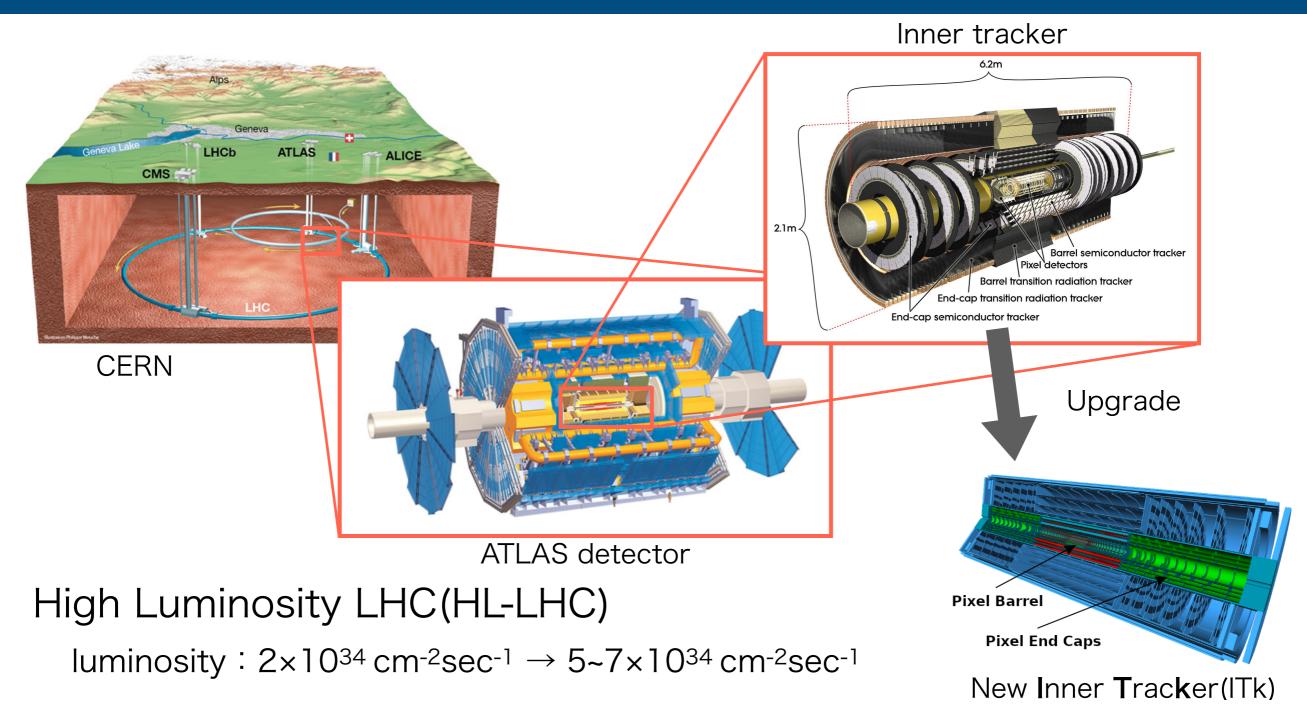
Development of a defect detection tool for visual inspection in the HL-LHC ATLAS pixel detectors production

Yukiko Fujita, Yamanaka Lab.

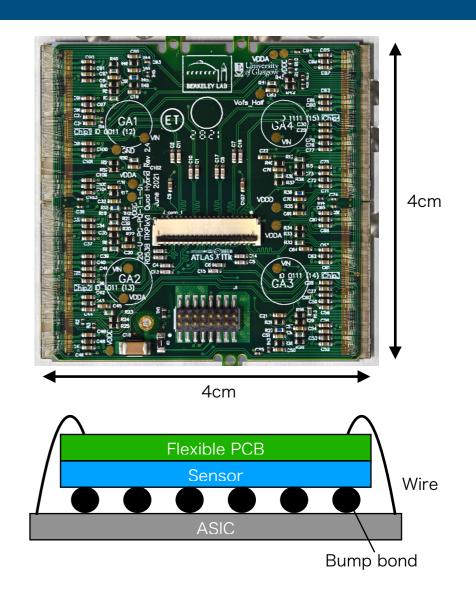
ATLAS Experiment



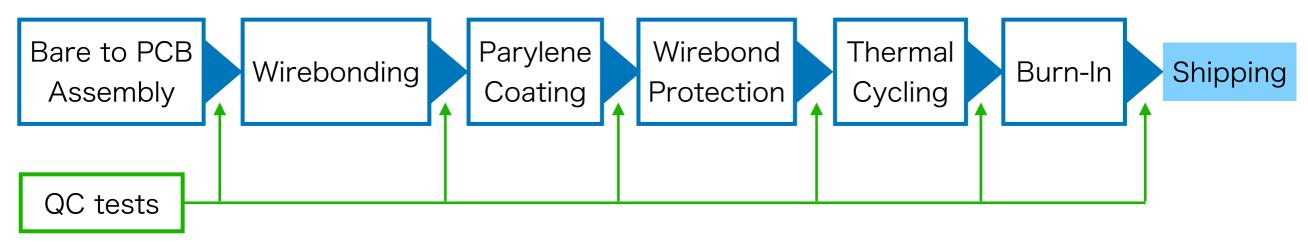
→ Will upgrade ATLAS detector too improve readout speed, radiation tolerance, etc.

Pixel Detector Production

- Silicon pixel detectors for new inner tracker
- Will produce10000 pixel detectors in the world, include 2000 in Japan
- Perform quality control(QC) tests at each stages of production



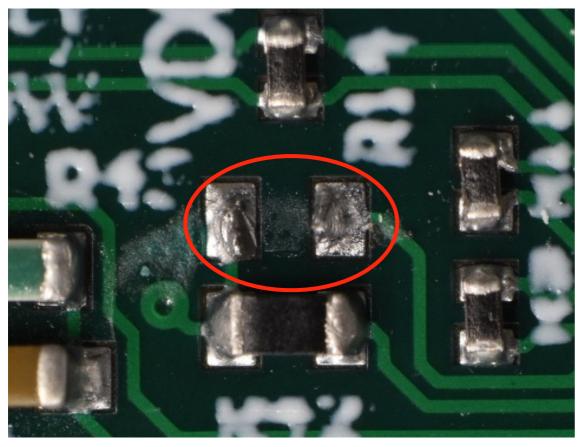
Now preparing for mass production



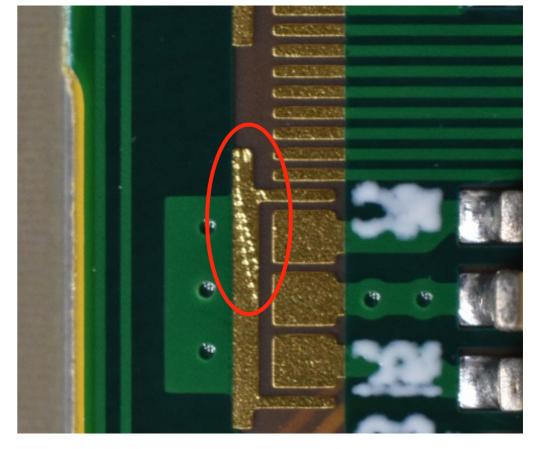
Visual Inspection

- Take pictures and perform visual inspections on each stage of mass production
- Check them with human eyes for anomalies

