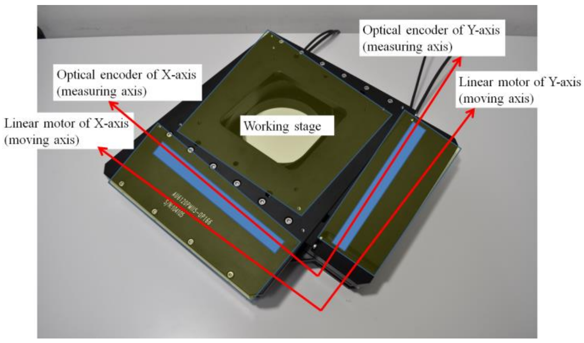
Research Highlights

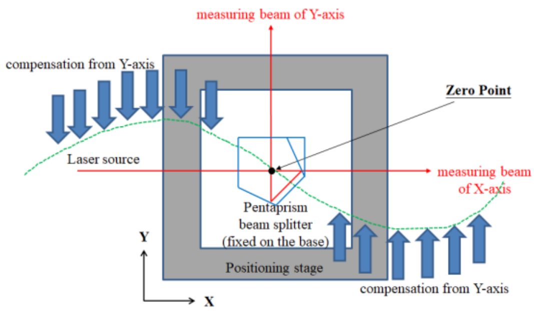
Associate Prof. Chung-Ping Chang

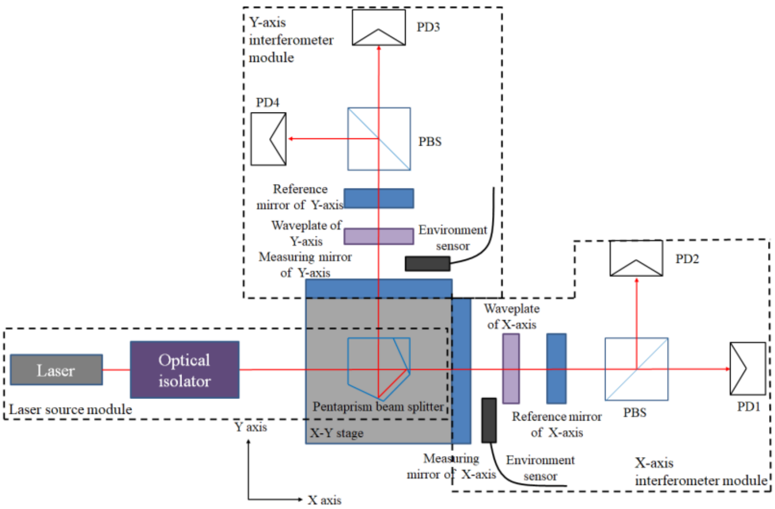
JOURNAL: Mechatronics

TOPIC: Laser Encoder System for X-Y Positioning Stage

ABSTRACT: In this investigation, a novel opto-mechatronics design of linear Laser encoder system which can eliminate geometrical errors of X-Y positioning stage was proposed. The eliminated geometrical errors, which are squareness error, straightness error and Abbe error, can be reduced by this Laser encoder system. Those errors are induced by the mechanical components and assemblies. In this design, a pentaprism beam splitter was employed to divide the laser beam into two encoder axes which are perpendicular to each other. For this arrangement, a real zero point of the positioning stage was set inside the pentaprism beam splitter. Therefore, those specific geometrical errors can be minimized by the proposed system. In this research, the design of the opto-mechatronics structure and its theoretical simulations will be studied. The experimental results which were obtained in the ordinary environment revealed that the resolution of the proposed positioning stage is about 15.8 nm. In addition, the maximum standard deviation of static positioning error is about 50 nm. The Laser encoder system presented in this study is recommended to be used in the precision machinery and semiconductor industries for the precision positioning purpose.







