Development Real Time Monitoring System of FTTH Using Fiber Bragg Grating Sensors

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***Abstract*—This paper deals with an optical fiber remote monitoring system by installing a reflecting filter in a Fiber to the Home Network. The existing FTTH technologies can't provide centralized real-time detection of optical cable failure and splitter degradation. To address this problem, this paper proposes a method for a real-time monitoring of Optical fiber Network and splitters using reflecting filters operating on the principle of fiber Bragg grating sensors. A reflecting filter enables remote monitoring of the optical cable bending status, connector status, and splitter degradation so that the telecommunication service provider's central office can identify faulty fiber and failure location**

Keywords—reflecting; FTTH; real-time; FGB; Monitoring;

I. Introduction

As Big data, AR/VR, etc wearable devices become more in our daily lives, traditional communication networks are facing tremendous challenges [1]. These diverse innovative services increase customer's traffic. Therefore Telecommunication Network providers have been evolving towards Fiber-to-the Home (FTTH) Network that offers optical network to subscriber's home. In line with this trend, intensive research has been carried out on different methods of real-time FTTH network monitoring [2]. Existing studies have revolved around monitoring systems based on backscattering using dark fiber [2]. However, Network monitoring using dark fiber cannot be applied to feeder networks in areas with high penetration rates. In this case, an active optical access network device using lit optical fiber is required; however, there is no device capable of concurrently monitoring both optical line and splitter. A monitoring system should ensure the subscriber-side dB values and detect intrusion in real time using downstream wavelengths. That is, this system monitors both service and monitoring wavelengths in the FTTH network through a reflecting filter in the PON splitter installed in the subscriber's access network. In order for the reflecting filter real-time monitoring up to the subscriber drop line, a coupler should be installed between the provider-sider line concentration switch (LCSW) and fiber distribution frame (FDF), and the reflecting filter in an optical network terminal (ONT) serving a single subscriber or in an optical splitter serving a multifamily dwelling unit via live optical fiber. In this study, a reflecting filter was installed in a 1:8 splitter port using customer's served by a real FTTH network to enable a real-time optical fiber monitoring. This enabled an accurate diagnosis of the cause of a subscriber-side equipment or line fault and, consequently, a high-quality optical network and efficient line management, providing before-service instead of after-service on receiving complaints. The section of this paper dealing with the reflecting filter describes the details of the field test carried out in a region with subscribers served by an FTTH network, using a prototype provided by an iOLM (EXFO) device supplier and a reflecting filter manufacturer. The results of the field test were described based on the ITU-T recommendations for gigabit-capable passive optical Network (G-PON) of the FTTH Network.

II. Theories and Methods

A. Mechanism of the FTTH network monitoring system using Fiber Bragg Grating Sensor

In an FTTH network, installed in the telecommunications company optical signals are broadcast from the OLT PON port to individual subscribers' ONTs using passive optical splitters via P2MP topology. The upstream transmission takes place in unicast from ONT to OLT[3]. In this process of upstream-downstream traffics, the optic line between OLT and ONT is exposed to various damage risks, such as online outputs of an unspecified number of network participants, road and building construction sites, and utility pole relocation[4].

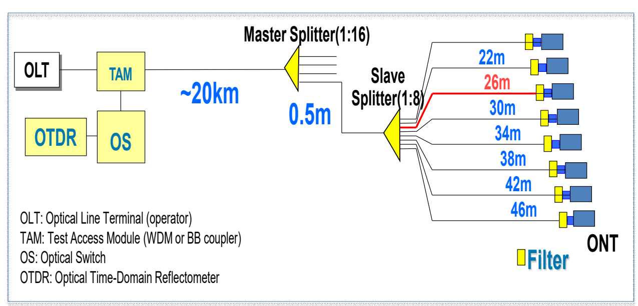

Fig. 1. A functional/structural block diagram between OTDR and reflecting filter[4]

Fig. 1 shows that a coupler consists of a test access module (TAM) and an optical switch (OS). Without the TAM module, if the OLT is connected to one of the coupler arms and optical fiber, OTDR emits signals, whereby the signals between OTDR and coupler and those between OTDR and OLT can collide, resulting in network failure. TAM is installed between

OLT and coupler and serves and wavelength division multiplexing (WDM) and coupler. TAM can combine the signals emitted from OTDR and OLT and send them to a plurality of filters [5][6]. A filter is placed between a splitter and each of the ONTs connected to it. Each filter consists of a ferrule cladding optical fiber and thin films with different refractive indices. Each filter has multiple stacked layers within the optical line in the direction of optical signals and reflects signals that have wavelengths of 1625-1650nm. The mechanism by which a reflecting filter works is as follows: in addition to the traditionally used OLT-side signal wavelengths of 1310nm, 1490nm, and 1550nm, a coupler1 using monitoring wavelengths of 1625nm and 1650nm is installed to monitor the reflecting filter installed in the ONT-side optical line serving detached house and apartment house dwelling units.

