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Integration with Opto-Mechanical System Design and Servo-Motor for Computer Aided Z-Scan Experimental Setup

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Abstract: In this study, the design, fabrication and assembly stages of a computer aided servo motor controlled unique mechanical system used for the z-scan technique, which is one of the methods used to determine the nonlinear properties of optical materials and optical characterization (optical permeability) will be explained in the nonlinear optical field. This design combines different disciplines, such as basic mechanics, control systems, computer-aided design and manufacturing (CAD/CAM) and hydraulic pneumatics, scientifically and technically. The main automation units of the system are; Siemens S71200 CPU1212 from the new generation PLC systems, Siemens S-1F6 series compatible with this system; 1FL6042-1AF61-0AA1, 0.4 kW 3-AC Servo Motor, Siemens 6SL3210-5FE10-8UA0 V-90 Servo Motor driver and various shafts, roller bearings, lightweight aluminum alloys, mechanical rails and carier integrated in these systems and stainless steel mechanical double joint coupling for reducing the workload of the servo motor. The system whose fabrication has been completed has far superior mechanical and automation properties when compared to the other systems which are used in the field of opto-mechanical manufacturing and which enable the precise measurement to be taken. CNC Lathe and CNC Milling machines and labs of our vocational school were used in all of the manufacturing stages of all the units of the system. The design, fabrication, and assembly stages of the system will be explained in depth with technical data and photographs.

Keywords: Engineering applications, Mechanical design, Z-Scan, Opto-mechanical systems, Optical measurement

Introductıon

A weighted spring that can be vibrated by effective forces might react in a non-linear way. In the same way, it is expected that a forceful light beam might produce abundant non-linear optical effects. Electrical fields of beams emanating from ordinary light sources are rather inefficient for observing such behaviours readily. Being non-linear, parameter in materials has been realized by discovering of laser beams. Some theoretical previsions regarding the subject have been implemented. However, experimental studies were initiated in 1960's. Providing non-linear parameters is very substantial in terms of material characterization. Some techniques implemented within the framework of the subject are Third Harmonic Generation (THG), Optical Kerr Gate, Electric Field Induced Second Harmonic (EFISH), Non-linear Fabry-Perot Method, Degenerate Four-Wave Mixing (DFWM) and Z-Scanning (Wilson, J., Hawkes, J.F.B., 1993).

In today's world, non-linear optics is quite actual and active and the studies in respect with the subject have been rising. Non-linear optics is applicable and in use in a broad area from semiconductor technology to isootropic decomposing.

Another scope of application comprises photochemistry, spectroscopy with force of high resolution, optical radar (LIDAR), describing and defining atmospheric pollutants remotely (Eugene, H., 2002).

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Theory

When forceful light field which is permeable into the material, the link between light field and force that brought about by polarization cannot be explained by equations of linear electrodynamics. In the end, a non-linear bind is brought about between P and E.

$$P = \chi^{(1)}E^{(1)} + \chi^{(2)}E^{(2)} + \chi^{(3)}E^{(3)} + \dots \quad (1)$$

As a result of studying the terms of above proposition, it could be possible to find out diverse non-linear optical facts corresponding to them. As each next term is smaller than the previous one Ea times (Ea is defined as the force of electrical field in an atom) possibility in occurring of non-linear event corresponding to each next term is also smaller. Here $\chi^{(1)}$ linear coefficient is $\chi^{(2)}$, $\chi^{(3)}$ non-linear polarization coefficients with two or more degree. Non-linear coefficients are related to the medium characteristics just like linear coefficient. They lead to the parametrical spreading with $\chi^{(2)}$ single photon and $\chi^{(3)}$ four photons, $\chi^{(2)}$and $\chi^{(3)}$ parametrical enchancing of light and production of $\chi^{(4)}$ fourth, $\chi^{(5)}$ fifth harmonics. Non-linear polarization coefficients with higher degree cause other non-linear optical events (Goca, N., 2000).

