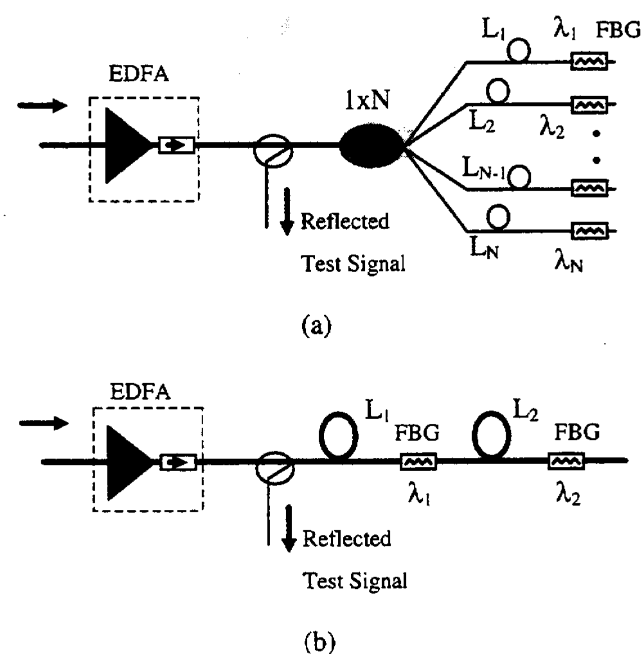
TuK1 **2:00pm**

A passive surveillance scheme for passive branched optical networks

C.K. Chan, Frank Tong,* L.K. Chen, J. Song,* Dennis Lam,+
Department of Information Engineering, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong; E-mail: ckchan3@ie.cuhk.edu.hk

Passive branched optical networks (PBON) are very cost effective and promising architectures for future subscriber networks such as CATV and FTTH. With the advent of erbium-doped fiber amplifiers (EDFAs), the transmission span and the number of fan-outs can be greatly improved. In order to maintain high service availability, it is essential to have a good surveillance system to identify possible fiber-link faults while the data channels are in service. Recently, several methods, based on multiwavelength optical time-domain reflectometry (OTDR), have been proposed.[1–4] However, they all require a wavelength-tunable pulse light source for the test signals and, thus, impose high maintenance cost. In this paper, we propose a novel passive surveillance scheme for fault identification in optically amplified PBON using fiber Bragg gratings (FBG) without using any extra light source for the test signals.

Figure 1 shows our proposed surveillance schemes for (a) a tree-branched network, and (b) a single feeder. An EDFA is put at the head end before splitting. The services are usually carried on wavelengths between 1540 nm and 1556 nm because of the relatively flat ASE spectrum. In our scheme, instead of using an extra light source for monitoring, we use an FBG at each branch's end to slice the enormous unused ASE spectrum as individual fault identification test signals. All reflected sliced ASE signals are tapped out using an optical circulator or a fiber coupler and detected by a grating-based wavelength-division multiplexed receiver array. If the received ASE power at any assigned test wavelength is below detection threshold, this indicates possible link breakage at the corresponding fiber branch or segment. The monitoring



TuK1 Fig. 1. Proposed surveillance scheme in (a) a 1 × N tree-branched PBON and (b) a single feeder.

information can be transmitted back to the service provider via telephone lines or putting it on a specific subcarrier (SCM) in the upstream channel.

