Optical Fiber Strain/Loss Analyzer
AQ8602/8602B

- Strain/loss distribution measuring instrument utilizing Brillouin scattering and Coherent detection (B/COTDR)
- Distance resolution of strain measurement: 1 m (AQ8602B)

GP-IB

General

The optical time domain reflectometer (OTDR) is extensively used to measure the loss distribution from the ends of optical fibers, and to detect line discontinuities. Under tensil strain, optical fiber strength degrades and eventually causes fiber breakage, but until now OTDRs have been unable to detect tensile strain without optical loss. For exactly this reason, high-precision strain measurement has been required in industries handling the manufacturing, installation and maintenance of optical fiber.
The high-performance AQ8602 Optical Fiber Strain/Loss Analyzer provides all the functions needed for both Brillouin OTDR and Coherent OTDR applications. In addition to optical fiber loss and fault location measurements, it is also invaluable in preventive maintenance, such as prediction of breakage (life prediction of optical fiber).
Recently, OTDR is drawing attention from the civil engineering and construction industry for its application in the strain measurement of structures, etc. Ando's AQ8602/AQ8602B measures strain by line or surface using optical fibers as sensors, while conventional strain sensors measure only by points.

Features

● **High strain measurement accuracy: ±0.01 % (AQ8602B)**

● **BOTDR and COTDR are switchable**
The optical frequency translating and coherent detection techniques enable high sensitive measurement of strain distribution and loss distribution from one end of optical fiber. Easy fault locating of optical fiber is made possible as well.
- Dynamic range in strain measurement: 20 dB (1µs pulsewidth)
- Dynamic range in loss measurement: 32 dB (1µs pulsewidth)

● **High sample resolution**
Provides a sampling resolution of 5 cm.

● **Distance resolution: min. 1 m (AQ8602B)**
Provides a high distance resolution of 1 m in strain measurement (AQ8602B).

● **High-speed measurement/data processing**
Ando’s digital sampling technique has enabled the high-speed data processing and trace display.

● **Various analysis functions**
Strain distribution (average, scatter), Brillouin spectral distribution, loss distribution waveform and other analysis functions.

● **Various external interfaces**
External equipment (keyboard, printer, display, etc.) can be connected.

● **Data storage capabilities**
- Built-in 3.5-inch FDD (2HD)
- Built-in hard disc

● **Large-size color LCD (9.4-inch)**
9.4-inch color LCD screen assure superb readability.

● **Built-in high-speed printer**

Applications

■ Evaluation of optical fiber cable installation process.
■ Maintenance and monitoring of an installed optical fiber cable.
■ Strain/loss distribution measurement at production of optical fiber cable.
■ Research and development of optical fiber cable.
■ Research of optical fiber sensing (temperature, tension, bending)
■ Application in the strain measurement of building and construction

Brillouin scattered light

A typical scattered light spectrum in the optical fiber is shown in Fig. 1.
Brillouin scattered light occurs by an interaction between a high-coherence incident light and an acoustic wave generated by the incident light in an optical fiber. The scattered light frequency is shifted from incident light frequency by an amount determined by the material.
This frequency is called Brillouin frequency shift and it is given by the following equation (1).

$\nu_B = 2\,nV_A/\lambda$..........(1)

n : Refractive index
V_A : Acoustic wave velocity
λ : Wavelength of incident light

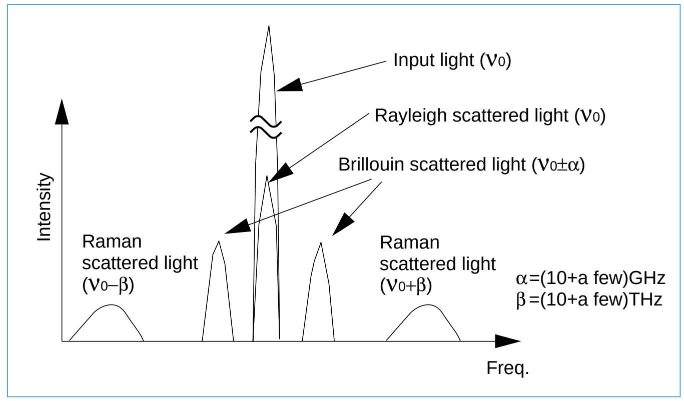


Fig. 1 Scattered light spectrum in the optical fiber

Typical Brillouin frequency shift is ±13 GHz (1.3 µm band), ±11 GHz (1.55µm band).
The Brillouin frequency shift is in proportion to the change of strain/temperature as shown in Fig. 2 and Fig. 3. The strain/temperature dependence of the Brillouin frequency shift at 1.3 µm and 1.55 µm bands is tabulated in Table 1.

