Remote Smoke Sensing Technique Based on OTDR

Chun-Liang Yang [a] and Yi-Heng Yang [b]

Department of Electrical and Computer Engineering, Tamkang University,
No. 151, Yingzhuan Rd., Tamsui Dist.,
New Taipei City 25137, Taiwan, R.O.C.
[a] clyang@mail.tku.edu.tw, [b] fly3470@gmail.com

Abstract

In this paper, we have demonstrated the OTDR-based smoke sensing technique via a reel of 5-km standard single-mode fiber, which employs two fiber ends that are the ultra physical contact polish and the 8-degree angled physical contact polish as the smoke sensing probes and utilizes an OTDR to measure their optical return losses remotely.

Keywords: Smoke Sensing, Optical Fiber, Optical Return Loss, Optical Time-Domain Reflectometer

Introduction

In recent years, the remote indoor monitoring has become more and more popular due to the development trend of Internet of Things (IoT). If we can detect the indoor disaster immediately, then the protective measures will be better, and people can reduce the loss of life and property in the event. Although the use of electronic smoke sensors has a good performance at present, they still need a power supply nearby and a long-distance data transmission system. Additionally, they have a high risk of losing electrical power and disabling their function in a disaster area. In general, the indoor smoke sensors only detect the presence of smoke appearing in the space below the ceiling. Thus, we propose a fiber-optic smoke sensing technique, which has a small size and is very suitable for monitoring both spaces above and below the ceiling simultaneously and remotely.

In this work, after injecting 5-second smoke into the experimental bottle connected to an 8-degree angled physical contact (APC) connector, we obtained a significant 11-dB difference and extreme transient fluctuations in optical return loss (ORL) during the smoke sensing. Although the measured ORL under two different polish types had the respective curves, the proposed scheme could effectively achieve the purpose of remote smoke sensing.

Operating Principle

Optical Time Domain Reflectometer (OTDR) is a well-established tool for characterizing the length of optical fiber cables and measuring fiber attenuation, splice or connector loss and ORL, and fault loss [1]. Based on these functions, it is very suitable for the optical cable maintenance and construction. Moreover, OTDR is most effective when testing long cables or cable plants with splices by illustrating where the cables are terminated and confirming the quality of the fibers, connectors, and splices. The technique involves launching a short pulse of light into the fiber and measuring the temporal behavior of the backscattered light which returns to the launch end. The end of the fiber link is indicated by a pulse corresponding to the Fresnel reflection incurred at the output end face of the fiber.

To demonstrate this work, we adopted two types of optical connectors such as ultra physical contact (UPC) and angled physical contact (APC) [2,3]. The main difference between APC and UPC connectors is the fiber end face. APC connector features a fiber end face that has polish at an 8-degree angle, while UPC connector has polish without a specific angle. UPC connectors possess a slight curvature for better core alignment. However, manufacturing techniques have improved significantly to create more precise angles on APC connectors. The industry standard is a minimum of -50 dB for UPC back reflection measurement. An APC polished connector has an industry standard minimum of -60 dB measurement. APC fiber ends have low back reflection even when disconnected. APC connectors are identifiable by their green color.

With UPC connectors, the reflected light at the fiber end to air is about 4%. The angled end face of the APC connector causes reflected light to reflect at an angle into the cladding, so it is less backward to the light source end shown in Fig. 1. This feature causes some differences in ORL for two types of connectors.

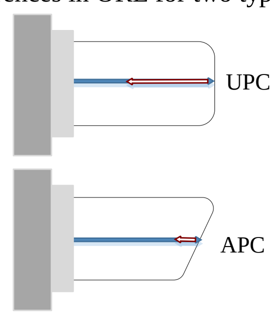

Fig.1 An illustration of UPC connector and APC connector.

Experimental Setup and Result

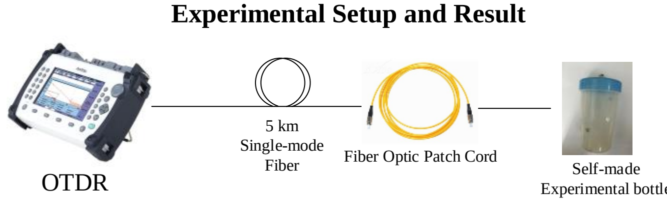

Fig. 2 Block diagram of experimental setup.

