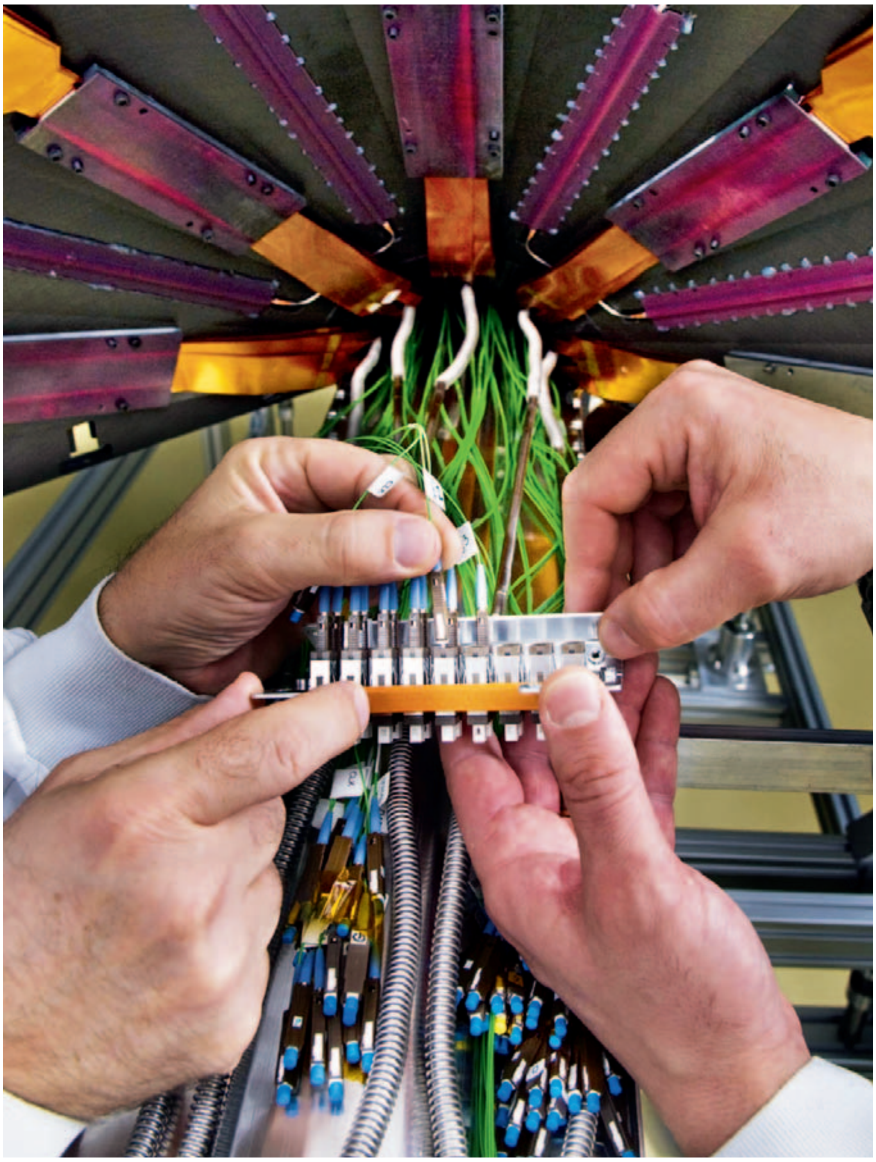
Glass fibers help provide insights into the fabric of space and time

THE GERMAN COMPANY tde – trans data elektronik IS RESPONSIBLE FOR PART OF THE OPTICAL CABLING AT THE CERN PARTICLE RESEARCH CENTER

The CERN particle research center near Geneva in Switzerland uses one of the world's largest glass fiber networks to transport data. The network is designed to transmit 1TB/s, for which the installation of application-specific custom produced fiber optics was necessary.

WILFRIED SCHNEIDER



The CERN research center, officially the European Organization for Nuclear Research, is located in the Swiss Canton of Geneva and was established in 1954 as a European joint venture. CERN is the largest and most modern particle physics research center in the world (Figure 1). Scientists from all over the world are currently using a huge particle accelerator to probe how our universe came into existence, what materials where created from and which forces hold them together. It has become widely known as the Big Bang Experiment.