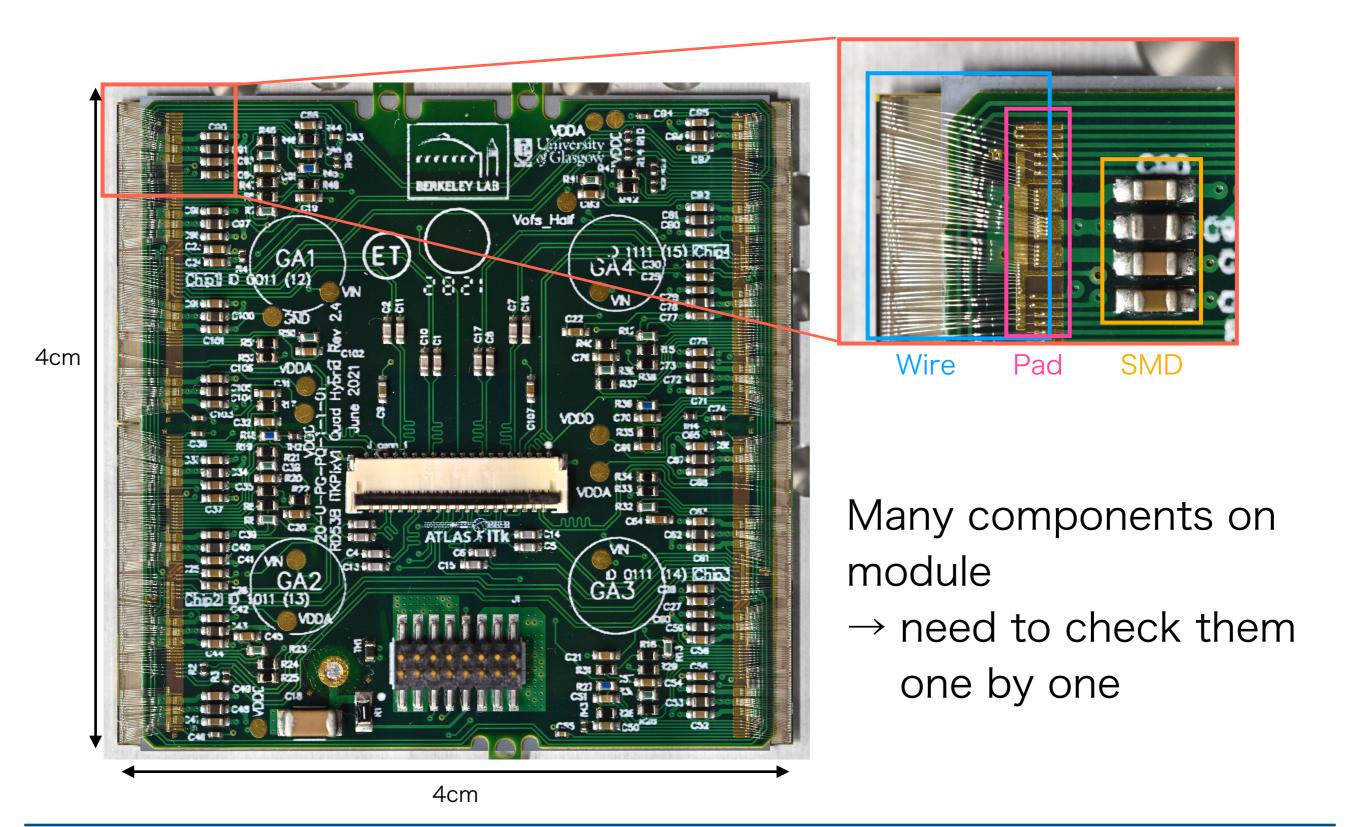
Defect of SMD(Surface Mount Device)



Scratch on pads



Appearance of Pixel Detector



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Current Visual Inspection Window



Checklist

Users check each component using checklist

- Takes time
- Might overlook SMD defects

a tool to support users and improve inspection efficiency and accuracy

SMD Defect Detect

- Developing a tool that alerts users by highlighting areas where SMD may be missing
- Don't want to overlook any SMD defects (even if it highlights areas with SMDs)

Detection procedure

① Trim the image within a certain range

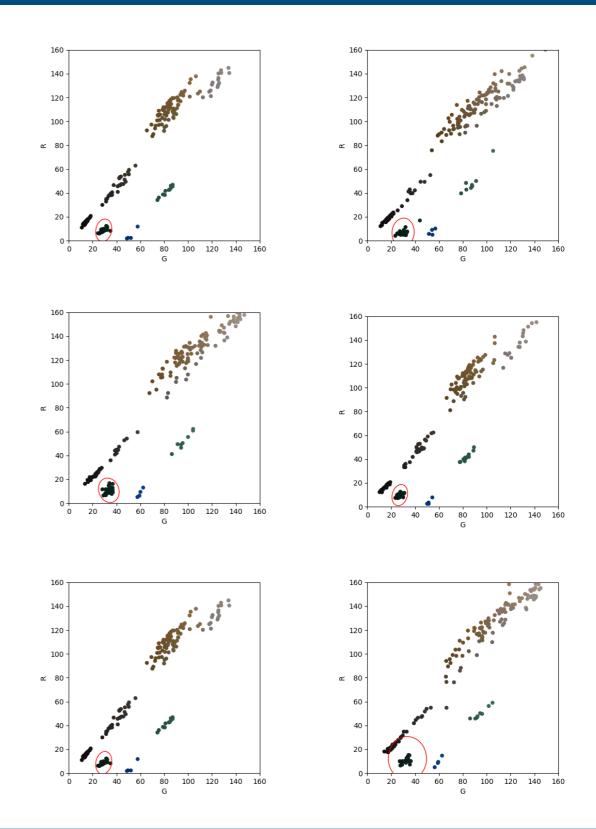
- ② Get color information(RGB) of each SMD and PCB location
- ③ Compare SMD and PCB color, and highlight the area that are the same color as PCB(not have SMD)

Classification to PCB or SMD

- For simplicity, distinguished the PCB color using 2 values, R and G
- Determined the PCB range from RG values of the points known to be PCB