Z-Scan Technique

Nowadays, different methods and techniques are used in the calculation of nonlinear parameters, however z scanning technique is superior to other techniques and efficiency in terms of accuracy of obtained parameters. Optical characterization of various organic structures and liquid crystals can be made by Z-scanning technique.
By the agency of z scanning technique, measurements of samples of unknown characterization can be made by using a single experimental setup. The efficiency and applicability of z scanning technique has been proven by tests and measurements. Our experimental contrivance is designed computer aided. The parameters are obtained by scanning the materials to be examined along the z-axis. When the sample is moved , the amount of the light transmitted by the sample provides sufficient information for nonlinear parameters.

The material to be inspected is placed in a way that its front side should be in vertical position to the focus of laser beams. Sample holder is settled over the linear transfering setup moving along z axis of laser beams. When the material moves the amount of laser beams transferred from the material, it provides adequate information for non-linear parameters. Z-Scanning technique can be used for calculating non-linear optical coefficients by using a single experimental setup (Artkin, F., 2014)

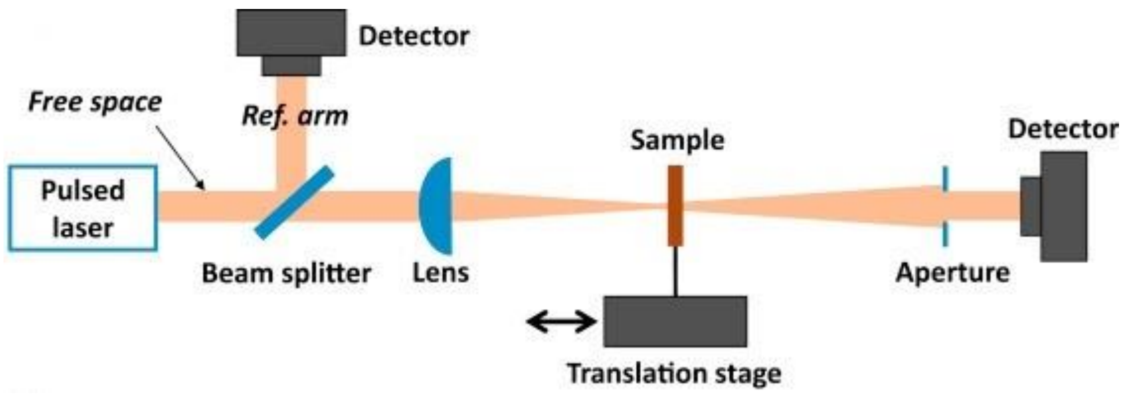

Figure 1. Setup for z-scan measurements. The transmission through the aperture is measured as a function of the sample position. The left detector is used for monitoring the incident pulse energy

Versatility and sensitivity of Z-Scanning technique for the non-linear optical measurements are the advantages separating it from the other techniques. Z-Scanning technique has been proved by experiments and measurements that have made it efficient and applicable (J. Blewett, I, Stokes, J, Tookey A, K. Kar A, S. Wherrett, B.1998).

Opto-Mechanical Design

The mechanical parts of the system are; two 800-mm-long slide rail linear motion unit support shafts diameter Ø2; linear stage with aged aluminum with black color of 150×150 mm; two 800 mm long chrome plated (0.2-0.33 µm) trapeze shafts; one 800-mm-long main shaft with 2-mm step range integrated with universal 20x20 mm stainless steel mechanical double joint coupling. The Aluminium alloys used in the system are 6063 and 7075 series.

