WD200 WDM MONITOR

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We have developed the WD200, a channel monitor for dense wavelength division multiplexing (WDM) transmission systems. This monitor has adopted a polychromator method employing an in-house 640-pixel InGaAs (Indium-Gallium-Arsenide) photodiode array, so that WD200 enables not only the high resolution for 50-GHz channel spacing DWDM signals, but also compact (220 × 170 × 28 mm) and 1.5-kg-lightweight body.

INTRODUCTION

Buoyed by potential demand, fiber-optic communication systems typified by fiber-optic submarine cable systems and infrastructural transmission systems across metropolises have been steadily advanced to accommodate larger capacities and cover longer transmission distances since first coming into operation. The quantum leap of the Internet resulted in a sharp increase in data communication demand. To facilitate the necessary larger transmission capacity, wavelength division multiplexing (WDM) systems were thus adopted for long-distance networks in North America. This triggered a fierce race for development of more efficient data transmission techniques, including dense WDM (DWDM). [1]

The application of WDM to photonic networks is also anticipated, thereby enabling the speed of node processing, which has traditionally been processed electrically in communication nodes, to be boosted by the application of opto-electronic technologies. Optical networks are being spread in various realms such as linking IP networks to WDM systems based on wavelength routing and connection of submarine cable networks to land communication cable networks via an optical cross connect (OXC).

Another aspect of WDM is that since an increase in wavelength divisions results in a rise in costs for terminal stations, enhancement of the speed in each channel (bit rate increase) is being aggressively pursued as a means to minimize the total cost while reserving sufficient transmission capacity. Today, the predominant practical WDM systems are 10-Gbps, 50-GHz channel spacing systems and technology development for next-generation systems offering 20 or 40 Gbps has moved into high gear.

The tasks to be addressed to realize these systems include:

(1) Dispersion management of transmission paths, in which the nonlinear optical effect of optical fibers are taken into account
(2) Planarization of the gain of each light amplifier (optical amplifier), and optimization of signal levels in which signal-to-noise ratio (SNR) and non-linearity are taken into account
(3) Development of a modulation (encoding) method which is highly immune against factors degrading transmission quality, such as dispersion and non-linearity

As these tasks are correlated, a comprehensive solution is required.[2]

Light measurement technologies are not only applicable to these tasks but also play important roles when systems are operational, such as in monitoring the transmission quality.[3] Yokogawa, which had already put the WD100 WDM monitor on the market[4], has released the WD200 as a high-resolution monitor for monitoring DWDM signals with narrow channel spacing (25 or 50 GHz).[5] The WD200 is shown in Figure 1 below. This paper highlights the technical aspects of the WD200.

STRUCTURE OF WD200

Figure 2 shows an overall block diagram of the WD200. It is comprised of a polychromatic spectroscopic unit with no mechanical moving parts, measurement sequences, communication control, and various computations being carried out electronically. With its compact and lightweight body, high-speed measurement capabilities and excellent reliability, the WD200 is designed as an

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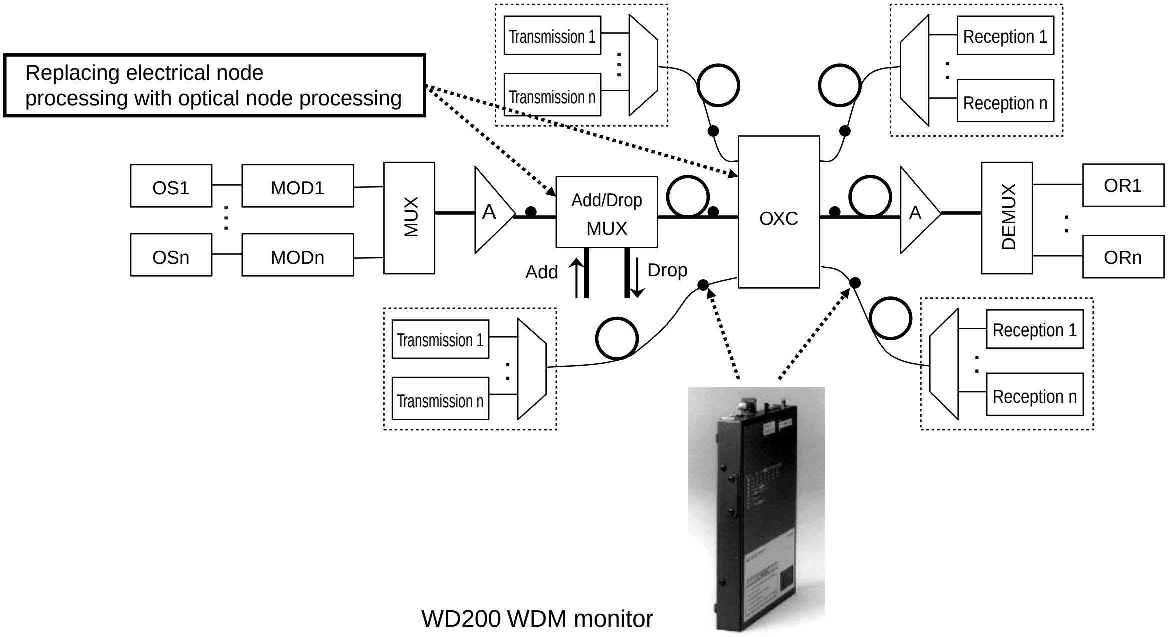

