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A Study on the Mechanism of a New High Speed Scanning Miniature Nano-Measurement Probe

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Abstract. The primary purpose of this research is to adopt a commercially available DVD pickup head and modify it to become a high-speed scanning nano-measurement probe. With the principle of astigmatism the probe can execute the autofocusing motion by an imbedded voice coil motor (VCM) following the height change of the tested object in the vertical Z-direction. Given high precision triangular current signal with appropriate frequency to the input ports of tracking, the same VCM can be moved along the lateral X-direction for profile scanning. Firstly this paper presents the structure of DVD pickup head, the theory of autofocusing and auto scanning, and the developed controller. Then experimental setups and accuracy calibration will be introduced. In order to achieve a bi-directional precision measurement in autofocusing and scanning, this study has developed a hysteresis error compensation scheme by a DSP-32 integrated system. In association with a high precision linear stage in Y-direction, this high precision micro/nano optical probe can measure the 3D profile of the miniature object successfully at fast speed.

Introduction

Technologies of high precision inspection have been developed in recent years all over the world, among which the probe design is the key issue of all measurement systems. As far as in the development of ultrahigh precision CMM with nanometer accuracy in progress is concerned, SPM probe was adopted by NIST, MIT in the United States and SIOS Co. in Germany [1,2]. The touch triggered probe (TTP) with light detector was developed by Tokyo University in Japan, PTB in Germany, BUPE in South Korean, and NPL in UK [3-5]. The structure of all the above probes is very complex and expensive. In addition, the stylus tip of TTP is still limited in its physical size to unable access the dimension below 50μm. This research aims at studying the characteristics of autofocusing and tracking on a commercially available DVD pickup head and modifying it to achieve a high-speed scanning nano-measurement probe with optical tip size below 1μm.

Structure of the Probe System

Market available DVD pickup head as shown in Fig. 1 (such as HITACHI HOP-1120) mainly contains the following components: laser diode, grating, polarization beam splitter and 1/4λ plate, four-quadrant photodiode IC, objective lens and voice coil motor (VCM), as shown in Fig. 2. Our research purpose is to fully use the properties of these components with advanced skills to convert the pickup head into a non-contact measuring probe.

Laser Diode. A low-power laser diode (about 5 mW) that emits light at 630 nm to 650 nm is integrated in the DVD pickup head. The laser beam can be collimated and then focused to a small spot at the diffraction limit [6]. Because of the wavelength shift of several nanometers due to temperature effect, the auto power compensation (APC) circuit is required [7].

Grating. Due to the diffraction effect the laser beam will transmit the grating plate and generate three diffractive beams. The main beam of the zero-order is used for autofocusing the disk while two side beams of the ±1-order is used for auto tracking of the disk in CD.