

Intermediate Tracker(INTT)

- sPHENIX experiment will start 2023 to study Quark Gluon Plasma(QGP) at RHIC(Relativistic Heavy Ion Collider)
- Silicon detection in one of the particle track detectors：INTT(Intermediate Tracker)
- The silicon ladder consists of two silicon strip sensors and 26 FPHX readout chips.

Silicon strip detector



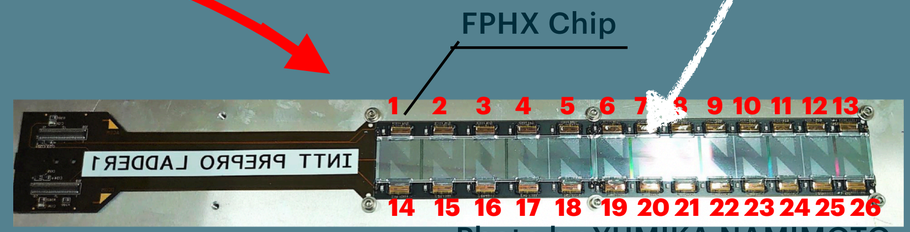
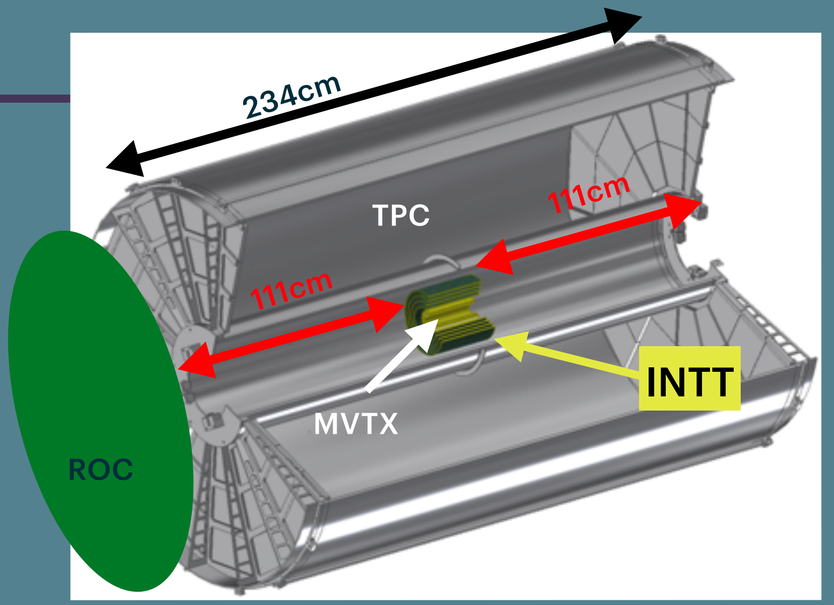


Photo by YUMIKA NAMIMOTO

Half Ladder

INTRODUCTION

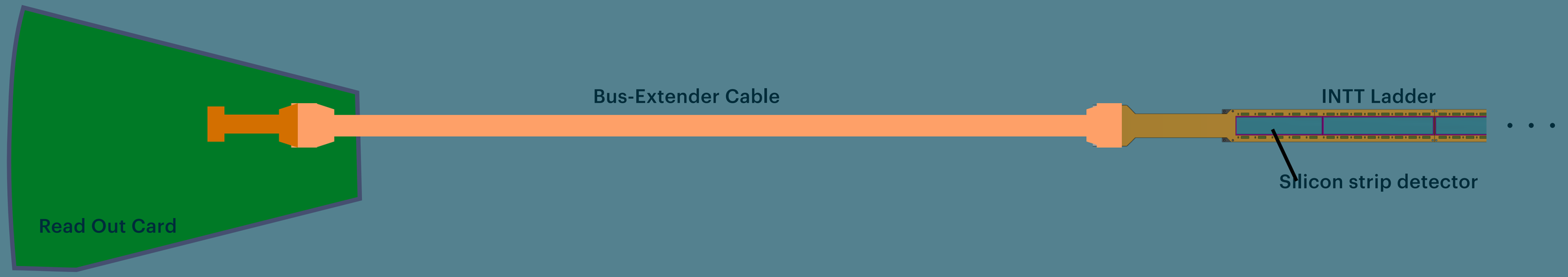


- **Bus-Extender Cable(BEX)**

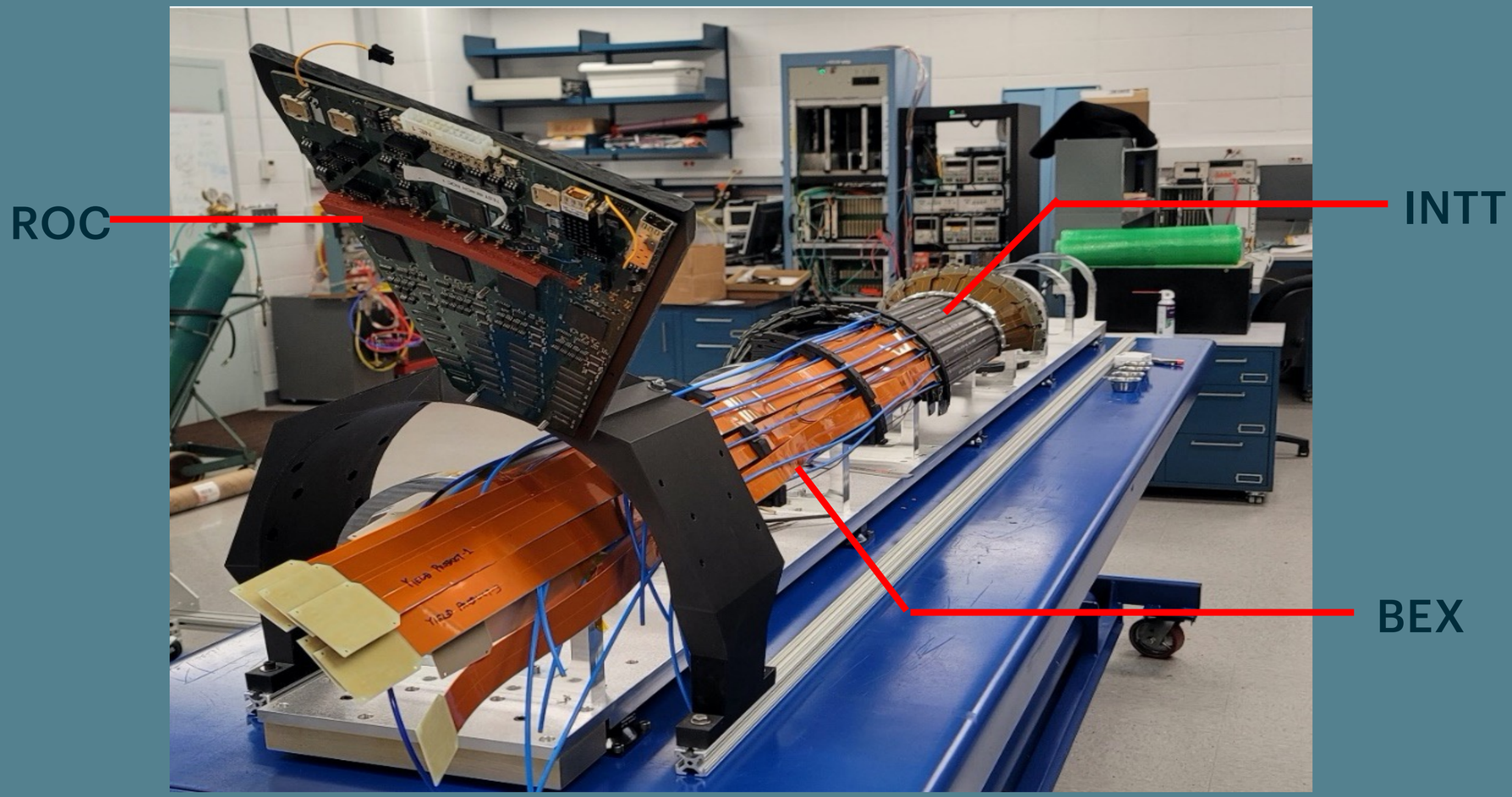
- This Cable send signals from INTT to Read Out Card(ROC).

[Requirement]

- Long, High-speed Communication, High-density Transmission, Flexibility etc.



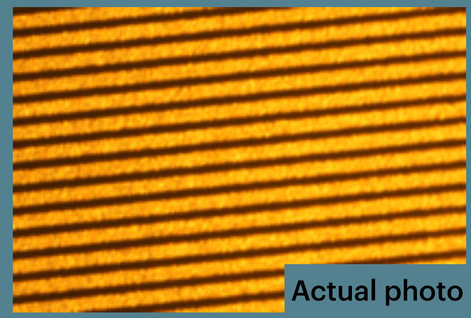
INTT Barrel MockUp (@BNL)



INTRODUCTION

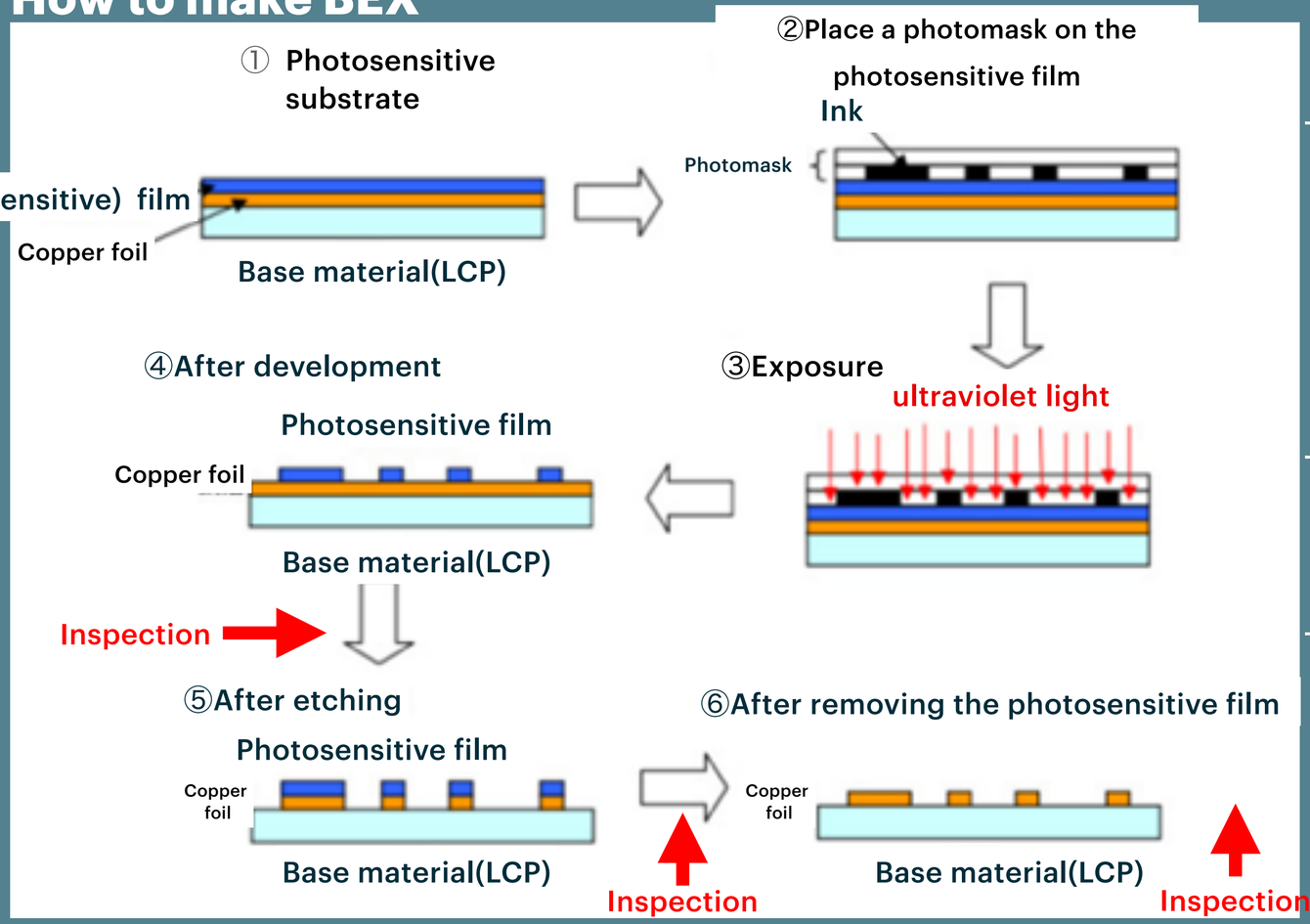
BEX Outline

- Length: 111cm, width: 3.5cm
- Number of signal lines：124 lines
- Signal line spacing：130μm
- 4 BEXs are printed on each sheet.



