Development of inspection system for bus extender cable of RHIC-sPHENIX INTT detector

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The sPHNEIX experiment is scheduled to begin at Brookhaven National Laboratory (BNL) in 2023, study quark-gluon plasma (QGP) by using a heavy-ion accelerator.[1)] We have developed a long, high-signal-line-density, flexible substrate cable to transmit data from one of the tracking detectors, INTermediate Tracker (INTT), to a downstream data-processing circuit board. The cable is called Bus Extender (BEX), which is 111 cm long and comprises 124 signal lines separated by a space of 130 μm.

After five years of research and development, the cable is meets the specifications required by sPHENIX in terms of both mechanical and electrical performances. However, there is one remaining technical issue, namely, a poor yield rate (30–50%) in mass production mainly due to dust contamination during signal-line patterning. The contaminated dust causes abnormal patterns in the signal lines, which tends to result in either short or broken signal lines. The anomaly used to be manually inspected using a magnifying glass during the prototyping stage of the cable, which is not practical for mass production because of the large area (a pattern sheet accommodates four BEXs and the size is about 120 cm $\times$ 25 cm) to be inspected for 120 BEXs in total. The motivation of this study was to establish a semi-automated process for pattern inspection.

For this purpose, we developed an inspection fixture, which consists of a high-resolution microscope camera on a moving aluminum frame, as shown in Fig. 1. The aluminum base frame is set along the BEX signal line, and the camera moves along the base frame, as shown with the red arrow. A pattern image taken by the camera is then analyzed using a pattern-recognition software developed by us. The algorithm for anomaly detection from the image is as follows. First, the color image is converted to black and white. Next, the number of pixels for each line and space in a direction perpendicular to the signal lines is counted for both black and white zones and fill number of pixel histograms, respectively, to evaluate the mean and standard deviations of the number of pixels as references. Finally, the algorithm detects anomaly spots on the image, where the pattern deviates by more than 5σ from the reference. The process described above is repeated to scan through the 111-cm-long signal lines. One of the abnormal patterns detected with this algorithm is indicated using the red circle in Fig. 2. This technique facilitated inspections in mass production, which would have been impossible otherwise.

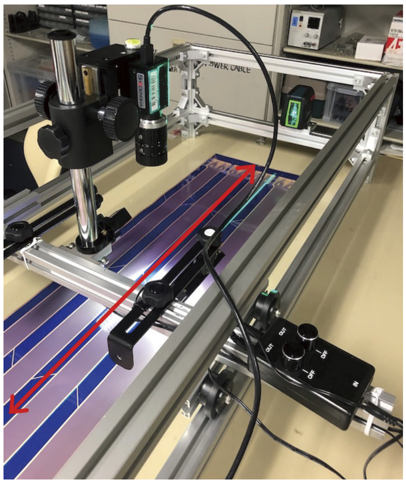

Fig. 1. Inspection fixture and camera for the signal-line pattern of BEX.

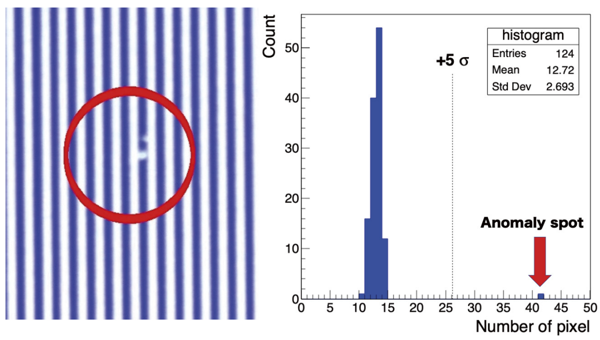

Fig. 2. Example of anomaly spot and histogram of signal-line pattern detected by the algorithm.

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Reference

1) I. Nakagawa *et al.*, in this report.