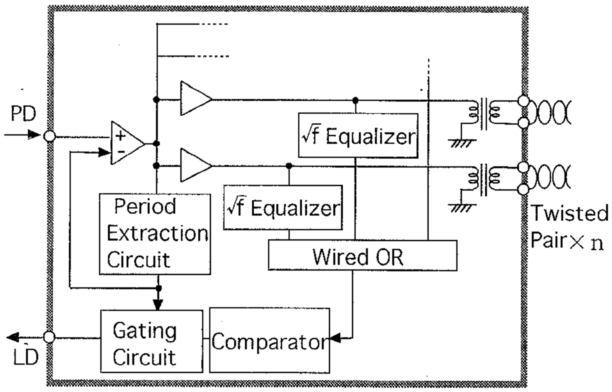



FD2 Fig. 2. The ONU for this experiment.

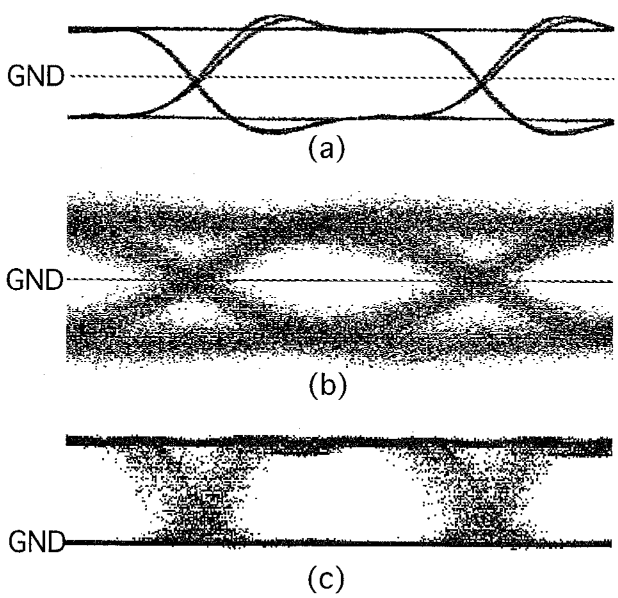
The functions of the ONU are independent of the signal format and the bit rate. The 2B1Q, which is used in the conventional metallic transmission, and NRZ, which is appropriate to the fiber-to-the-home system[3] in the next generation, can be provided simultaneously.

Figure 2 shows the ONU used in this experiment. It has two branches for metallic PDS. The 150 m (0.4 mm φ) twisted pair cables were used. In this experiment, the O/E converter and optical fiber were omitted.

The test burst signal was NRZ, pseudo-random bit sequence (21 stages in upstream, 23 stages in downstream), without the bit scrambling. Its baud rate was 50 Mbit/s. The burst period was 1 m sec, the downstream signal was 12.5 M bit/s and the upstream signal was 5 M bit/s.

Figure 3 shows the waveforms in the upstream direction. The eye patterns of the last three bits in the frame are shown. The signal before the transmission [Fig. 3(a)], the equalized signal [Fig. 3(b)] and the output signal [Fig. 3(c)] are shown.

The error free transmissions (bit error rate $< 10^{-9}$) were confirmed in both directions.




FD2 Fig. 3. The signal in upstream. The eye patterns of the last 3 bits in the frame are shown. (a) Signal before the transmission; (b) equalized signal; (c) output signal.

We have proposed a novel metallic PDS. 12.5 M bit/s NRZ signal in downstream and 5 M bit/s NRZ signals in upstream were successfully transmitted with 150 m twisted pair cable, and showed the HFP system's feasibility.