B. Reflecting filter structure and fabrication method

Germanium (Ge), Boron (B) etc. may be added to improve the sensitivity of the optical core, or Hydrogen may be used. Canada Researchers found that Germanium, the element that is commonly used to raise the refractive index of silica in the core region of an optical fiber, when exposed to high intensity visible or ultraviolet (UV) light, further increased the core refractive index[7]. Optical cable that Germanium, the element that is commonly used to raise the refractive index of silica in the core region of an optical fiber, when exposed to high intensity visible or ultraviolet (UV) light, further increased the core refractive index. This principle can be used to produce Fiber Bragg Grating [8] [9]. An FBG filter is an optical fiber version of a thin film filter, whereby the periodical structure allows it to function as a filter. Refractive index changed through irradiation of intense UV, and Germanium (Ge) or Boron (B) may be added, or hydrogen treatment may be given in order to increase the sensitivity of optical fiber[8][9].

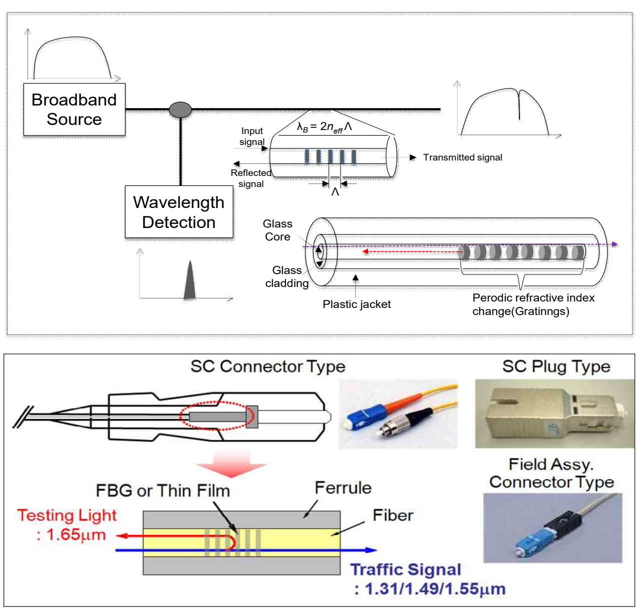

Fig. 2. Schematics of the operating principle of fiber Bragg grating [5][9][10]

As illustrated in Fig. 2, when a broadband source is transmitted from the central office to the FBG, specific wavelengths are reflected as defined by Eq. (1), and all other wavelengths pass through the FBG. The reflected wavelengths are called Bragg wavelengths. Optical fiber operates on the principle of total internal reflection of light at a certain angle of incidence at the boundary between two media with different refractive indices while traveling from a medium with a higher refractive index to a medium with a lower refractive index. Based on this phenomenon, FBG is achieved by a periodic modulation of the refractive index within the optical fiber's core [10][11][12][13][14]. Bragg wavelength is a function of the effective refractive index and the grating period, as expressed by Eq. [10][12][14]:

$$\lambda_B = 2n_{eff}\Lambda,\ \Lambda = \lambda_B/2n_{eff} \quad (1)$$

The reflected wavelength of light from the grating is $\lambda_B = 2n_{eff}\Lambda$ where n_{eff} is the effective refractive index seen by the light propagating down the fiber, and Λ is the period of the index modulation that makes up the grating[7]. λ_B are Bragg wavelength, n_{eff} is effective refractive index of the fiber core and Λ is grating period[11]. respectively, The relationship between effective refractive index and Bragg wavelength is determined by the relationship between Bragg wavelength and grating period; a specific wavelength is determined by applying the grating waveguide to the optical device of the reflecting filter. Controlling Bragg wavelength λ_B of the measure of the functionality of a reflecting filter [10][12]. The next section describes the details of the field experiment carried out with a reflecting filter installed on each of the splitter servings a subscriber group of an active FTTH Network.

