Reflection Induced Voltage Change of Surface Emitting Laser in Near-field Regime and Its Application for 2-D Optical Probing

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1. Introduction

High density optical data storage has been attracting much interest for future Tera byte memories. The storage density of conventional optical technologies such as CD and DVD is limited by optical diffraction limit and seems not to meet the future demand. The optical near-field technology is considered to make the breakthrough on the diffraction-limited storage capacity [1].

Betzig and coworkers demonstrated an optical recording by a near–field scanning optical microscope (NSOM) and suggested a possibility of Tera byte data storage[2]. Goto proposed a Tera byte optical memory system using a vertical cavity surface emitting laser (VCSEL) array [3]. The proposed optical disk system is based on an optical head consisting of a 2-dimensional VCSEL array. We proposed and demonstrated a micro-apertured VCSEL for producing optical near field [4), 5]. However, a way to read out the stored data in such near-field storage systems has not been established yet. One possible way is to use reflection-induced voltage change of lasers [6),7].

In this paper, we examine a possibility of a VCSEL-based contact head technology to read out the stored data. The voltage change of a VCSEL optical head can be induced by the interaction between the VCSEL head and storage media. We measure the reflection induced voltage change of 850nm VCSELs operating at constant current in near-field regime. A two-dimensional image probing is successfully demonstrated.

2. Modeling on reflection-induced voltage change of VCSELs

We carried out modeling on the voltage change of a VCSEL induced by reflection change. Figure 1 shows the schematic view of a VCSEL optical head with a contact head technology[7]. The evanescent wave emitted from a small metal aperture formed on a VCSEL surface is irradiated to an optical disk, such as a phase change optical disk. The refractive index change on the disk may induce the change of effective reflectivity of the cavity of a VCSEL, resulting in the change of threshold conditions of VCSELs. Thus, when we operate a VCSEL with a constant current, the voltage change is dependent on the refractive index of the

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disk surface. This voltage signal can be used to read out the signal. This setup looks very simple and we can use the same optical head for writing and reading out the data.

We calculated the voltage of an 850 nm VCSEL operating at constant current as a function of reflectivity as shown in Fig. 2. It is noted that a small change of 1 % in reflectivity induces a voltage change of several tens mV.

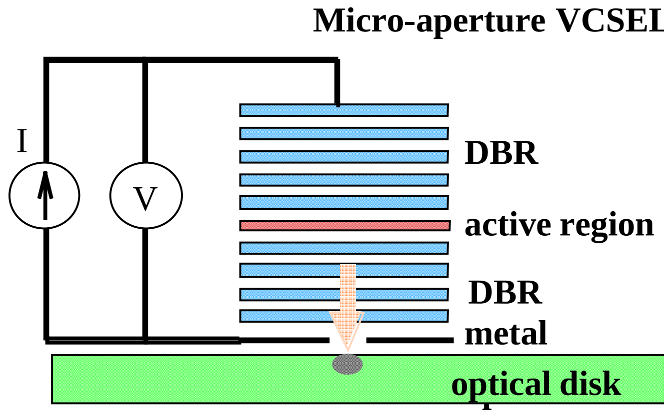

Fig. 1 VCSEL optical head to read out data.

3. Experimental setup and result

We carried out the experiment to examine the reflection-induced voltage change of an 850 nm VCSEL in near-field regime. The experimental setup is shown in Fig. 3. The GaAs VCSEL used in the experiment consists of GaAs quantum well active region and an oxide aperture with a diameter of 3 µm. The VCSEL includes 19 pair p-type top DBR and 35 pair n-type bottom DBR. The threshold current is as low as 0.3 mA. The device operates in fundamental transverse mode and the measured near-filed pattern shows a spot size of 4 µm. The VCSEL used in the experiment is conventional and has not a metal micro-aperture.

A metallic probe (Pt-In) with a tip diameter of less than 100 nm was scanned in the surface of the VCSEL along the X and Y direction. For precise positioning of the probe, three position controllers with a piezo actuator were used. A VCSEL was operated at constant current of 2 mA. The metallic probe was moved near the output aperture of a VCSEL

