Product Trends of Optical *E*-field Sensor

Yoshikazu Toba[1], **Jun Ichijoh**[1], **Takehiro Morioka**[2], **Masanobu Hirose**[2], **and Satoru Kurokawa**[2]

[1]SEIKOH GIKEN Co., Ltd. 296-1, Matsuhidai, Matsudo, Chiba 270-2214, Japan
[2]National Institute of Advanced Industrial Science and Technology
1-1-1, Umezono, Tsukuba, Ibaraki 305-8563, Japan

Abstract— We have developed the Optical Electric Field Sensor utilizing the Pockels effect of lithium niobate ($LiNbO_3$), and proposed it for EMC measurement.

This sensor can measure not only E-field strength but also frequency and phase. The feature of this sensor are: mitigating disturbance of the surrounding E-field, high-accuracy, elimination of common noise, small sensor head, measurement ability of any kinds of modulations such as AM, FM, CDMA and so on and wide frequency range such as 100 kHz to 10 GHz.

In this paper, we introduce some applications of the optical electric field sensor. And we describe the efforts of some of the future.

1. INTRODUCTION

In recent years, the damage to other electronic devices by electromagnetic radiation has becomes a problem depending on spread to wireless devices. Therefore, Measurement technique which can accurately measure the electromagnetic wave is required.

We have developed Optical E-field Sensor and measurement technology using RoF (Radio over Fiber) technology. And we have introduced them for EMC (electro-magnetic compatibility) field [1–3]. Features of this sensor utilizing Pockels effect of lithium niobate are shown below:

a. Passive acquisition of signals, mitigating disturbances of the surrounding E-field.
b. Precise measurements of Frequency, Phase, and E-field.
c. High sensitivity and linear response over a broad frequency range.
d. Miniaturized sensor heads.
e. Elimination of common noise.

In the measurement of the Free-space E-field strength, the conventional method of using antenna had been degraded accuracy of E-field measurement by feed line (coaxial cable). Namely, the coaxial cable induce disturbance of the surrounding E-field. This Optical E-field Sensor with above features can be expected accuracy of E-field measurement improvement.

The radio waves are shortened by the high frequency of wireless device, so the sensor is required to minute spatial resolution. The conventional method could not increase the resolution of the measurement. Optical E-field Sensor is formed antenna elements on the LN substrate, so sensor head can be reduced the dimension.

In this paper, we introduce some applications of the Optical E-field Sensor. And I describe the efforts of some of the future.

2. OPTICAL *E*-FIELD SENSOR

2.1. Structure of the Optical *E*-field Sensor

As shown in Fig. 1, the Optical E-field Sensor consists of a sensor head, controller, single-mode optical fibers for signal transfer, and spectrum analyzer for signal analysis.

The controller consists of an optical source unit, optical circulator, optical fiber amplifier, O/E converter, and control circuit. Here, optical fiber amplifier compensate the fluctuation of the optical power due to optical fiber bending or contact.

Un-modulated light emitted from the optical source unit (optical wavelength: 1550 nm) passes through the optical circulator, and is guided to the sensor head. This sensor head consist of a $3(W) \times 13(L) \times 0.5(t)$ mm LN (x-cut) crystal substrate, on which a 6 μm-wide optical waveguide, reflector, and optical fiber are formed via Ti diffusion.

Figure 2 shows an external view of sensor head. The sensor head uses interferometric branched optical modulators that branch the incoming light, and then combine it again. The LN crystal exhibits the Pockels effect. If an E-field is applied to this crystal, its refractive index is modulated. This modulation caused the speed of optical wave on the wave-guide to go faster or slower. The Mach-Zehnder interferometer converts this optical wave speed modulation to amplitude modulation.

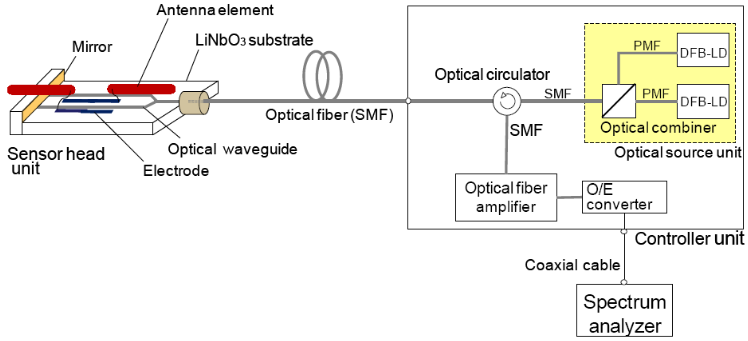

Figure 1: System diagram of the optical E-field sensor.

The light which has been amplitude modulated via a spatial E-field, returns again to the optical circulator, and is guided to the O/E converter. It is possible to measure the output on after O/E conversion with a spectrum analyzer, and measure the E-field strength near the sensor head.

In order to detect weak electric fields, this sensor uses an optical source with low relative intensity noise (RIN) and high light intensity, and it uses a reflective structure [4] that has about twice the round-trip sensitivity as a transmission type with the same modulation electrode length. The reflective structure only requires one optical fiber, which is an effective for miniaturizing the sensor head.