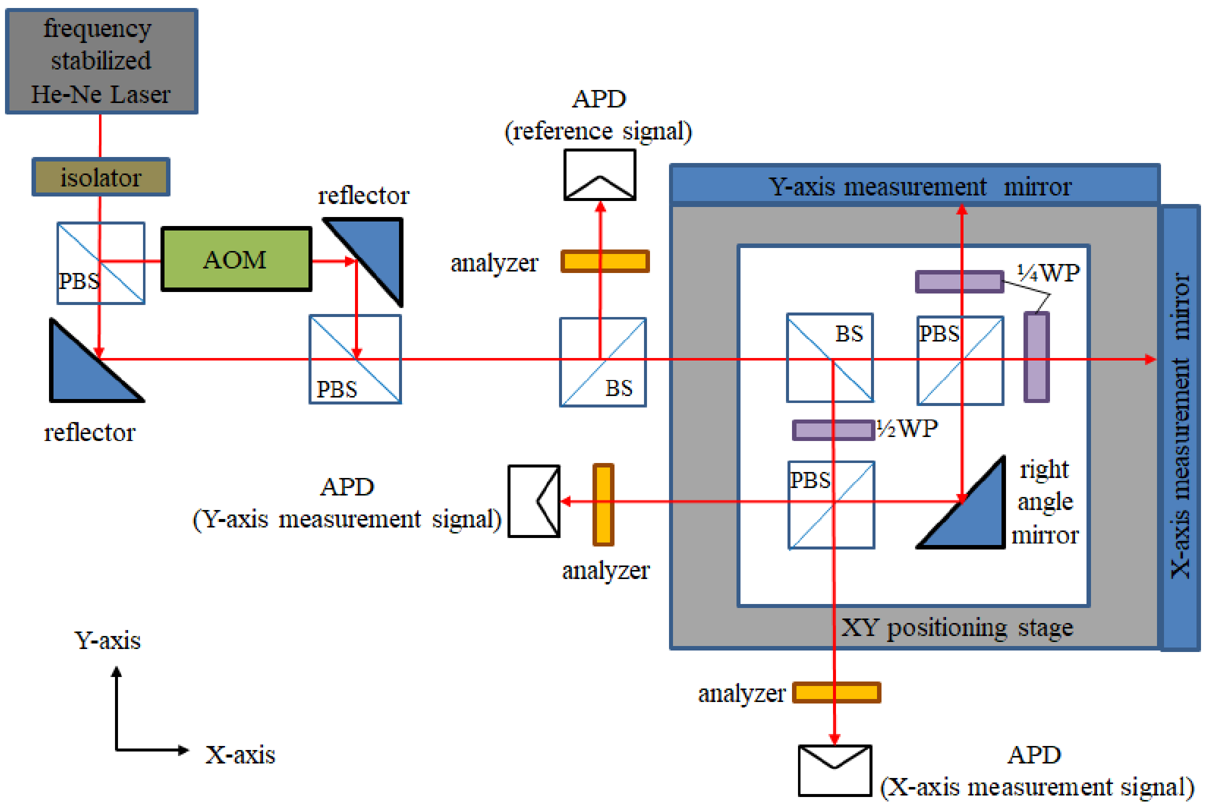
Research Highlights

Associate Prof. Chung-Ping Chang

JOURNAL: Sensors

TOPIC: Development of the heterodyne Laser encoder system for the X-Y positioning stage

ABSTRACT: This investigation develops a Laser encoder system based on a heterodyne Laser interferometer. For eliminating geometric errors, the optical structure of the proposed encoder system was carried out with the internal zero-point method. The designed structure can eliminate the geometric errors include positioning error, straightness error, squareness error, Abbe error of the positioning stage. The signal processing system is composed of commercial integrated circuits (ICs). The signal type of the proposed encoding system is a differential signal that is compatible with most motion control systems. The proposed encoder system has embedded in a two-dimensional positioning stage. By the experimental results of the positioning test in the measuring range of 27 mm * 27 mm with the resolution of 15.8 nm, the maximum values of the positioning error and standard deviation are 12.64 nm and 126.4 nm in the positioning experiments. The result shows that the proposed encoder system can fit the positioning requirements of the optoelectronic and semiconductor industries.

