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A2 (Plenary)

MICRO-OPTICAL 2-D ARRAY DEVICES FOR OPTICAL DISK HEAD OF ULTRA-HIGH DATA RATE AND DENSITY USING VCSEL

Kenya Goto
Dept. of Inform. & Commun. Tech., School of High-Technology for Human Welfare,
Tokai University: 317 Nishino, Numazu-city, Shizuoka 410-0395, Japan
Tel: +81-559-1111, Fax: +81-559-68-1155, E-mail: kenya@wing.ncc.u-tokai.ac.jp

Very high density and very high data transfer rate in the memory disk system are really needed in the information and communication technology in near future. The aerial density and data transfer rate used for an ultimate disk memory will be one Tbits/in^2 and 60Gbits/s using a 2-D VCSEL array and a 2-D Nano probe array with micro-lens on the input surface fabricated simultaneously. In this technology a semiconductor micro probe array with several 10 nano meter apertures in each flat tip top of the probe, the near-field technology, and the technology of surface plasmon are absolutely inevitable.

Figure 1 shows one unit of a cross sectional diagram of the 2-D micro optical array head, where the VCSEL array and the pyramidal prism probe (PPP) array with micro-lens are main components of the super-parallel head (shown in Fig. 2) for the ultra-high data rate and density optical disk[1-3]. When the wavelength used in this VCSEL are 670nm, 405nm, then the cut-off wavelength of the pyramidal prism probe aperture are 145nm, 93.4nm each using high refractive index semiconductor probes of GaP and GaN. In order to collect output beam effectively from an each VCSEL output window a micro-lens consisted of high refractive index material, which is usually as same material as the probe, is focused in the very near part of the probe aperture. When the beam from the aperture of the top flat tip of PPP is diffracted in the air, then the beam is called as near-field light or evanescent wave and the power will be rapidly decreased exponentially in proportion with the distance from the flat tip of the PPP. With this type of the near-field probe the larger throughput efficiency had been obtained because of the less decrement of light transmission in higher refractive indexes material compared to in those case of lower refractive index material like optical fiber[4]. The throughput data using 100nm apertures of a GaP probe array and a 670nm VCSEL array show several percent, which is two order larger than has ever reported before. We are now continuing improvement of this data using phase matching technology between optical waves and surface plasmon waves which will enhance the evanescent wave.

Figure 2 shows a brief cross-sectional schematic diagram of the optical head, 2-D VCSEL array,

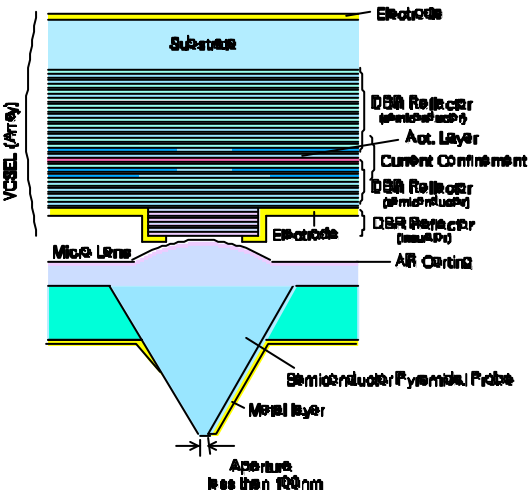


Fig.1 One unit of the Micro-Optical 2-D array head.