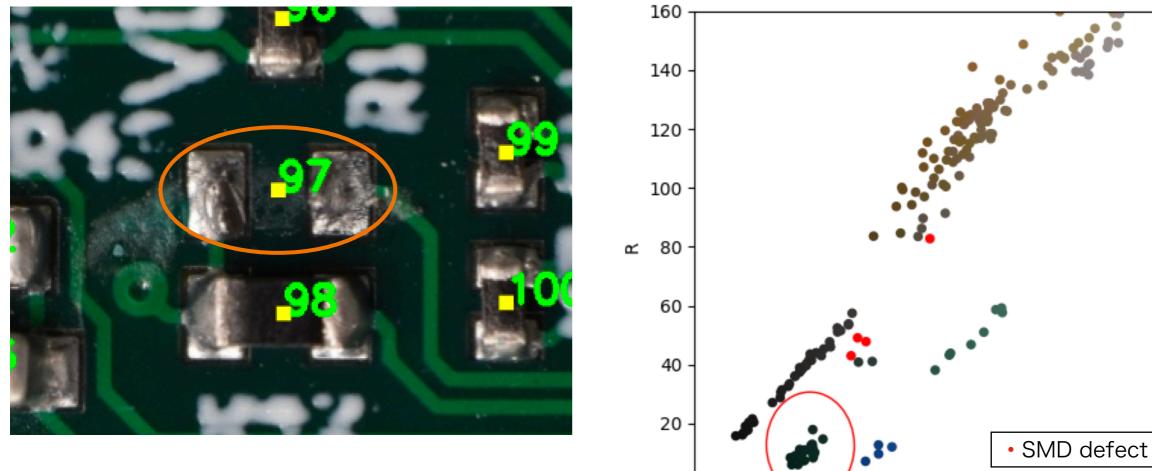
Verified with 7 normal modules

- Failure to classify to PCB
 3/(25×7) = 1.7±1.0 %
- Failure to classify to SMD 20/(164×7) = 1.74±0.15 %



Verification with Defects

Missing SMDs cannot be detected if the surface is dirty



Solutions

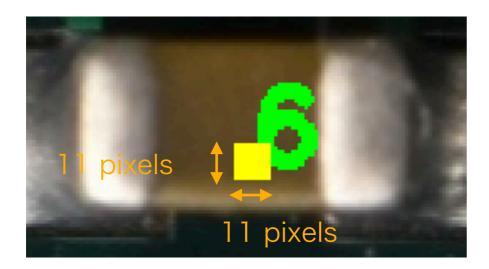
- Check for uneven color distribution in the acquisition area
- Check for deviations from the known SMD color distribution

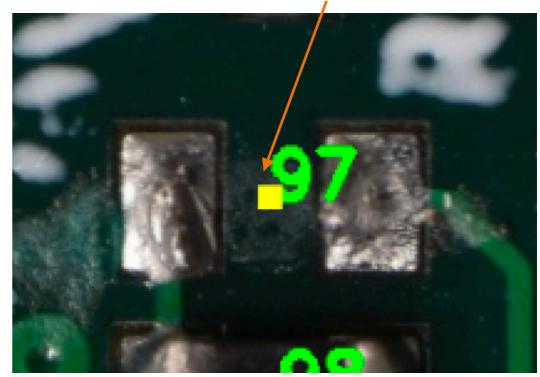
G

Color Deviation

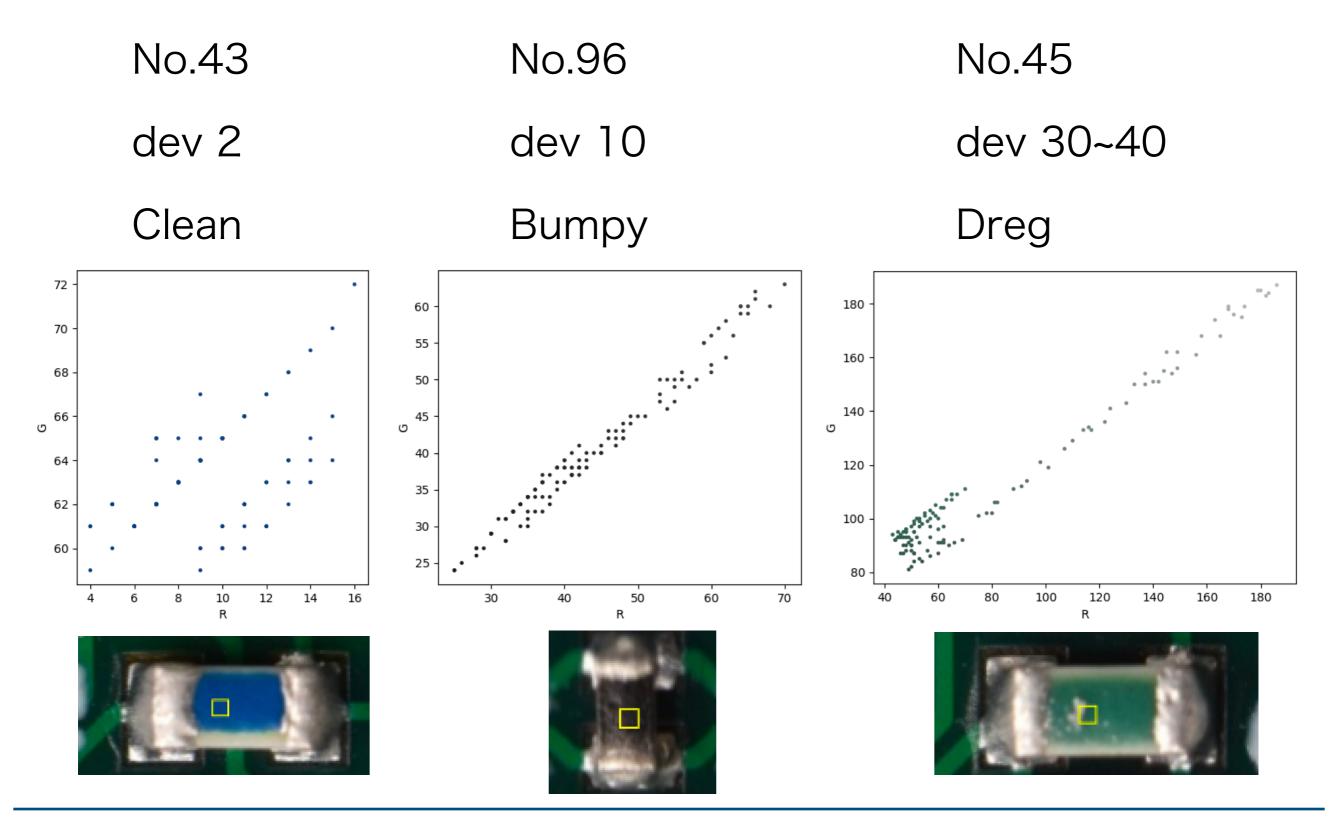
- Get RGB values in range 11x11 pixels and compare with PCB color
- Used only mean RG values
- \rightarrow Try to use color distribution in the acquisition area