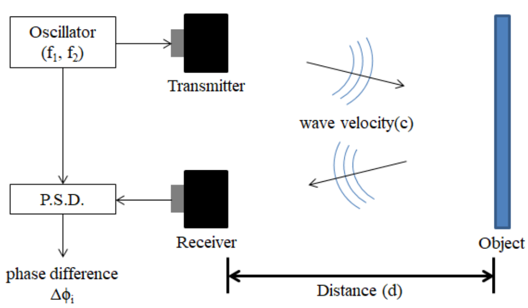


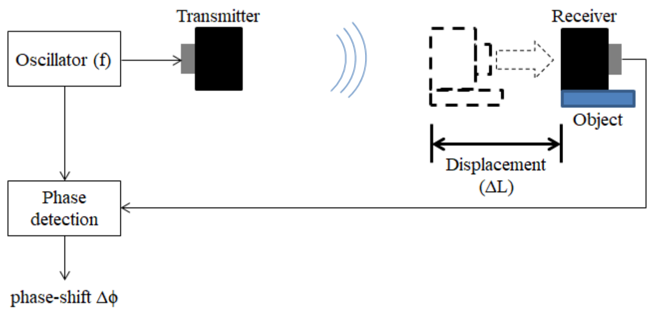
Associate Prof. Chung-Ping Chang

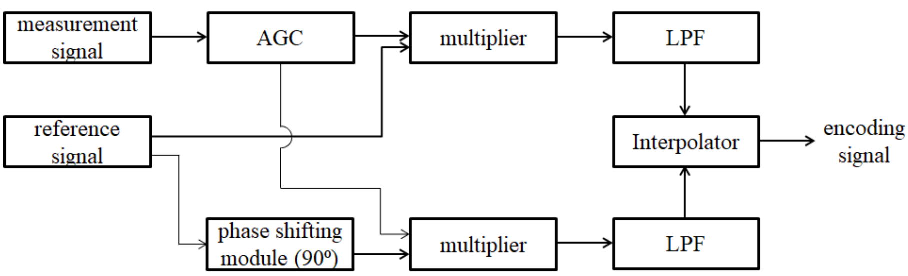
JOURNAL: Sensor Review

TOPIC: Development of an Ultrasonic Linear Encoder

ABSTRACT: Purpose – In this investigation, a linear encoder system based on the ultrasonic transducer has been proposed. Ultrasonic transducers are usually designed for the distance measurements, such as the time of flight (ToF) method and sonar system. Those applications are defined as discrete-length measurement technology. In this research, a continuous displacement measurement method of ultrasonic transducers has been introduced. Design/methodology/approach – A modified signal processing based on heterodyne signaling is implemented in this system. In the proposed signal processing, there is an automatic gain control (AGC) module, a phase-shifting module, a phase detection module, the interpolation module, and especially the frequency multiplication module, which can enhance the resolution and reduce the interpolation error simultaneously. Findings – The proposed system can generate the encoding signals and is compatible with most motion control systems. For the experimental result, the maximum measurement error and standard deviation are about -0.027 mm and 0.048 mm. It shows that the proposed encoder system has the potential for displacement measurement tasks. Originality – This study reveals an ultrasonic linear encoder that is capable of generating an incremental encoding signal, accompanied by a corresponding signal processing methodology. In contrast to the conventional heterodyne signal processing approach, the proposed multiplication method effectively reduces the interpolation error that arises due to multiple reflections.