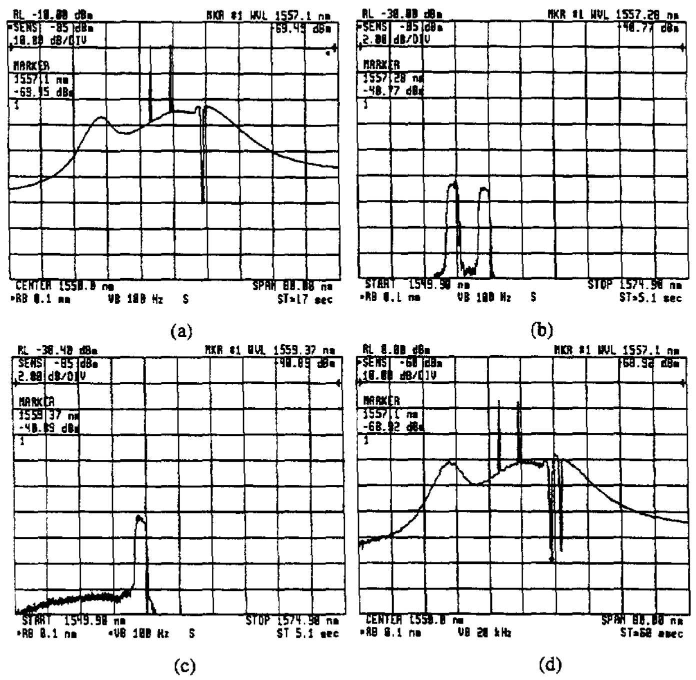
We have experimentally demonstrated our proposed scheme. As shown in Fig. 1(a), the three-branched network has four branches with fiber lengths $L_1 = 4.4$ km, $L_2 = 8.8$ km, and FBG center wavelengths at $\lambda_1 = 1557.5$ nm, $\lambda_2 = 1559.9$ nm. The 3-dB bandwidth of each FBG is 0.9 nm and the reflectivity is about 90%. Two data channels at 1550 nm and 1545 nm, each with transmitted power 4 dBm, are inputted to the branches. Figure 2 shows (a) the transmitted spectrum at branch 1, (b) the reflected spectrum, and (c) the reflected spectrum when branch 1 is broken. Figure 2(d) shows the transmitted spectrum with system configuration as in Fig. 1(b) where the FBGs are placed at several check points to localize the fault identification along a feeder for $L_1 = 6.6$ km and $L_2 = 8.8$ km, with FBG center wavelengths at $\lambda_1 = 1557.5$ nm and $\lambda_2 = 1559.9$ nm. The experimental results show that our proposed scheme is very feasible.

Furthermore, we analyze the dynamic range of the monitoring system. Consider a $1 \times N$ tree-branched PBON with an EDFA placed before the tree-coupler and an FBG located at the far end of each branch. The fiber span L of each branch should be:

$$L \leq \{P - 2C - 20log_{10}N + 10log_{10}R - D\}/2\alpha \qquad \text{(in km)}$$

where P is the ASE power in dBm at the specific wavelength, C is the insertion loss of the circulator or 1×2 coupler in dB, α is the fiber loss in dB/km, R is the reflectivity and D is the detection threshold in dBm. For example, for $P = -20$ dBm, $C = 1$ dB (for circulator), $R = 0.9$, $D = -50$ dBm, $\alpha = 0.25$ dB/km and $L = 10$ km, the maximum number of branches (N) allowed is 15. In addition, the approximate unused ASE spectrum is about 25 nm. This allows more than 15 wavelengths for monitoring if wavelength spacing of 0.5 nm and FBG passband of 1 nm are assumed.

In summary, we have proposed and experimentally demonstrated a practical in-service surveillance scheme using FBGs for fault identification in branched optically amplified networks without requiring any extra light source.



TuK1 Fig. 2. Experimental results: (a)–(c) tree-branched network: (a) transmitted spectrum at branch 1, (b) reflected spectrum, (c) reflected spectrum when branch 1 is broken, (d) single feeder case: transmitted spectrum.

**On leave from IBM T.J. Watson Research Center, Yorktown Heights, New York 10532*

***On leave from Department of Electronic Engineering, Tsinghua University, Beijing, China*

†*JDS FITEL Inc., Ontario, K2G 5W8 Canada*

1. I. Sankawa, IEEE Photon. Technol. Lett. **2,** 766–768 (1990).
2. Y. Koyamada *et al.*, presented at 100C'95, Hong Kong, 1995, paper FA1-4.
3. M. Shigehara *et al.*, in *Optical Fiber Communication Conference*, Vol. 2 of 1996 OSA Technical Digest (Optical Society of America, Washington, D.C., 1996), paper WK13.
4. K. Tanaka *et al.*, IEEE Photon. Technol. Lett., **8,** 915–917 (1996).