\INTRODUCTION\

How to make BEX



—A yield often occurs in patterning the inner signal layer.
Any abnormalities in the pattern should be detected as early stage as possible to improve the yield rate.

—A continuity test can be executed only after Step 6.

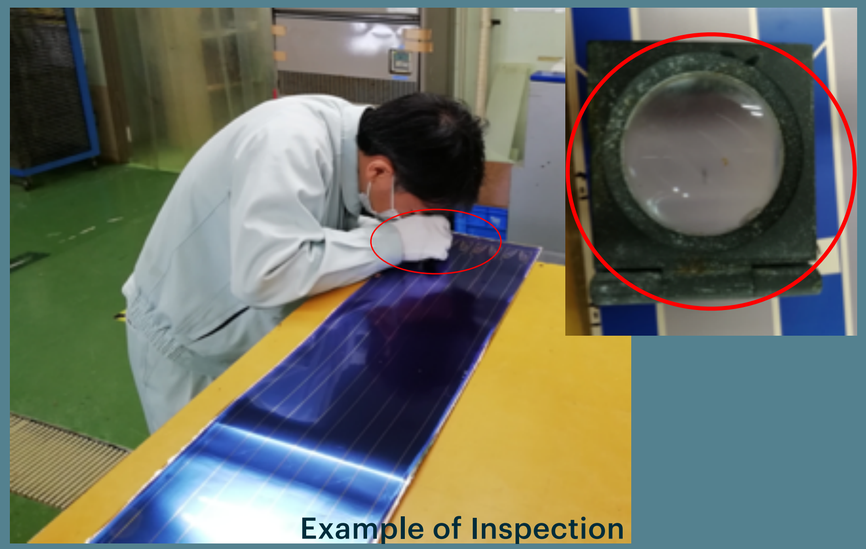
—If a defect is found in the pre-etching process, The dry film can be reattached.

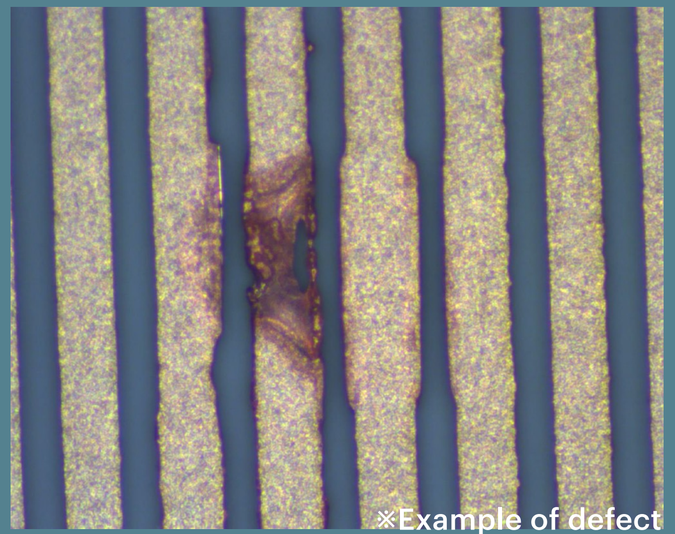
→Additional inspection is performed between processes using a dedicated fixture.

\MOTIVATION\

Conventional inspection method

Until now, companies have visually inspected 128lines ×111cm signal lines using a magnify lens





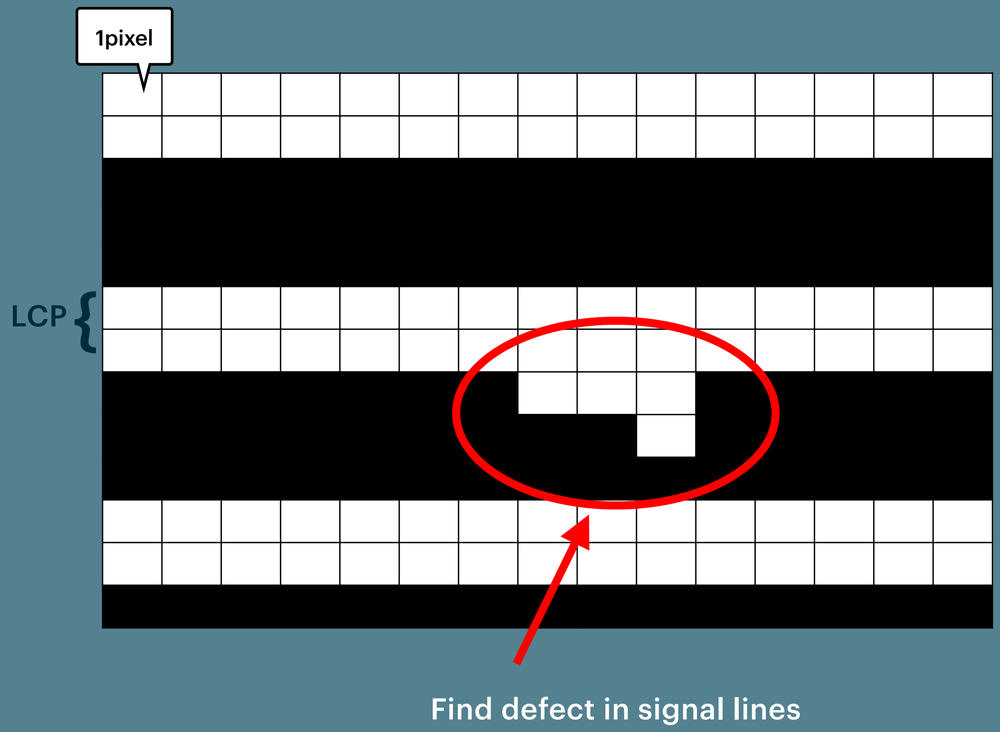
Mass production is planned to be 140 pieces.
If the yield rate is 50%, 35sheets.
If the yield rate is 100%, 70sheets.

→Due to the huge burden, the inspection process has to be somewhat reduced by the automation.

＼ANALYSIS METHOD＼

Initial analysis method

1. Take a high resolution photo of signal lines.
2. Convert image to black and white for a simplification.



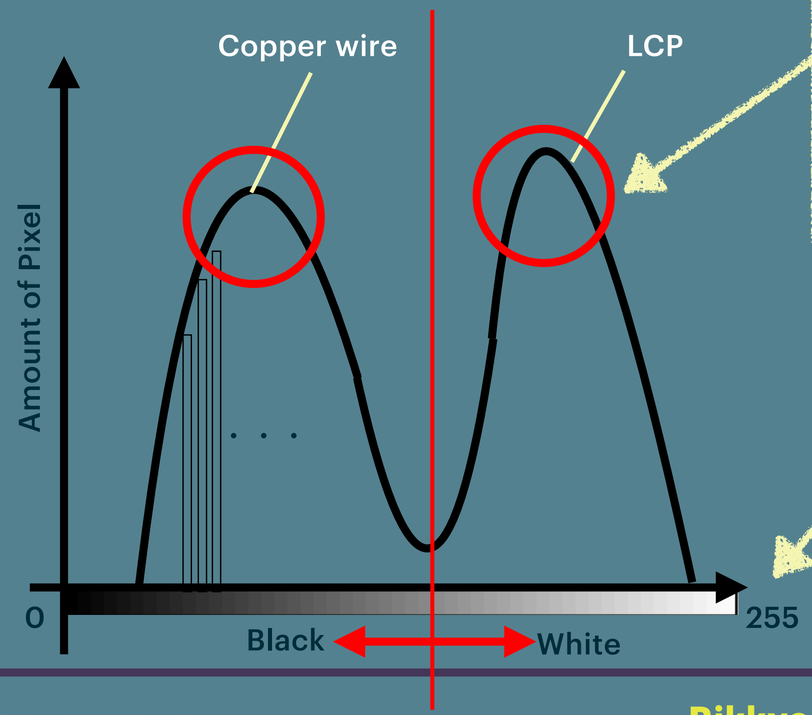
- **White：LCP**
- **Black：Copper wire**

→Preferably, increase the number of pixels assigned to the signal line (Copper wire)

→The larger the number of pixels, the better the precision to find defects.

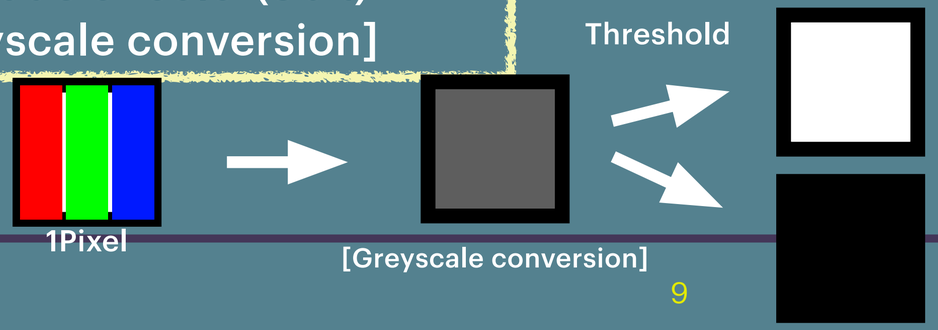
＼ANALYSIS METHOD＼

- The dimensions of the line (Copper) and space (LCP) are 130 and 130um, respectively.
  →Due to the difference in the color between the copper and LCP, *ideally* two distinctive peaks are expected to appear in color histogram(s).