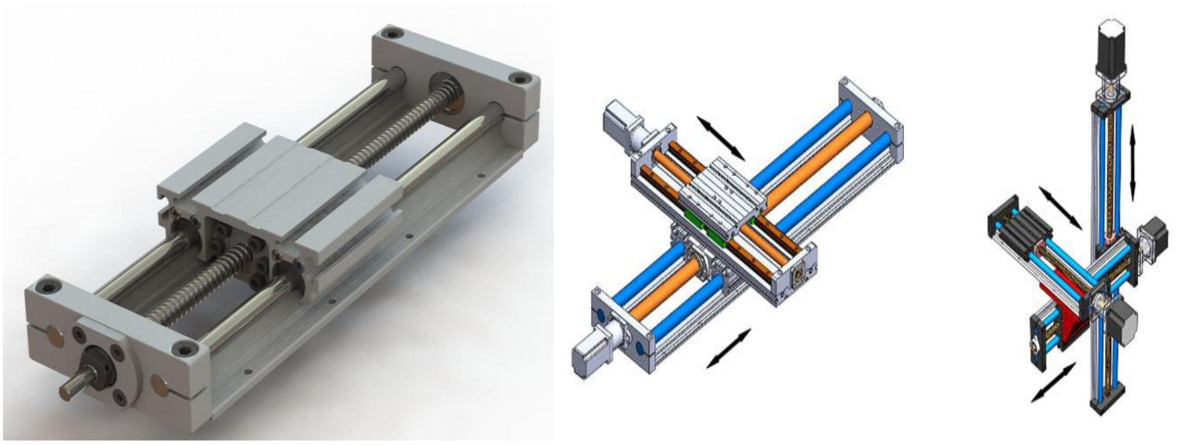

Figure 2. Similar mechanical design, Applications of mechanical designs in machine tools with servo motor integration(horizontal and vertical)(doguskalıp.com)

All the mechanical parts are coated with black static paint because they are sensitive to that color in the high-powerful laser measurements. All the mechanical parts are coated with black static paint for the optical measurements to be made more accurately. The whole weight of the mechanical system is 16.65 kg, including the servo motor (Artkin F., 2016).

Figure 3. Completed parts of the opto- mechanic system before fitting

Any kind of process in mechanic and automatization systems is ensured via progressive circular and linear motions. Regardless of the type of the process, any process should be placed in an axial guide and bearing so that the motion is maintained in an appropriate and stable way. For any kind of loading and speed implementation, abrasion should be avoided in order to keep bearing sensitivity and tolerance figures. For this reason bedding materials are made of hardened and spesific materials.

The moment and the stimulation alternatives needed for the axial motions are composed in accordance with the units in which they are used. The bearing materials placed on the Aluminum profile frames provides practical implementation and avoid unnecessary loading on the system. The canal structures on the current surfaces ensure that any kind of additional part is included during the process and facilitates adjustment.

It is possible to direct axial coordination motions via the controller and control board in accordance with the process due to the integration of various engines in linear motion systems. While these units provide standard options in the category of Linear Motion Systems, they also make specific various sizes and additional options available (elega.lt).

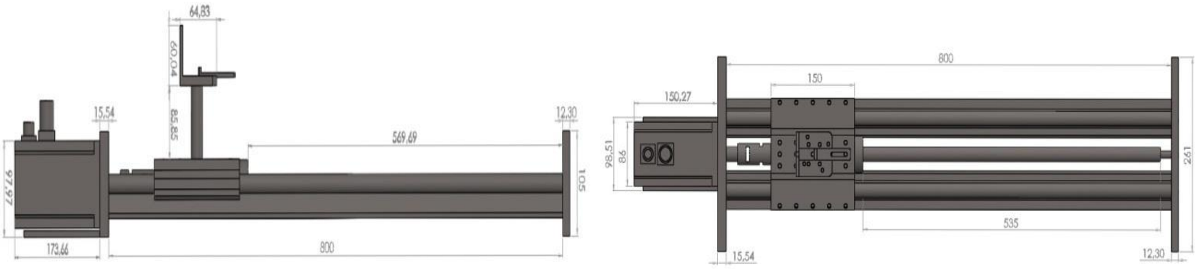

Figure 4. Detailed technical pictures of the electromechanical system whose designs have been completed, view of side (on the left), top view (on the right). Drawings have been completed by Solidworks 2015