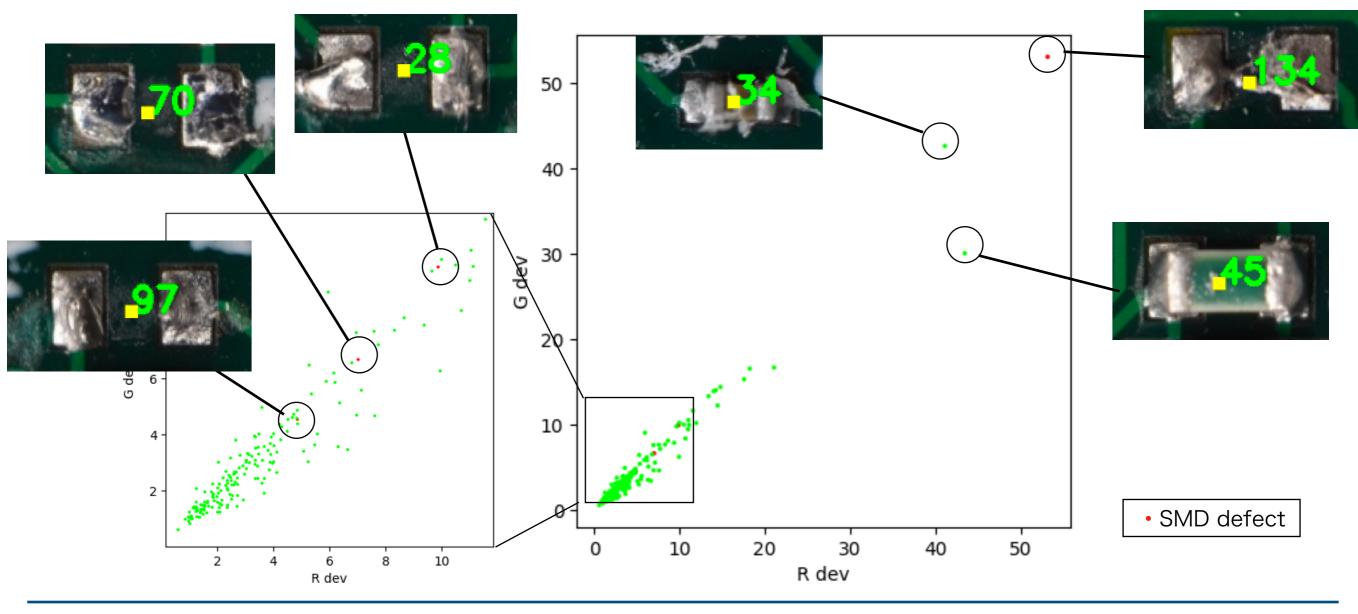


Color Distribution



Color Deviation

Tried with the module 4 SMDs missing
→ Couldn't distinguish SMDs and missing points,
but could find dregs on modules



Conclusion

- Will upgrade ATLAS detector for HL-LHC and produce 10000 pixel detectors
- Visual inspection will be performed in each production stage
- To support visual inspection, developing a tool to detect SMD defects

Surface is clean : can distinguish the PCB color Surface is dirty : can't detect SMD defects → Now improving

Back up

Flow of QC Helper

🗧 🕘 📃 🔀 QC Helper	🗧 🗧 📉 QC Helper		😑 😑 🛛 🔀 QC Helper	
	Choose the options you want			
Log in to Production DB	Which mode will you do?		Input ATLAS Serial Number	
	 Upload result of QC test to localDB Register Bare-module 	♦		
ITKDB ACCESS CODE 1:				
ITKDB ACCESS CODE 2:			ATLAS Serial Number:	
practice mode <u>N</u> ext	<u>B</u> ack <u>N</u> ext		<u>B</u> ack <u>N</u> ext	
Current user :	Current user :		Current user :	

	X QC Helper			X QC Helper
ITkPD registration information				
ATLAS Serial Number	r: 20UPGM20012019)		
Component Type: MODULE)	Log in	to Local
Institution:	Laboratoire de Physique des 2 Infinis Irène Joliot-Curie			
Current Location:	Laboratoire de Physique des 2 Infinis Irène Joliot-Curie			
Component Name:	Outer system quad module		User:	
Current Stage:	Initial module characterisation			
			Password:	
Back	Next)	Back	
Current user :			Current user :	