Simulating the Big Bang

The CERN particle accelerator, known as the Large Hadron Collider (LHC), has a total length of around 27 km. Inside it, protons and charged atomic nuclei are accelerated to close to the speed of light using 1300 superconducting electromagnets and then made to collide. The ›LHC‹ project is made up of the ›ATLAS‹, ›CMS‹, ›ALICE‹ and ›LHCb‹ laboratories, as well as four other experiments, all of them operated by international teams. The laboratories and experiments are located on the surface of the CERN complex, seven in France and one in Switzerland. Four LHC detectors are installed at a depth of

1 Bird's eye view of the extent of the underground CERN particle accelerator

100 m underground, in the tunnels along the underground LHC accelerator ring. The detectors reveal the paths of the collision particles and allow their properties and reactions to be studied.

Since November 2009, beams have been injected into the accelerator that reach an energy of up to 7 teravolts (TeV). With particle collisions thus totaling up to 14TeV, the aim is to gain information on the origins of our universe.

Highly complex passive infrastructure

To implement the project, a high-tech communication network has been developed and installed over the last seven years. It is made up of 2000 km of glass fiber cable, comprising around 20 000 lengths with around 25 million meters of fiber. This is comparable to the cabling structure of an entire city (**Figure 2**). The network has built-in redundance and is primarily designed to synchronize the particle acceleration and transmit the measured data in real time. Central applications of the glass fiber network are the internal CERN GbE network and the main experiment itself. Various control and security systems are also integrated. The core switches and routers for the technical network are located in control rooms at surface level, the edge devices in the technical facilities around the LHC.

The ›Beam Instrumentation System‹ has its own network. An observation point is stationed around every 50 m in the tunnel (**Figure 3**), so that the exact position of the particles in the LHC can be identified. Approximately 5000 devices around the accelerator send around 600 different signals to the surface and into the main control room. To ensure that no runtime problems occur, the glass fiber connections have exceptionally low attenuation and meet very stringent length tolerances. To achieve a desired beam synchronization in the 10 ps range, electronic equipment such as phase-locked loops are also used, enabling stable frequencies to be achieved in the optical transmission media.

Tailored solutions

The choice of optical fibers was primarily limited to two types: G.651 50/125 µm multimode gradient index fibers for the surface cabling and G.652.B 9/125 µm singlemode fibers. In the tunnel only the latter were used, as singlemode fibers do not contain any dopants and thus do not darken as quickly under the influence of collision particle radiation. Many of these are also special designs, for example with a 14-fold lower temperature coefficient.

It was clear from the outset that the optical fibers in the tunnel would be exposed to high energy physical radiation, thus increasing the attenuation in the fibers over time. As a result, special radiation-resistant cables from the Japanese glass fiber specialists Fujikura were used.

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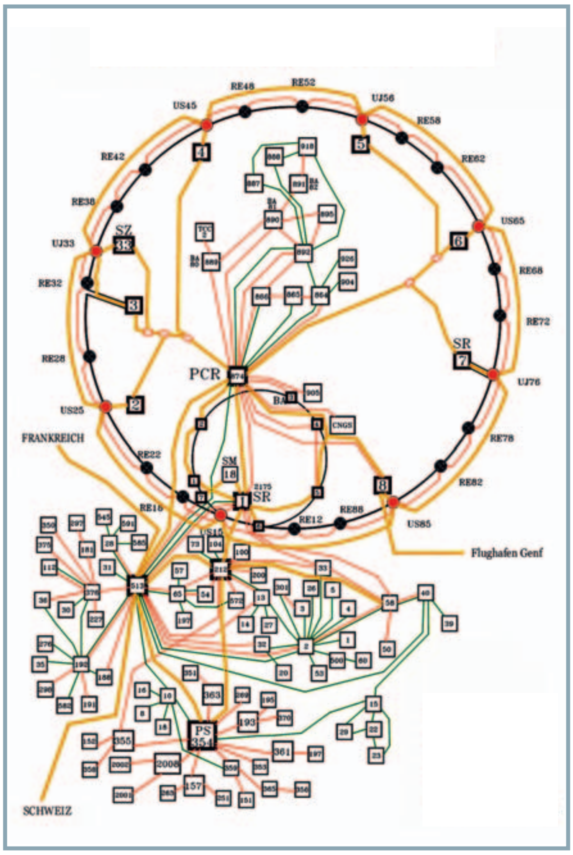
To obtain optimum insertion and return attenuation values at the fiber termination, tde - trans data elektronik invested heavily in new technologies and developed new production processes. For example, all singlemode fibers were terminated with E2000/APC connections with 8° angled polish, a totally new technology at the time of installation.