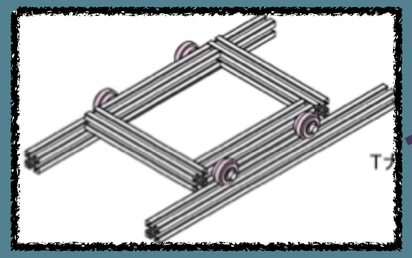


If two peaks appear neatly like this,I can set a threshold and distinguish between LCP and copper wire.
→If there is only one peak the gap is filled between two peaks, the threshold cannot be set and it is difficult to distinguish.

Converts RGB embedded in 1Pixel to shade of color(8bit)
[Greyscale conversion]



Conseptual design of the inspection fixture(side view)



\CURRENT SETUP\

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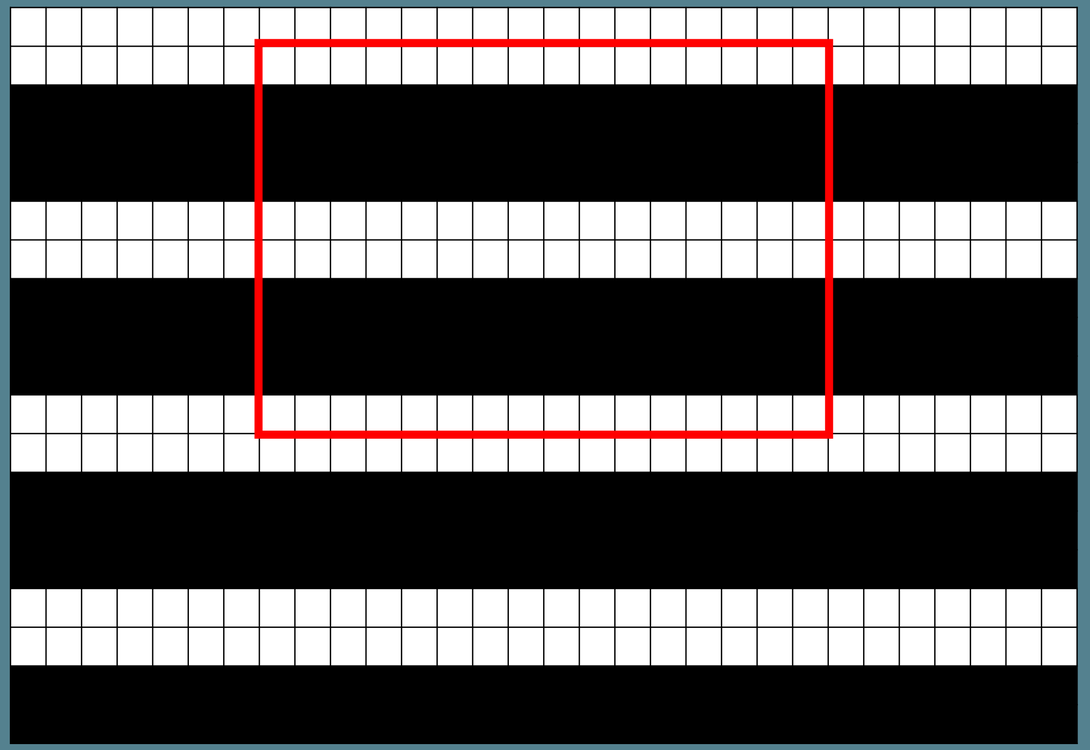
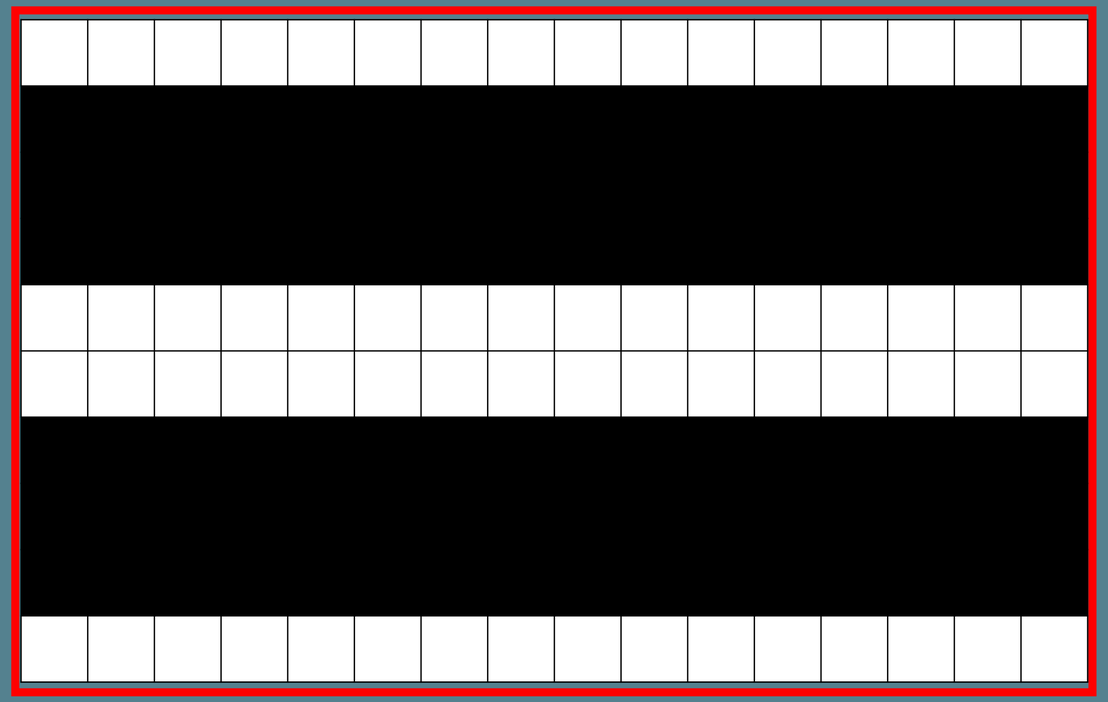
DIGITAL VS OPTICAL ZOOM

Digital zoom



30×19 = 570pixels

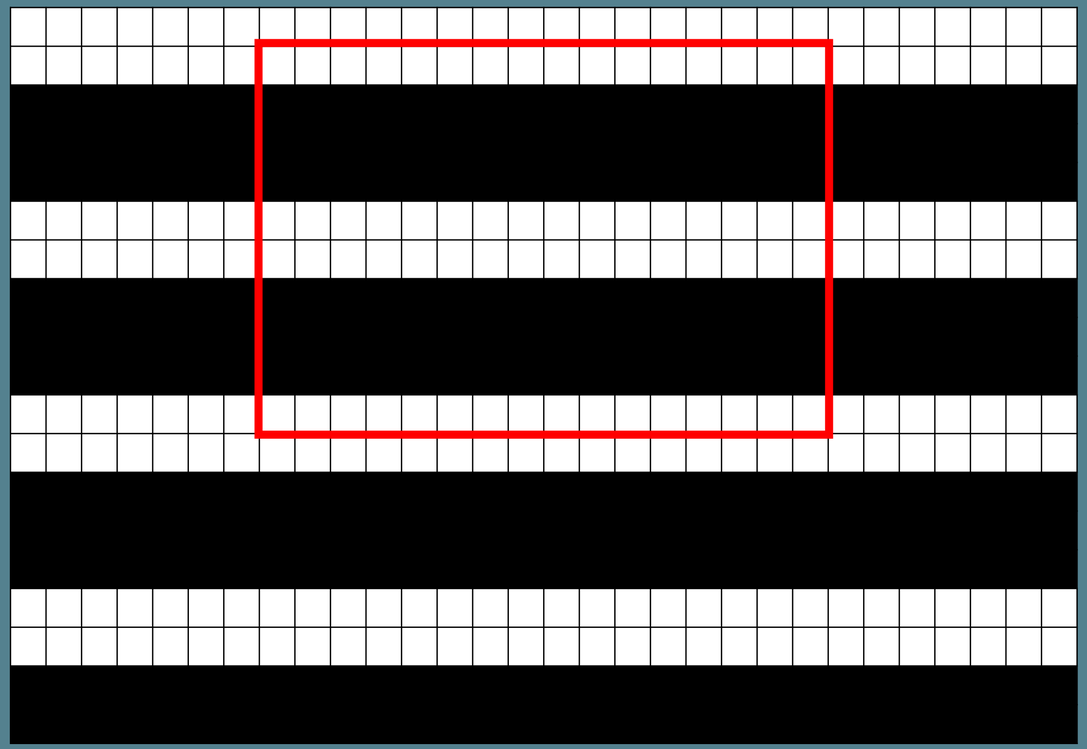


16×10 = 160pixels

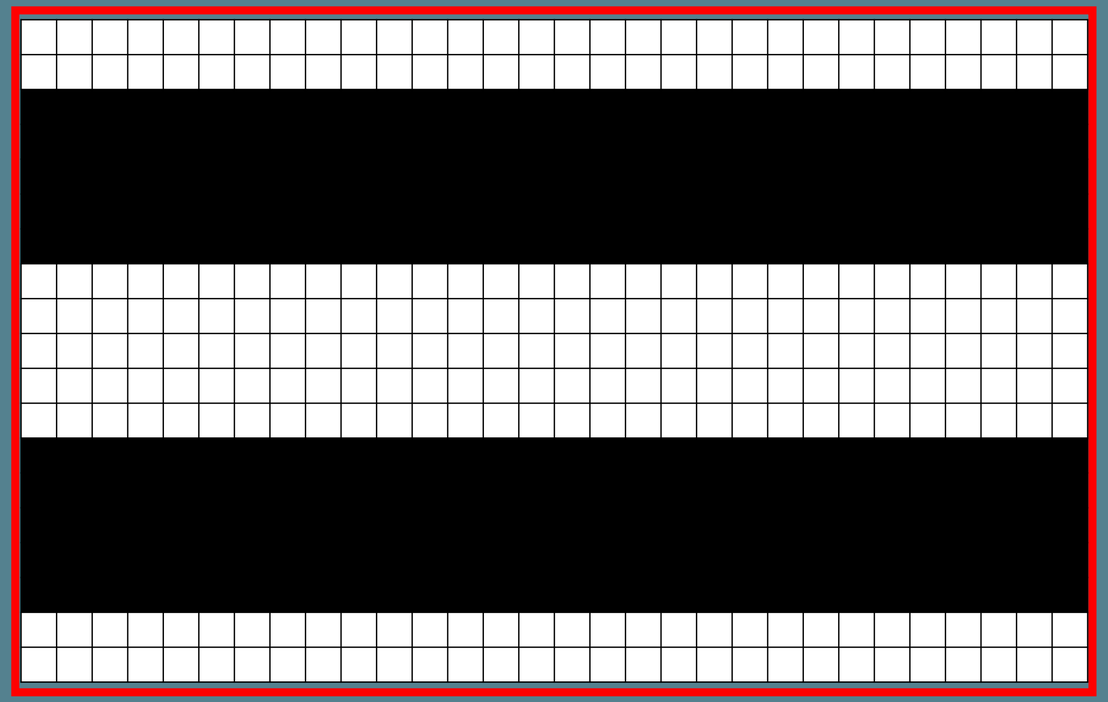
The number of Pixels will decrease.