DB

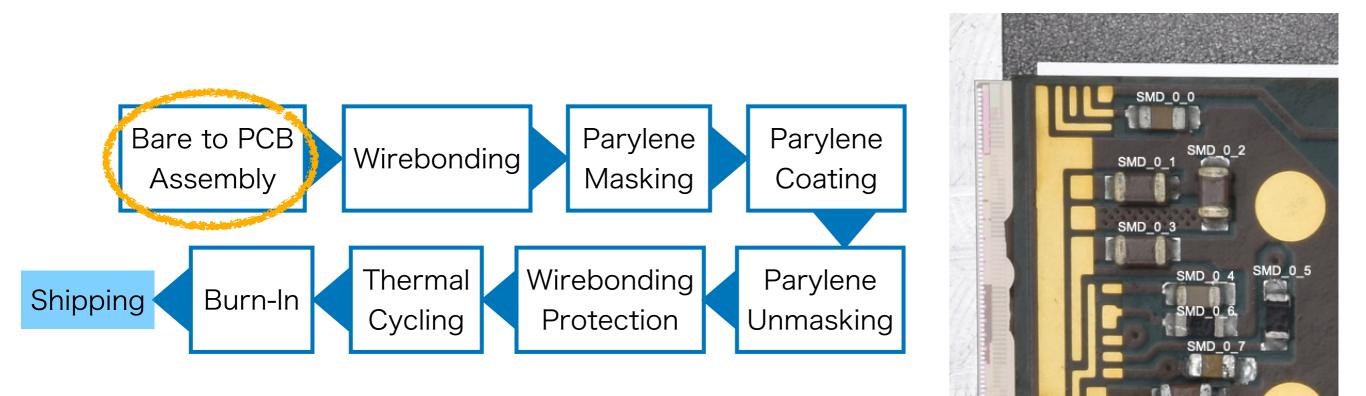
Next

Flow of QC Helper

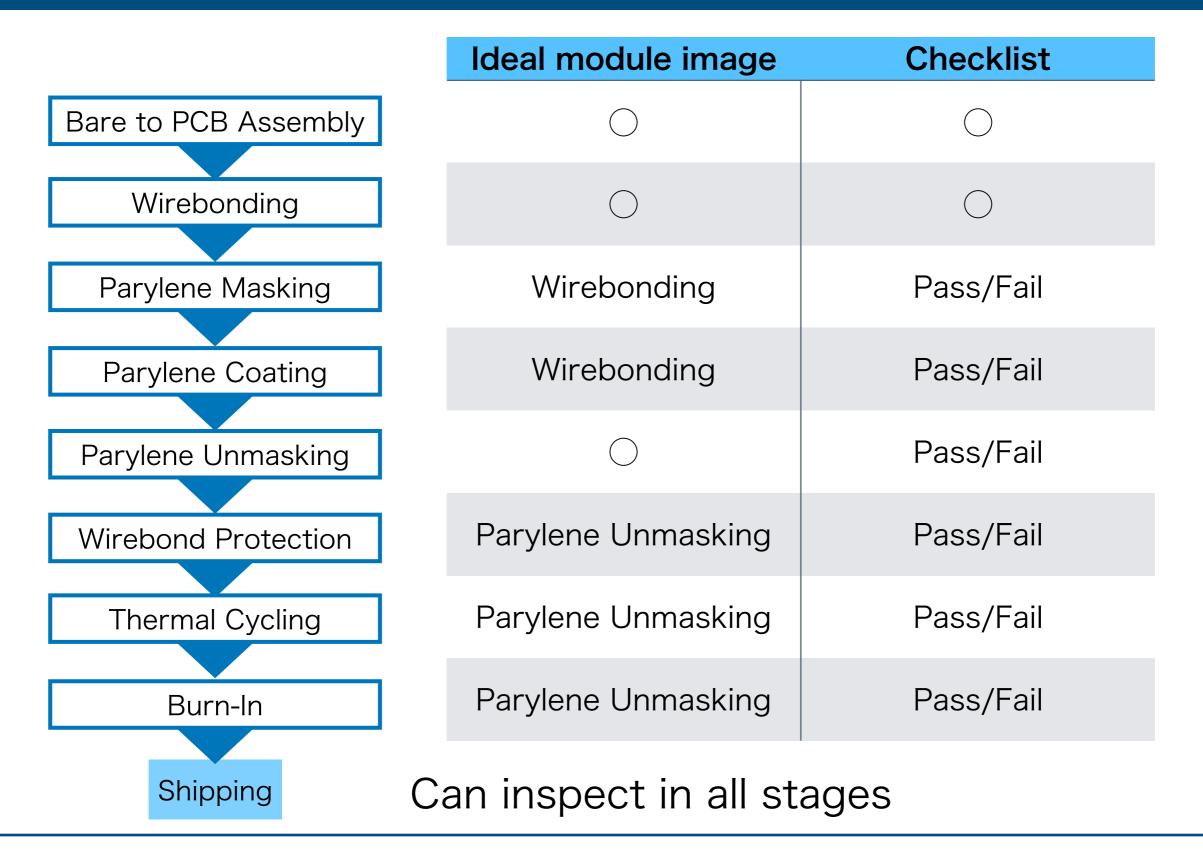
● ● ●		
Choose your inspection		
Serial Number : 20UPGR10099999		
Test Stage : MODULETOPCB	🛑 😑 📄 🔣 Mass Measurem	lent
Test name Upload status in 1 • Mass Measurement None		1
 o mass measurement o source scan at 30degC None 	Input mass \	Value
• Flatness None		
O Wirebond pull tests	Total weight (without carrier) :	g
O Wirebonding Information None	Scalo Accuracy	
O Parylene Properties None	Scale Accuracy :	g
• Glue Information Module+Flex Attach None		
O Thermal Cycling None		
<pre>Optical Inspection None</pre>	comment :	
O Metrology None		
Sensor IV at 30 degC None		Neut
○ Sensor IV at 20 degC None	Back	Next
Sensor IV at -15 degC None	Current user : itkqc	
O SLDO VI	current user i Tekqe	
O Wire bonding roof envelope		
Back Current user : itkqc	Next	
urrent user : Itkdt		
	🗧 😑 🔹 🔀 QC Helper	
	Confirm before uploading to the database	
	contrin before uptoauting to the database	
	Current Stage : MODULETOPCB	
	Test Type : MASS	
	Total weight : 1.0 g	
•	Scale accuracy : 1.0 g	Upload successful!
		(CÉRN) Up toau successful!
•	Comment :	Do you want to continue to
		another inspection?
		Ves 🕘 No
	<u>Back</u> <u>Check json (for expert)</u> <u>Upload!</u>	
	Current user : itkqc	

Upgrade of QC Helper

- Only the first stage was supported
 → supported all stages
- SMDs or other components names are written only on ideal images
 - \rightarrow wrote the names also on inspection target images