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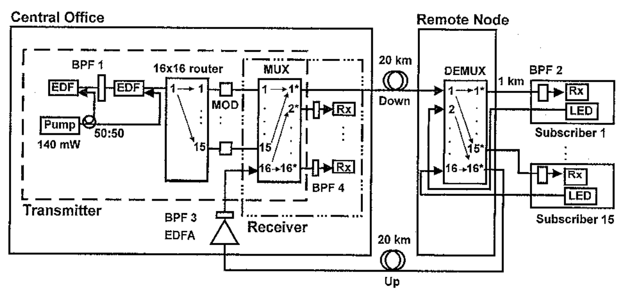
## FD3 9:15am

### WDM PON based on spectrum-sliced fiber amplifier light source

D.K. Jung, S.K. Shin, C.-H. Lee, Y.C. Chung, *Korea Advanced Institute of Science and Technology, Department of Electrical Engineering, 373-1 Kusong-dong, Yusong-gu, Taejon 305-701, Korea*

Wavelength-division multiplexing passive optical networks (WDM PONs) offer the potential of large capacity, network security, and upgradability.[1] However, these networks require low-cost sources, and efficient routing at the central office (CO) and remote nodes (RN) for practical implementation. Proposed WDM PON architectures have used multifrequency lasers, super-luminescent diodes, or distributed feedback (DFB) laser arrays as WDM sources and most employ underutilized waveguide grating routers (WGR) for multiplexing and demultiplexing the upstream and downstream traffic.[1–3] In this paper, we demonstrate a 15-channel WDM PON (downstream: 500 Mbit/s, upstream: 155 Mbit/s) using a spectrum-sliced fiber amplifier light source[4] and a new architecture that requires only one, fully utilized WGR at the central office and one at the remote node for bi-directional communication.

Figure 1 shows the experimental setup. The spectrum-sliced source at the CO contained a two-stage erbium-doped fiber amplifier (EDFA) pumped with 140 mW at 1.48 μm. A 13.5-nm filter centered at 1553 nm was placed between the stages to limit the spectral width of the source to one free spectral range of the spectrum-slicing router. The total output power of +15.5 dBm was coupled to port 1 of a 16 × 16 WGR (channel spacing: 100 GHz) for slicing into 0.35-nm wide, −6 dBm channels. Fifteen of the channels were coupled to the corresponding ports of a multiplexing WGR (MUX). A test channel passed through a polarizer and polarization controller and was then modulated with a 500-Mbit/s NRZ signal prior to multiplexing. Port 16 of the MUX was reserved for use by the upstream data. After transmission through 20 km of conven-

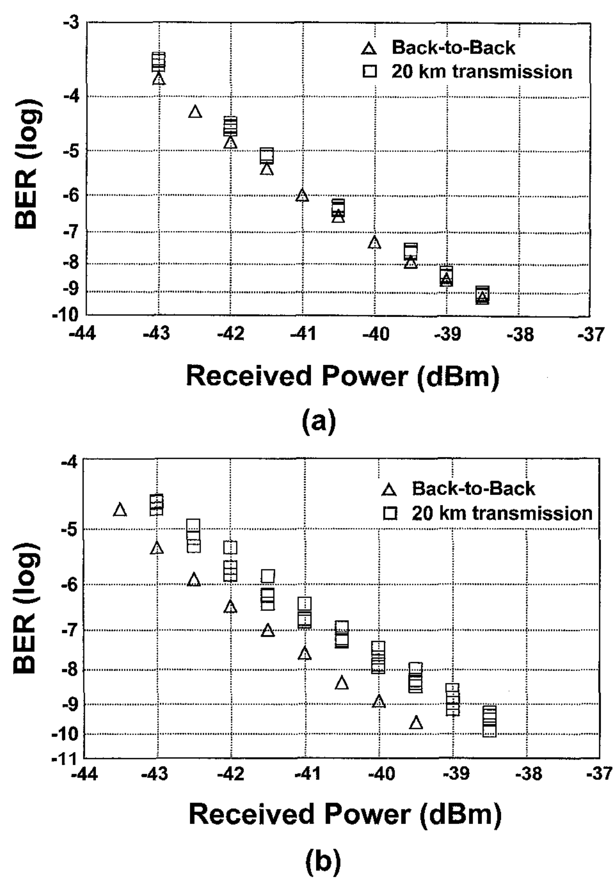



FD3 Fig. 1. The configuration used to characterize operation of WDM PON with 15 spectrum-sliced channels, each carrying 500 Mbit/s downstream and 155 Mbit/s upstream.