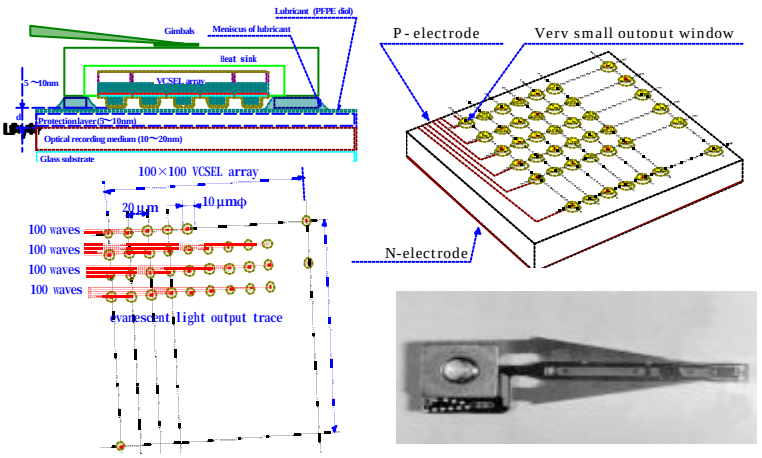
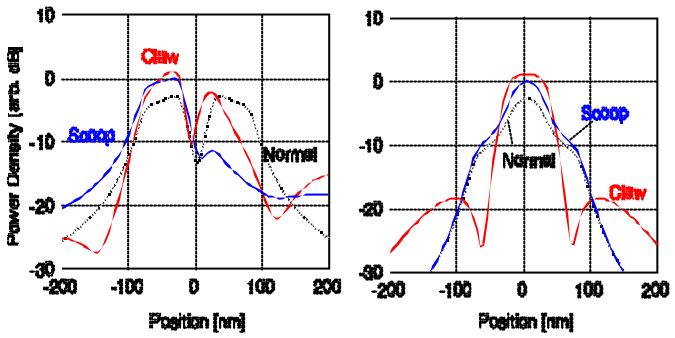


Fig.2 Cross-sectional diagram of the head, 2-D VCSEL array & traces on the disk

evanescent wave traces figure from each micro-optical device unit, and a suspension & gimbals where the 2-D head array is settled. Figure 3 shows one of the results of mutual coupling between the evanescent wave and the surface plasmon generated from silver metal film coated on the surface of the PPP, which absorb light (transversal) waves and convert them into surface plasmon (longitudinal) waves

The each picture shows electric field intensity distribution versus shape of the covered metal film on the PPP. It was found that there is a specific thickness in metal film cover and a specific angle in the pyramidal probe shape in order to get strong enhancement from the surface plasmon in the evanescent waves of the top tip of the PPP. If the phases of the both waves can be matched each other, then the evanescent waves from the apertures of the PPP will show narrow and strong light intensity.



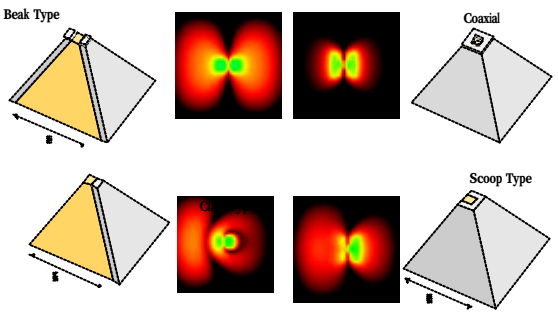
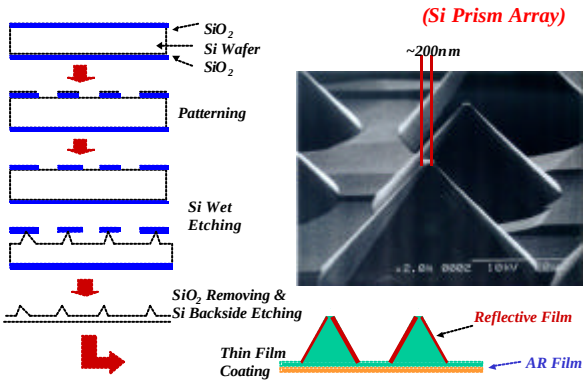


Fig.3a Light intensity characteristics for various types of anti-symmetric metalic coatings covered the surfaces of the pyramidal prism probes

Fig.3b Various pyramidal prism probes with different anti-symmetric Silver cover coated

The schematic conception for the 2-D array head shown in Fig.2 shows the evanescent wave traces toward the tangential direction of the optical disk rotation[1]. In order to get these fine traces the micro-optics device unit like one described in Fig. 1 is most important. To obtain 100 x 100 of 2-D array



