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The New Designed Mechanical Systems and Protypes for Z-Scan and Nonlinear Measurements

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Abstract: In this study is explained a new mechanical design for z-scanning and nonlinear measurements. Three systems are designed for measurements. The last system has better constructions and design parameters than the other systems designed in 2005 and 2014. The last system has been manufactured from various shafts, roller bearings, mechanical holders, mechanical rails and carrier integrated in these systems and stainless steel mechanical double joint coupling for reducing the workload of the main system and the aluminium alloys used in the system are 6063 and 7075. The z-scan measurement technique is often used for measuring the strength of the magnitude of the nonlinear index n2 of an optical material. Essentially, a sample of the material under investigation is moved through the focus of a laser beam, and the beam radius (or the on-axis intensity) is measured at some point behind the focus as a function of the sample position. These quantities are affected by the self-focusing effect. Various materials in nonlinear optics (liquids, organic structures, semiconductors, thin films…) the nonlinear optical properties used for definning one of the methods the z-scanning techniques for new designed mechanical system is described. The obtained parameters within the measurement will be more accurate and reliable with new designed mechanical system. The system brought into the active mode upon the completion of its design is closed-loop mechanical checking system. It is a control mechanism capable of moving according to the desired display values. Being very important in the industrial and vocational applications, the number of cycles, the speed, direction control of the engine can be done in this system the design of which has been completed. The present academic study in intended to introduce the design and control mechanism of the system and its place in the vocational and technical applications.

Keywords: Mechanical design, Mechanical engineering, Engineering applications, Measurement techniques, protypes.

Introduction

In this study, servo control can be provided at the level of micro signals. It provides great convenience to users in stages such as instant access and intervention to many information, fault detection and commissioning. The system, whose design has been completed and activated, is a closed-loop electromechanical control system. It is a control mechanism that acts according to the desired indicator values. Which is very important in industrial and professional applications; The revolution number, speed and direction control of the servo motor can be done in this system whose design has been completed. In the content of this study; The design of the system, its control mechanism and its importance in professional and technical applications will be explained in detail.

This study is intended to bring together universal 20x20 mm stainless steel mechanical double joint coupling (coupling) used to lower the work load of servo motor, various shafts, mechanical rails and carrier, mini ball bearings, Siemens Simatic S71200, which is a new-generation PLC system, and Siemens AC 1FL6042, 0.4 kW servo motor compatible with this system as well as a variety of mechanical appurtenances; it is also intended to drive a new opto-mechanical system, to control the system with Siemens 6SL3210 Sinamics V-90 servo driver

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and to integrate the whole system by using a compatible software with the help of a computer from a single control panel.

The main automation units of the newly designed system; Siemens 6SL3210-5FE10-8UA0 Sinamics V-90 servo motor driver is from Siemens Simatic S71200 CPU1212C PLC, Siemens Simotics S-1F6 series; 1FL6042-1AF61-0AA1 consists of 0.4 kW, servo motor AC (Artkin, 2016; Artkin, 2017).

Figure 1. System components, automation units used in the system; V-90 Servo Driver, S71200 PLC, S-1F6 1FL6042 0.4 Kw Servo Motor.

Z Scan and Non-linear Measurements

The z-scan measurement technique is often applied to size the Kerr nonlinearity's strength (i.e. the magnitude of the nonlinear index n_2) of an optical material. Essentially, a sample of the material under investigation is moved along the laser beam's focus, and the beam radius (or the on-axis intensity) is measured at some point by keeping behind of the focal area to show the function position of sample (Artkin, 2014).

These quantities are affected by the self-focusing effect. If the nonlinear index is positive, and the sample is placed behind the focus (as in Figure 2), self-focusing reduces the beam divergence and thus increases the detector signal. If the sample is put on the left-hand focal point's side, the focus shifts to the left, and the stronger divergence after the focus decreases the detector signal. From the measured dependence of the detector signal on the sample position, the nonlinear index' magnitude can be calculated (E. Van Stryland et. al., 1993).

The refractive index *n* of nonlinear materials depends on the intensity of light *I*:

$$n = n_0 + n_2 I \qquad (1)$$

where n_2, the nonlinear refraction coefficient, is in proportion with the original part of third order nonlinear sensivity Re $\{\chi^{(3)}\}$. One of the effects of a Third order nonlinearity is so called self-refraction. For the laser beam propagating through a nonlinear material the density of energy in the beam cross-section is altering and the refractive index is changing too. Depending on the nonlinearity the change of refractive index Δn can be positive or negative (Sheik Bahae et. al., 1990; Geoffrey, 2011).

