Study of a Micro Lightwave Antenna Manufactured by MEMS Technology

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1. Introduction

Lightwave communication is one of the promising systems in the future inter satellite communication networks, and local area networks. There are, however, many development issues, in order to construct realistic systems. A small and high gain light wave antenna is required for that purpose. The high performance antenna requires optional curved surfaces to acquire high aperture efficiency.

In a lens-type lightwave antenna, the surface requires smooth and high-level mechanical preciseness. The surface is aspheric. However, it is difficult to fabricate the smooth curve of a micro lightwave antenna by the present technology based on machining. Turning is based on a programmable machining technique, which make use of a machine and a cutting tool to obtain smooth curved profiles with minimal roughness. However, this approach is limited to low aperture efficiency and rotationally symmetric elements. Moreover, the implementation of this method by use of a glass substrate is difficult because glass is a brittle material.

Furthermore an aspheric curve lens needs thick structure such as conventional lens. To reduce the thickness of the lightwave antenna, multilevel phase step structure, which is the approximated to aspheric curve antenna, is a suitable approach.

We have developed a novel micro lightwave antenna by using MEMS (Micro Electro Mechanical Systems) technology. In this paper, we describe the approximation method of antenna surface, and the practical applications.

2. Design Method

A design method of a micro lightwave antenna is shown in Fig.1. The details are as follows:

(a) The smooth curved surface is assumed as an ideal lightwave antenna.
(b) The smooth curved surface is discriminated by a constant step. The height of the constant step is defined by a part of the wavelength of the incident light.
(c) When the stepped level arrives at a wave length of the incident light, the stepped level returns to the initial level.

By using this design method, the antenna can be made thinner than conventional antenna. The performance of this optical antenna depends on the processing technology. By using multilevel step structure, a precise micro antenna can be fabricated by MEMS technology. The performance of the lightwave antenna is improved by increasing the number of these steps.

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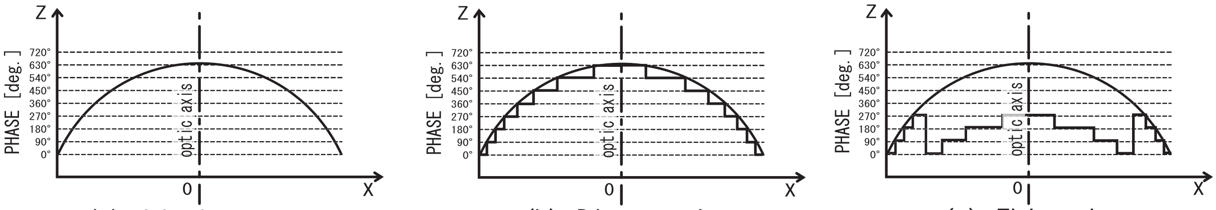

(a) Ideal curve (b) Discreted (c) Thinned

Fig. 1 Desgin process

3. Fabrication Process

The fabrication process in MEMS technology is shown in Fig.2. The details are as follows:

(a) A silicon dioxide(SiO_2) plate is coated with photo resist.
(b) The photo resist is patterned by using designed photo-mask.
(c) The plate is etched by RIE (Reactive Ion Etching). The etched depth is the desired depth of one step.
(d) The photo resist is removed.

To make multilevel-step structure, these processes are repeated. By using this fabrication method, multilevel-step light wave antenna can be fabricated.

4. Fabrication Model

A light wave antenna is produced as a trial. The design parameters are as follows,

- Wavelength; λ =633 nm (as light length of He-Ne gas laser)
- Effective area diameter; 4 mm,
- Focus length; f=1.0m.
- The height of one step is 346 nm (1/4 wavelengths the incident light path length in SiO_2.)
- The number of steps; 3

The cross section profile of the designed antenna is shown in Fig.3. The profile of the fabricated antenna was measured by a direct surface profiler (stylus type measuring instrument). The result is shown in Fig.3. The remnant of etching is left on the edge of the step due to an alignment error. The fabricated light wave antenna is shown in Fig.4.