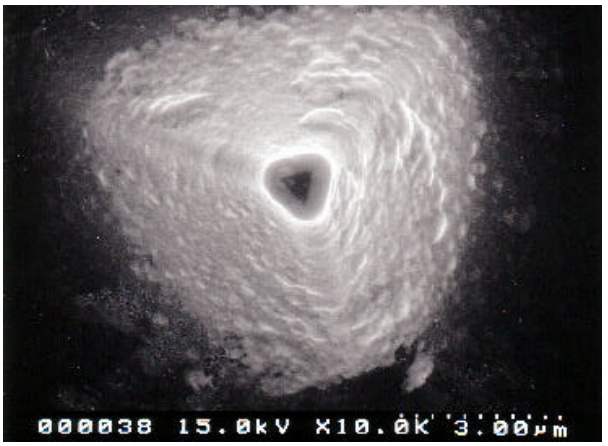


Fig. 4a One example of fabrication of Si Pyramidal Prism Probe array. Fig.4b One example of Silver coated GaP PPP array with aperture.

consisted of this unit only one 100 x 100 mask for VCSEL, micro-lens, PPP array is used to fabricate all 2-D array components, because adjusting all axes in line is essentially needed. Figure 4 shows one of results of aperture formation processes[5] of the semiconductor near-field probe array, which can make all the aperture fabricated simultaneously by ion beam shower generated in the ion milling machine[7]. This method utilizes beam intensity difference by the angle characteristics toward face to be fabricated by ion

beam milling machine. Before this cover metal coating and the aperture forming simultaneously for all probes the most important process for this micro-optical device unit is the lens and the near-field probe fabrication. Figure 5a shows one example of fabrication process for both micro-lens array and near-field probe array, where the mask for both process is exactly same as used in VCSEL array process. Figure 5b is a monolithically fabricated 2-D optical head consisted of VCSEL, micro-lens, and micro-probe arrays.

