A fully digital technology for IceCube

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IceCube is a proposed neutrino detector to be located at the South Pole. It will consist of 80 strings , each string having 60 optical modules located at depths from 1400 m to 2300 m. With a horizontal spacing between strings of 125 m, the enclosed volume will be approximately one cubic kilometer. The cables connecting the optical modules to the surface will be of the order of 2.5 km long. Given this long length and the finality of modules frozen in the ice, the choice of technology for bringing the information from optical module to surface becomes paramount.

LBNL has proposed a fully digital technology in which the signal from the photomultiplier tube is digitized in the optical module, and all information is sent to surface in digital form. This makes it possible to preserve the fast timing information of the PMT anode signal and, at the same time, use rugged copper connectors and cables to join the surface electronics to the modules at depth. Additional features include waveform digitization at speeds of 500MHz, a local coincidence timing requirement among adjacent modules, automatic time synchronization and calibration, multiplexing of several modules on a single twisted copper pair, and remote control of the system.

In November, 1998 the AMANDA collaboration agreed to the proposal that LBNL design and build 42 digital optical modules (DOMs) for deployment during the 99-00 austral summer.

Attaining the desired functionality required a correspondingly sophisticated and complex design. The Analog Transient Waveform Digitizer (a custom chip designed at LBNL), a high capacity Field Programmable Gate Array, a CPU of the type used in palm-top computers, external memory, a specially designed digital communications system, DC-DC power supply, and other components were included on an 8-layer printed circuit board having about 600 individual parts. An additional PCB holding six UV light-emitting diodes was also designed for the DOM for use in string timing calibration. Finally, a communications "test board" was designed and built. This board is, in effect, a DAQ that can communicate with a single DOM over a 2.5 km long cable.

By September of 1999 the DOM design had gone through two stages of prototyping and testing, and was submitted for production. Testing of the production boards was completed by mid November. The DOMs were assembled and tested in an intense two-week period at the Physical Sciences Laboratory (Madison, WI) by LBNL and PSL staff. 42 modules were completed and shipped by the end of the month. They arrived at the South Pole on the 27th of December. Testing of the system at the Pole with the actual electrical cable to be used indicated the need for modifications. All DOMs were opened, modified, resealed, and tested in time for a January 16 deployment in the ice. The deployment was highly successful. All modules tested satisfactorily at the time they were attached to their electrical and fiber optic cables. A total of 41 DOMs were deployed; the 42nd module was retained for subsequent diagnostic and developmental work.

The DOMs all worked after being deployed. Data are now being taken in order to evaluate the system performance. Further development work continues.

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