III. EXPERIMENTAL

Fig.3 graphs show the results of the bending test after the central office labelled the reflecting filters installed in the target splitters in an active FTTH network. It was tested whether the NMS in the central office can detect the events such as bending and breaking artificially incurred under near-reality conditions. As experimental testing setup, we installed a reflecting filter in each of the target slave splitters in Optical cable from the OLT installed in the central office. Specifically, it was tested whether the analysis values can be read by visual assessment in the NMS of live-OTDR in the event of externally imposed fiber bending and splitter degradation in the reflecting filter installed at a distance of 2.95~3.05km. In the Fault & Bending test, Splitter 2 in the first screen of Fig. 4 displays changing dB values before and after the fiber core bending event. In the screen, which displays the dB values during the event, SL_RN(Splitter) 1, 2, 4 show normal dB values, whereas Splitter 3 and Green color SL_RN(Splitter) 1,2 shows fault & bending-induced loss that is visible on the NMS screen and triggers a sound alarm, demonstrating the remote fault detection performance of the proposed monitoring system.

Fig. 4 shows the screen for banding and fault results, and no OTDR knowledge, multiple OTDR traces are automatically performed and analyzed. It Provides a single set of result data that is easy to parse and display.

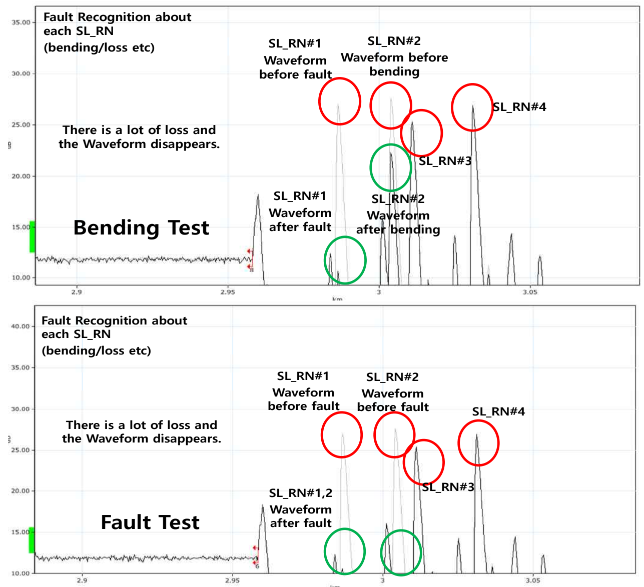

Fig. 3. Fault & Bending test result using Pon-OTDR

Fig.4 Show the results of testing on an FTTH Network. In other words, OTDR Fault analysis and location can be performed.

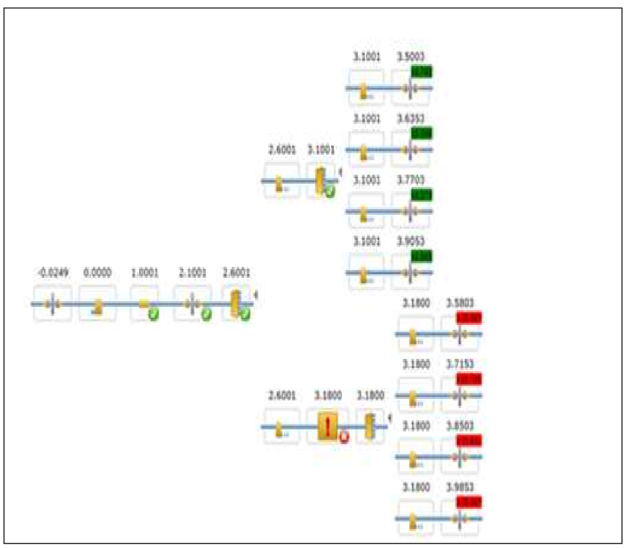

Fig.4. Banding & Fault location Link Result

IV. Conclusion

This paper proposes a reflecting filter that enables a real-time monitoring system by using live monitoring wavelengths of 1625nm and 1650nm in addition to currently operating wavelengths without separately configuring dark fiber, thereby monitoring equipment connectors or splitters used for B2C and B2B transactions. The proposed reflecting filter enables real-time monitoring of optical cables and splitters, whereby one reflecting filter is installed in each optical branching splitter in the Optical cable rings. In general, real-time monitoring is cost-intensive because it requires a coupler in the central office and a reflecting filter in each slave splitter. Moreover, real-time monitoring of various Optical cable rings

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