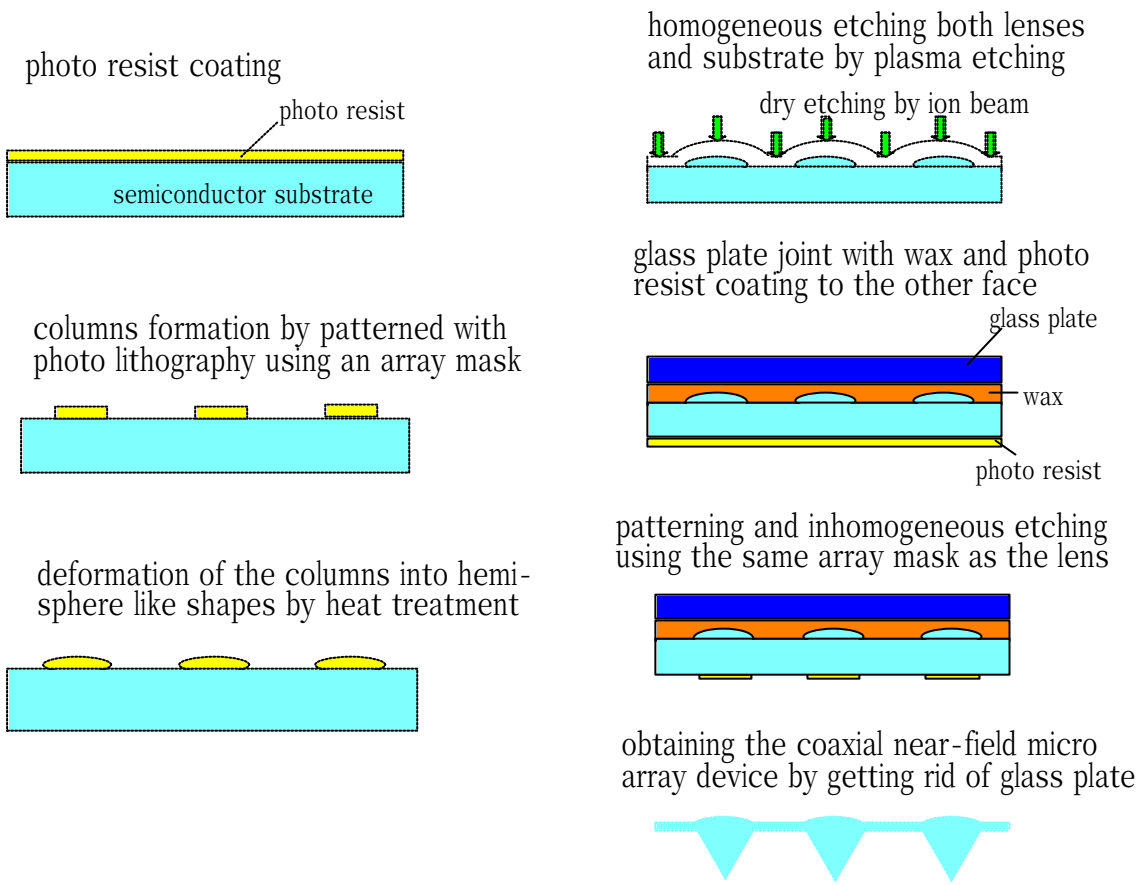
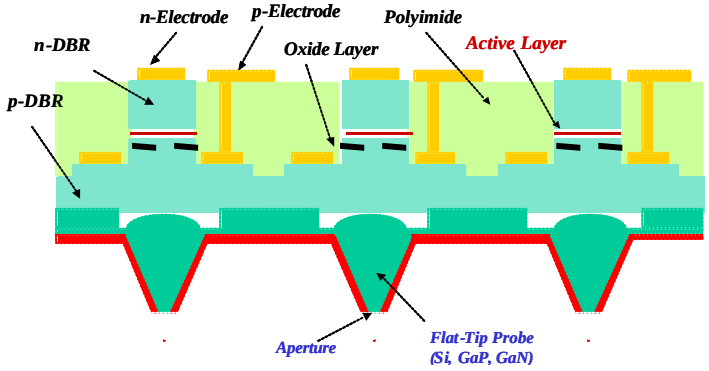


Fig.5a One example of fabrication process for both nano fabrication the coaxial micro-lens and the near-field pyramidal prism probe array, where the mask for every photo lithography used in lens formation and in PPP formation is the exactly same as VCSEL array had processed.



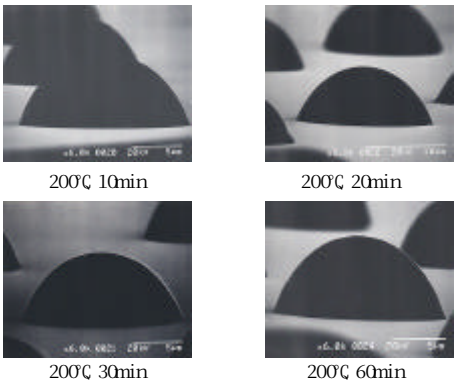


Fig.5b Schematic picture of the micro optical device for a super-parallel array head. The VCSEL, micro-lens and pyramidal prism probe are coaxial because only one mask is used in every process (VCSEL process, lens making process and PPP process)

Fig.5c One example data for the heat treatment in forming the hemispherical shape. The shape is slightly different with temperature and time.

The required power density on the surface of the optical disk is 50-100uW/100nm^2 . The throughput efficiency of our micro-optical device is however about 5 % which is fairly lower than estimated. This reason is mostly inferred from that the micro-lens curvature is still a kind of spherical shape, then spherical aberration is now occurred and the spot size in focal point inside the probe tip would be larger than the calculation data. To compensate the aberration aspherical curvature for the micro-lens is really needed[6]. Figure 6 is one of the aberration data for the micro-lens with one aspherical curvature.

