Electrical and mechanical properties of the bus-extender

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The sPHENIX experiment at the Relativistic Heavy Ion Collider (RHIC) is scheduled to start in 2023 in Brookhaven National Laboratory (BNL). The INTermediate Tracker (INTT)[1] is a silicon sensor strip detector to be implemented in the central rapidity region. The massive raw data generated in INTT need to be transmitted to downstream readout electronics through a quite narrow and curving cabling path for 1.2 m. As there is no commercial cable available, a high-signal-density cable was developed using flexible printed cable technology. The cable is called "bus-extender" and has 62 pairs of 130-µm-width signal lines. The bus extender mainly transmits digital signals. The development of the bus extender is in the final stage.[2]

Owing to the long path length of high-density flexible printed cables, the poor performance of signal transmission of high-frequency data is a major concern. A simulation predicts 30% attenuation for a 200 MHz signal.

An eye diagram is a useful tool to visually inspect the attenuation and distortion of the signal pulse. We measured the eye diagram by overlaying the waveforms of various bit patterns. The transmission efficiency can be evaluated qualitatively by the size of the opening of the eye. Figure 1(a) and (b) show the eye diagram of the low-voltage differential signaling (LVDS) signals before and after passing the bus-extender. From the comparison, the attenuation of the signal is determined as 33%. The result is consistent with the simulation. It is found that the eye opening after the bus-extender is too small to receive the signals at the readout electronics. To solve the problem, we increase the drawing current of the LVDS signals from 2 mA to 8 mA to effectively obtain a sufficiently wider eye opening.

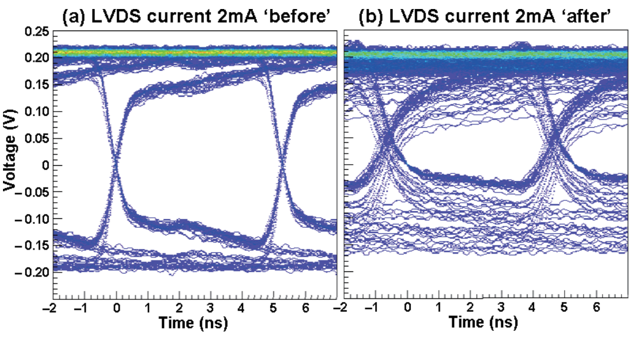

Fig. 1. Eye diagrams (a) before and (b) after the bus-extender in the readout chain.

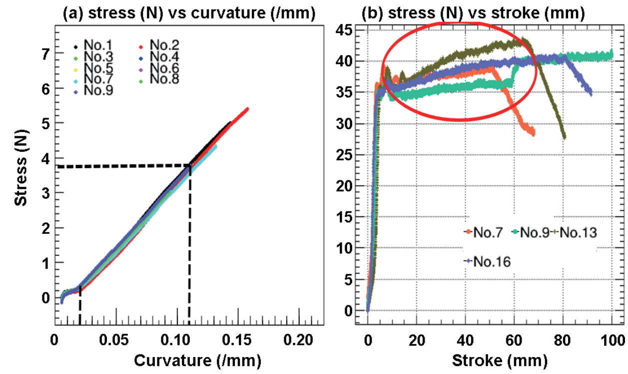

Fig. 2. (a) Stress concerning the U-shaped curvature of test pieces. (b) Peeling strength as a function of the peeled length, evaluated in the region covered by a red circle.

The mechanical properties are also important to assess the long-term stability and radiation hardness. The bus extender needs to survive at least three years of operation in a high-radiation environment. The bus-extender is made using a liquid crystal polymer (LCP) as substrate, instead of a polyimide, which is generally used for flexible cables. LCP is a new material used for high-energy physics experiments. Therefore, we studied its mechanical properties by comparing it with polyimide. In addition, this study provides a baseline to assess the radiation hardness.

We measured two quantities: (1) flexibility and (2) peeling strength between layers of the multilayered cable. Here, the results of the 2-cm-wide specimen used are shown instead of results per unit. The former is measured by bending the cable in the middle by 180° as it forms a "U-shape" inside view. The stress from the cable is recorded for several test samples as a function of curvature and is plotted in Fig. 2(a). The flexibility is evaluated by the slope of a 4 N increase in the curvature region from 0.02 to 0.11/mm. This result is further compared to that from cables exposed to radiation, and no drastic change was found.[3] Therefore, we could obtain the reference value for flexibility. The latter is measured by recording the stress of peeling off the cable as a function of the stroke. The result plotted in Fig. 2(b) shows a peeling strength of 34 to 44 N. This value is twice that of the polyimide.

We plan to start the mass production of bus-extenders in 2021. The continuity of all signal lines will be tested using newly developed test equipment.[4]

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