MPO for high density requirements

In recent years, tde has developed an increasing number of customized products for the LHC, some of them under severe time constraints. For the experiments alone, a large number of special optical installations were needed. The ALICE ▶



2 The most important glass fiber sections

3 In the particle accelerator tunnel

experiment, for example, required extremely complex high density installations.

For this project, tde installed singlemode and multimode MPO capability in-house. »We developed special polishing processes, purchased a high precision bonding robot and experimented with adhesive metering and production temperatures to deliver the right products – now part of the internal tML system – when it came to assembling the fibers,« explains tde Chief Executive André Engel. »To ensure that there are no signal runtime differences in the glass fiber trunk cables, the lengths of the individual cables were subject to very narrow tolerances.« For ALICE, the products included ten 48-fiber, 96.27 m singlemode trunk cables with pre-assembled MPO connectors, with length differences of just a few centimeters. In total, more than 4000 singlemode and multimode MPO assemblies are installed at CERN.

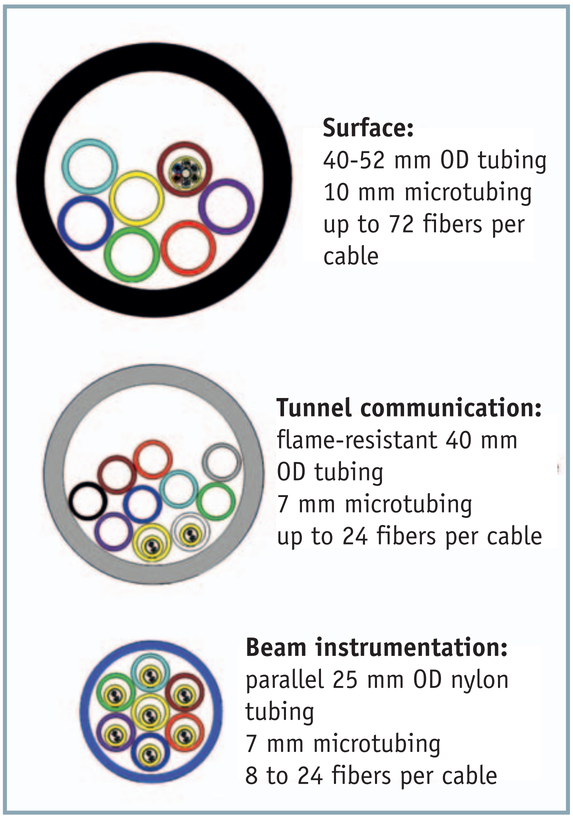
Microtubing and cables

During the installation, engineers at the research center have injected more than 2000 km of metal-free microtubing with a diameter of 7 to 10 mm into larger protective tubing. A microjet was used for the minicables. With cascaded equipment, they managed to achieve injection distances of up to 3.4 km. As well as discharge protection, this system provides other advantages: ›pay as you grow‹, branchings without splicing and easy replacement of damaged or older cables.

In the ducts between the LHC and the surface, the cables run in high-density polyethylene tubing parallel to the power cables. Some of them are designated ›loose tube‹ cables with up to 216 fibers, while some have up to 72-fibre minicables in microtubing. For the underground LHC communication and machine control network, CERN uses flame-retardant protective tubing (Figure 4). Around the accelerator are four parallel 25 mm nylon tubes, each of which has seven 7 mm microtubing injected into it, extending through the entire tunnel. This enabled a branch to be created every 350 m and an outlet every 50 m, from each of which a pair of the beam position checks is started with six to eight singlemode fibers.

Fiber monitoring

To meet the stringent requirements for fault-free transmission, continuous fiber monitoring is also necessary. The Geneva CERN laboratory uses optical time domain reflectometry (OTDR) with a wavelength of 1550 nm, in which the glass fiber itself acts as the measurement sensor. If physical parameters such as temperature, pressure and tensile forces are acting on the glass fibers, the properties of the light cables in the fiber networks change locally. Based on the increasing scatter that is caused by higher attenuation, the exact location of the external influence can be identified and the optical fibers can be replaced in good time – around every three to five years in high radiation areas – and within just a few hours.