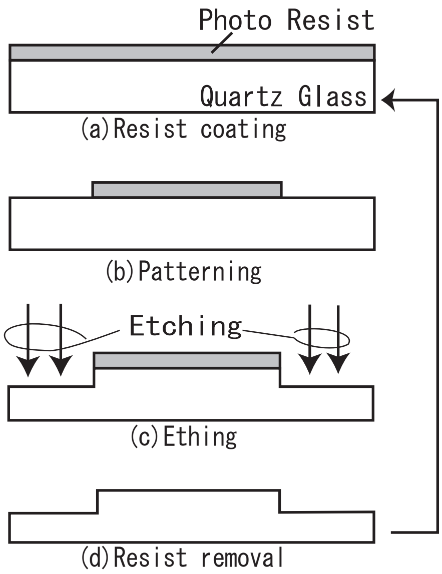

Fig. 2 Manufacture process

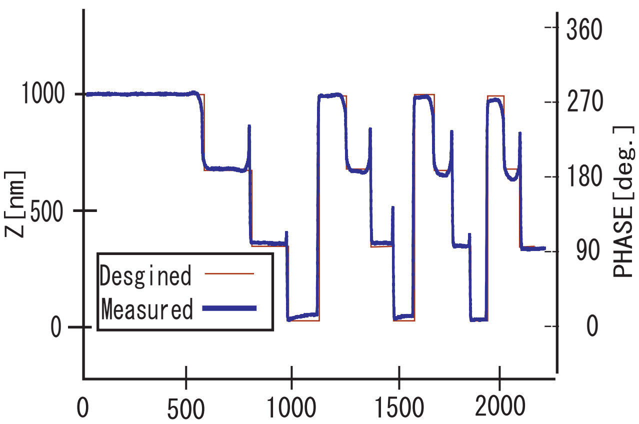

Fig. 3 Measurement of manufactured antenna

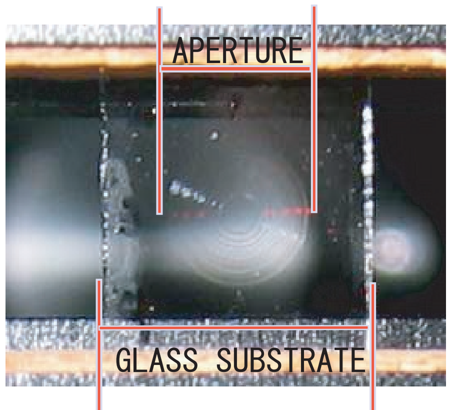

Fig. 4 Outlook of the manufactured antenna

5. Calculation Result

To demonstrate the advantages of the presented approach design method, computer simulation was carried out. The degradation due to the approximation error of the designed lightwave antenna is calculated. A radiating pattern $f(\theta)$ is given by,

$$f(\theta)=\int f(x) \cdot Exp(j \cdot k \cdot sin\theta \cdot x)dx \quad \cdots (1)$$

where, x is distance from the axis, $f(x)$ is complex amplitude distribution on an effective area, k is wave number, θ is an angle of the radiation pattern from the lightwave antenna. Equation (1) is calculated about the designed antenna and the ideal smooth curved surface antenna, when the light intensity distribution is gaussian on an effective area. The result of the radiating pattern is shown in Fig.5. In characteristics of the designed antenna, there is 0.92dB decrease power of main robe, and the first side robe level is -15.01dB. Quantization robe level is observed -30dB to -35dB at a wide range of from θ =1.0 mrad to 4.0 mrad.

