SHORT RANGE DISPLACEMENT SENSOR USING OPTICAL PICK-UP TRACKING SIGNAL

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INSTRUCTIONS

Recently there are a lot of micro high added value products. Micro stage is used frequently to produce or study these products. This micro stage is required full closed-loop control to satisfy demanded accuracy. For full closed-loop control in micro stage, short range displacement sensor is required with micrometer resolution. Measurement range of this sensor is from a few millimeters to several tens millimeters and the resolution must become micrometer or sub-micrometer. Conventional displacement sensor is used linear scale or gap sensor etc. Liner scale is displacement sensor with a resolution of sub-micrometer in several hundred millimeters measurement range. But generally a head size of linear scale is big and expensive for the micro stage. The resolution of gap sensor is very high but the measurement range is too short to use in micro stage. So short range displacement for the micro stage is developed with a resolution of one micrometer in this study.

The principle of this sensor is optical pick-up tracking signal method called three-beam method. When the tracks are helically formed on the optical disk, since the sectors of a single track are not equidistant from the center of the rotation of the disk, tracking control is necessary in the read mode. This tracking control has been conventionally performed by a push-pull method or a three beam method wherein the single laser beam is separated into three beams. The three beam method is more often used because it is more stable for the tilting of optical disk or the defect of optical disk than the push-pull method. As high track density is increased, the improvement of the precision in the optical pick-up is needed. The track pitch of CD is 1.6 µm, the track pitch of DVD is 0.74 µm and the track pitch of blue-ray disk is 0.32 µm. Sensor resolution which is using optical disk track signal is sufficient to apply the micro-stage. The resolution of this sensor by dividing electrically may have a higher resolution. The sensor using optical pick-up is cost-effective for micro stage.

MEASURING PRINCIPLE

Optical pick-up consists of laser diode, diffraction grating, polarizer, polarizer beam splitter, collimating lens, quarter wave plate, objective lens and photodiode. The laser beam is divided into three beams by the diffraction grating. The three beams go through a polarized beam splitter and are polarized parallel to the page of polarizer beam splitter. Polarizer beam splitter is only transmits polarizations parallel to the page. The three beams are collimated and pass through a quarter-wave plate. The three beams are converted into the circular polarized beams. The circular polarized three beams are focused on the optical disk by an object lens. The intensity of three beams is modulated according to the pit on the disc. The reflected three beams pass through the quarter wave plate again and converted into polarized perpendicular to the original beam. Polarizer beam splitter is transmits polarizations parallel to the page but is reflected polarizations vertical to the page. The three beams go through the cylindrical lens and the intensity of three beams is detected by a photodiode. The cylindrical lens generates the focusing signal.
EXPERIMENT SETUP

Experimental consists of an optical pick-up, a reference grating, a control board, an oscilloscope and three micro stages. The optical pick-up is used currently so parts can be supplied cheaply. The operating temperature is from 0 °C to 65 °C. The pick-up is available for both the DVD and CD. In this paper, CD mode is used.

Three micro stages consist of X, Y, Z 3-axis with micrometer position resolution. These stages are manual type. Z-axis stage is separated from X-axis, Y-axis stage. X-axis and Y-axis stage moves the grating. X-axis stage is used to select the grating and Y-axis stage is used to move the grating so track signal is generated. Z-axis stage is used to move the pick-up to focus onto the grating. In this experimental setup, focusing servo is not operated to evaluate the performance of track signal in accordance with the focus error. When the relative motion of pick-up and grating is generated to make a track signal, grating is moved to prevent the oscillation of object lens.

The control board can select CD or DVD mode and control laser diode power. This board also can generate the focus and track signal from the photodiode signal.

<table>
<thead>
<tr>
<th>Group 1 (pitch:8 μm)</th>
<th>Group 2 (pitch:10 μm)</th>
<th>Group 3 (pitch:20 μm)</th>
<th>Group 4 (pitch:20 μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land : pit</td>
<td>Land : pit</td>
<td>Land : pit</td>
<td>Land : pit</td>
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<tr>
<td>2 : 6</td>
<td>2 : 8</td>
<td>2 : 18</td>
<td>10 : 10</td>
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<td>3 : 5</td>
<td>4 : 6</td>
<td>4 : 16</td>
<td>12 : 8</td>
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<td>5 : 3</td>
<td>6 : 4</td>
<td>6 : 14</td>
<td>14 : 6</td>
</tr>
<tr>
<td>6 : 2</td>
<td>8 : 2</td>
<td>8 : 12</td>
<td>16 : 4</td>
</tr>
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</table>
The reference grating has 4 groups which have 4 different patterns, so there are 16 different patterns. Pit in this pattern is connected unlike the CD disk as shown in figure 4. The height of pit is $\lambda/4$ so that track signal is maximum. Figure 5 and table 1 show the different pattern configurations. Pattern group is divided by the length of the pitch. The length of pitch is 8 $\mu$m, 10 $\mu$m and 20 $\mu$m. The reason why the pitch of the pattern is not equal to the pitch of CD is easy to display. The pitch of the pattern must be an integer times. The reason why the pitch of pattern is longer is beneficial to create the precision pattern. The resolution of sensor is acquired by electrical dividing the signal. Through experiments, the pattern is founded with the maximum signal to noise ratio. In this study, focusing beam is used unlike conventional linear scale, so the relation between the length of focus and signal to noise ratio is studied. If mechanical moving error is out of focus range, pick-up sensor is not available.

**EXPERIMENTAL RESULT**

Figure 6 and figure 7 shows the track signal and focus signal. The blue line stands for track signal and the red line stands for focus signal. These patterns in figure 6 and figure 7 are outstanding in signal to noise ratio. If there is 10 $\mu$m focus error, the track signal distortion is less than 5%.

Sensor using optical pick-up can be applied to the micro stage that vertical moving error is less than 10 $\mu$m.

![Figure 6. Group 1 land 2 $\mu$m, pit 6 $\mu$m](image1)

![Figure 7. Group 1 land 6 $\mu$m, pit 2 $\mu$m](image2)

![Figure 8. Group 2 land 4 $\mu$m, pit 6 $\mu$m](image3)

![Figure 9. Group 3 land 6 $\mu$m, pit 14 $\mu$m](image4)

![Figure 10. Group 4 land 14 $\mu$m, pit 6 $\mu$m](image5)

Figure 8, figure 9 and figure 10 also show the track signal and focus signal. As shown figure the track signal is difficult to use the position sensor signal. Because the difference between the pitch of the pattern and the pitch of CD is too much, the signal distortion is large not to be used. The other patterns are similar to these patterns.

**GRATING PRODUCTION**

In this study, the grating can be made by CD manufacturing method. This method provides a cheap grating. Figure 11 shows a grating produced in CD manufacturing. But this grating is amiss for a displacement sensor grating,
because this grating is shrunk in process of production. Different shrinkage depending on the location of the disk is very difficult to correct. It does not make to secure accuracy of displacement sensor. To solve this problem, a wafer produced by lithography is used for displacement sensor grating in this paper. But the disadvantage is that prices of grating are rising. Figure 12 shows the grating produced by lithography process.

FUTURE WORK

In this study, basic experiments is performed to evaluate that pick-up is available as a displacement sensor. Optical system will be design to fit into displacement sensor for micro stage. A compact optical system and control board must be designed for micro stage. Figure 13 shows the first design sensor head to be simplified. The controller must be designed to operate this head. The accuracy and reliability of this sensor also must be evaluated.

REFERENCES