DIGITAL VS OPTICAL ZOOM

Optical zoom



30×19 = 570pixels



30×19 = 570pixels

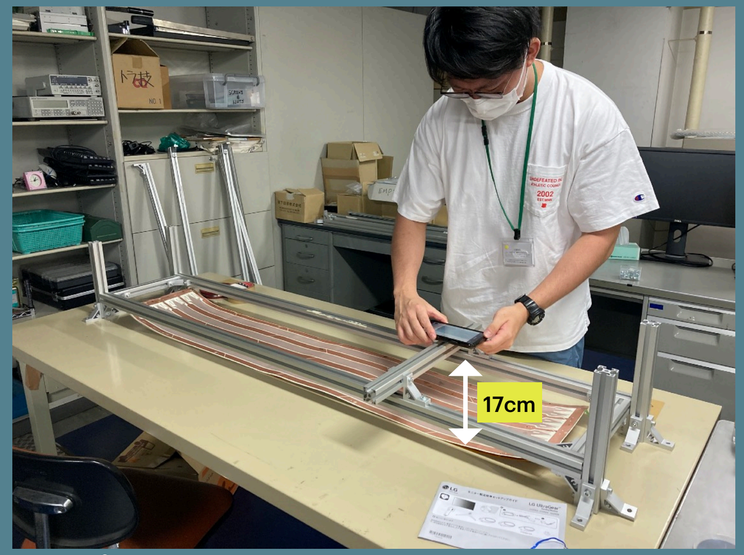
Number of pixels doesn't change

CAMERA SELECTION

iPhone

〈Spec〉

- Number of pixels：12 million Pixels
- Zoom　　：Digital
- Real time display output：Possible



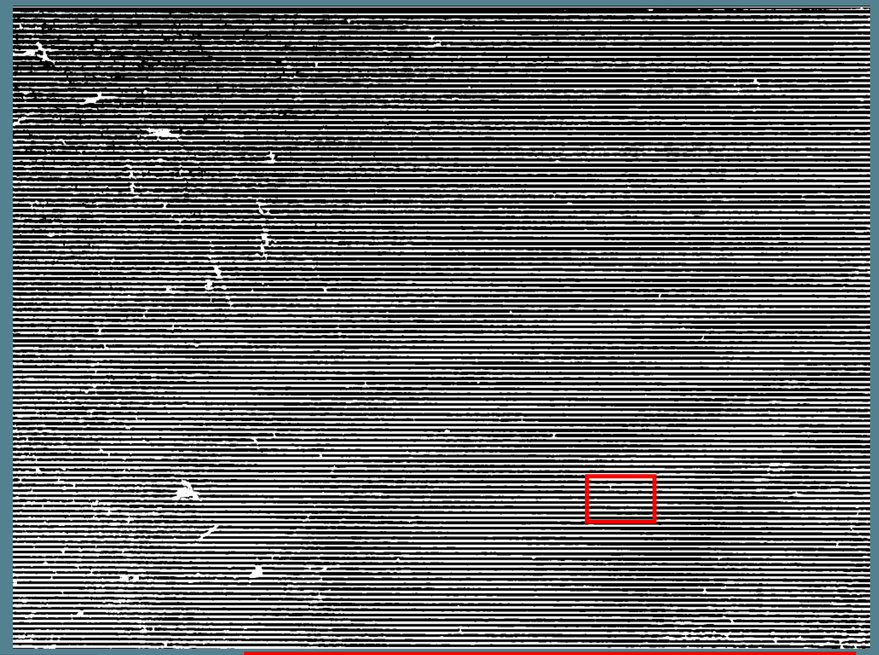
Merit

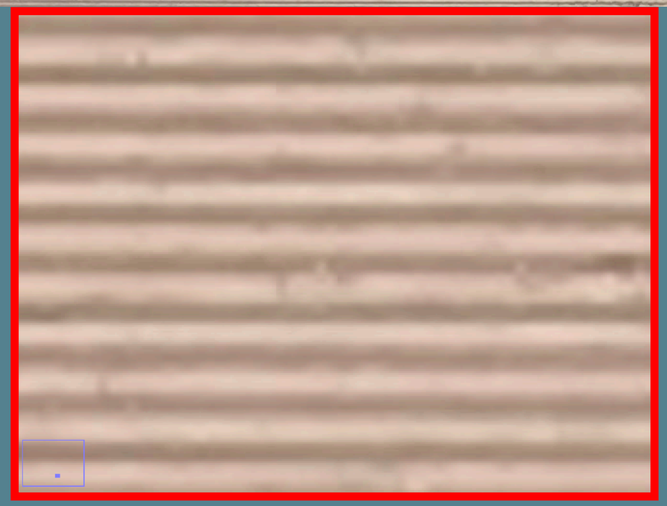
- Wireless communication is possible.
- Easy focus adjustment.
- Use to it.

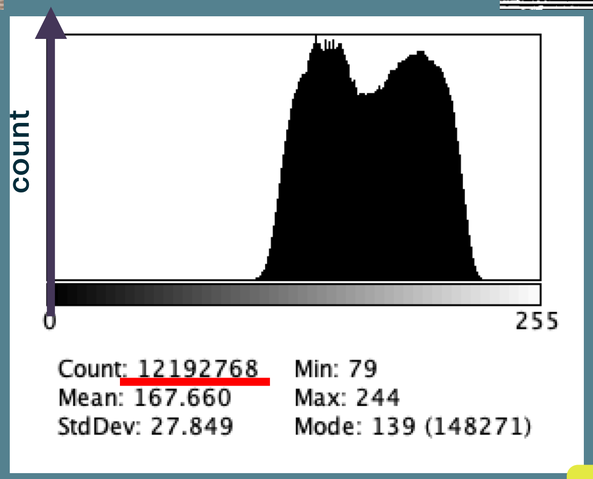
Demerit

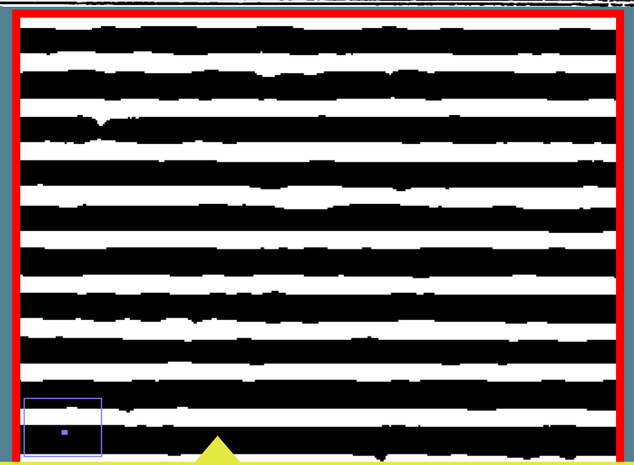
- The number of pixels drops due to digital zoom.
- Comes with other unnecessary features

Photographs taken with a iPhone









The width of copper wire is't constant and it's difficult to distinguish between LCP and copper wire.
Shooting range is limited due to the focus.
→Difficult to identify defective parts, and it takes time to shoot.

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＼CAMERA SELECTION／

single-lens reflex camera

Canon kiss Digital X

〈Spec〉

- Number of pixels：10 million Pixels
- Zoom　　：Optical
- Real time display output：Impossible

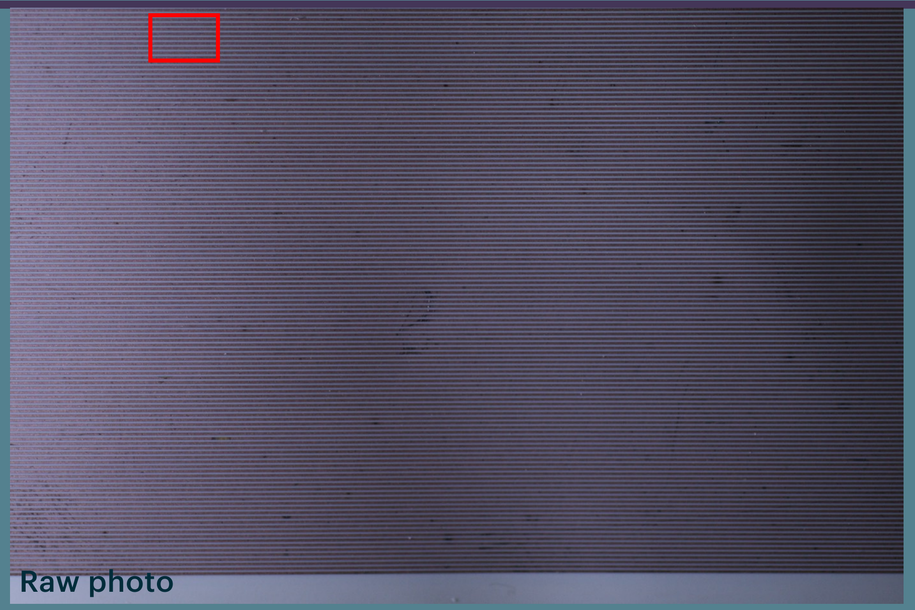
Merit

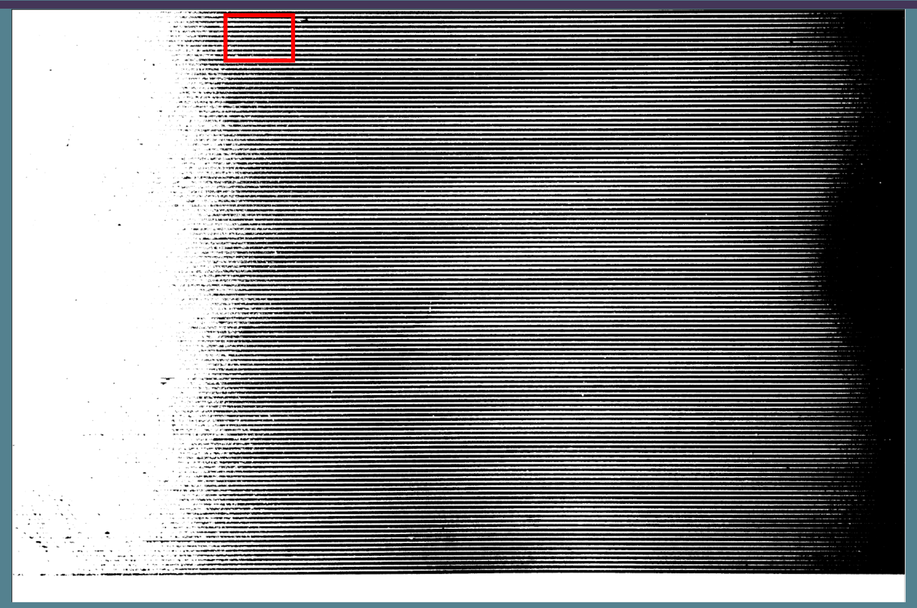
- Fine settings are possible.
  (ISO sensitivity, shutter speed, etc.)
- Thanks to the optical close up lens, the target photo can be clearly taken without dropping the resolution.