Servo systems are the feedback control system that produces mechanical positioning, speed or acceleration parameters. Servo Mechanism; is a feedback control system with output size, location, speed or acceleration. For instance; servo control systems are used in joint motors of a welding robot. Fully automatic operation of mechanical system or machine with the programmed commands can be performed with the help of servo systems.. Servo Mechanisms are control mechanisms that acting according to desired indicator values. In automation systems, servo motors are preferred especially in systems where control is very sensitive.. The encoder is assembled behind the servo motor to control the angle and direction of rotation and rotational speed.

This information from the encoder is then sent back to the Servo Amplifier fold (Control Level) as feedback. As one of the main elements that can be adjusted quickly, numerical control and robotic systems are indispensable elements. They are widely used because of their high efficiency. Servo motors are one of the main reasons for the transition from hydraulic systems to electrical systems (Artkin F., 2017).

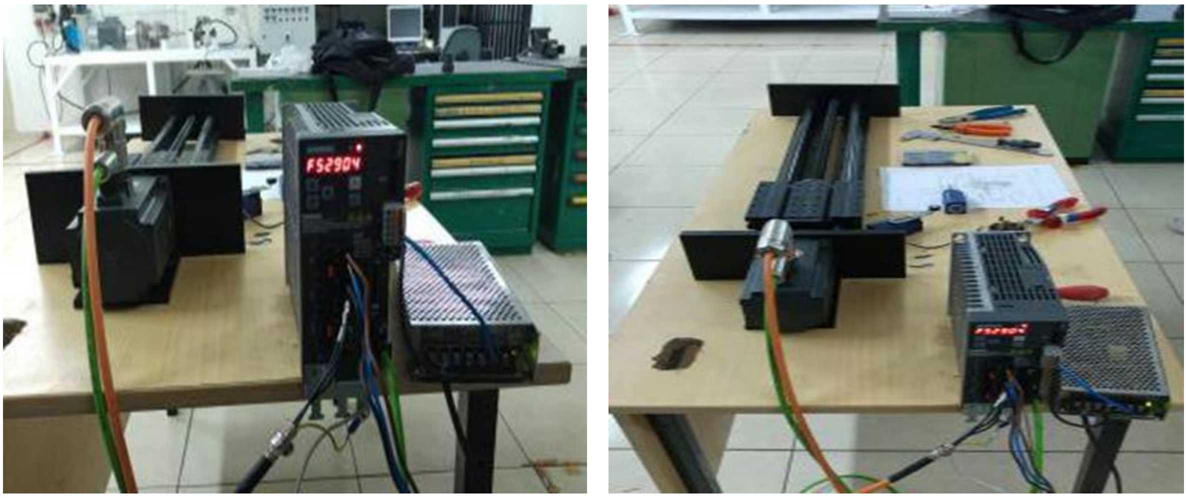

Figure 5. The commissioning of the opto-mechanical system whose design have been completed in the Machine-Manufacturing Laboratory

Motion Basics and Standards is the first significant parameter for mechanical systems. The function of a phase is to constrain motion to a intended direction. For a linear stage, the intended motion is along an ideal straight line. Any motion in a constrained direction will contribute to deviation from the ideal trajectory and/or position. Other contributors to deviation include load forces and everything related to the formidable task of designing and building a perfect stage in a world where perfect machining and ideal materials do not exist. To put it mildly, high performance motion systems are complicated, so failing to notice a seemingly trivial issue, either in design or in an application, can create unwanted and unplanned outcomes. Thus, the intended utilization of a product along with the various measures of performance must be scrutinizingly reviewed. Second important parameter is Motion Control Coordinate System, any positioning phase is considered to have six degrees of freedom: three linear, along the x, y, and z-axes and three rotational about those same axes (see Figure 6) (newport.com).