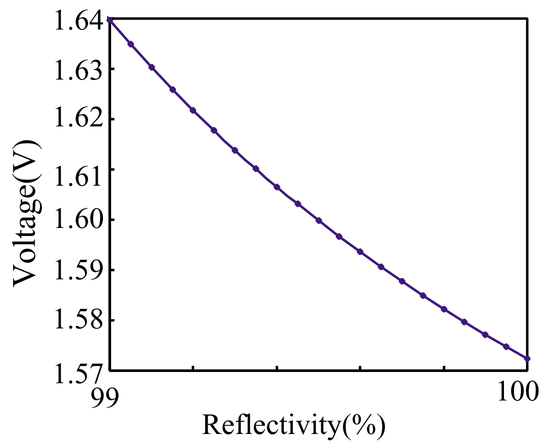

Fig. 2 Voltage change of VCSELs as function of reflectivity

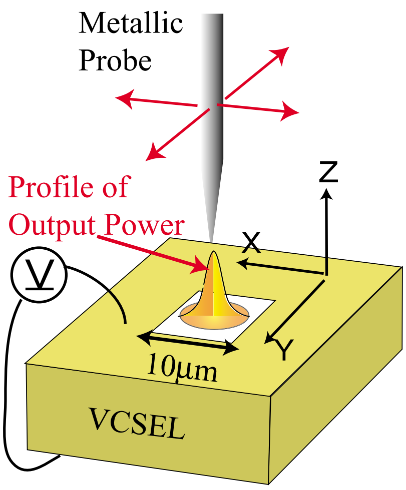

Fig. 3 Experimental setup

with a constant distance of less than 1 μm between the probe and the surface of the VCSEL. The scanning area with the metallic probe is 10μm square with an interval of 0.25μm.

The measured profile of voltage change is shown in Fig. 4. The full width at half of maximum (FWHM) of the voltage signal is almost the same as the spot size of near-field pattern. The maximum voltage change is about 10mV.

We also carried out two-dimensional probe imaging by replacing a metallic probe with Au mesh patterned on a glass plate shown in Fig. 4. The VCSEL used for this measurement operated in the first-order mode. The width of the Au grid is 2 μm. The glass plate with Au mesh was placed on the VCSEL. The distance between the Au mesh and the top surface of a VCSEL was about 350 nm, which is limited by the thickness of the top electrode of the VCSEL. As a result the 2-D profile of voltage change can be clearly observed as shown in Fig. 6.

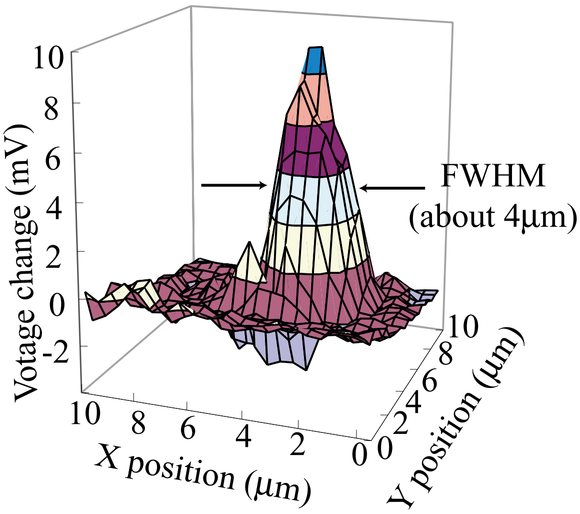

Fig. 4 Voltage change with metallic probe

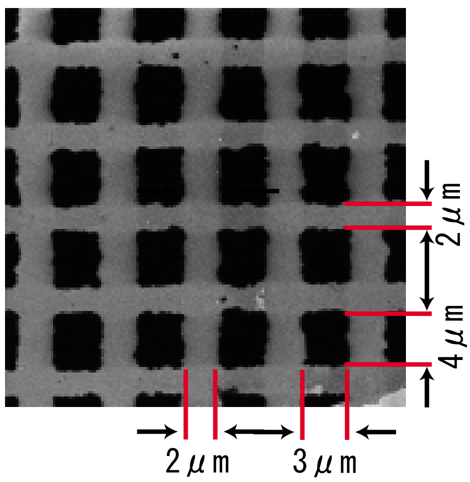

Fig. 5 Image of Au mesh on glass plate

4. Conclusion

We measured the voltage change of a VCSEL induced by external reflection. 2-dimensional imaging was successfully demonstrated by using the voltage signal of the VCSEL. The resolution is currently limited by the spot size of a VCSEL. Thus, if we are able to realize a micro-aperture VCSEL with a spot-size of below 100 nm, a VCSEL-based contact head

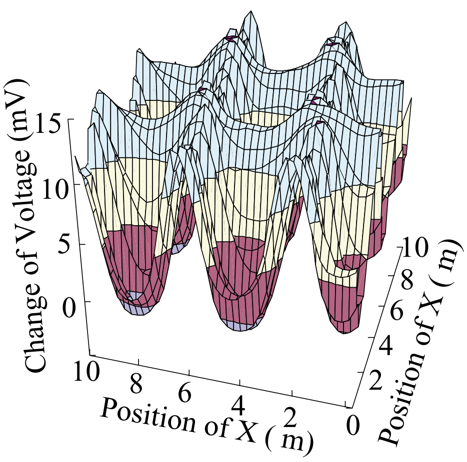

Fig. 6 Voltage change of VCSELs with Au mesh

technology to read out can be expected for high density optical storage. The comparison with theory and experiment is currently under study.

Acknowledgement

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