FIBER OPTICS

DEWETRON

THE MEASURABLE DIFFERENCE

In this whitepaper, we cover the following points:

> **Advantages of fiber optics**

> **Fiber optic cable types – single mode & multi mode**

> **Transmitter and receiver (SFP)**

> **Selection of the appropriate switch and connecting the network**

FURTHER INFORMATION

Visit www.DEWETRON.com

INTRODUCTION

The Ethernet standard has come a long way since its creation in the 1970s. At that time, the transmission rate was only around 10 Mb/s, but today it is possible to realize speeds of up to 100 Gb/s.

Today, companies have a wide range of connectivity options available to build their network infrastructure. IT professionals are increasingly challenged in deciding which network connectivity option is best. In addition to copper, it is common today to implement network connections over fiber optic lines. Here again the question arises which fiber type is the right one, which cable type shall be chosen, which transmitter and receiver is the correct one?

This white paper is intended to provide insight and guidance on how to implement a fiber optic network and connect DEWETRON's data acquisition devices to the network.

ADVANTAGES OF FIBER OPTICS

In today's world, where the Internet and also the demand for internal networks is growing, a large bandwidth is of great importance. Bandwidth indicates the amount of information that can be transmitted per second with the same cable cross-section. Fiber optic cables offer a bandwidth of 10 Gb/s and beyond. It should be noted here that the fiber speed depends on the type of fiber used as well as the fiber category, which will be discussed in more detail later.

Another major advantage besides the speed of fiber optics compared to copper cables is the distance that can be realized. With classic twisted-pair copper cables, the distance is limited to 100 m, whereas with fiber optic cables distances of 550 m in 10 Gb/s multi mode or over 40 km with single mode cables are possible.

The general security of fiber optic systems is also higher than that of copper lines. Fiber optic cables are not only immune to environmental influences due to the non-conductive core material, but also offer the advantage that they do not emit any signals and are difficult to tap from the outside. If it were possible to tap into such a system from the outside, it would be noticed immediately in the system because light would be lost, and malfunctions would occur in the system.

FIBER OPTIC CABLE TYPES – SINGLE MODE & MULTI MODE

Basically, there are two different cable types for fiber optic cables, namely single mode and multi mode. The difference between the two modes is that the core of a single mode cable is very small (9 µm) and the light propagates in a straight line. Whereas the light in the larger core of a multi mode cable (50 µm or 62.5 µm) does not propagate in a straight line, but bounces off the cladding glass again and again, which also leads to a higher propagation time. This is shown in more detail in the following figure.

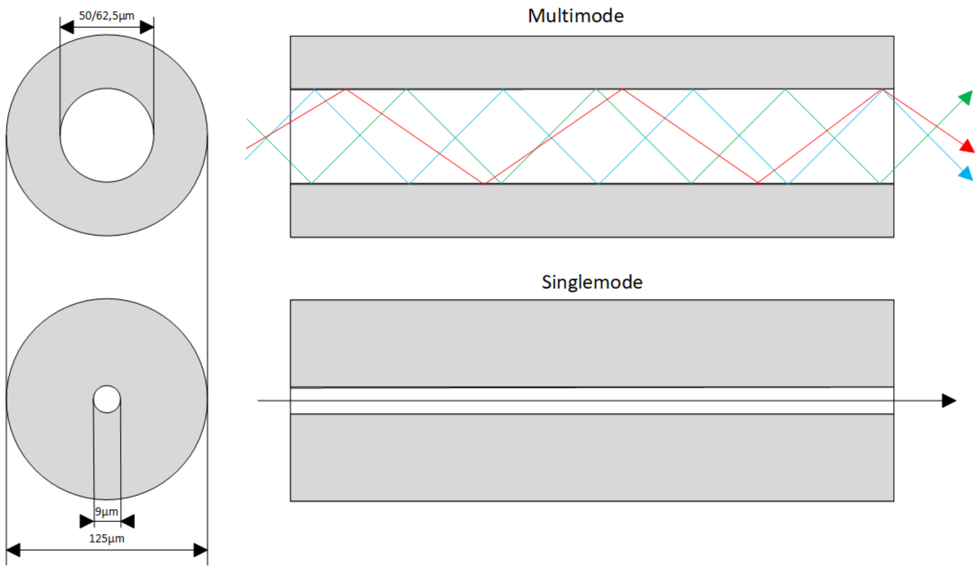

Fig. 1: Multi mode vs. single mode of a fiber optic cable

Therefore, single mode cables are very well suited for long distances (greater than 500 m) with high bandwidth. Due to the small diameter of the core, only one light mode can propagate, which will be typically generated by a laser diode as light source. The consequences are very low attenuation values, minimal signal loss and distortion. Multi mode cables on the other hand are very well suited for shorter distances (less than 500 m). With Multi mode cables it is possible to transmit more data at a short distance. Light waves are dispersed into numerous paths, which can lead to signal distortion on the receiver side at longer distances due to overlapping light pulses, which may lead to incomplete data transmissions, but multi mode cables are generally cheaper to manufacture than single mode cables. Thus, it is of great importance to define the cables according to the network requirements.