Fig. 2 shows the block diagram of experimental setup. We adopted an OTDR whose brand model is Anritsu MT9083A, a reel of 5-km standard single-mode fiber, two 1-m fiber-optic patch cords that one is FC/UPC to FC/UPC and the other one is FC/UPC to FC/APC, and a self-made experimental bottle. The operating parameters on OTDR have the distance of 25 km, the wavelength of 1550 nm, the pulse width of 200 ns, and the average time of 20 seconds.

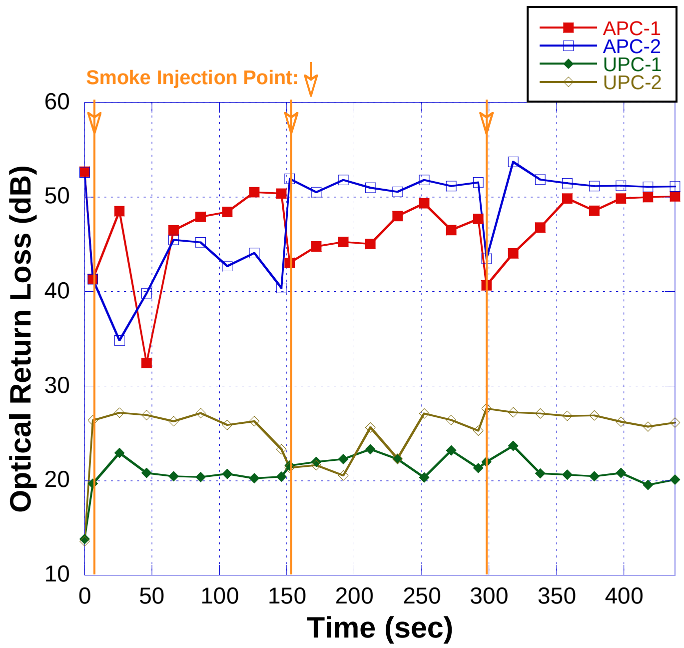

Fig. 3 The ORL curves of smoke sensing under different fiber ends.

Fig. 3 plots the ORL of the smoke sensing under different fiber ends. The experiment divided into two groups: the first is the APC fiber end as the smoke sensor and the second is the UPC fiber end as the smoke sensor. We injected the 5-second smoke into the self-made experimental bottle in the 1st, 150th and 300th second and observed the ORL in the bottle for 140 seconds. Each group was carried out two experiments to obtain two experimental curve data, which is conducive to comparison and analysis. The source of the smoke was smoke detector tester and was the UL listed for testing a smoke detector's function per National Fire Protection Association (NFPA) and for use with smoke alarms listed to UL standards 217 and 268 [4-7].

At the beginning (the zero second position), the measured ORL of UPC fiber end to air in the bottle is 13.71 dB and the ORL under the free space is 13.75 dB, so we could confirm that the experimental bottle did not impact the measurement. The first second injecting the smoke, we could see the values of ORL had a rising trend so that the fiber end could detect the appearance of smoke thanks to the occurrence of Fresnel reflection at the fiber end face. According to Fig. 3, in the 150th to 300th second, the smoke in the bottle did not have a stable state. After the 300th second, the value of ORL we could see stayed in a stable state.

At the beginning (the zero second position), the ORL of APC fiber end to air in the bottle is 53.63 dB and the ORL under the free space is 53.07 dB, so we could also confirm that the experimental bottle did not impact the measurement. Due to the structure of APC fiber end face, there is an extreme difference of fiber reflectance initially. Thus, smoke had a significant effect on APC end face, the value of ORL had a large amount of change because of the backscattered light increased. According to Fig. 3, the ORL of APC fiber end presented about 11-dB gap declining at the beginning of 5 seconds. At the point of the 400th second, we nearly obtained the initial value of ORL so that the APC end could reach the repeatability of smoke sensing. The value of ORL difference is over 5 dB, and therefore the APC fiber end face had a great detection sensitivity of smoke.

Conclusion and Discussion

In this paper, we have verified the smoke sensing technique based on an OTDR, which employed the UPC fiber end and 8-degree APC fiber end as the smoke sensing probes and utilized the OTDR to measure their ORL under smoke. The experimental result could proof the feasibility and effectiveness of the smoke sensing technology of the OTDR proposed in this paper.

Despite the fact that two different physical contact fiber end faces had the respective curves, they could effectively achieve the purpose of remote smoke sensing.

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