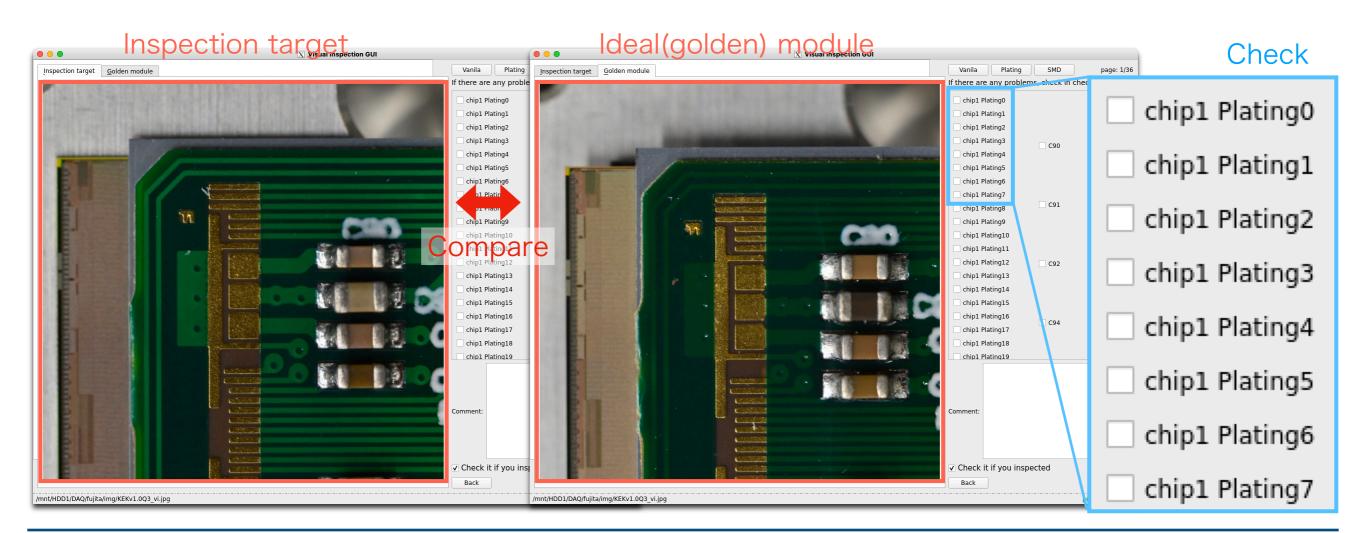


Support All Stages



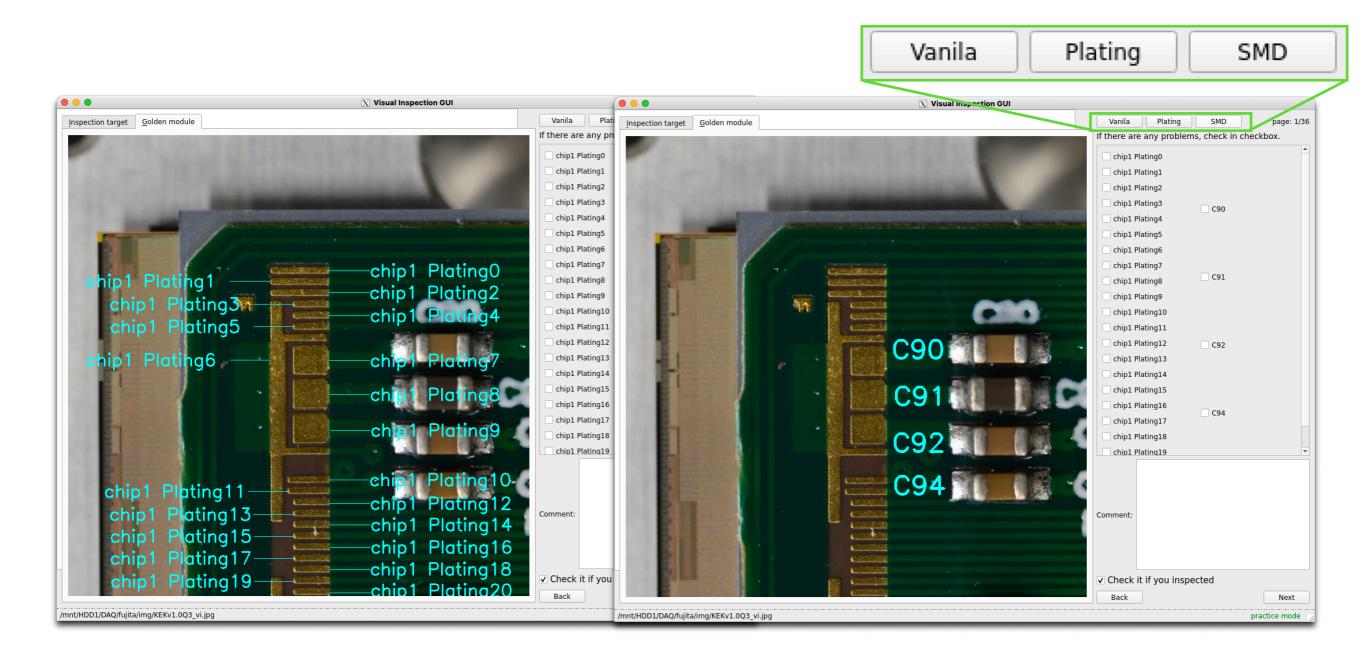
Visual Inspection Tool

- Trim inspection image and split it to 36 tiles
- Compare them with the ideal module image
- Check the checklist if there are any anomalies



Names on Images

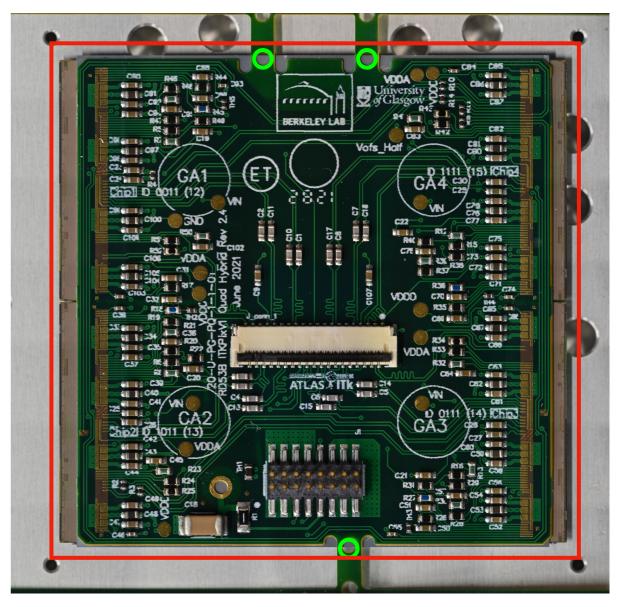
Can see names by pushing buttons

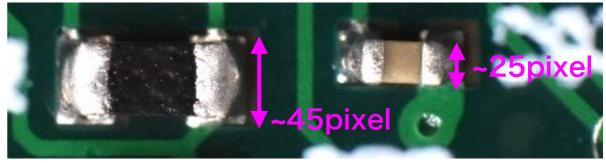


Trimming Images

Method

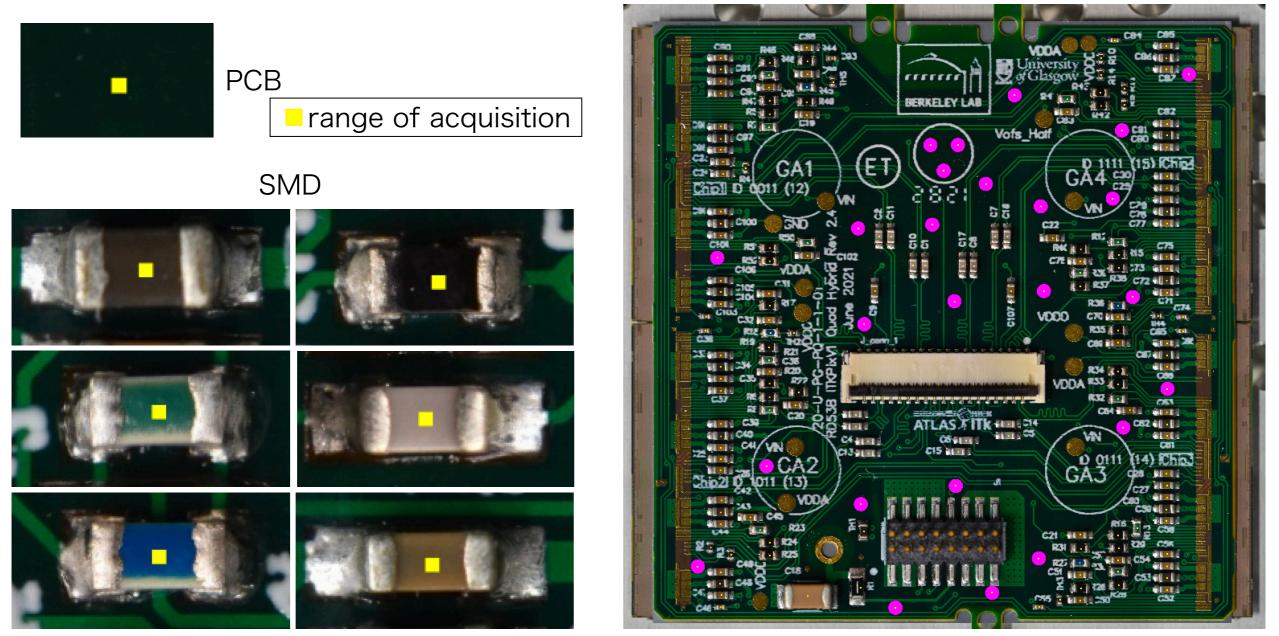
- Get position coordinates of 3 point on the image(O)
- ② From ① result, calculate the range to trim()
- Position accuracy~±5pixel
 ~trimming accuracy
- The size of minimum SMD \sim 25pixel
- ➡ The range of ±5pixels from the center position of the SMD is the range on the SMD





