Topics

Miniaturized Integrated-Optical Voltage Sensor - Effective for Electromagnetic Interference Tests and Measurements

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Of late, with the rapid realization of an information oriented society, the importance of EMI (Electro-Magnetic Interference) /EMC (Electro-Magnetic Compatibility) investigation has been increasing in many fields. Furthermore, in recent years, specification of the malfunctioning circuit elements and measurement of the induced EMI current / voltage in the investigated equipment has been strongly needed for detail evaluation of EMI and an appropriate countermeasure. However, with conventional measuring instruments, it was impossible to separately measure the circuit voltage since a large interference voltage was induced into the measuring probe itself and the metallic signal cable. The newly developed miniatured integrated-optical voltage sensor is configured with an integrated optical circuit and an optical fiber and is mostly composed of non-metallic materials. Consequently, the new sensor can measure the circuit voltage in electronic equipment even in a strong electromagnetic field.

Fig. 1 shows the appearance and the principle of operation of the sensor. Light from a semiconductor laser is passed through the optical fiber to the sensor section composed of integrated optical circuits. The intensity of light passed through the integrated optical circuit is modulated in linear proportion to the voltage applied to the sensor. The light transmitted to the end is reflected by the reflective film on the end face and returns to the photo detector along the same path. By measuring the intensity of the optical signal with the photo detector, the voltage applied to the sensor can be measured. The integrated-optical circuit is a unique retro-reflective optical modulator[1, 2], and, as the figure shows, it is designed as if an ordinary interferometer type light modulator is cut through the center and a metal reflective film is deposited on the end face. It is characterized by its compact size (1/2), high sensitivity (2 times) and the fact that it requires only a single optical fiber, in addition to high stability, reliability and low cost. Moreover, the modulator has a reduced capacity of one half and increased high frequency characteristics. The photographs show the integrated optical voltage sensor prototype. The upper shows the $LiNbO_3$ substrate (1 x 20 x 0.5t mm) of the integrated optical circuit and the lower, the sensor (ϕ3 x 30mm), both having the smallest geometry in the world. Two points contributed to the realization of this ultra-compact voltage sensor : one was development of the above-mentioned retro-reflective optical modulator, and another was development of technology[3] to process a fine V-groove directly on an $LiNbO_3$ substrate using excima laser ablation for connecting to an optical fiber (**Fig. 2**). The above-mentioned method achieved sharp downsizing and high reliability compared with the conventional fiber/ waveguide connection method using butt-joint and adhesion techniques with precision jigs. Adjusting the gain of the photodetector and pre-amplifiler, the sensor can be used similar to an ordinary 10:1 oscilloscope (input impedance being 10GΩ). Regarding the frequency characteristics, they are almost flat up to about 400MHz, beyond which they fluctuate 1 to 2dB, but the sensor responds until it reaches 1.2GHz. In an examination of the characteristics performed in an electrical field of

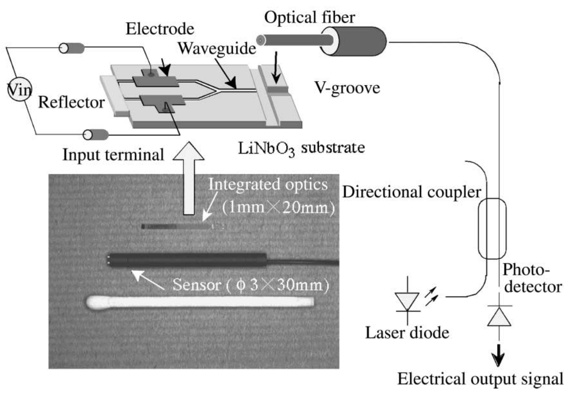

Fig. 1 Photograph and schematic configuration of the miniaturized integrated-optical voltage sensor.

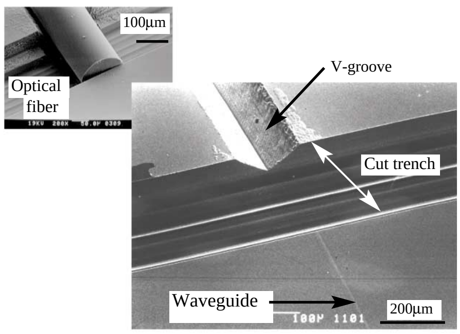

Fig. 2 Scanning-electron microscope photograph of the V groove fabricated on $LiNbO_3$ substrate.

100V/m, it was confirmed that the sensor can measure circuit operation under an inductive voltage 1/100 that of a conventional oscilloscope probe even when connected to a 30mm piece of metal lead used for circuit connection. This sensor enables detailed analysis of circuit operation of electronic equipment to be investigated, which was thus far impossible under a strong electromagnetic field environment. By quickly identifying the affected part, it enables us to take appropriate countermeasure against electromagnetic interference. Consequently, this sensor is expected to sharply reduce development time and cost, thus contributing to energy saving.

References

1) Ichikawa, T. and Ito, H. : Soc. of Instrum. and Control Eng., SICE'92, (1992), D545-2
2) Ito, H., et al. : ICO Topical Meet., (1994), 4
3) Ichikawa, T., et al. : Opt. Lett., 23-14(1998), 1138

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