

Redefining Measurement

Use Case: Research Institute

Dispersion independent photon counting OTDR design with the ID900 Time Controller



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Customer Name: Information and Quantum Laboratories (InQuLabs)

University of Electronic Science and Technology of China (UESTC)

Research Field: Quantum science and engineering

Country: China

Customer need



Single-photon detection at very high count rates without saturation.

Solution



ID900-Master Time Controller to detect up to 100 Mcps per channel with a 100 ps timing resolution.

Results



Successful demonstration of dispersion insensitive photon counting OTDR (PC-OTDR) for long-haul fiber links.

Customer need

InQuLabs is an experimental lab devoted to cutting-edge quantum information science and technologies. The Single-Photon Detection and Distributed Sensing group at InQuLabs focuses on single-photon detection to solve real-world problems and develop advanced techniques for optical sensors, measurements, and metrology.

One meaningful work being done by the Single-Photon Detection and Distributed Sensing group at InQuLabs is to develop a PC-OTDR (Photon Counting OTDR) system independent from fiber dispersion effects, with the aim of eliminating the need for high performance short-pulse lasers, and keeping the spatial resolution unchanged along long-haul fiber links.

With the development of single-photon detection (SPD) technology, PC-OTDR based on SPD technic has received increasing attention because of its higher spatial resolution and higher dynamic range capabilities. Currently, as the spatial resolution of PC-OTDR is directly related to the laser pulse width, short pulses are essential to achieve high spatial resolution.

However, short laser pulses have a large spectral bandwidth, which results in pulse broadening due to fiber dispersion, causing inevitable deterioration of the spatial resolution, especially in the case of measurements of long-haul fiber links.

To obtain a PC-OTDR trace, known as the fiber loss profile, the time delay between the launch of a laser pulse and the detection of Rayleigh backscattered or Fresnel reflected photons should be recorded with high timing precision. Furthermore, it is necessary to accurately measure single-photon counts at very high rates without saturation. A novel approach to conventional OTDR technique, the so-called infinite backscatter technique [1] was recently proposed to improve the spatial resolution performance, which is here further improved using Single-Photon detection and high speed TDC-based counting. The ultimate objective being to achieve dispersion insensitive long-haul PC-OTDR measurement. [2]

Solution

The institute chose to use IDQ's ID900 Time Controller to perform single-photon detection, since the ID900 has the highest detection rate capabilities available on the market, being able to detect 100 Mcps per channel with a 100 ps temporal resolution in High Speed Mode. Additionally, each input channel has internal adjustable timing offsets and the maximum number of time bins is 16,384, making it easier to record the input signal in different spans of time.

ID Quantique has developed a very intuitive and reliable graphical user interface that allows real-time monitoring of photon counts and displays OTDR curve in the different coordinates, which is extremely helpful for alignment of the experimental set-up and its optimization.

The main advantages of the ID900 Time Controller over other devices are its extremely high-count rate capability, as well as the user-friendly GUI and rich data file saving function.

Results

An EDFA with a spectral width of about 30 nm was used to test a fiber under test (FUT) with a length of more than 45 km. The time-bin width of the ID900 Time Controller was set to 40 ns and the output light of the EDFA is modulated into pulses with a period of 1.0 ms and a pulse width of 80.0 ns. The assumption here is that, when the time-bin width is smaller than the pulse edge, the spatial resolution is mainly determined by the rising and falling edges of probe pulses in this proof of principle demonstration. The EDFA laser pulses have a rising edge and a falling edge of 10 ns respectively, which is equivalent to a spatial distance of 1 m. The FUT is made up of six segments of SMF connected through connectors with lengths of 50 m, 10 m, 25 km, 20 km, 10 m and 50 m, respectively to test the evolution of the spatial resolution over distance and the possible degradation due to fiber dispersion.

As shown in Figure 1, with the same data set according to the output of ID900 Time Controller, PC-OTDR with high dynamic range (spatial resolution) can be achieved by increasing (decreasing) the value of N, where N is a positive integer and represents the interval between the indexes of time bins used to calculate the backscattered photon counts.