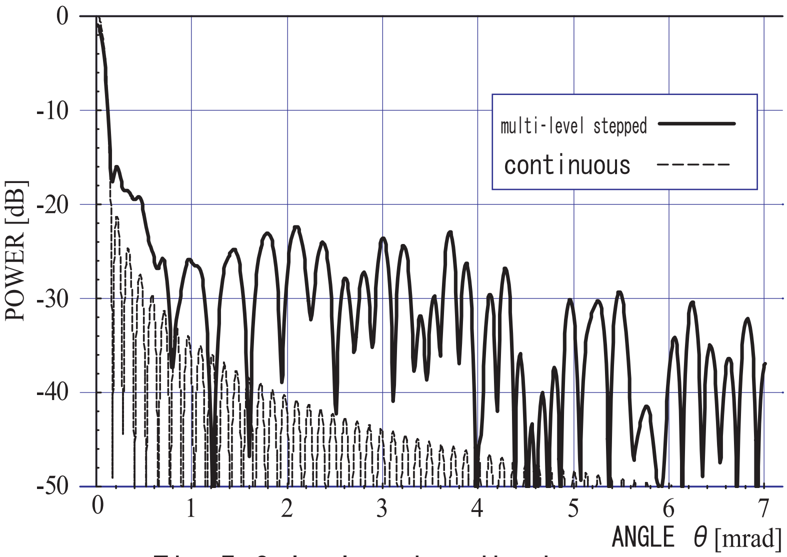

Fig. 5 Calculated radiation pattern

6. Experimental Result

We have measured the radiating pattern of the fabricated lightwave antenna by pin-hole scanning method. In this measurement, we use optical power meter with φ=20μm pin-hole. The pin-hole scans intensity of illumination along the line which is perpendicular to optic axis. The scanning line is at focus point of Fourier Transform Lens. The measurement setup is shown in Fig.6. After, the intensity of illumination pattern is translated to the power radiation pattern.

The power radiating of the antenna is shown in fig.7. There is the first side robe level is around -15dB. Quantization robe level is observed -25dB at a range of from θ =1.5 rad to 4.0 mrad. These points are in agreement with simulation result.

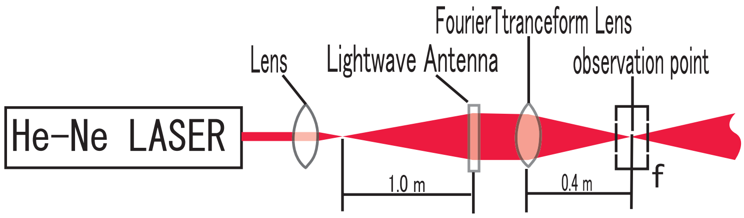

Fig. 6 Composition of the experiment setup

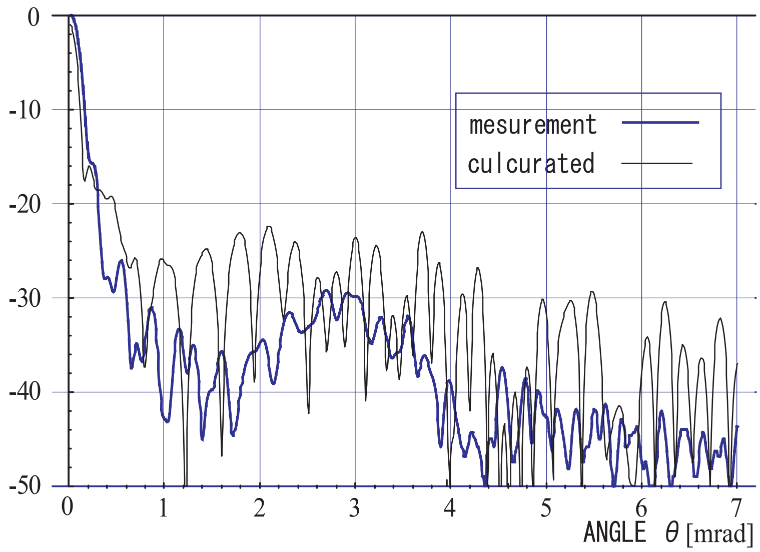

Fig. 7 Measured radiation pattern

7. Conclusion

(1) We have designed a micro lightwave antenna by applying the MEMS technology, and demonstrate its validity.
(2) The experimental results and the theoretical values show good agreement.
(3) For practical applications, several issues are classified.
(4) Especially, more precise discretization is needed.

References

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