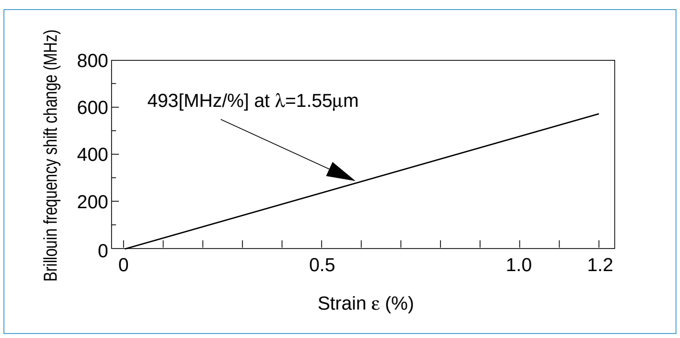


Fig. 2 Strain dependence of Brillouin frequency shift change

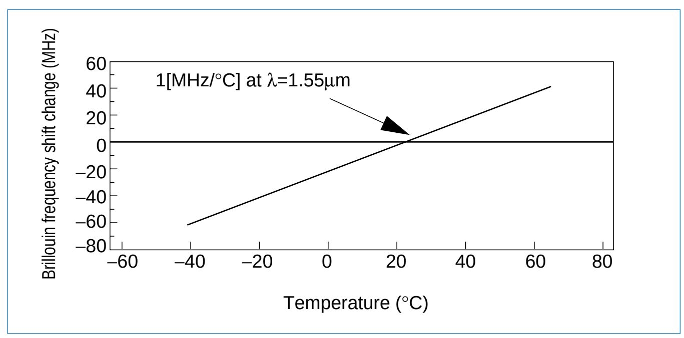


Fig. 3 Temperature dependence of Brillouin frequency shift change

Table. 1 The strain/temperature dependence of Brillouin frequency shift (UV coated optical fiber)

Item	1.3 µm band	1.55 µm band
Temp. ($d\nu_B/dT$)	1.22 MHz/°C	1 MHz/°C
Strain ($d\nu_B/d\varepsilon$)	581 MHz/%	493 MHz/%

ν_B : Brillouin frequency shift
T : Temperature
ε : Strain

Table. 1 shows that the strain measurement error caused by the temperature change of optical fiber is quite small (0.002 %/°C). This means that the strain measurement error caused by 5 °C of temperature change is equivalent to the measurement accuracy of this instrument (0.01 %). Therefore, the strain added to the optical fiber can be calculated by measuring the Brillouin frequency shift.