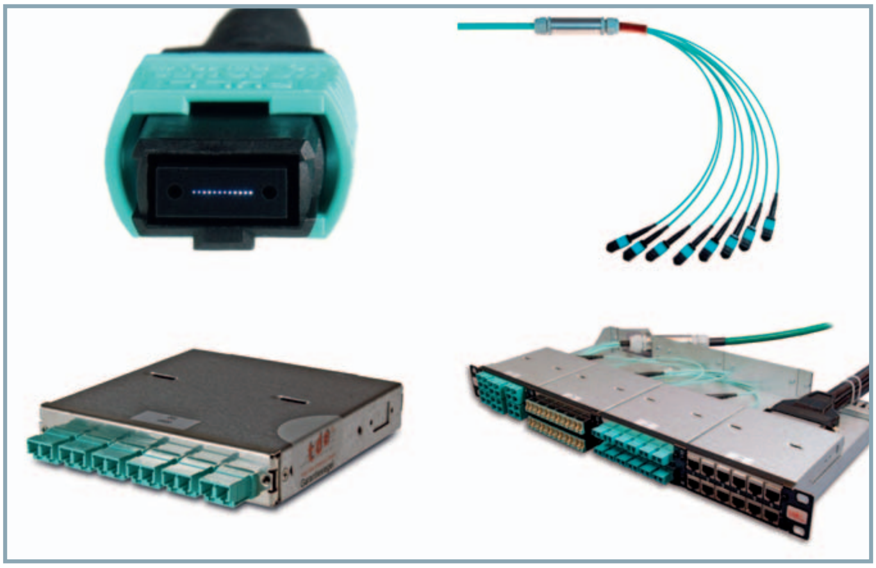
4 Different fiber installations at the CERN research center

From CERN to the data center

The know how gained during the CERN project has been directly utilized by tde in its own ›tML‹ cabling system. ›tML – tde Modular Link‹ is a modular concept made up of the core components of the module, trunk cable and module carrier (**Figure 5**). This flexible and compact cabling system is quick to install, requires few resources and little energy and can be scaled at any time to future transmission speeds of up to 100 Gigabit Ethernet.

»The tML system is based on our experiences and developments made during the CERN project. It enables us to offer companies that are aiming to make savings on cabling with a modular system featuring state-of-the-art technology and with maximum component density,« explains André Engel. Despite the system offering greater functionality than conventional cabling systems, the costs and fire loads are considerably lower and, thanks to the modular design, installing the components is extremely easy.

As it halves the space required in cabinets and cable ducts, tML is an extremely lean solution. For example, one cable with a diameter of just 14 mm is sufficient to connect two ›6 port RJ45‹ modules. At the same time, the pre-assembled modules and cables can be installed in a fraction of the time of those from conventional systems – there is no need for splicing and fitting, which also eliminates possible sources of faults. Long term savings are also achieved when expanding or modifying the system, as this can be done at any time and at minimal cost.



5 **tML MPO-Modul‹ from tde - trans data elektronik**

The three core components – module, trunk cable and module carrier – are factory pre-assembled and tested system components that are suitable of plug&play on-site installation in next to no time at all. The fact that system components can be reused means that changes or expansions are cost-effective and fast, guaranteeing excellent investment protection.

Summary

For many years, the CERN research center has been initiating technological developments that have enriched the life of mankind in the long term – we need only think of the World Wide Web. Despite all of the fears, the world is still turning – even though on March 30, 2010, the CERN project's Large Hadron Collider fired together atoms at almost the speed of light to approximate the conditions of the Big Bang. A huge amount of valuable measurement data has been gathered. Many of the developments made during the CERN project have been incorporated into mainstream cabling technology and now contribute to a critical improvement in the passive infrastructure of data centers and in conventional building cabling.

AUTHOR

WILFRIED SCHNEIDER is Chief Technology Officer (CTO) at tde - trans data elektronik. As a member of the DKE/VDE standardization committee on »Optical fiber connection technology and passive optical components«, he is involved in drawing up international standards for IEC and CENELEC.