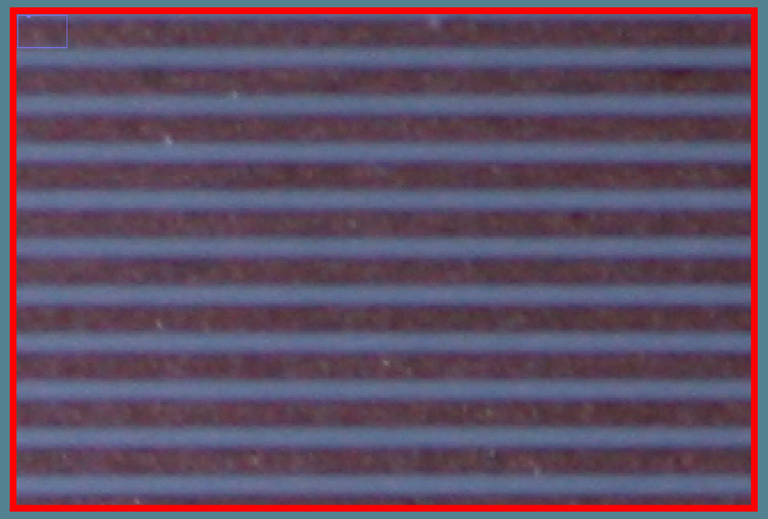
Demerit

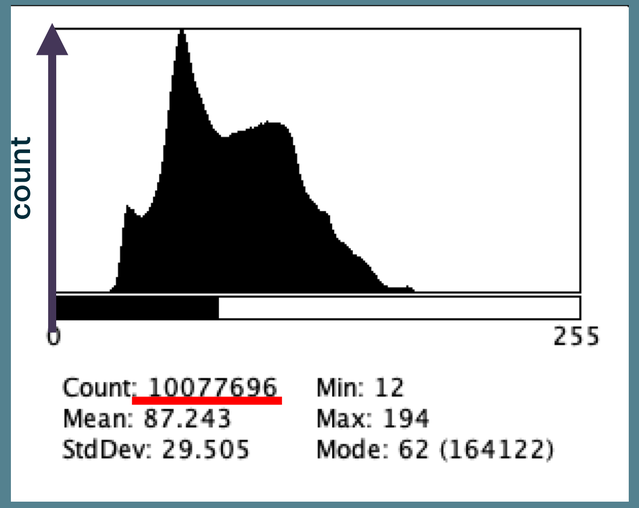
- Support structure becomes massive
- Difficult to adjust focus.
- Real time monitor output and video recording are not possible.

Photographs taken with a single-lens reflex camera









Fluctuation in the width of copper wire have decreased. I was able to expand shooting range, but it was very difficult to adjust focus and the setup was large.

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CAMERA SELECTION

Micro scope

〈Spec〉

- Number of pixels：300,000 Pixels
- Zoom　　：Digital
- Real time display output：Possible

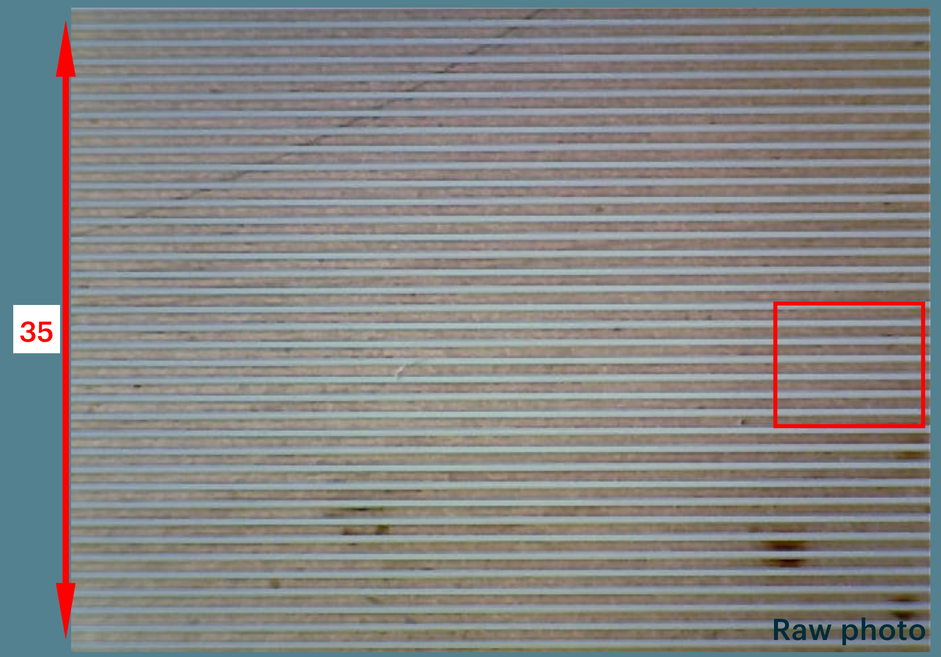
Merit

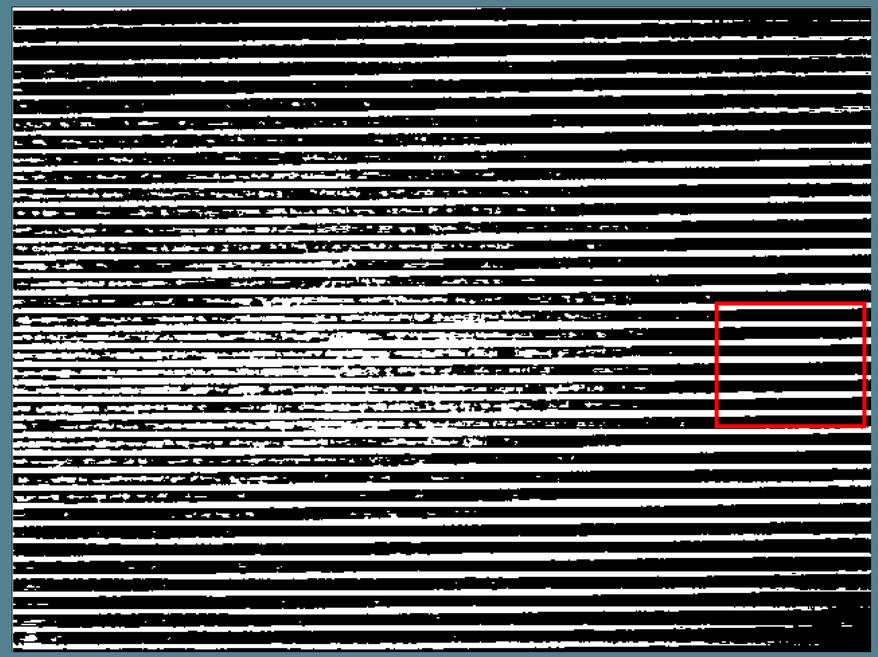
- Close-Up photography is possible
- Easy focus adjustment.

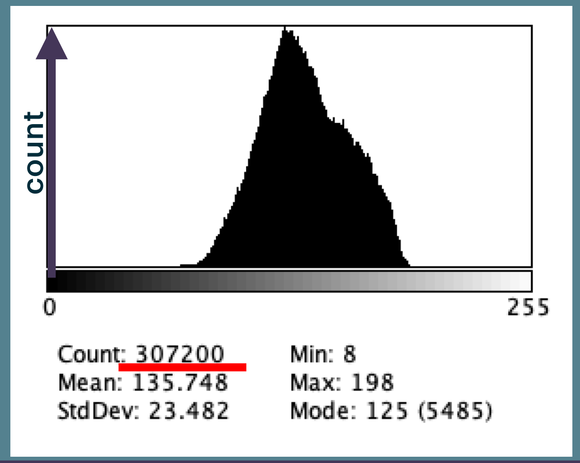
Demerit

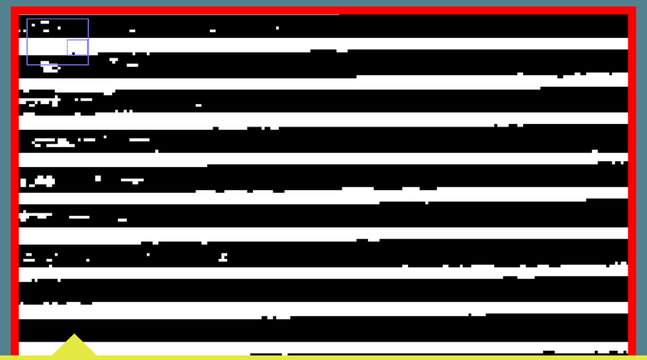
- The number of pixels drops due to digital zoom.
- It takes time to shoot because the shooting range is narrow.

Photographs taken by microscope.









The width of the copper wire isn't constant, and the total number of pixels is also small.
So the pixels distributed to the copper wire part become small.
→Difficult to identify defective part

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＼CAMERA SELECTION＼

CS2000-C

https://www.shodensha-inc.co.jp/ja/cs2000-b/

〈Spec〉

- Number of pixels：20 million Pixels
- Zoom　　：Optical
- Real time display output：Possible

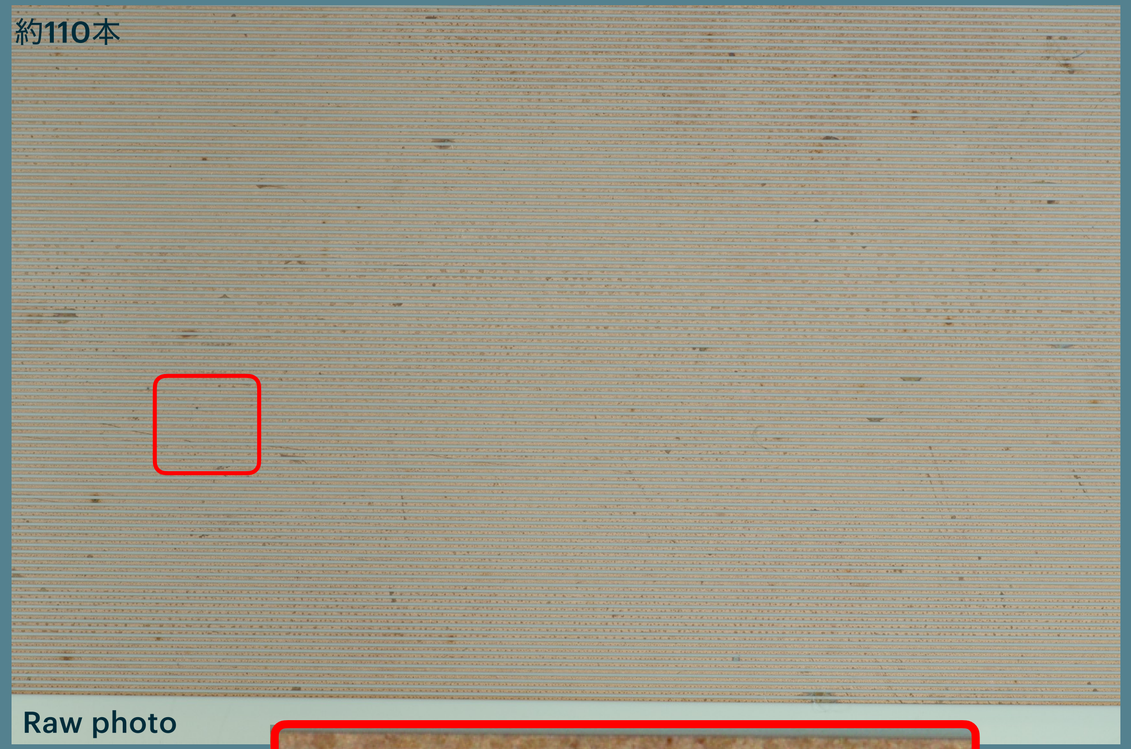
Merit

- Small size and easy to setting.
- The number of pixels is the highest.
- Simultaneous monitor output is possible.