Multi mode and single mode cables are graded into different categories. Each individual gradation has different capacities regarding the maximum bandwidth and different distances can be realized with it. Multi mode cables are graded into the categories OM1, OM2, OM3, OM4 and OM5. For example, with an OM1 multi mode cable and a transmission rate of 10 Gb/s about 30 m can be realized, whereas with an OM4 multi mode cable up to 500 m can be realized. Single mode cables, on the other hand, are divided into the OS1 and OS2 groups. Both single mode cable categories have different attenuation and maximum bandwidth. Depending on the transmitter and receiver side and the transmission rate, up to 200 km with single mode cables are possible.

It is important to note that single mode and multi mode cables are not compatible with each other, simply because of the different diameter of the core.

TRANSMITTER AND RECEIVER (SFP)

However, the cable type itself and the category used are not the only factors that define the distances that can be achieved with fiber optic cables. The transmitter or receiver side is also very important. Nowadays, so-called SFP modules (Small Form-factor Pluggable) are often used as optical transceivers for switches etc., which are also often referred to as mini-GBIC.

Fig. 2: SFP module

The wavelength of the light used by the SFP modules is very important. The most common variants are 850nm, 1310 nm and 1550 nm. The higher the wavelength used by SFP modules, the greater the distances over which data can be transferred. Furthermore, the SFP modules differ in the transmission rate and connection type (multi mode or single mode).

Fig. 3: SFP module attached to switch

At this point it is very important to choose the correct modules when defining a network over fiber optic cables. At first it is important to choose an SFP-module for the correct cable type (multi mode and single mode). Furthermore, the transmitter and the receiver must work with the same wavelength, e.g. if a module with a wavelength of 850 nm is used as transmitter, a module with a wavelength of 1310 nm cannot be used as reciever since the communication is not possible – the wavelength has to be the same.
Nowadays, there are several generations of SFP modules. Normal SFP modules are designed for up to 5 GB/s. SFP+ offers as the next generation up to 10 GB/s and SFP28 even up to 25 GB/s.

SELECTING THE APPROPRIATE SWITCH AND CONNECTING THE NETWORK

Now we know which cable types exist for fiber and which type of SFP adapter we must use. Now we will set up a complete network to interconnect DEWETRON's measurement devices via fiber optics. What is still missing are the appropriate switches.

To illustrate the connection of DEWETRON's data acquisition devices over a fiber optic network, let's take 2 NEX[DAQ]'s as an example, which are connected in series over 500m and the measurement data are acquired together at a control PC.

The NEX[DAQ] has 2 M12 Ethernet connectors to connect it to a PC or notebook for data acquisition on the one hand, and to connect several NEX[DAQ]s together in series on the other hand. In addition, it is possible to provide power supply, data transfer and synchronization of the individual measuring devices via only one cable. It is also possible to supply the NEX[DAQ] via USB-C or LEMO, but in this example we use the supply via Ethernet (POE-Power Over Ethernet).

Fig. 4: The NEX[DAQ] is DEWETRONs compact and robust DAQ system

As mentioned earlier, the NEX[DAQ] can be powered via Ethernet, which makes it necessary to use a switch with POE (Power Over Ethernet). Additionally, it is important to cover the possible data rates that arise. For our application with 2 NEX[DAQ]'s 1 GB/s is completely sufficient. Therefore, we can use a switch that provides at least one SFP interface. For our application we decide for example for the following SFP module: 1000BASE-SX. This is a SFP module for multi mode, therefore the appropriate cable must be chosen correctly, here we choose a 500 m multi mode cable with category OM4.

One last point is not covered in this example though. As mentioned before, the 2 NEX[DAQ]'s connected in series are synchronized with each other, this works via PTP (Precision Time Protocol), a network protocol with which the synchronicity of several devices in a network can be guaranteed. However, this protocol must also be supported by the selected switch. PTP is defined in IEEE 1588, and either a switch is marked as supporting PTP or as supporting IEEE 1588. It is important to mention here that there are 3 variants for the support of PTP.

> Grandmaster clock: The switch acts as a PTP master and devices are synchronized by the switch.

> Boundary clock: The switch needs an additional PTP master but takes over the management of all slaves connected to the switch. This means that it receives the PTP synchronization signal from the PTP master and then takes over the management of all slaves for the PTP master.

> Transparent clock: The synchronization signal from the PTP master is simply forwarded to the connected slaves, this is also the simplest and cheapest variant and completely sufficient for our application.

Now as we have defined the 2 corresponding switches, the 2 necessary SFP modules and the fiber optic cable, we are only missing 3 copper cables to connect all devices in our network, the copper cables are necessary as the NEX[DAQ] does not support the connection to fiber optic cables itself. Schematically this network is shown in the following picture.

