New high-speed integrated circuit for world's biggest physics experiment is fastest of its kind

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A new high-speed integrated circuit to reliably transmit data in the demanding environment of the world's largest physics experiment is the fastest of its kind.

This new "link-on-chip" — or LOC serializer circuit — was designed by physicists at Southern Methodist University in Dallas for use in a key experiment of the Large Hadron Collider particle accelerator in Europe.

The miniscule SMU LOC serializer was designed for ATLAS, which is the largest particle detector at the Large Hadron Collider, or LHC. The LHC is a massive, high-tech tunnel about 100 meters underground. Within the circular, 17-mile-long tunnel, protons traveling at high energy are smashed together and broken apart so physicists worldwide can analyze the resulting particle shower detailed in a flood of electronic data.

The data is transmitted from the LHC via a tiny serializer circuit enabling electronic readouts. Physicists analyze the data to discover answers to unsolved scientific mysteries such as the Big Bang, dark matter, black holes, the nature of the universe and the Higgs particle that gives mass to quarks and electrons. SMU is a member of the ATLAS Experiment.

In March, the LHC successfully began colliding protons at an energy

three and a half times higher than previously achieved at any particle accelerator. The LHC is a program of the Geneva-based international scientific consortium CERN, the European Organization for Nuclear Research.

SMU's new world's-fastest LOC serializer is what the industry calls an integrated circuit made for a specific use, or "ASIC" for application-specific integrated circuit. It was designed for the LHC's high-radiation environment, as well as for high data bandwidth, low-power dissipation and extremely high reliability, said physicist Jingbo Ye, an associate professor of physics who led development of SMU's LOC serializer. An added feature of the SMU LOC serializer is that it can operate at cryogenic temperatures and has been tested down to liquid nitrogen temperatures of -346 degrees Fahrenheit.

The SMU LOC serializer was perfected over the past three years in the SMU Physics Department's Research Laboratory for Optoelectronics and ASIC Development.

It was designed to transmit data for the optical link readout system of the ATLAS Liquid Argon Calorimeter, an ATLAS sub-detector that measures the energies of electrons and photons generated at the center of ATLAS where protons collide. Because the electronic readout components are in the center of the ATLAS detector, they are essentially inaccessible for routine maintenance, so reliability is paramount, Ye said.

With a data transmission rate of 5.8 billion-bits per second, the SMU LOC serializer represents the first milestone for the SMU team. The team plans to develop an even faster ASIC serializer that transmits data at up to 10 billion-bits per second. Faster circuits are critical as CERN continues increasing the LHC's luminosity, thereby generating more and more data.

"SMU's LOC serializer is the fastest in our field for the moment," Ye said. "CERN is developing another fast ASIC serializer that does not yet match our speed. SMU's next goal is to increase both the data speed and the number of data lanes to produce an even faster LOC serializer. In the next few years, we hope to increase the total speed by a factor of 62 more than what is installed in ATLAS."

Ye presented the SMU LOC serializer design in February at CERN. Made of complementary metal-oxide-semiconductor transistors in silicon-on-sapphire, the serializer's design details also will be presented to scientists in April in Hamburg during the ATLAS Upgrade Week at the DESY laboratory, Germany's premier research center for particle physics. For links to more information see www.smuresearch.com. The SMU LOC serializer research was funded by the National Science Foundation and the U.S. Department of Energy.

The existing LOC serializer in use at present in the ATLAS Liquid Argon Calorimeter was previously developed and installed by an SMU-led team of physicists and engineers from France, Sweden, Taiwan and the United States.

SMU's new LOC serializer is critical for the upgrade of the Large Hadron Collider, called the Super LHC, which is planned to go online in 2017, Ye said.

"The original ATLAS design used a commercial serializer that was purchased from Agilent Technologies," Ye said. "But for the Super LHC there is no commercial device that would meet the requirements, so — being typical physicists — we set out to design it ourselves."

The ATLAS Liquid Argon Calorimeter's existing optical link system, delivered by SMU physicists, has a data bandwidth of 2.4 terabits per second over 1,524 fibers, or 1.6 billion bits per second per fiber, more

than 1,000 times faster than a T1 line of 1.544 megabits per second. The next generation of this optical link system will be based on the new SMU LOC serializer, and it will reach 152.4 terabits per second for the whole system.

"Fast information transfer from the detector to the computer processing system is a necessity for handling the significantly increasing amounts of data expected in the next round of LHC experiments," said Ryszard Stroynowski, U.S. Coordinator for the ATLAS Liquid Argon Calorimeter, and chair and professor of physics at SMU. "It will allow ATLAS to be more selective in the choices of events sent for further analysis."

A radiation-tolerant, high-speed and low-power LOC serializer is critical for optical link systems in particle physics experiments, Ye said, noting that specialized ASIC devices are now common components of most readout systems.

"The ever increasing complexity of particle physics experiments imposes new and challenging constraints on the electronics," he said.

Provided by Southern Methodist University

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