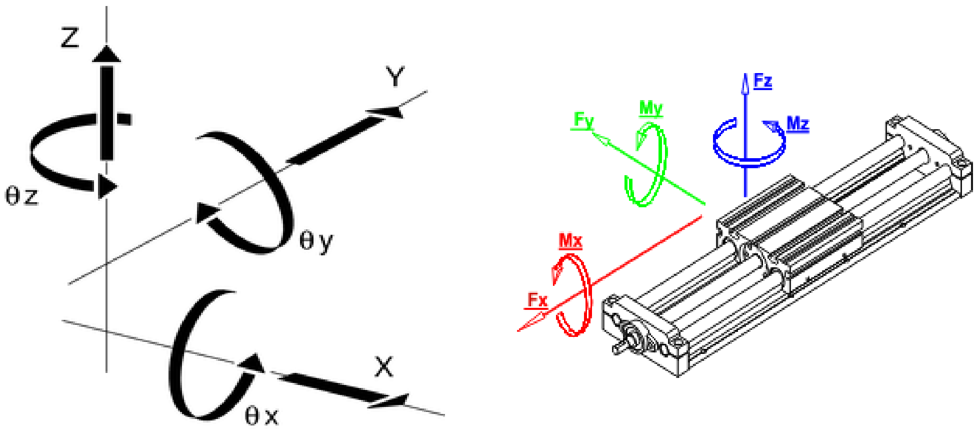

Figure 6. Right-hand coordinate system showing six degrees of freedom on the left. Coordinate systems and torque directions for Linear Motion Systems on the right (doguskalip.com.tr).

All motions described here follow the right-hand coordinate system convention. The cross-product of the +X and +Y axes (second and third fingers) is the +Z axis (thumb). Also, if the thumb of the right hand points in the positive direction of an axis, the fingers will wrap around the axis in the direction of positive rotation about that axis. All movements are composed of translations along and/or rotations about the coordinate axes. Generally, the X and Y axes are on the horizontal plane, the direction of travel of the first or bottom stage being aligned with the X axis, and the Z-axis as vertical (www.newport.com/Motion-Basics-and-Standards).

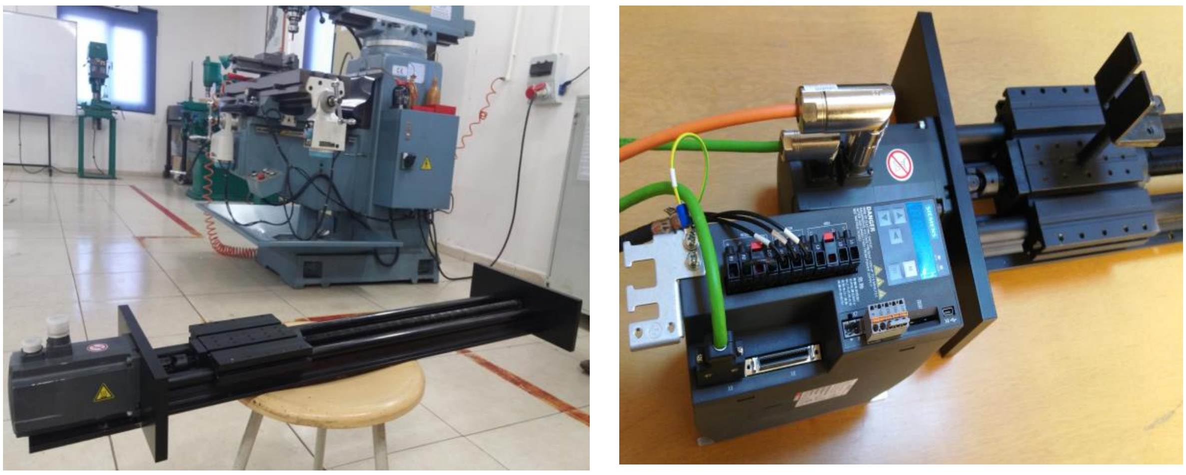

Figure 7. Integration of Siemens Simotics S-1F6, 1FL6042, 1AF61-0AA1 servo motor with Siemens 6SL3210-5FE10-8UA0 Sinamics V-90 servo motor on the right. Stages of Manufacturing for Linear Motion System integrated with Siemens FL6042 servo motor with CNC Lathe and Universal Milling machines in the Manufacturing Laboratory of Hereke Vocational School on the left.