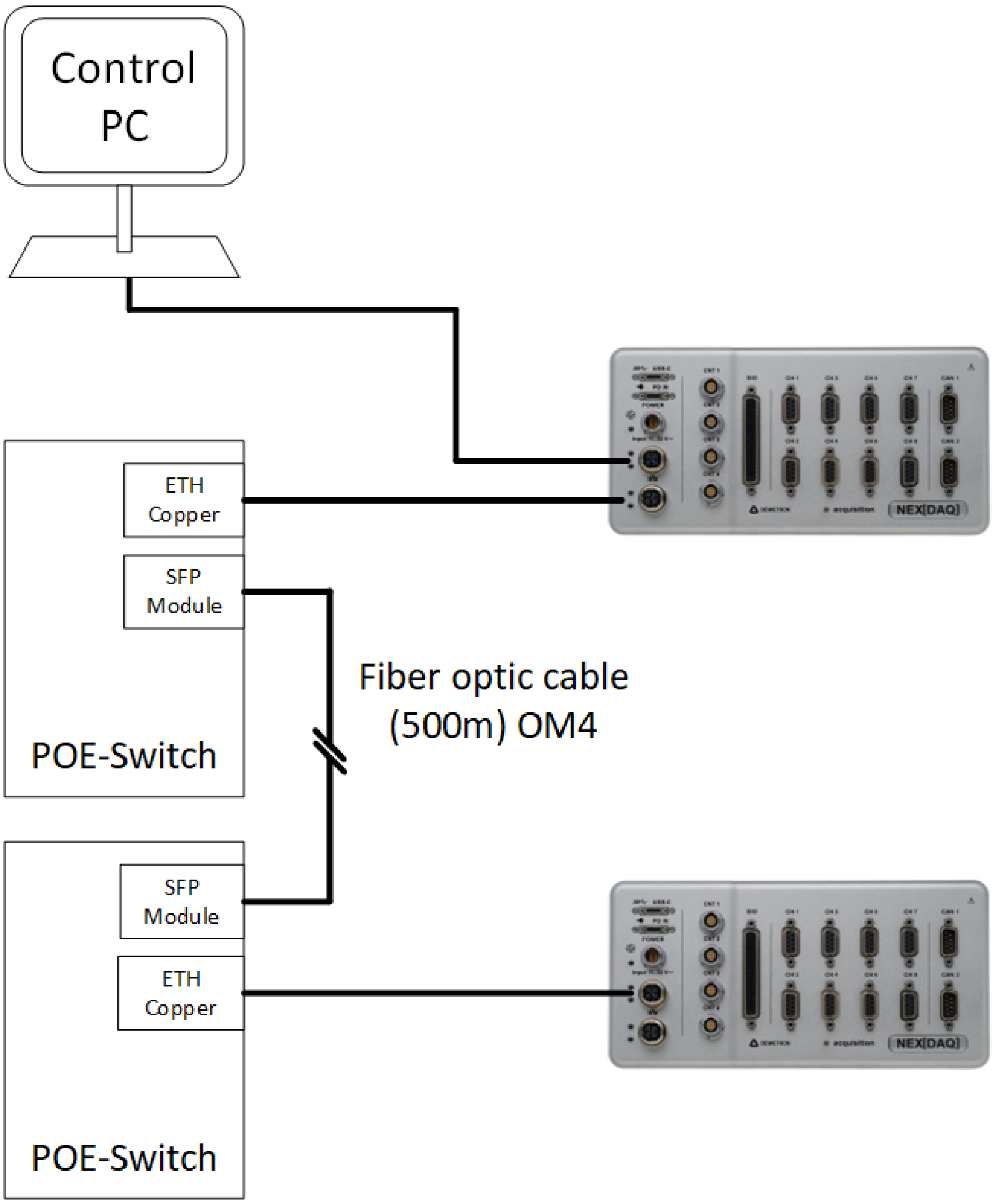

Fig. 5: NEX[DAQ] connected via fiber optic

The control PC is connected to the first NEX[DAQ] via a normal copper cable. The first NEX[DAQ] in the series also acts as a PTP master, so all subsequent devices are synchronized to the first NEX[DAQ]. Now we need another copper cable to connect the data acquisition device to the switch. Connecting our fiber optic cable to the two SFP modules in the switches and connecting the last NEX[DAQ] to the 2nd switch via the remaining copper cable will complete this network.

SUMMARY

Fiber optic cables offer many advantages over copper cables. Higher bandwidths can be achieved, and longer distances are possible. In addition, fiber optic cables are less expensive and lighter than copper cables, especially over long distances and are immune to environmental influences. All these advantages make fiber optic networks very attractive for many applications, particularly where the length or bandwidth requirements cannot be met with copper-bound networks.

DEWETRON is a specialist in the field of measurement technology. The goal is to produce measuring equipment that meets the highest possible quality standards, is modular and versatile, as well as easy to use.

If you want to learn more about DEWETRON, you can visit our DEWETRON website. There you will find further whitepapers as well as blogposts and video tutorials. We are also active on social media. Take a look at our Twitter, LinkedIn or YouTube pages.

THE EXPERT

Michael Fuchs has worked as an application engineer for a Graz-based company in the automotive supply industry since 2011. During his employment, he specialized in the post-processing of measurement data from emission test systems in accordance with global technical regulations. In 2022, he joined DEWETRON as an application engineer for automotive, e-mobility, energy applications, test benches and general test and measurement solutions.

FURTHER QUESTIONS? **CONTACT THE AUTHOR:**
michael.fuchs@DEWETRON.com