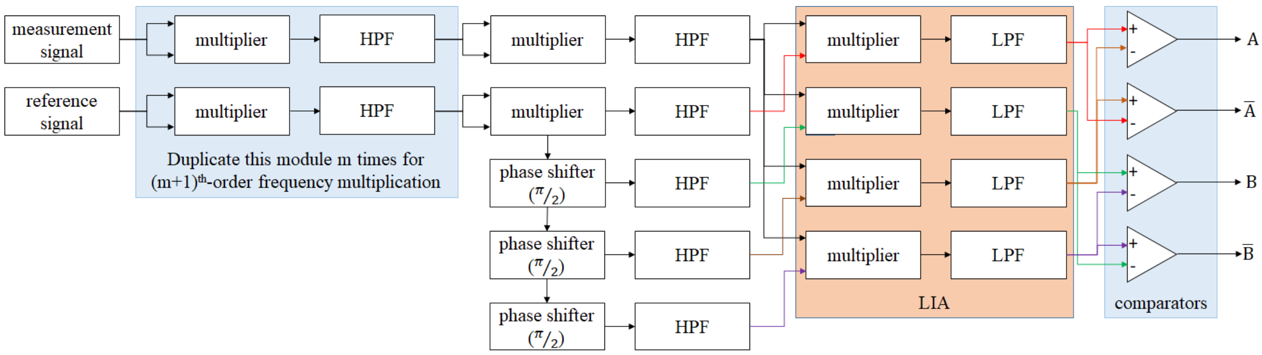


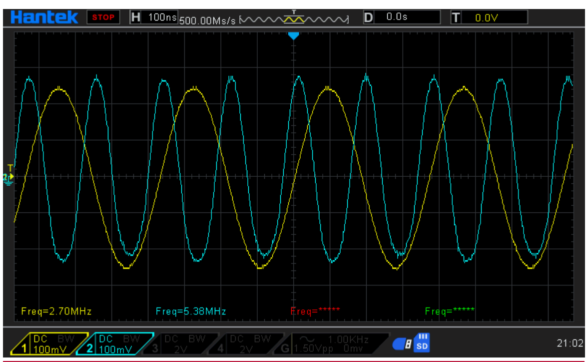


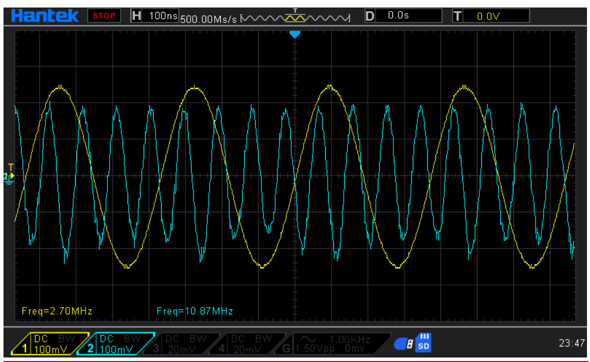
JOURNAL: Micromachines

TOPIC: A Novel Analog Interpolation Method for Heterodyne Laser Interferometer

ABSTRACT: The laser interferometer technology is used in the precision positioning stage as an encoder. For a better resolution, the laser interferometers usually work with interpolation devices. According to the interpolation factor, those devices can convert an orthogonal sinusoidal signal into sever-al square-wave signals via digital processing. The bandwidth of the processing will be the limi-tation of the moving speed of the positioning stage. Therefore, the user needs to make a trade-off between the interpolation factor and the moving speed. In this investigation, a novel analog interpolation method for a heterodyne laser interferometer has been proposed. This method is based on the principle of lock-in amplifier (LIA). By using the proposed interpolation method, the bandwidth of the laser encoder system can be independent of the interpolation fac-tor. It will be a significant benefit for the ultra-high resolution encoder system as the laser inter-ferometers. The concept, design, and experiment are revealed in this manuscript. The experi-mental result yields that the proposed interpolation method can reach nanometer resolution with a heterodyne laser interferometer, and the bandwidth of the signal is independent of the resolution.







Research Highlights

Associate Prof. Chung-Ping Chang

JOURNAL: Machines

TOPIC: Developing an Interferogram-Based Module with Machine Learning for Maintaining Leveling of Glass Substrates

ABSTRACT: In this research, we propose a method that utilizes machine learning to maintain the parallelism of the resonant cavity in a Fabry–Perot interferometer designed specifically for glass substrates. Based on the optical principle and theory, we establish a proportional relationship between interference fringes and the inclination angle of the mirrors. This enables an accurate determination of the inclination angle using supervised learning, specifically classification. By training a machine learning model with labeled data, interference fringe patterns are categorized into three levels, with approximately 100 training data available for each level in each location. The experimental results of Level 2 and Level 3 classification indicate an average number of corrections of 2.55 and 3.55 times, respectively, in achieving the target position with a correction error of less than 30 arc seconds. These findings demonstrate the essential nature of this parallelism maintenance technology for the semiconductor industry and precision mechanical engineering.