Principle

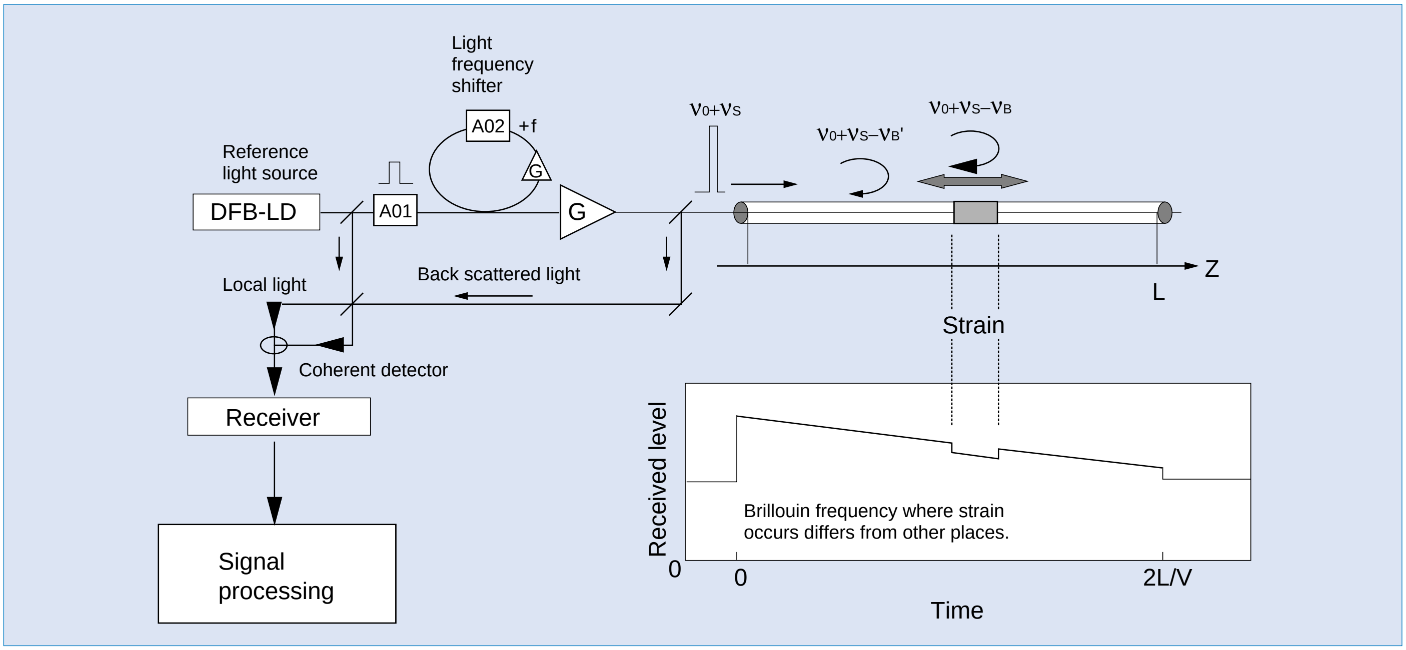


Fig. 4 AQ8602 basic configuration and signal waveform

The basic configuration and signal waveform of the AQ8602 are indicated in Fig. 4.
Pulsed light is input from the end of the optical fiber to be measured, and the return light (Brillouin scatter, Rayleigh scatter) detected by the coherent detection circuit. In Brillouin scattering the frequency is shifted from the input pulse by the Brillouin frequency shift ν_B, which means that matching ν_S (the difference between the light pulse $\nu_0+\nu_S$ and the local light frequency ν_0) to the Brillouin frequency shift ν_B will allow detection of Brillouin light. If the optical frequency of the pulsed light is varied, the Brillouin scattering at each frequency can be determined, yielding a spectrogram of Brillouin scattering. The peak reception level in this spectrogram is the Brillouin frequency shift ($\nu_B(\varepsilon)$).
The relation between the Brillouin frequency shift ($\nu_B(\varepsilon)$) and the tensile strain on the optical fiber is given by Expression (2). As a result, it is possible to determine the strain distribution from the Brillouin frequency shift ($\nu_B(\varepsilon)$) in the optical fiber axial direction.

$$\nu_B(\varepsilon)=\nu_B(0)(1+C\cdot\varepsilon)\text{.......................(2)}$$

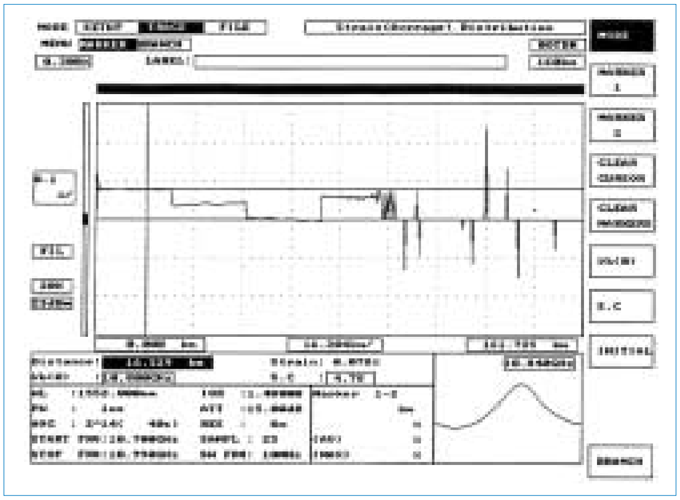
$\nu_B(\varepsilon)$: Brillouin frequency shift with a strain
$\nu_B(0)$: Brillouin frequency shift without a strain
C : Strain coefficient
ε : Strain

Additionally, Rayleigh scattered light can be detected also when the frequencies of measuring pulsed light and local light agree.
The AQ8602 is capable of measuring both the strain distribution (BOTDR) and the loss distribution (COTDR) by switching the frequency of the pulsed light accordingly.

