ABSTRACT: Deployment of optical fibers in the access network is expected to have a large impact on the realization of multimedia services such as video on demand and home shopping. The passive optical network (PON) method allows for implementation of the Fiber to the Home (FTTH) service at low cost, due to sharing of the optical transmission facilities and fiber-optic cables by many subscribers. In addition, by using wavelength multiplexing technology, voice signals and video signals can be sent simultaneously on the same optical fiber. Hitachi, Ltd. has developed, under the guidance of Nippon Telegraph and Telephone Corporation (NTT), two types of cost-effective PON optical transmission systems: FTTH for home applications and Fiber to the Office (FTTO) for business applications.

INTRODUCTION

THERE are two approaches considered for optical transmission: (a) Fiber to the Home (FTTH), a method to connect fiber-optic cables to each home for ordinary households and small offices of business users, and (b) Fiber to the Office (FTTO), a method to connect optical fibers to business offices. This report gives a description of the system overview, the developed technologies, and key technological devices, such as optical devices used in both types of passive optical network (PON) systems.

PON SYSTEM

The PON system connects the central office to subscribers in a star configuration using an optical splitter (a passive element). The PON system method allows the sharing of optical transmission facilities and fiber-optic cables by many subscribers, thus reducing the installation cost per subscriber.

FTTH FOR ORDINARY HOUSEHOLDS (STM-PON SYSTEM)

For voice/data services, the STM-PON system provides an analog telephone service (POTS) and narrowband ISDN (integrated services digital network) basic rate services.

For video services, a 1.5 µm optical wavelength signal is used instead of the 1.3 µm optical wavelength signal used for voice/data services. Fig. 1 illustrates the equipment configuration, and Table 1 lists the

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Fig. 1—Equipment Configuration of STM-PON.
major specifications of the STM-PON system.

Major Technologies
The multiplexing method between the SLT and ONUs is described below.
(1) Upstream/downstream multiplexing
Upstream/downstream multiplexing is implemented by the time compression multiplexing (TCM) method. The TCM method uses one transmission path. The time axis is compressed by one half, and upstream and downstream signals are transmitted alternately for bidirectional communication.
(2) ONU-to-ONU multiplexing
ONU-to-ONU multiplexing of the upstream signals from ONUs is implemented by the time division multiple access (TDMA) method. TCM upstream signals must be positioned by securing intervals between the signals so that upstream signals (up to 32 ONUs) do not collide in the optical splitter. The upstream signal transmission timing for each ONU is determined by measuring the transmission delay for each ONU, a delay which occurs because of the different optical transmission distances from the SLT to each ONU. The upstream transmission time is notified to each ONU using the downstream signal.

Equipment Configuration of STM-PON
The major functions of the SLT are: (a) TCM/TDMA control; (b) analog telephone/ISDN basic rate service setting allocation; and (c) wavelength multiplexing (WDM). The external dimensions of the SLT cabinet are 800 mm × 600 mm × 1800 mm. It can accommodate up to 1920 ONUs.
For the ONU, which is installed in the subscriber premises, there exists two types. The single subscriber-type ONU accommodates up to 3 subscriber lines while the residential complex-type ONU accommodates up to 16 subscriber lines. The major functions of the ONU are: (a) optical transmission path termination; (b) accommodation of an analog telephone line and ISDN basic rate interface card; and (c) WDM. The external dimensions of the ONU are 240 mm × 260 mm × 55 mm for the single subscriber-type and 425 mm × 130 mm × 250 mm for the residential complex-type, with dimensions for both types including the back-up battery for power outages. Fig. 1 shows the ONUs. Commercial CATV service using these ONUs was started in July 1997.

In the future, product development of residential complex-type ONUs that can support many subscribers and realize a low cost system looks promising in the deployment of optical fiber access networks.

FTTO FOR BUSINESSES
(ATM-PON SYSTEM)
The ATM-PON system can support and extend multiple services flexibly by processing all the information into packets called ATM cells using ATM technology. Fig. 2 illustrates the equipment configuration, and Table 2 lists the major specifications. By distributing 156-Mbit/s bandwidth among 16 destinations, each ONU is allocated a bandwidth of approximately 7 Mbit/s on average. The example in Fig. 2 shows that one ONU can accommodate up to 48 telephone lines, or three ATM lines (156 Mbit/s), or a combination of both services.

Table 1: Major Specifications of the STM-PON System

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity of provided service</td>
<td>Up to 48B per ONU (average for 32 splitting : 8B) (B = 64 kbit/s)</td>
</tr>
<tr>
<td>Transmission wavelength</td>
<td>1.3 µm</td>
</tr>
<tr>
<td>Transmission distance</td>
<td>Average for 32 splitting : 7 km</td>
</tr>
<tr>
<td>Transmission speed</td>
<td>49 Mbit/s</td>
</tr>
<tr>
<td>Upstream/downstream multiplexing</td>
<td>TCM</td>
</tr>
<tr>
<td>Multiplexing between ONUs</td>
<td>TDMA</td>
</tr>
<tr>
<td>Video distribution</td>
<td>WDM (transmission wavelength : 1.5 µm)</td>
</tr>
</tbody>
</table>
traffic. By using TDMA technology, the differences in fiber length to each ONU are measured to the nearest meter, and upstream transmission is adjusted.