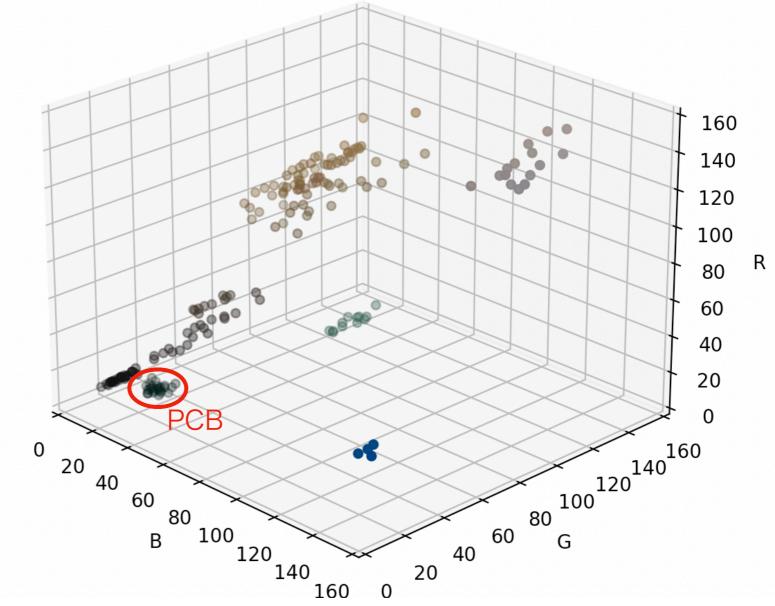
Acquisition RBG Values

- Get the average of RGB values of SMD center 11×11pixels
- Get PCB color of 25 location as well



Acquisition RBG Values

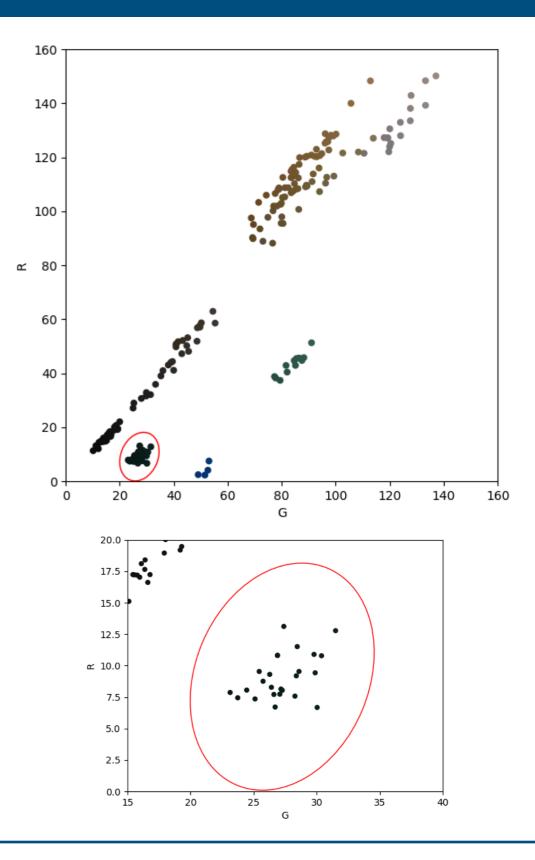
- Got RBG values of each SMD and PCB(25 location)
- Distinguished the points that have the same color with PCB from this



Distinction of PCB Color

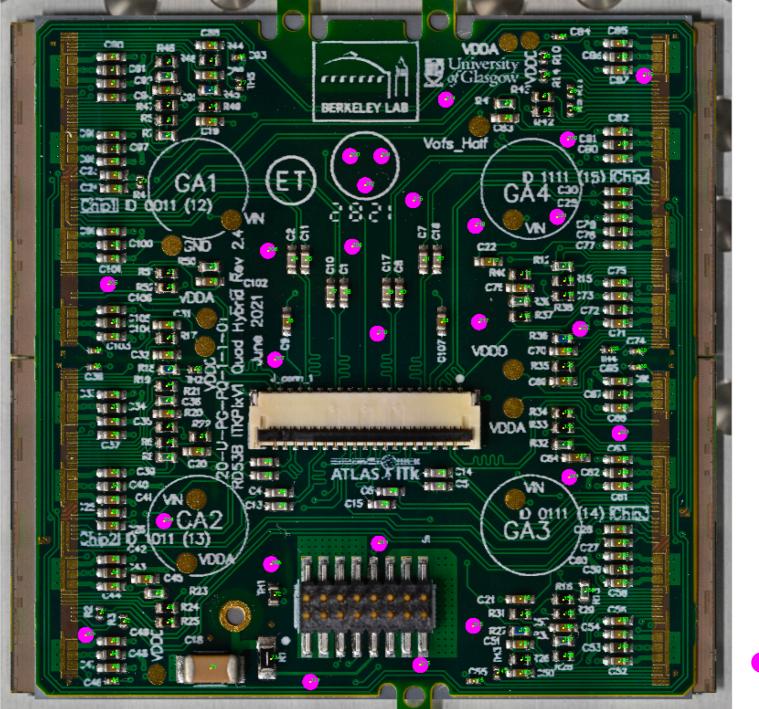
Distinguished the PCB color using 2 values, R and G

- Calculate average, deviation and correlation coefficient of R and G of PCB color
- ② Assume two-dimensional normal distribution, and calculate the ellipse that 99% of the time the point will fit inside
- ③ To prevent to overlook the same color as PCB(=defect), judge points that fit within an ellipse twice the size of ② to be the PCB color