Measurement example

■ Strain (average) distribution waveform: BOTDR MODE

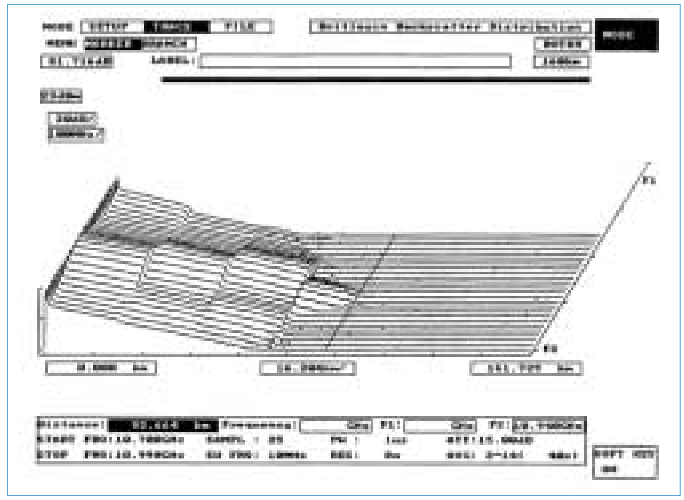
The trace below is an example of a measurement of a 100 km long SMF composed of four kinds of fiber (25 km each) connected by fusion splices.



H. scale: Distance (16 km/div)
V. scale: Strain (0.1 %/div)
Distance resolution: 100 m

■ Brillouin scattering distribution waveform (3D): BOTDR MODE

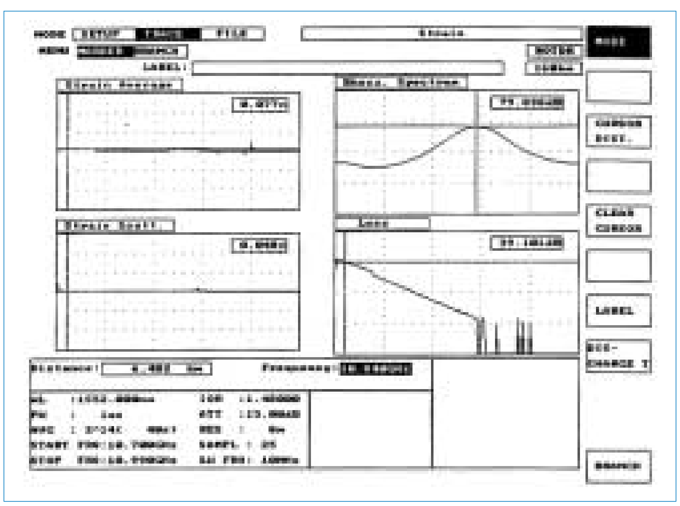
The trace below is an example of a measurement of a 100 km long SMF composed of four kinds of fiber (25 km each) connected by fusion splices.



H. scale: Distance (16 km/div)
V. scale: Scattering power (20 dB/div)
Z. scale: Optical frequency (100 MHz/div)

■ Multi-waveform display of test results: BOTDR MODE

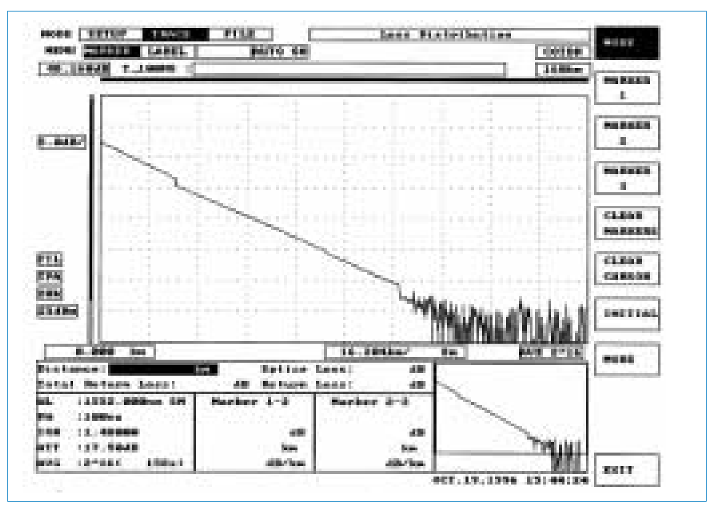
The trace below is an example of a measurement of a 100 km long SMF composed of four kinds of fiber (25 km each) connected by fusion splices.



- Strain (average) waveform
- Strain (scatter) waveform
- Brillouin scattering spectrum
- Loss waveform

■ Loss distribution measurement waveform: COTDR MODE

The trace below is an example of a measurement of a 100 km long SMF.