Figure 1 Networking WDM Systems and WDM Monitors

in-line monitor ideal to be embedded into a DWDM system.

Table 1 shows major specifications. The WD200 is a WDM monitor measuring powers, wavelengths, and optical signal-to-noise ratios over an approximately 40-nm wavelength range for the C-band or L-band at high resolution (minimum channel spacing of 0.2 nm ≒ 25 GHz)

OPTICAL SYSTEM AND OPERATIONS

Figure 3 shows a photograph of WD200's optical system, consisting of the following components fixed to a stainless block:

- Diffraction grating (combined with a prism) serving as a dispersion device
- InGaAs photodiode array (PDA) serving as an array detector
- Lens 1 for collimating the measured beam emitted from a single-mode fiber
- Lens 2 for image-formation on the array device of the spectrum produced by the spectroscopic unit
- Mirrors 1 and 2 for returning the beam
- Depolarizer for randomizing polarization state

These components are fixed to a stainless block. The WDM signal spectrum produced by the dispersion device is received by the PDA, then the original signal is reproduced from the sampling data picked up by the PDA to obtain the wavelength, power, and optical signal-to-noise ratio (OSNR).

To attain the required functionality and performance within the limited space, the individual components are optimized. From among these, two devices of particular importance, the

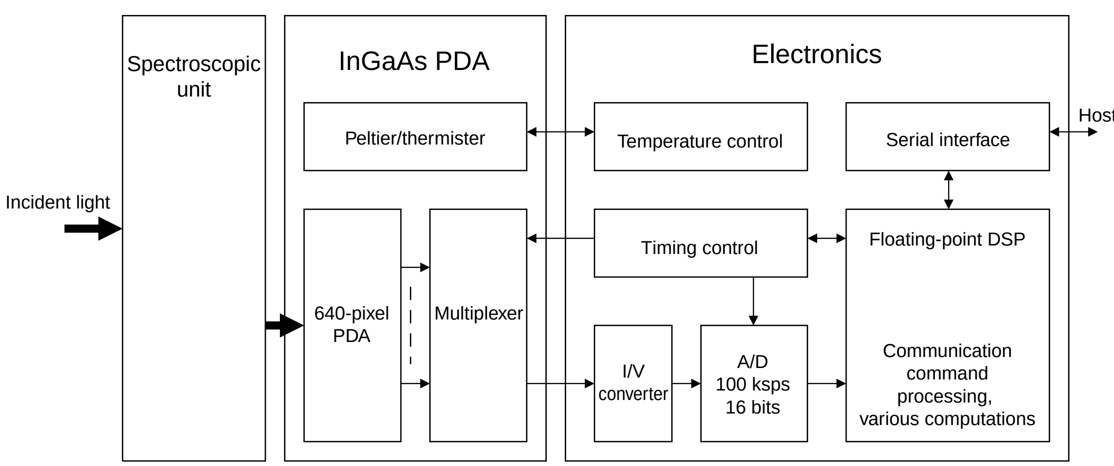

Figure 2 WD200 Block Diagram

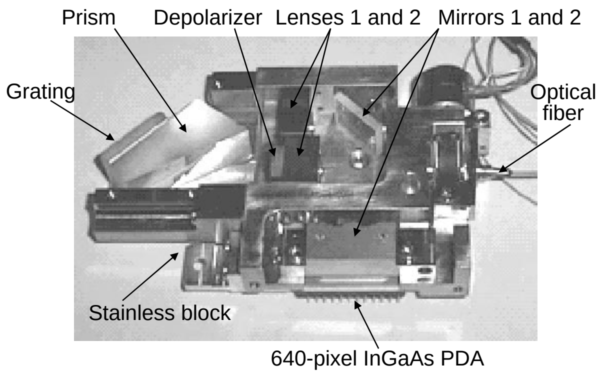

Figure 3 Optical System

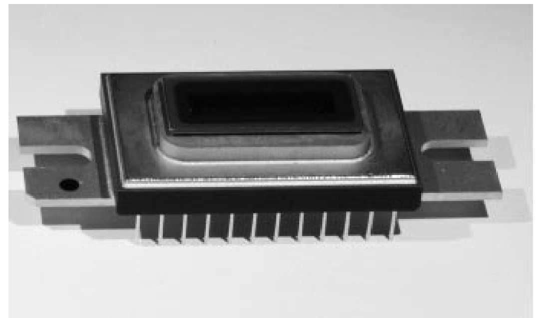

Figure 5 640-pixel InGaAs PDA

dispersion device and InGaAs PDA are detailed below.

(a) Dispersion Device

This is basically a diffraction grating, but is combined with a prism in order to not only secure the necessary optical resolution but also render the dispersive characteristic within the measured wavelength range uniform (see Figure 4). The nonlinear characteristic of the diffraction grating, in which dispersion is less for a shorter wavelength, is cancelled by the normal dispersion of the prism, so that the overall dispersion device can have a uniform dispersion characteristic.

(b) PDA