Check in the Original Image

Could highlight the 25 points that were used for PCB color

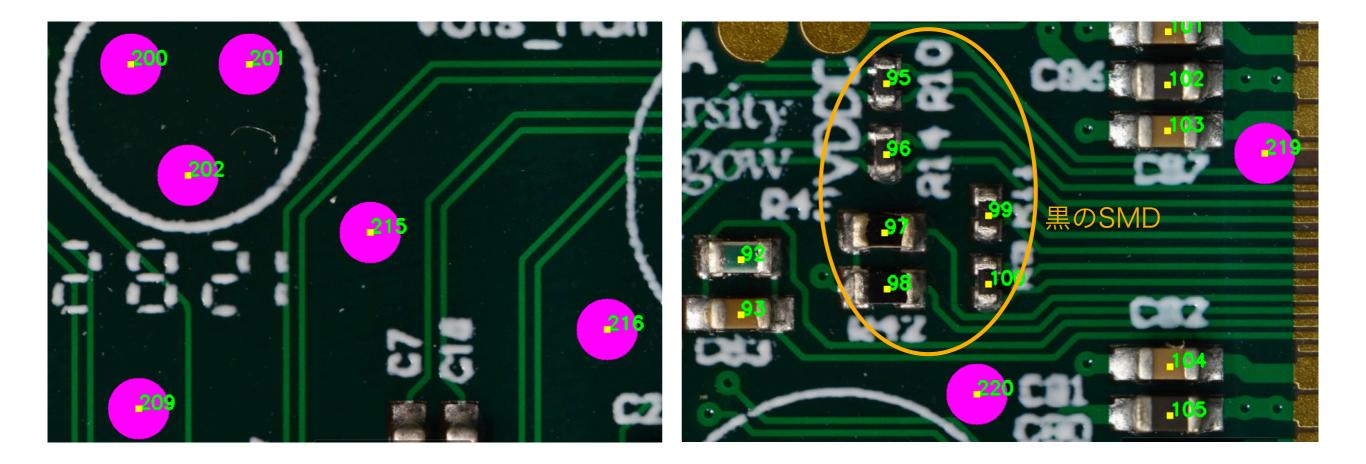


highlight position

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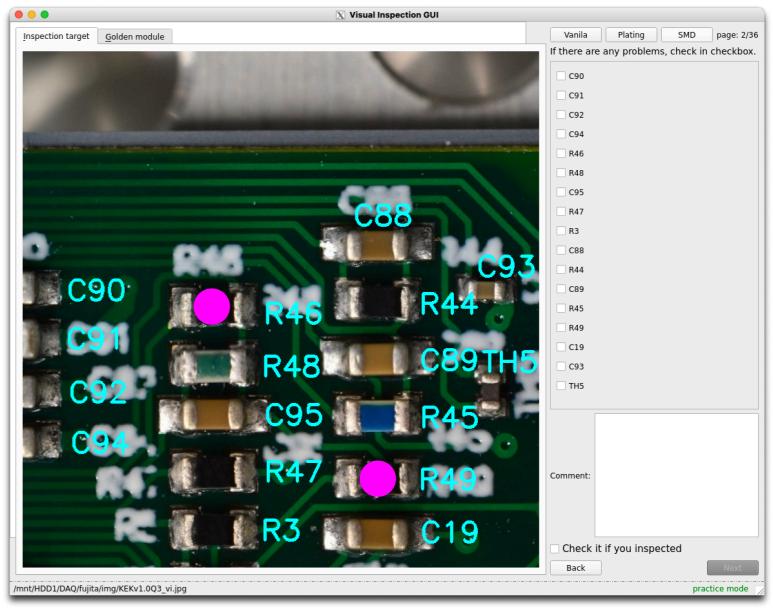
Check in the Original Image

The black(close to PCB color) SMDs are not highlighted \rightarrow Can distinguish from PCB



Implementation in QC Helper

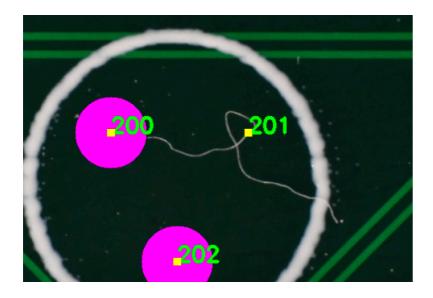
Will implement SMD defect detection function in QC Helper → Will prevent user overlook and increases inspection accuracy and efficiency



Classification Failures

Failure to classify to PCB

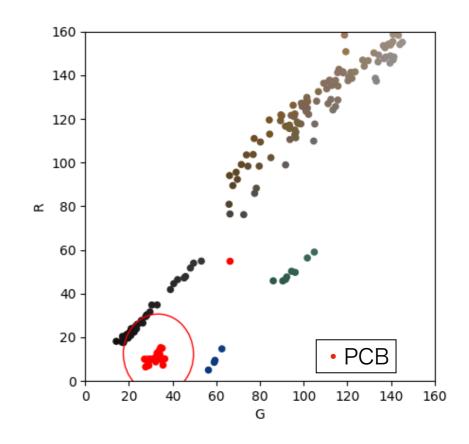
 Got the color of dust on PCB



Solution

Check for abrupt change in RGB values within the acquisition range Failure to classify to SMD

 The PCB point at large outliers makes the PCB range larger

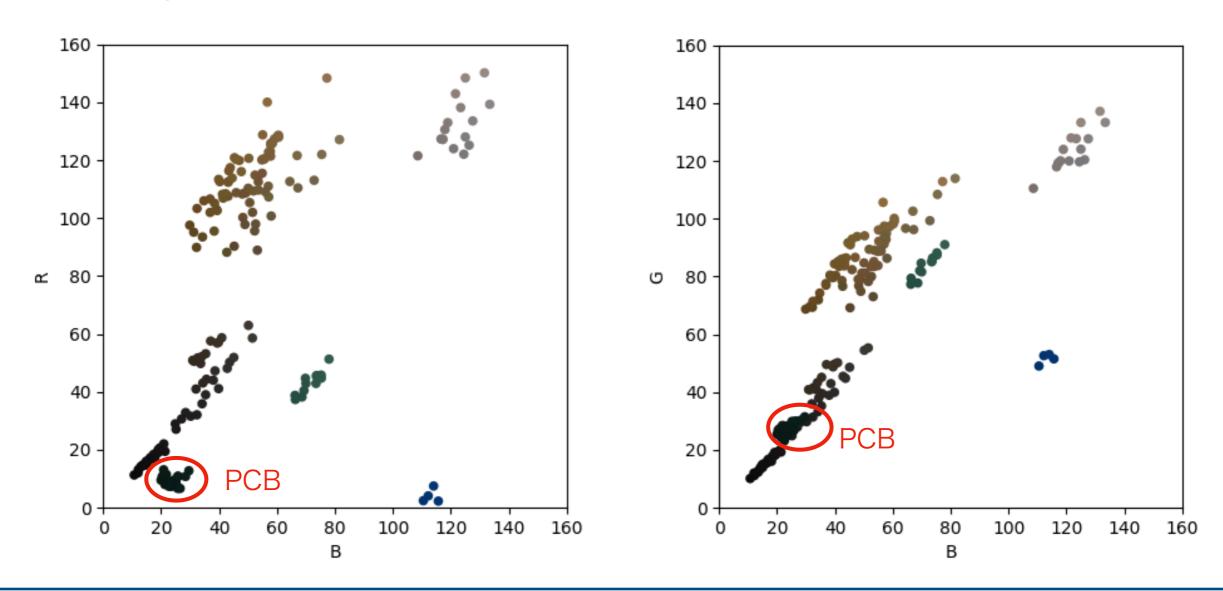


Plot Using B Value

GB

RB

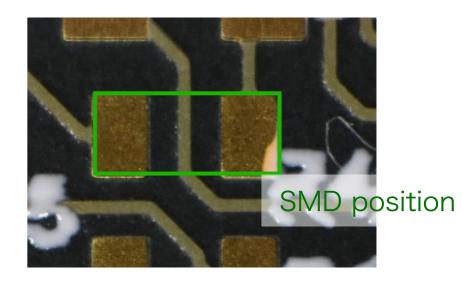
- Should be able to distinguish the PCB color
- Can't distinguish the colors



Future Outlook

Another problem

There are some lines under SMDs
 → will solve by registering the line
 color and checking color distribution



To do

- Verify with different colors PCBs and final version ones
- Implement SMD detection function in QC Helper