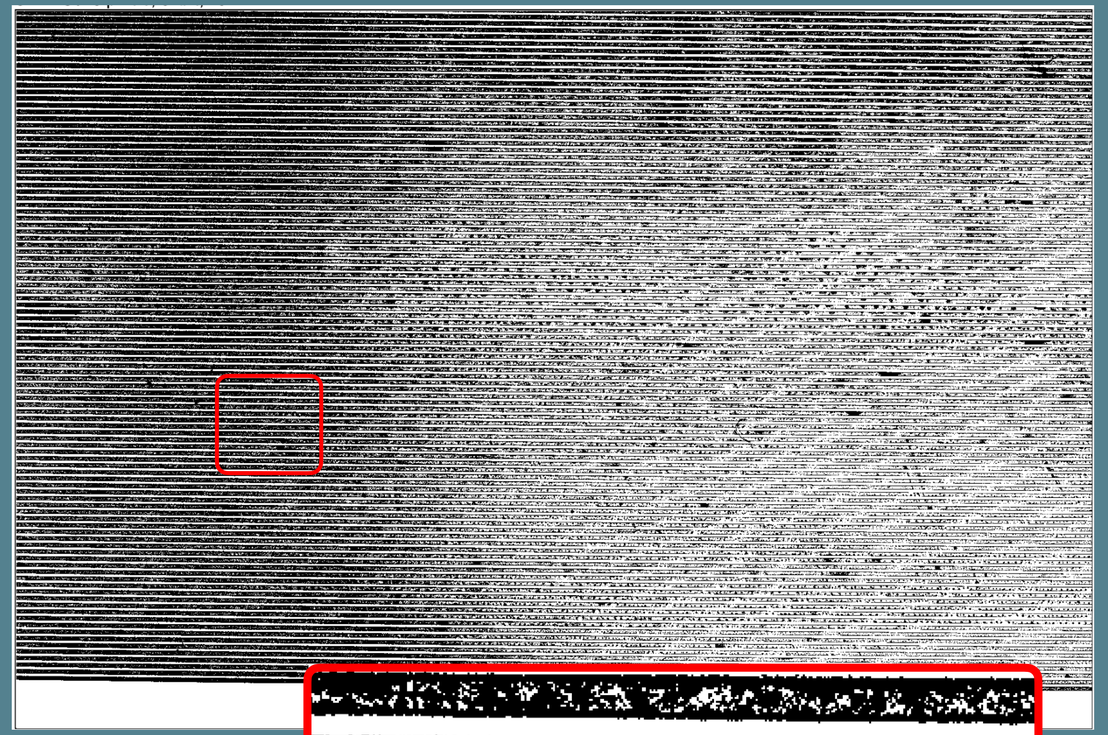
Demerit

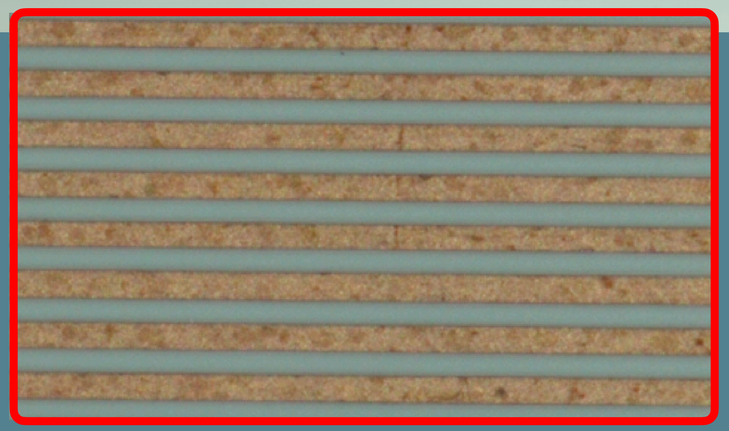
- Frame rate is a little slow due to the large amount of pixels.

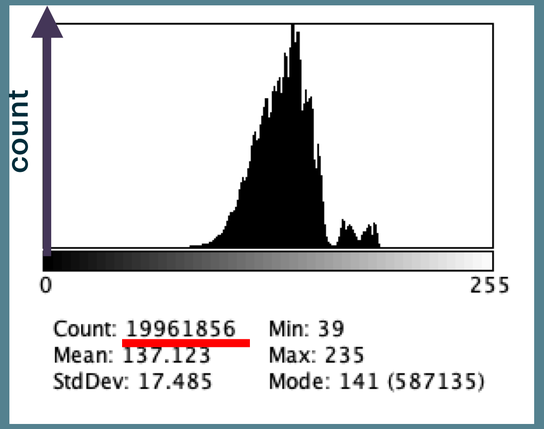
Photographs taken by CS2000-C.



Raw photo







The boundary between the LCP and the copper wire was separated linearly。

However, white spots are noticeable inside the copper wire.
→Next slide

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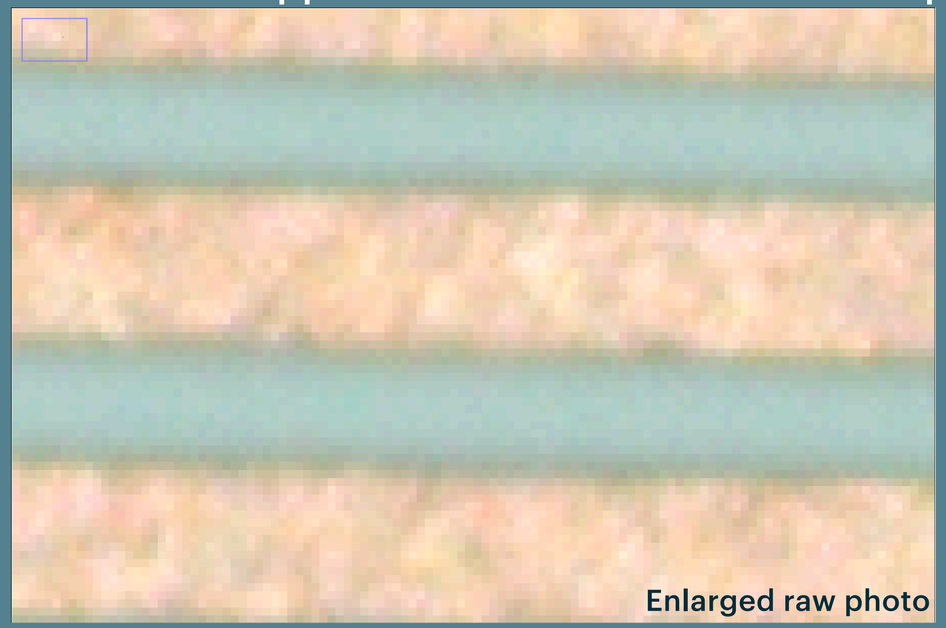
＼SUPPLEMENT＼

- **This color unevenness of signal line isn’t related to lighting, but due to the tiny unevenness on the surface of the copper wire that occur during etching.**

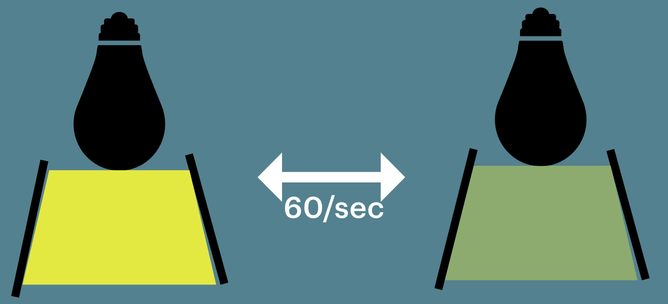
This small unevenness appers in black and white for each part.



Enlarged raw photo

→By shooting with a camera with large number of pixels, such small unevenness of light was reflected in the B-W photograph
→Focus on HSB space（Imai-San）

LIGHTING



Fluorescent light

- The power frequency in Tokyo is 60Hz. Oscillate between invisible light and darkness.
- When shooting under the fluorescent light, a flicker phenomenon occurs due to difference between the frame rate and the frequency of the fluorescent light. →Affect shooting.

Flicker phenomenon

＼LIGHTING＼

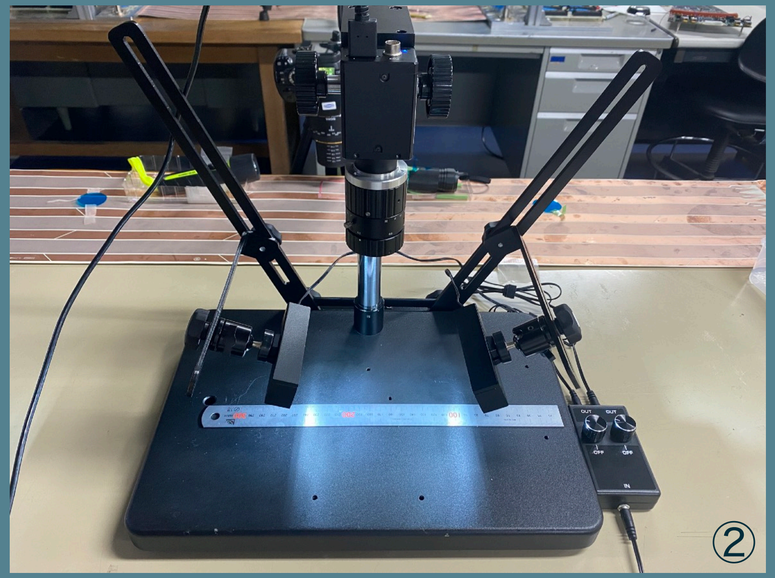
LED

① Since the LED is always on, the flicker phenomenon doesn’t occur

(Static lighting)

→ Clearer shooting is possible

② By shining light on the object from both sides, unevenness of light is suppressed.