To assure separation of adjacent spectrums (spectral peaks) and to enable measurement of inter-channel optical noise levels, six pixels are assigned to each channel (0.4-nm spacing) in the WD200 channel monitor. This means that at least 600 pixels are required for 100 channels. Taking into consideration the margin in temperature characteristics, a 640-pixel InGaAs PDA (Figure 5) was adopted accordingly. This device has also been developed in-house in line with the development of the WD200.

BASIC PERFORMANCE

Major specifications are shown in Table 1. The following details the implications of some of these performance values.

(a) Minimum Channel Spacing

Figure 6 shows separation of two adjacent channel signals (0.2-nm spacing). Even though the optical resolution that is determined by the number of microgrooves of the grating is high enough to separate signals in intended peak spacing of 0.2 nm, these two peaks (waves) need to be separated by a minimum of three pixels or more. This is necessary in order to allow the original two peaks to be reproduced by the output of the array device (sampling data from fixed points). Namely, the minimum channel spacing of 0.2 nm, shown as a specification, is derived from the following limitation:

Pixel resolution × 3 pixels = 0.067 nm × 3 = 0.2 nm

(b) Power Flatness

When using an array device as a photoreceptor for spectrum beams, the resolving power, (i.e., the spectral bandwidth of the spectroscope) should be set to approximate the array pitch of the device. This will restrain variations in the power of incident light depending on the point of irradiation (where on the array device the beams are irradiated). The drop in power of the light passing across the array element is approximately 0.05 dBpp (see Figure 7).

(c) Optical Signal-to-noise Ratio

Since an OSNR is the ratio of optical signal power to optical noise power, capability of measuring relatively low-power optical noise is essential to measure OSNR. In general, it is difficult to construct a polychromator spectroscope to cut off stray light appearing near a line spectrum as in a double monochromator, which is inferior in optical dynamic range and is thus likely to allow stray light to affect the power measurement of optical noise. When the OSNR is high, in other words, when the optical noise is relatively low in power,