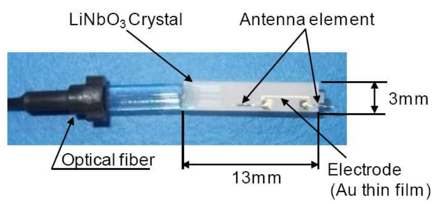

Figure 2: External view of sensor head.

2.2. Isotropic Composition

E-field sensor is required isotropic. So these three LN optical modulators are arranged onto the three sides of a triangle prism, obtaining isotropy as shown in Fig. 3 [5]. In other words, the three LN optical modulators are arranged so that they are at right angles to each other, and their maximum radiation angle from the optical waveguide is 54.7 deg., thus achieving isotropy. It is possible to measure the output on each axis, and measure the E-field strength (E) by applying the following formula.

$$E = \sqrt{E_x^2 + E_y^2 + E_z^2} \tag{1}$$

Here, E_x is the E-field strength on the X axis; E_y is the E-field strength on the Y axis; and E_z is the E-field strength on the Z axis.

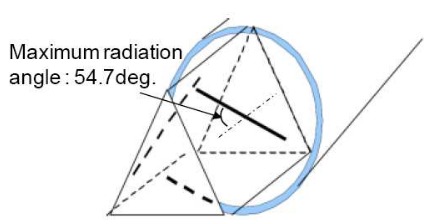

Figure 3: Structure of isotropic sensor head.

2.3. Product Family

Figure 4 shows the dynamic range of Isotropic Optical E-field Sensor which is commercialized. These sensors obtain wide frequency response (100 kHz–10 GHz) and wide dynamic range.

SH-10EL has miniaturized a sensor head by forming an electric field-detection antenna pattern on an LN crystal substrate. It is used to SAR (Specific Absorption Rate) measurement.

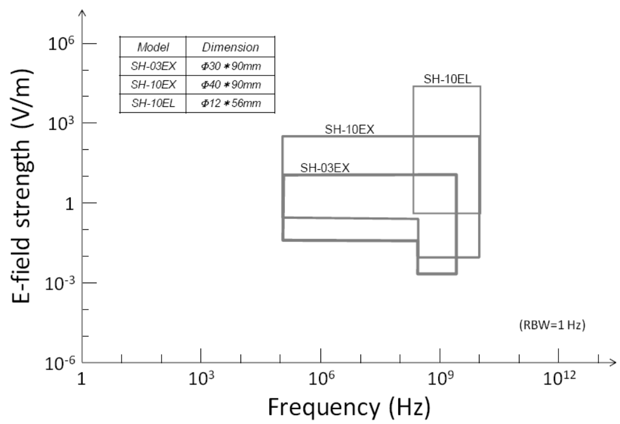

Figure 4: Dynamic range of isotropic optical E-field sensor.

3. PROPOSAL TO FIELD TRANSFER PROBE

The standard E-field is ordinary generated in an anechoic chamber or a TEM (transverse electromagnetic) cell. Since usable frequency and scale of the system, these methods are usually used for the primary standard field generation. In contrast to these methods, a G-TEM (Gigahertz-TEM) cell can realize a compact and wide frequency range E-field generation system. However, a field transfer probe is necessary for the E-field strength calibration of the G-TEM. So we expect that Optical E-field Sensor is adopted a field transfer probe from its features.

We studied the factors of output-power fluctuation of the optical E-field sensor. As a result, the output-power fluctuation factors are optical interference due to the cross talk of the optical circulator in addition to input optical power of the O/E converter. Improving the factors, this sensor obtained excellent performance of output-power fluctuation of 0.01 dB (Fig. 5). Uncertainty in E-field measurement using optical E-field sensor will be improved by it.

There is possibility that it will be adapted applications of standard E-field strength.

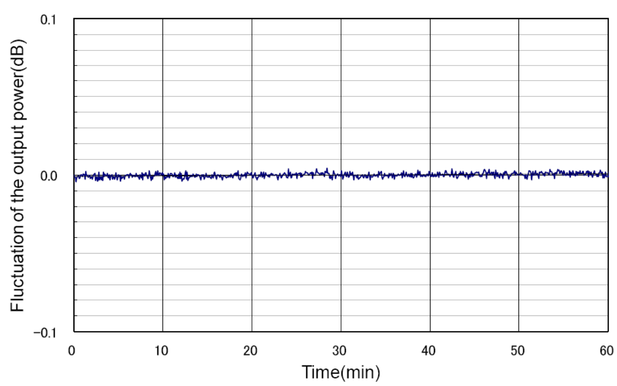

Figure 5: Stability of Optical E-field Sensor (25deg.) .

4. CONCLUSION

We described the structure and features of the optical E-field sensor using a Pockels effect of LN crystal. In the future, we will improve the uncertainty of the optical E-field sensor and establish of E-field measuring techniques in EMC field. In addition, we will propose to simple optical fiber link using RoF technologies for the improvement of disturbances of the surrounding E-field. We expect that it will find a wide variety of applications, including field distribution and high E-field measurement of transmission antennas and the like.

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