SUMMARY

Camera：CS2000-C
Light：LED

(Reduce light unevenness
By placing two light source)

＼NEXT STEP＼

[Hardware near term goal]

- **Real time output to a large monitor with CS2000-C and visually check for defects.**

（Time scale：Less than a month）

[From now on]

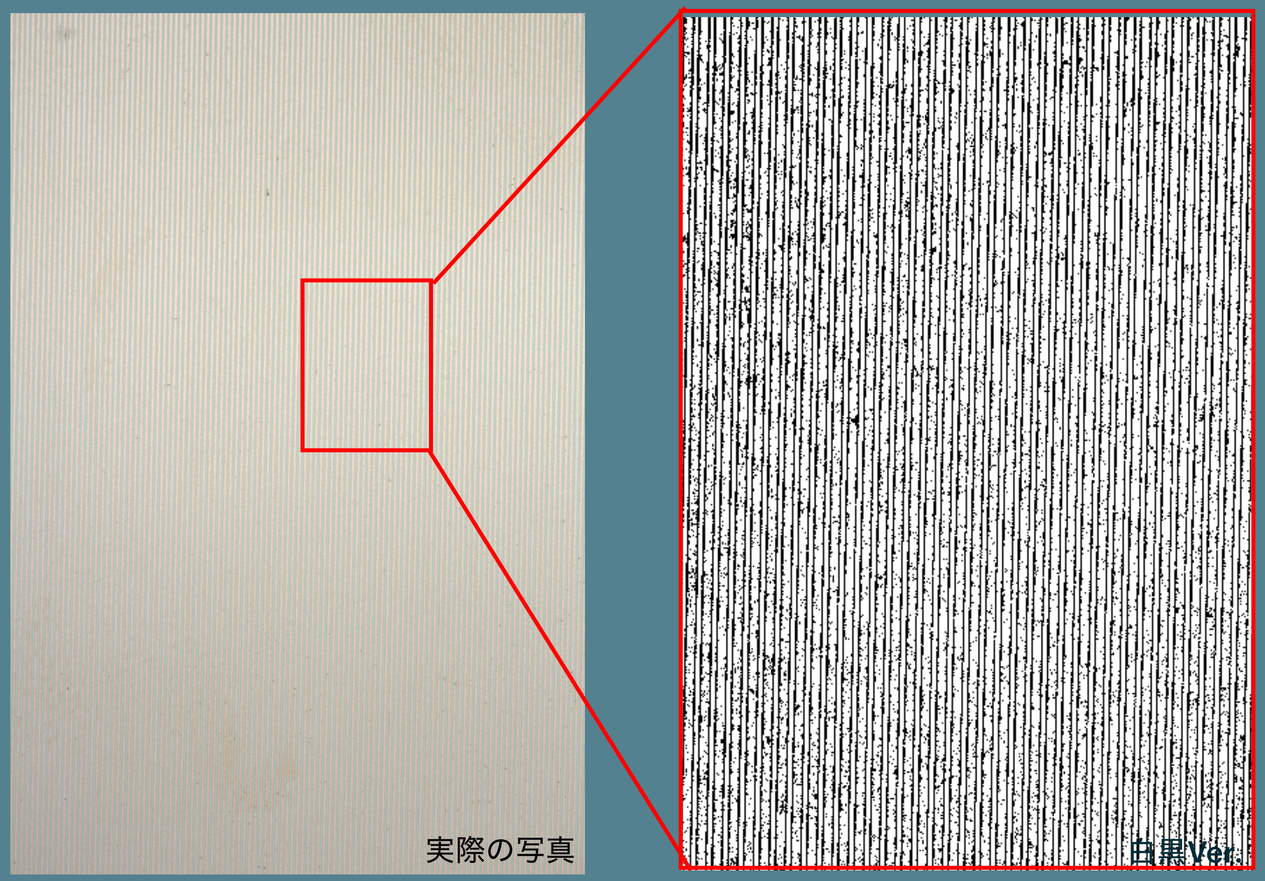
- ☑ **Camera selection**
- ☑ **Lighting**
- ☐ **How to fix the BEX sheet**
- ☐ **Camera support structure**
- ☐ **Motor drive camera position**

} fixture

BUCK UP

＼カメラの選定＼

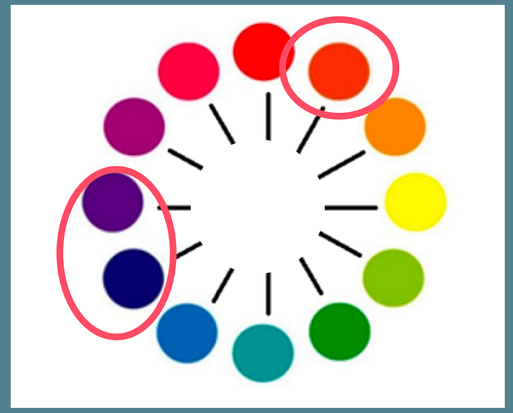
- **CS2000-C実際に撮影した写真**

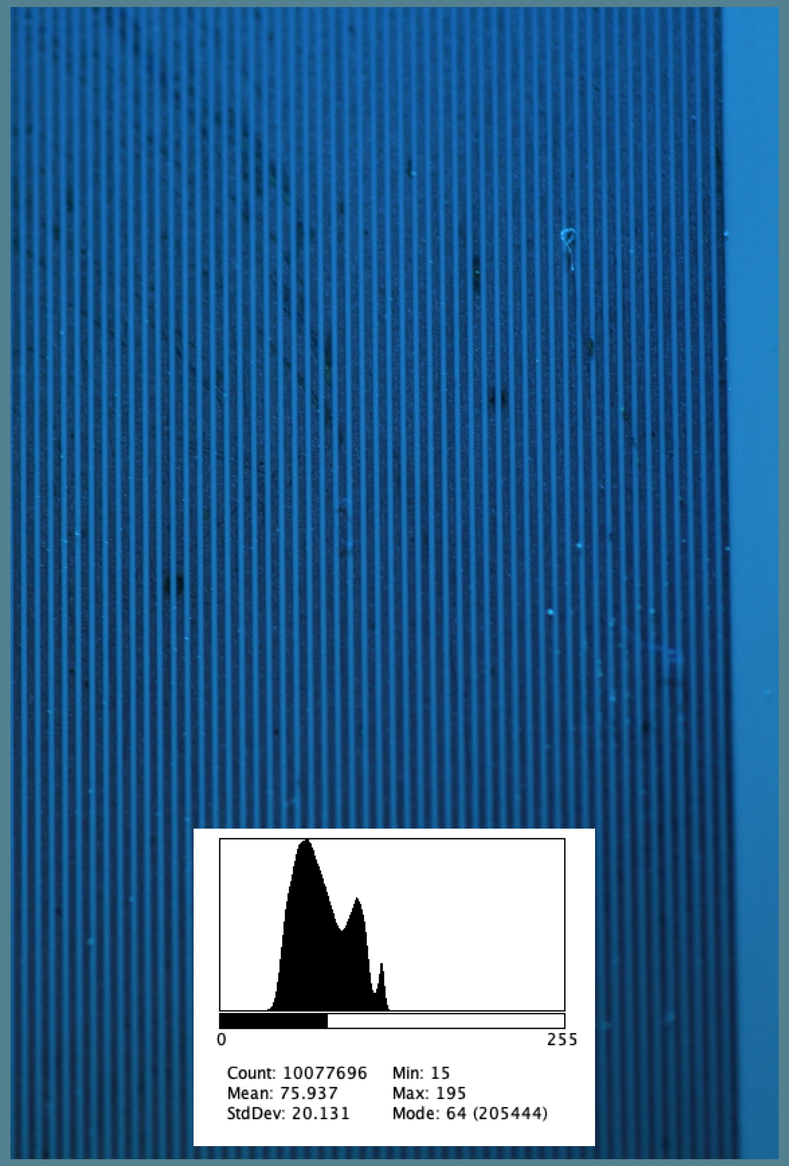


＼照明＼

吸収光

- 銅線とLCPの明暗をはっきりとさせるために吸収光を用いた撮影を行う。
- 銅線の色は暖色系（λ:長め）なので、吸収光は青〜紫と言った寒色系（λ:短い）が考えられる。
- 今回以下の３色のセロハンをライトに取り付けて、観測を行った。

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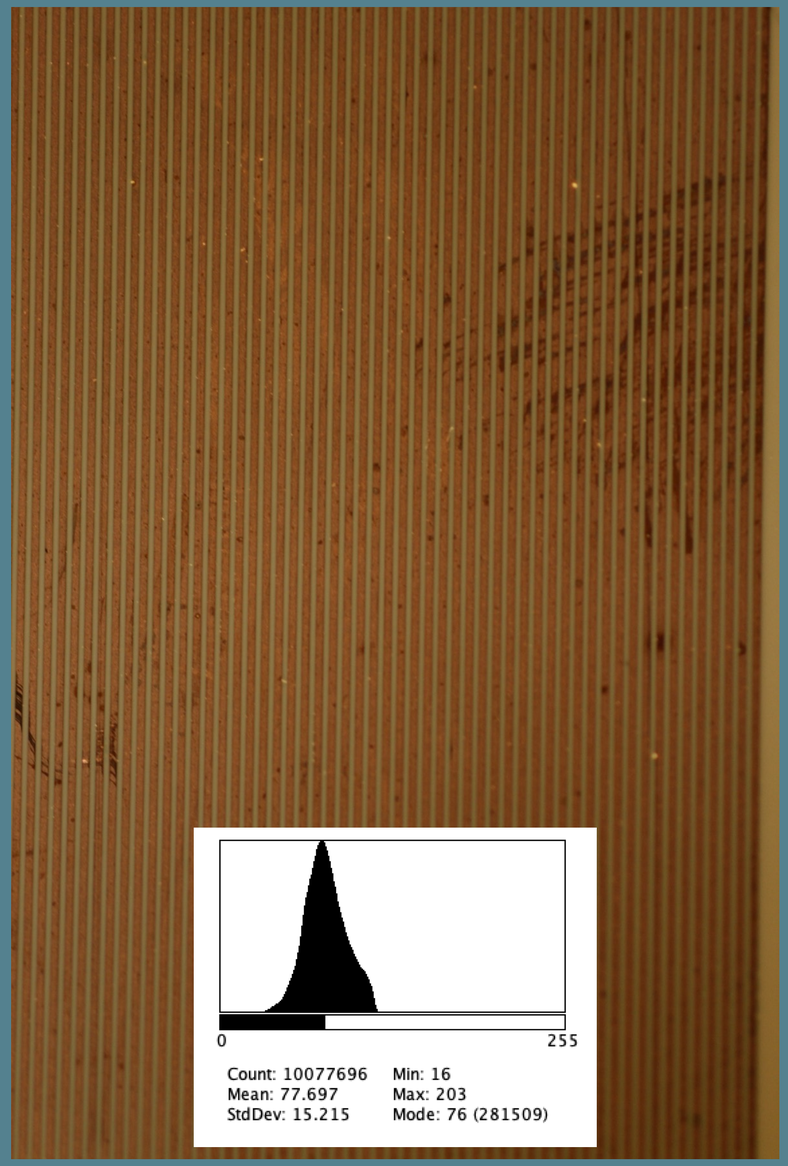
Mean: 75.937
StdDev: 20.131
Min: 15
Max: 195
Mode: 64 (205444)


