Terahertz Polarimetric Sensing for Linear Encoder

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Abstract

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Terahertz Polarimetric Sensing for Linear Encoder

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***Abstract*— We propose a linear encoder which utilizes Terahertz (THz) wave and polarization information. The encoder consists of a polarization angle reader as a read head and a periodic polarizer linear array as a scale. The read head determines its position based on polarization angle on the scale. This technology has possibility to have resistance to fine particles and gap fluctuation between the read head and scale. We experimentally demonstrated that the linear encoder based on the terahertz polarimetric sensing is useful for the industrial applications.**

I. INTRODUCTION AND PROPOSAL

Encoder plays an increasing important role for various systems to detect position. For example, encoder is applied to large machines such as robots in automated warehouses, cranes, and so on. The machines are often shaken and used in dirt environments. Therefore, the encoder for the machines are needed to have resistance to fine particles and gap fluctuation between the read head and the scale. However, conventional encoder doesn't satisfy the requirements. Optical encoder is weak to fine particles because light is scattered due to short wavelength. Magnetic encoder is weak to the gap fluctuation because distance between the read head and the scale must to be close.

To solve the problems, we have been proposing THz polarimetric encoder[1] utilizing the polarization properties of THz wave which has distinct features[2]. THz polarimetric encoder is an encoder that detects the position by reading polarization information of a scale by using THz wave. A schematic diagram of the encoder is shown in Fig. 1. The encoder consists of a polarization angle reader as a read head and a periodic polarizer linear array as a scale. Two orthogonal polarized THz waves emitted by the read head are reflected at the scale, and the received signal strengths (RSS) for both polarizations are detected at the read head. The angle of the polarizer for the scale can be detected by obtaining the differential RSS between the two orthogonal polarizations. When the polarization angle of THz wave corresponds with that of the polarizer, the RSS becomes maximum. Conversely, the RSS becomes minimum when polarization angles of the THz wave and polarizer are orthogonal. Since the polarizers with orthogonal angles are arranged periodically, the read head can determine its position by the polarizer's angle.

The use of THz wave is expected to have high resistance to fine particles because THz wave can propagate even in smoky environments by utilizing long wavelength[3]. The use of polarization information is expected to have high resistance to the gap fluctuation because polarization angle doesn't change unlike the signal strength.

In this paper, we present a fundamental experimental study for evaluating performance of our proposed encoder.

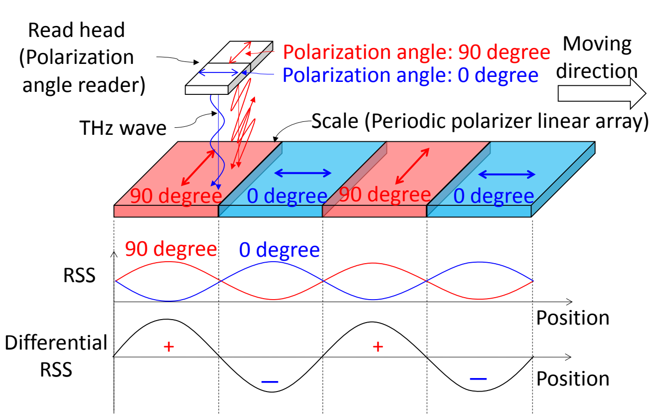

Fig. 1. The schematic diagram of THz polarimetric encoder.

II. EXPERIMENT AND RESULTS

Based on [4], we built a test bench which can transmit and receive two orthogonal polarized THz waves. A schematic diagram of the test bench is shown in Fig. 2. THz-TDS system in the reflection contained a THz-TDS instrument (TAS7400TS, ADVANTEST Corp.), optical components, and a positioning stage. THz wave irradiated from emitter was focused on the scale by using parabolic reflector whose focal length was 120 mm. It can be deemed that the distance between the read head and the scale is 120 mm which is comparable with that of conventional optical encoder. Beam width at 0.3 THz was 5.4 mm. Two polarizers (WGF[5], Asahi Kasei Corp.) as the scale were arranged periodically on the positioning stage to make their polarization angles 0 and 90 degrees, whose angles were horizontal and vertical directions in the test bench, respectively. Both sizes were 50 mm by 50 mm. RSS was measured in every 0.2 mm step movement of the scale. To observe RSS in each polarizations, three wire grid polarizers (WGP) were used. Polarization angle of THz wave from emitter was 0 degrees.

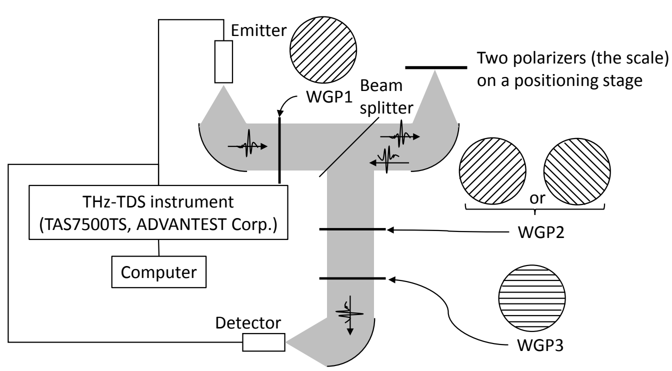

Fig. 2. The schematic diagram of the test bench.