Equipment Configuration of ATM-PON

The SLT is connected to an analog telephone switch, and also to the ATM backbone network through a 156 Mbit/s ATM transmission path. The ATM switch of the SLT provides a throughput of approximately 3.6 Gbit/s. The external dimensions of the SLT cabinet are 800 mm × 600 mm × 1800 mm. It can connect to up to 384 ONUs.

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity and physical interface of provided service</td>
<td>Up to 48 analog telephone lines per ONU and three 156-Mbit/s ATM lines</td>
</tr>
</tbody>
</table>
| Transmission wavelength                   | Downstream : 1.5 µm  
|                                          | Upstream : 1.3 µm                                    |
| Transmission distance                     | Maximum distance for 16 splitting : 10 km           |
| Transmission speed                        | 156 Mbit/s                                         |
| Downstream multiplexing                   | TDM                                               |
| Multiplexing between ONUs                 | TDMA                                              |

**OPTICAL TRANSCEIVER MODULE**

**Bi-Directional Burst Transceiver Module for FTTH**

The bi-directional burst transceiver module for FTTH is composed of a planar lightwave circuit (PLC) module and transmitter/receiver ICs.

1. **PLC module**

   The dimensions are 40 mm × 10 mm × 5 mm. It uses surface mount technology which allows the mounting of the optical element directly onto a silicon waveguide substrate. It is mounted with a beam-expanded laser diode (LD), waveguide-type photo diode (PD) chips, and a WDM filter. In addition, the adoption of the high-precision positioning of optical elements using the passive alignment method has made optical axis alignment easier.

2. **Optical module**

   Fig. 3 shows the optical module. Employing the Si bipolar process lowers the power consumption of the transmitter/receiver ICs. The receiver IC integrates the preamplifier, ATC (automatic threshold control), and automatic offset canceller circuits into a single chip.

**Burst Transceiver Module for FTTO**

The 156-Mbit/s burst transceiver module enables bi-directional communication of both burst and continuous transmissions using the WDM method. The burst transceiver module has a fiber-fused type WDM filter, and combines the transmitter and receiver into one module.

To make the optical module compact and consume less power, a front end module is fabricated by: (a) utilizing the Si bipolar process for the transmitting/
receiving ICs; (b) integrating the preamplifier circuit, ATC circuit and automatic offset canceller circuit of the center side receiver circuit into one chip; and (c) by installing a PIN-PD and a receiver IC as a bare chip to reduce the input capacity on the receiving side.

CONCLUSIONS
The authors have outlined the PON systems to construct an optical subscriber transmission system economically and described the major technologies as well as an introduction example. It is expected that the optical subscriber transmission equipment of the PON system will be developed and applied in a variety of ways to realize an all-optical access system according to different needs.

This PON technology is currently being discussed in organizations such as ITU-T International Standardization Committee, Full Service Access Network (FSAN) International Standardization Committee, etc. to be adopted as an international standard. With this technology, Hitachi plans product development of optical access networks with a watchful eye on developments in the international market. It is expected that the optical access system technology will spread globally.

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REFERENCES

ABOUT THE AUTHORS

Yoshio Miyamori
Joined Hitachi, Ltd. in 1980. Belongs to the Access System Development Center of the Telecommunications Division. Currently engaged in the research and development of ATM transmission and optical access transmission systems. Member of the Institute of Electronics, Information and Communication Engineers.
E-mail: miyamori@tcd.hitachi.co.jp

Yoshihiro Ashi
Joined Hitachi, Ltd. in 1985. Belongs to the Access System Development Center of the Telecommunications Division. Currently engaged in the research and development of ATM transmission systems. Member of the Institute of Electronics, Information and Communication Engineers.
E-mail: yoshihiro_ashi@cm.tcd.hitachi.co.jp

Eisuke Sato
Joined Hitachi, Ltd. in 1978. Belongs to the Fiber-Optic Transmission Operation of the Telecommunications Division. Currently engaged in the research and development of optical access transmission systems. Member of the Institute of Electronics, Information and Communication Engineers.
E-mail: eisuke_sato@cm.tcd.hitachi.co.jp

Mitsuhiro Takano
Joined Hitachi, Ltd. in 1984. Belongs to the Optical Link Department of the Telecommunications Division. Currently engaged in the research and development of optical transmission modules. Member of the Institute of Electronics, Information and Communication Engineers.
E-mail: mitsuhiro_takano@cm.tcd.hitachi.co.jp