0
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StdDev: 15.215
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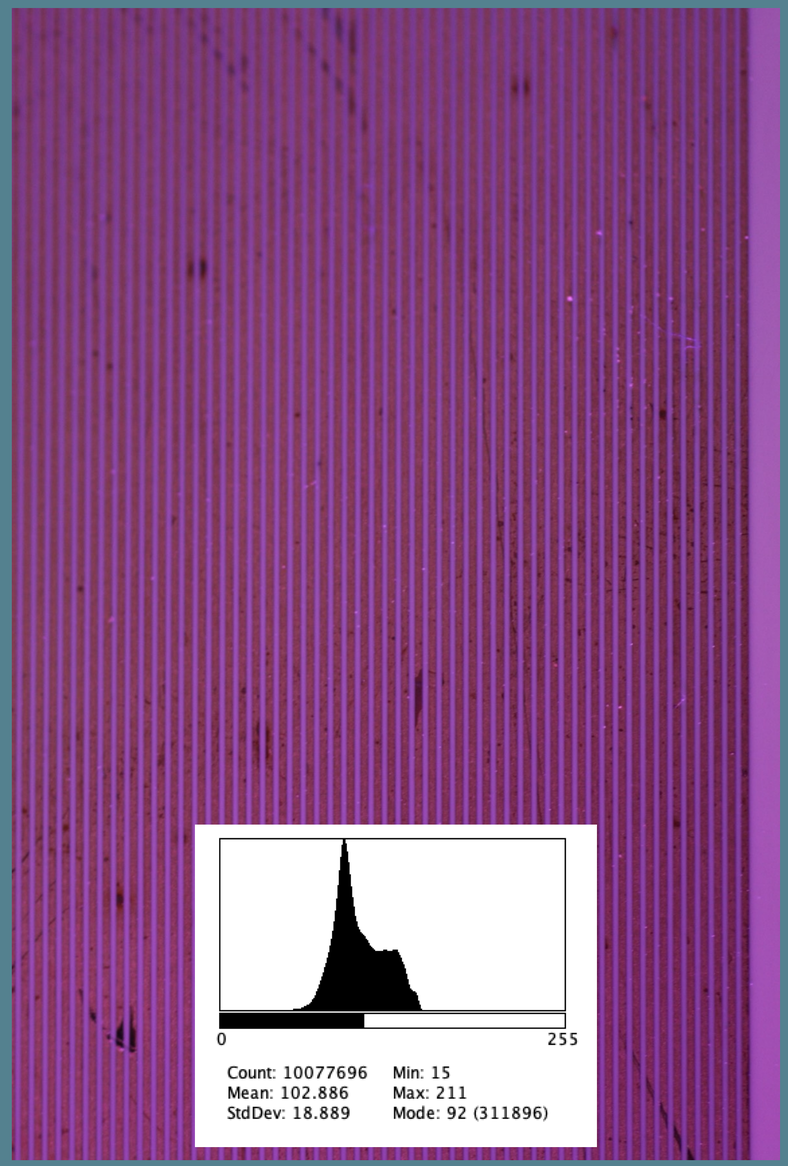
Max: 203
Mode: 76 (281509)


0
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StdDev: 18.889
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Max: 211
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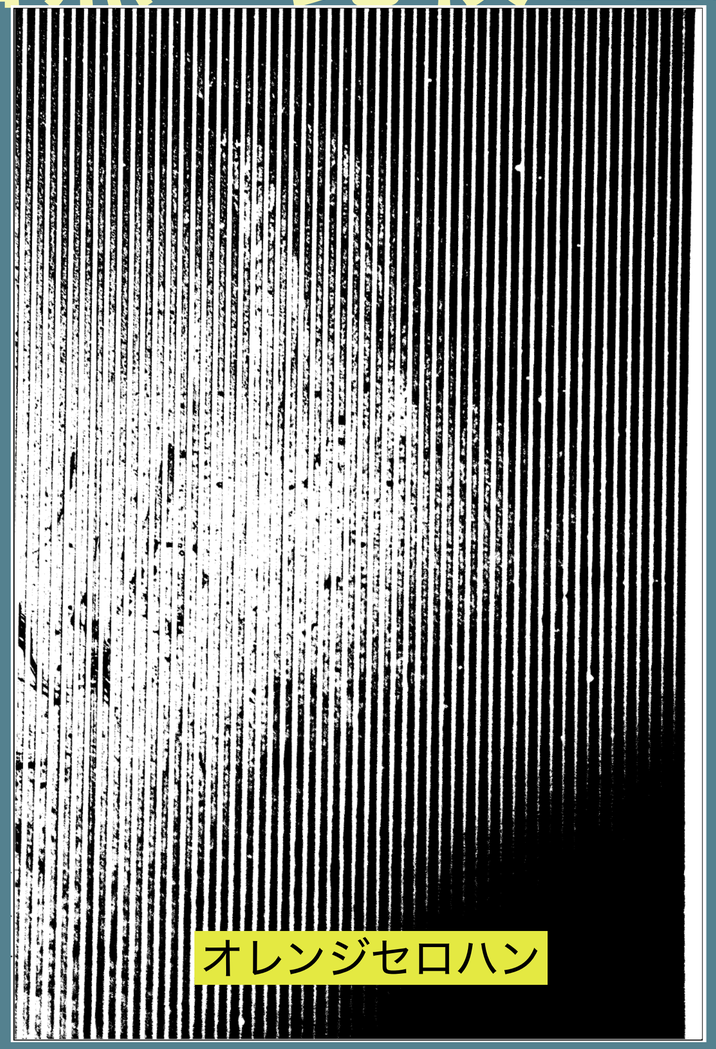
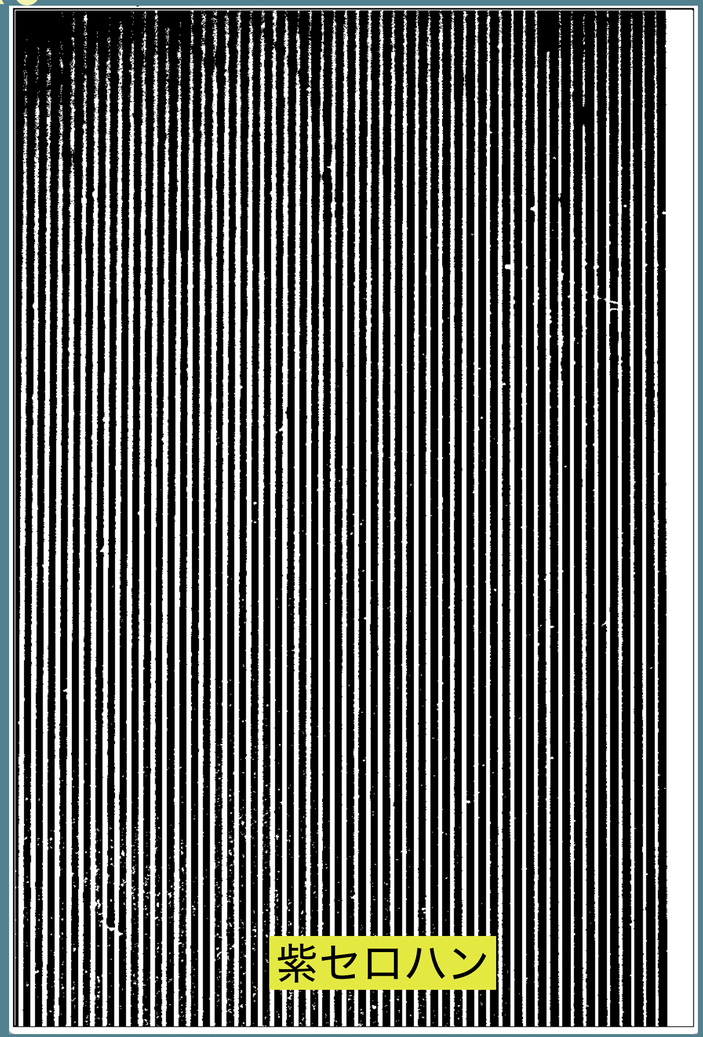
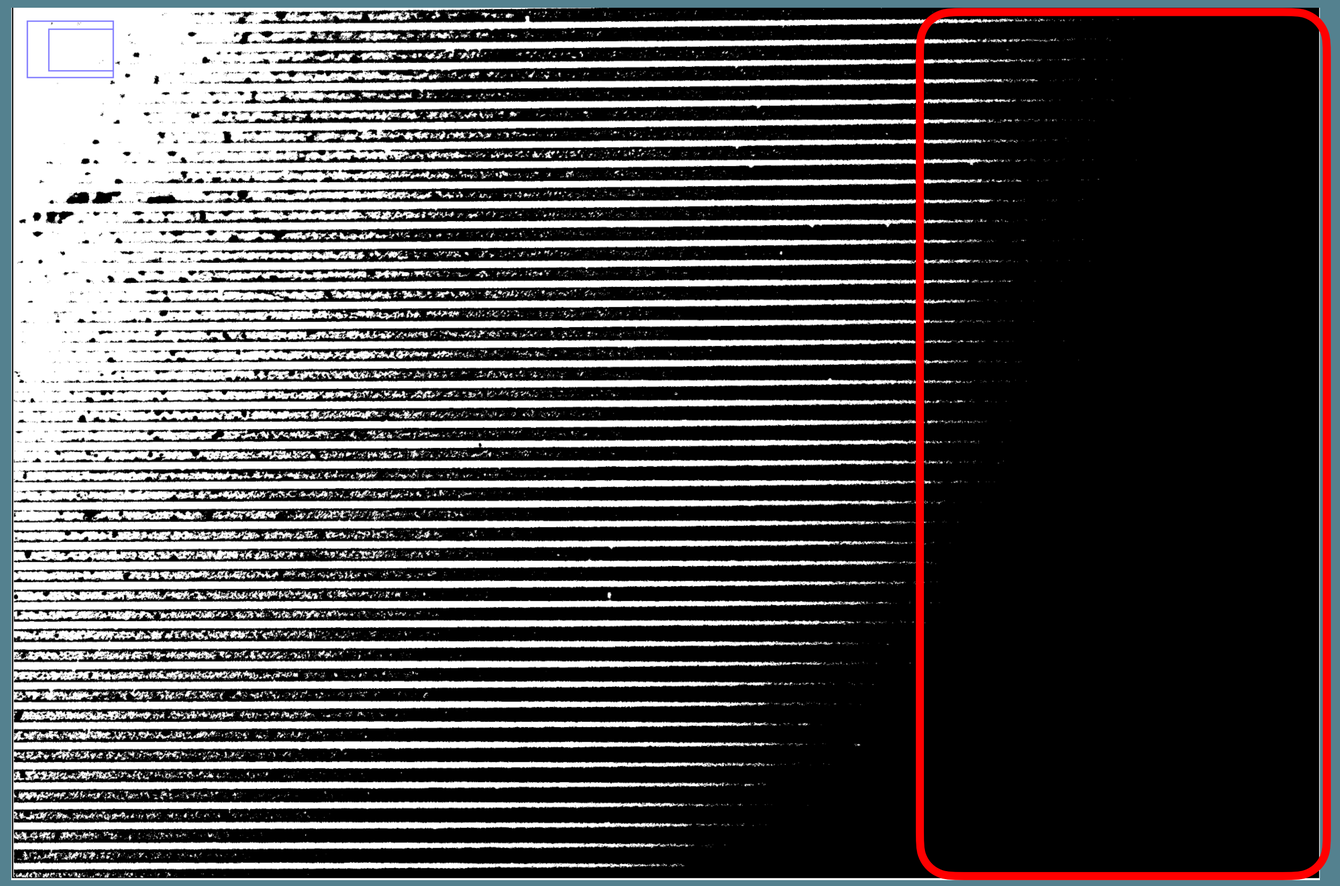
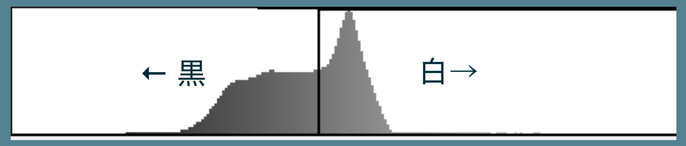
白黒　比較VER.





＼考察＼





←影の部分が真っ黒になっているため
これが小さなピークとなって現れる。