tional SMF, the multiplexed channels entered port 1 of the WGR at RN, which served as a demultiplexer (DEMUX). The data channel passed through a 0.84-nm-wide filter before being detected. This filter served to reduce cross talk arising from the simultaneous use of the DEMUX for

**FD3 Table 1.** Power Budget for the Proposed WDM PON Architecture

| | Downstream @ 500 Mb/s | Upstream @ 155 Mb/s |
|---|---|---|
| Power @ Tx | 15.5 dBm | -5.5 dBm |
| Slicing loss | 15.5 dB | 16 dB |
| Router loss | 6 dB | 6 dB |
| MOD loss | 11 dB | NA |
| Fiber loss (21 km) | 5.5 dB | 5.5 dB |
| EDFA gain | NA | 30 dB |
| Filter loss : | | |
| BPF 3 | NA | 1 dB |
| BPF 2 / 4 | 2 dB | 2 dB |
| Power @ Rx | -36.5 dBm | -18 dBm |
| Rx Sensitivity | -38.5 dBm | -39 dBm |




**FD3 Fig. 2.** BER curves (a) downstream transmission at 500 Mbit/s, (b) upstream transmission at 155 Mbit/s.

multiplexing upstream traffic. The upstream transmitters (1.5-μm LEDs) were directly modulated with a 155-Mbit/s signal and were coupled to the DEMUX, serving in this case as the upstream multiplexer. It routes the desired portion of each upstream source onto port 16*. This port is coupled to the upstream fiber for transmission to the CO. The upstream signals were then amplified and filtered using a bandpass filter centered at 1540 nm (passband: 13.5 nm) at CO before demultiplexing. This is to reduce the cross talk and dispersion penalty caused by the broad bandwidth of LEDs. The unused portion of the MUX at CO demultiplexed the upstream traffic onto ports 2* through 16*. The demultiplexed signals were filtered again and sent to an APD receiver for BER measurements. The power budget for this network is summarized in Table 1.

Figure 2 shows typical bit-error-rate (BER) performances for the downstream and upstream channels. There was no sign of an error-rate floor in either case. Note that the excellent error performance shows that the bandpass filters in front of the downstream receivers reduced cross talk from upstream traffic to negligible levels. These results demonstrate the practicality of the router reuse. A system employing this architecture will use about half the number of routers used by more conventional architectures.[1,3,5] The addition of a 1.3/1.5-μm WDM coupler at the CO and at the subscriber sites would allow the use of a single, bi-directional fiber. This advantage would come at the expense of a channel-number-dependent reduction of up to 18% in the number of upstream channels available, a result of wavelength dependence in the router channel spacing.

In summary, we have demonstrated the use of a new WDM-PON architecture to transmit 15 500-Mbit/s downstream channels and 15 155-Mbit/s upstream channels. Low cost is achieved through use of a spectrum-sliced source together with minimization of waveguide router count and use of LEDs for upstream traffic.

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**FD4** **9:30am**

## Wavelength-dependent modulation effects of light-emitting diodes in multiple-subband passive optical networks

P.P. Iannone, K.C. Reichmann, N.J. Frigo, *AT&T Labs-Research, 100 Schulz Drive, Red Bank, New Jersey 07701-7033; E-mail: ppi@research.att.com*

Optical spectral slicing has enabled the use of low-cost sources in point-to-point wavelength-division multiplexed (WDM) systems,[1] in point-to-multipoint WDM systems[2] and as the broadcast transmitter in a WDM network, which delivers both broadcast and point-to-point services.[3] Recently, we have introduced the concept of using properties of the waveguide grating router[4] to combine multiple point-to-point services with multiple broadcast services over a single fiber infrastructure by using reserved bands (as first demonstrated in Ref. 5 with lasers), filtered