Result and Conclusıon

In the measurements a Q-switched Nd-YAG laser with 532 nm (second harmonic) wavelength, two lenses with focal length of 10 cm, two photo-detectors and a slit with a radius of 0.75 cm are included. As the system uses a high-power laser beam; Nd 2 + 0.4 mW natural density filter was used. There may be fluctuations in the power of the laser. Therefore, the use of reference photo-detector 1 (FD1) allows for more accurate measurements. Non-linear optical transmittance values can be obtained by dividing the measurements obtained with the photo-detector 2 (FD2) at the output by the measurements obtained in the reference photo-detector (FD1) (FD2 / FD1). The position-dependent optical permeability values were obtained by moving the carbon disulfide (CS_2) focus from the negative z position to the positive z position.

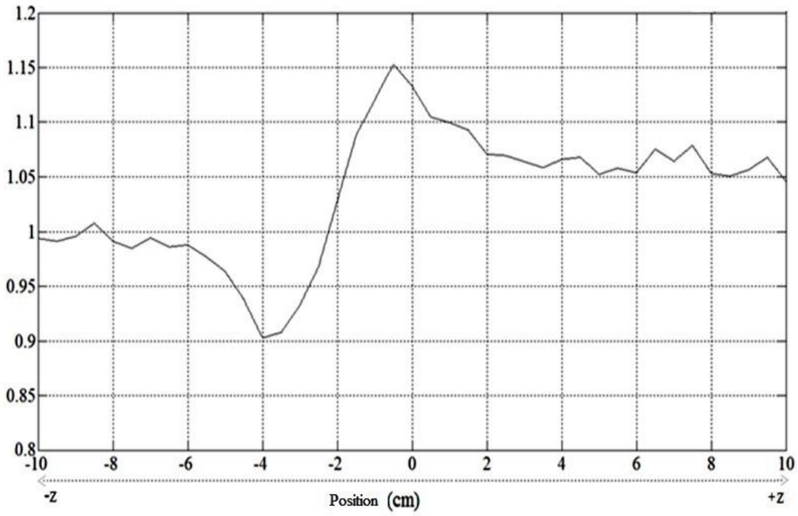

Figure 8. Results of Z-Scan experiment setup with the optical transmittance and position dependent of the CS_2.

The experimental results obtained in the motion resolution of 0.002 mm from -z (-10 cm) to the direction of + z (+10 cm) with the help of the opto-mechanical system design of which has been completed are shown in Figure 8. In this study, the intensity of the light at the focal point was calculated as 1.3 GW / cm^2. The Calculation of nonlinear parameters of Carbon Disulfide (CS_2), the material accepted in the literature, has been successfully performed.

The minimum pitch and maximum peaks can be determined in the change of optical transmission. This graph has been drawn with Matlab 8.2 R2013b using the result data obtained in the experiment. The difference between minimum and maximum values for nonlinear optical permeability coefficients was calculated as Tp = 1.15288, Tv = 0.90267 as a result of the first experimental measurements.

This study establishes the basis of my Phd studies at Sofia Technical University. My Phd studies are developed version of this study. Some of the information and data used in this article were used in the PhD study of Computer-aided Z-Scan Testing Apparatus Integrated Apparatus Integrated into Servo Motor and PLC for Investigation of Non-linear Materials’ Permeability. I would like to thank Prof. Dr. Fevzi Necati Ecevit from Gebze Technical University and Associate Professor Dr. Ivanka Kalimanova from Technical University of Sofia.

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