In developing appropriate lens surface fabrication process near-field probes with very high throughput

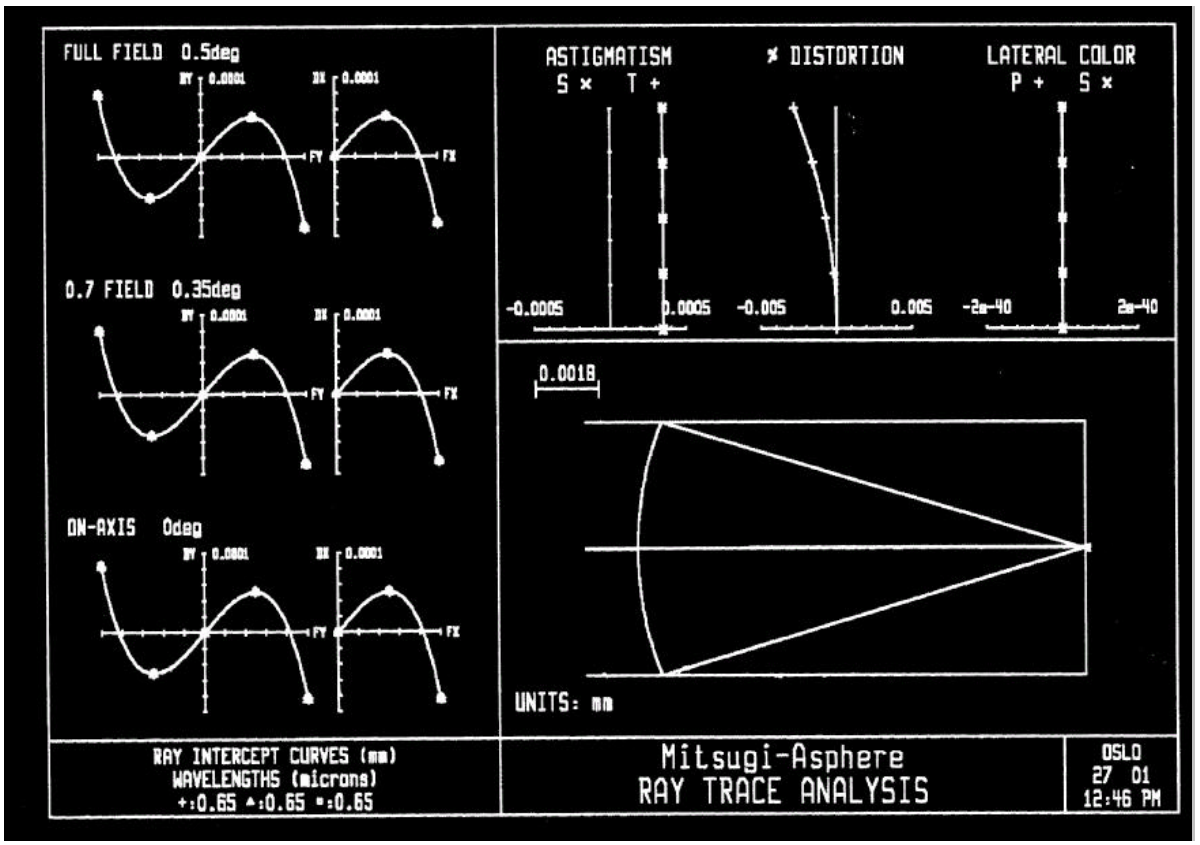


Fig.6 Ray tracing analysis for the micro-lens added near-field probes. With aspheric surface on the bottom of the PPP very small spot inside the probe will be realized. Total height of this probe is 15um and lens diameter in the bottom of the probe is 10um.

will be finished in a half year. And the conjunction with the surface plasmon to make enhancement to the evanescent light the output laser light will be less than 100uW for each VCSEL, because nowadays 1mW output from each VCSEL is enough to write on th e surface of the tera byte optical disk. I believe that the 21st century is the real 2-D opto-electronics era with the application of the VCSEL array, micro-lens array, and also various kind of micro-optical device arrays.

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