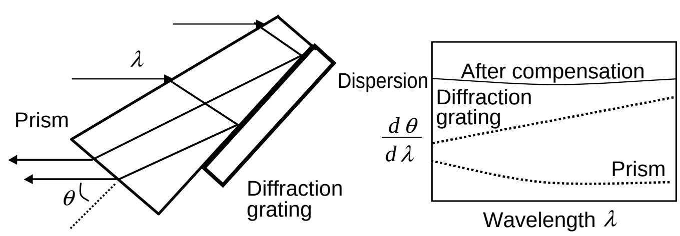

Figure 4 Optical System

Table 1 Specifications

Measured item	100 waves in 50-GHz intervals	WDM signals
Power	Power flatness	0.3 dBpp
	Polarization dependency	0.3 dBpp
	Power accuracy	±0.5 dB (typical)
Wavelength	Measured wavelength range	40 nm
	Wavelength accuracy	±50 pm (typical)
	Minimum channel spacing	0.2 nm
OSNR	Accuracy	±0.5 dB at OSNR of 20 dB
		±1.0 dB at OSNR of 25 dB
Working temperature		0°C to 60°C
Dimensions		220 × 170 × 28 mm

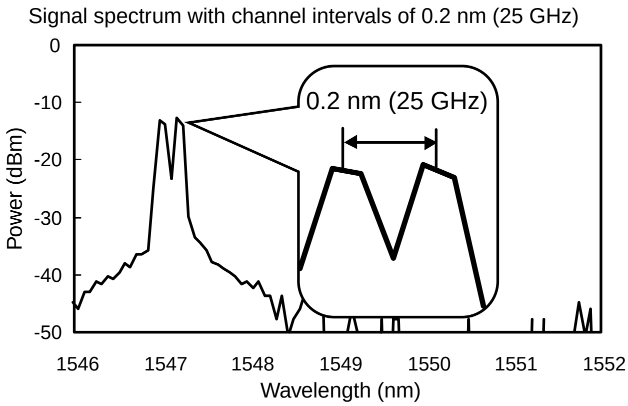

Figure 6 Channel Resolving Power

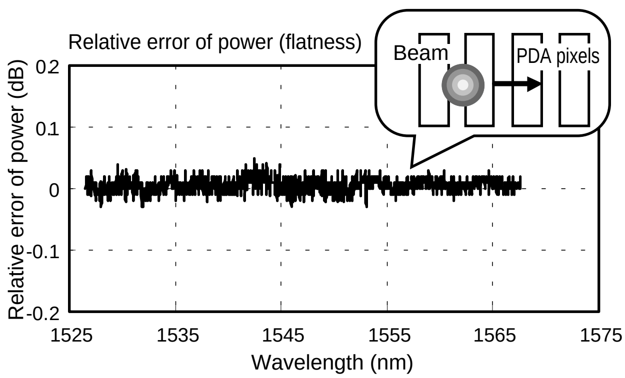

Figure 7 Power Flatness

this effect is significant and the error large (see Figure 8).

The WD200 has its own response function (broading in output for a line spectrum input) as internal data, and eliminates the stray light from a signal thereby slashing the error of OSNR readings to ±0.5 dB (at the OSNR of 20 dB).

CONCLUSION

From the outset of the application of WDM to submarine cable systems, Yokogawa's WDM monitors have been selected as components for the systems as WDM signal monitors and have established lots of proven track record. This paper has introduced the brand new WD200, a WDM monitor commercialized for monitoring DWDM transmissions. It is conceivable that increasingly more WDMs will be networking in line with an increase in demand for communication in the future, and that the significance of WDM monitors offering high speeds and high reliability will rise yet another notch. We remain committed to striving towards even higher performance levels, more compact design, and lower costs to meet systems' requirements. ◆

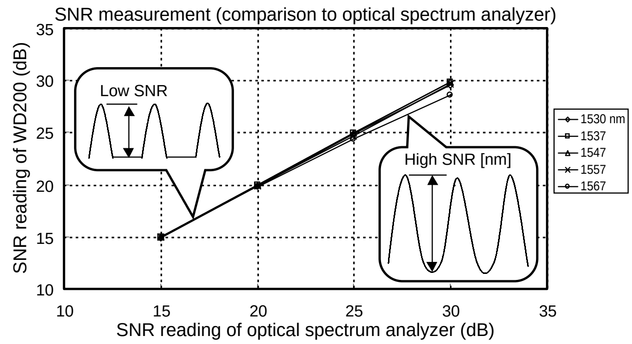

Figure 8 Signal-to-Noise Ratio (SNR) Measurement

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(5) "DWDM Channel Monitor," Ando Technical Bulletin: Special Optical Measurement Edition, November 2001, pp. 66-70

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