H. scale: 16km/div
V. scale: 5dB/div
Pulse width: 100ns

Specifications

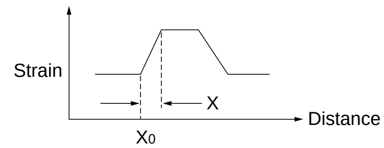
AQ8602 strain measurement mode (BOTDR mode)

Trace display		Strain distribution, Brillouin scattering spectrum, Brillouin scattering distribution				
Distance range (km)		10, 20, 40, 80, 160				
Strain display range (%)		–6.0 to +6.0				
Readout resolution (min.)	Distance	5 cm				
	Strain	0.001 %				
Strain measurement range (%)		3				
Pulse width (ns)		20	50	100	500	1000
Dynamic range (dB) 1)		8	12	15	17	20
Measurable distance 2)		Approx. 25 km	Approx. 45 km	Approx. 55 km	Approx. 65 km	Approx. 80 km
Distance resolution (m) 3)		2	5	11	55	110
Strain measurement accuracy (%)		±0.02	±0.01			

AQ8602B strain measurement mode (BOTDR mode)

Trace display		Strain distribution, Brillouin scattering spectrum, Brillouin scattering distribution			
Distance range (km)		2, 5, 10, 20, 40, 80, 160			
Strain display range (%)		–6.0 to +6.0			
Readout resolution (min.)	Distance	5 cm			
	Strain	0.0001 %			
Strain measurement range (%)		3			
Pulse width (ns)		10	20	50	100
Dynamic range (dB) 1)		4	8	12	15
Measurable distance 2)		Approx. 10 km	Approx. 25 km	Approx. 45 km	Approx. 55 km
Distance resolution (m) 3)		1	2	5	11
Strain measurement accuracy (%)		±0.01		±0.005	

Notes:
1) At averaging times=2^{16}, strain measurement accuracy ±0.02% or less (optical fiber loss for strain noise width within ±0.02%).
2) With an optical fiber transmission loss of 0.25dB/km, optical fiber strain is measured for each pulse width, and the optical fiber distance determined for the ±0.02% strain measurement precision (2^{16} average).
3) Minimum distance (X) from the rise point to true value (as indicated below) for optical fiber strain (average) distribution measurement waveforms, when specific strain is added from distance X_0.



AQ8602/8602B loss measurement mode (COTDR mode)

Trace display		Loss distribution					
Distance range (km)		2, 5, 10, 20, 40, 80, 160, 320					
Loss display range (dB)		0 to 49					
Readout resolution (min.)	Distance	5cm					
	Loss	0.001dB					
Pulse width (ns)		10	20	50	100	500	1000
Dynamic range (dB) 1)		15	19	23	26	30	32
Dead zone (m)		50			75	150	250

Notes:
1) At averaging times=2^{18}.

Overall

Center wavelength (nm)		1550±20
Optical output power setting range (dBm)		0 to +25 (1dB step)
Refractive index		1.00000 to 1.99999 (0.00001 step)
Averaging times setting range		2^{12} to 2^{24}
Distance measurement accuracy (m)		$\pm(2.0 \times 10^{-5} \times$measuring distance$+0.7)$
Number of sampling data		5,000 or 20,000 points
Data storage		3.5-inch FDD (2HD), Built-in hard disc (340Mbyte)
Display		9.4-inch color LCD 640×480 dots
Interface		Serial port: RS-232C compatible printer (9 pin D-sub) [1]
		Centronics: Centronics compatible printer (25 pin D-sub)
		Video output: VGA compatible (6 pin D-sub)
		Keyboard: 6 pin DIN, PS/2
		GP-IB
Optical connector		FC-SPC
Printer		Built-in high-speed printer
Power requirements		AC100 to 240V, 50/60Hz, 200VA max.
Environmental conditions	Operating temperature	BOTDR: +10°C to +40°C COTDR: 0°C to +40°C Note: Performance can be guaranteed in temperature range of +10°C to +40°C for COTDR
	Storage temperature	–10°C to +50°C
	Humidity	85%RH or less (no condensation)
Dimensions and mass		Approx. 436(W)×240(H)×480(D)mm, approx. 20kg
Accessories		Instruction manual: 1 ea., power cord: 1 ea., printer paper: 2 ea.

Notes:
1) Printer function at serial port are factory installed option.

Specifications are subject to change without notice.

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KT-1868-1 0010 KL230
Printed in Japan