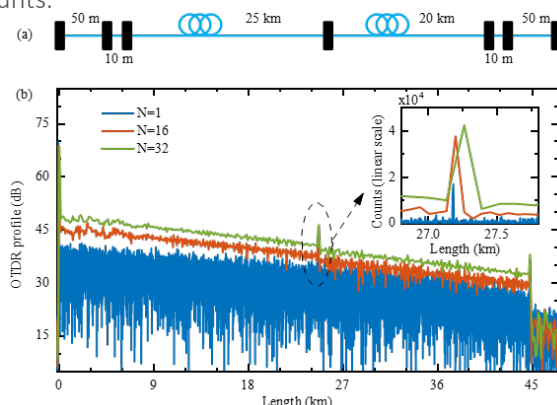


Figure 1. OTDR traces for the FUT of more than 45 km fiber.

(a) The connection structure of the FUT.
 (b) OTDR traces with different dynamic range (main figure) and spatial resolution (inset) for various resolution configurations

Bin Li, Ruiming Zhang, Yong Wang, et al. Dispersion independent long-haul photon-counting optical time-domain reflectometry. *Opt. Lett.* 45, 2640-2643 (2020)

To show that the PC-OTDR scheme is independent of the fiber dispersion properties, one checked the reflective events caused by the connection of two pieces of 10 m SMF at the front and rear ends of the FUT, as shown in Figure 2.

Figures 2(a) and 2(b) (showing the counts/ time-bin index distribution of both the front and rear ends sections) clearly demonstrates that the spatial resolution remains unchanged along the FUT by using our PC-OTDR scheme, i.e. 8.18 m in the shown example.

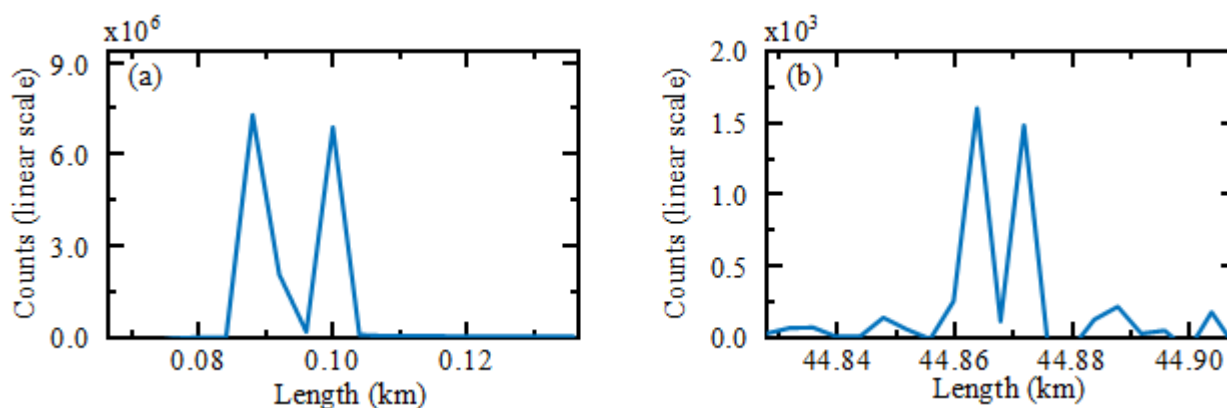


Figure 2. Reflective events caused by two pieces of 10 m SMF at both ends of a 45 km long FUT (arxiv : 1910.13040 Dispersion independent long-haul photon counting OTDR)

In this experiment, the ID900 Time Controller works in the histogramming mode, thus due to the limitation of the maximum number of time bins, the time-bin width should increase with the increasing long FUT. However, the time-tagging mode can be used to greatly improve measurement accuracy. The ID900's timestamping mode makes it possible to record single-photon counts with high time resolution, i.e. 100 ps, regardless of the number of time channels.

“ We have been using ID Quantique’s ID900 Time Controller for more than a year now. It makes our photon counting experiments more efficient and greatly improves the experimental results. In addition, its rich functions also meet the needs of other groups in the InQuLabs, and the multi-input and multi-output design allow it to be used by different groups at the same time. More importantly, ID Quantique provides timely technical support and provide continuous firmware updates to improve the performance of the device

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[1] D. Devicharan, T. Zahnley, S. Dahl, A. Gurusami, and I. McClean, “Low optical power embedded OTDR,” in Optical Fiber Communication Conference, OSA Technical Digest (online) (Optical Society of America, 2015), W4D.4.

[2] Bin Li, Ruiming Zhang, Yong Wang, et al. Dispersion independent long-haul photon-counting optical time-domain reflectometry. Opt. Lett. 45, 2640-2643 (2020)