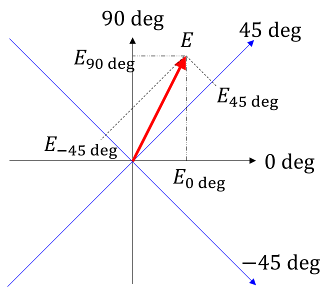

Fig. 3. The schematic diagram of the electric field in each polarization angle.

WGP1 was placed for the terahertz wave to be incident on the scale with 45 degrees component which has 0 degrees and 90 degrees components in the same amplitude. WGP2 was placed to resolve the polarization of the reflected THz wave from the scale into 45 degrees or −45 degrees components. WGP3 was placed for both 45 degrees and −45 degrees components to show the same amplitude transmittance of $1/\sqrt{2}$. Fig. 3. shows the schematic diagram of the electric field in each polarization angle. When WGP2 is tilted by 45 degrees, detected amplitude of THz wave $E_{45\ deg.}$ is given by

$$E_{45\ deg.} = \frac{1}{2}\left(E_{0\ deg.} + E_{90\ deg.}\right), \quad \cdot\cdot\cdot (1)$$

where $E_{0\ deg.}$ and $E_{90\ deg.}$ are amplitudes of THz wave whose polarization angles are 0 and 90 degrees respectively. On the other hand, when WGP2 is tilted by −45 degrees, detected amplitude of THz wave $E_{-45\ deg.}$ is given by

$$E_{-45\ deg.} = \frac{1}{2}\left(E_{0\ deg.} - E_{90\ deg.}\right). \quad \cdot\cdot\cdot (2)$$

Therefore, $E_{0\ deg}$ and $E_{90\ deg}$ are given by

$$E_{0\ deg.} = E_{45\ deg.} + E_{-45\ deg.}\ , \quad \cdot\cdot\cdot (3)$$

$$E_{90\ deg.} = E_{45\ deg.} - E_{-45\ deg.}\ . \quad \cdot\cdot\cdot (4)$$

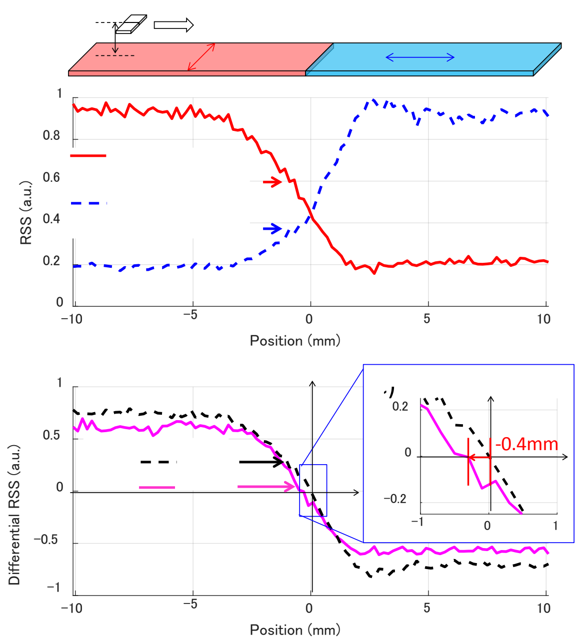

Fig. 4. (a) RSS at 0.3 THz. (b) Differential RSS between two orthogonal polarization angles at 0.3 THz. (c) Enlarged view of (b).

RSS in each polarizations at 0.3 THz is shown in Fig.4.(a). In this test, THz wave at 0.3 THz was used as it has low absorption by water vapor and less scattering by fine particles[6]. Horizontal axis indicates relative positions from the boundary of the two polarizers. Magnitude relationship between the two RSS changes at 0 mm. Differential RSS between two orthogonal polarizations at 0.3THz are shown in Fig.2 (b). The differential RSS (black dashed line) changes from plus to minus values at 0 mm. The differential RSS (pink solid line) is a result when gap displace that means changed distance between the polarizers and the parabolic reflector is 13 mm. As shown in Fig.2.(c), the positioning error is -0.4 mm. Conventional magnetic encoder can't detect the position on the condition. The gap, the resistance to the gap displace, and the positioning accuracy are nearly equivalent to those of conventional optical encoder that these are about 100 mm, 10 to 15 mm, and 0.5 mm respectively. Therefore, THz polarimetric encoder enables us to obtain the position information and has possibility to realize high resistance to fine particles and the gap fluctuation at the same time.

III. Conclusion

We proposed a THz polarimetric encoder. Experimental results showed that the use of polarization information makes encoder have resistance to the gap fluctuation between the read head and the encoder scale. We demonstrated the linear encoder with the THz polarimetric sensing can be utilized for positioning applications. In future works, we plan to evaluate the performance of the encoder under various conditions.

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