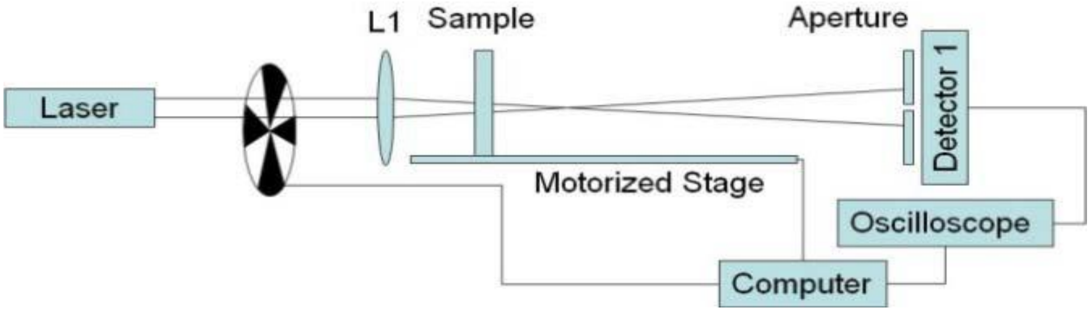


Figure 2. Setup for Z-scan measurements and experimental Z-scan setup units.

If Δn > 0 the plane wavefront becomes concave along direction of generation while the beam is concentrated on to the axis. This effect is referred to self-focusing if Δn < 0 the plane wavefront gets convex or the beam gets defocused. Because of diffraction effects a periodic focusing of beam propagating in a nonlinear medium is observed (Sheik-Bahae et.al.,1989). The path length of beam in the medium in which the beam is concentrated is referred to self-focusing length. The self-refraction effect sets basis of one of methods for measurement of cubic nonlinearity of materials -Z-scan method. The sample of thickness L scans the focused light beam alongside the direction of generation and the transmittance as the sample relative' a functional position to the focal plane is measured by a detector with an aperture of radius a in front of it (Artkin, 2014; Artkin, 2017) .

Linear Motion – Leadscrew / Ballscrew Drive

In evaluating a screw drive all of the following must be considered: Screw Inertia (*JS*): This can be determined using the inertia formula for a cylinder. Quite often, for a high pitch screw made of steel, the screw inertia is much larger than the reflected load inertia and the reflected load inertia can be ignored for initial calculations.

Friction Force (*FF*): This is the opposing force composed by the friction between the load and the load bearing surface. Do not confuse the coefficient of friction (μ) with the screw efficiency (*e*).

Nut Preload (*TP*): To eliminate backlash, the drive nut, through which the screw rotates, is sometimes preloaded. This preload composes an additional torque load on the motor.

When performing screw calculations do not confuse the screw pitch (*PS*) which has the units of rev/cm with the screw lead (*LS*) which has the units of cm/rev (See Figure 3).

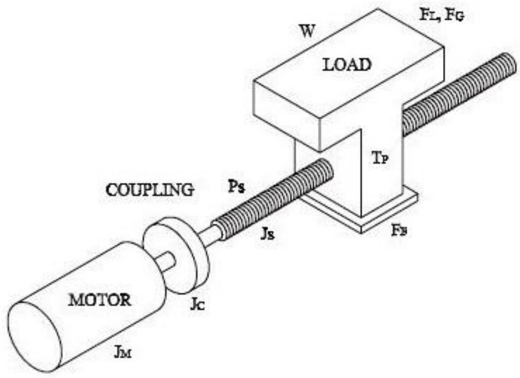


Figure 3. Linear motion; ballscrew drive and system components.

System Data: J_M = motor inertia (g cm s2), J_C = coupling inertia (g cm s2), W = load weight (g), T_P = preload torque (g cm), F_L = load force (g), F_G = gravity force = W (g), F_F = friction force = μW (g), J_S = screw inertia (g cm s^2), T_B = bearing torque (g cm), P_S = screw pitch (rev/cm), e = screw efficiency,μ = friction coefficient can be explained as.

Motion: Position: $\theta_M = (2\pi\ P_S)(S)$ (rad), Velocity: $\theta'_M = (2\pi\ P_S)(S')$(rad s^{-1}), Acc/Dec: $\theta''_M = (2\pi\ P_S)(S'')$ (rad s^{-2}) can be calculated as (Moritz Frederick G., 2014).

Prototypes

Mechanical parts of the last system; 2 x 800 mm long slide rail linear motion units support shaft diameter Ø2, 150×150 mm sized manufactured with aged aluminum in black color, 2 pcs trapezoidal shafts 800 mm long Chrome plated (0.2-0.33 µm), 1 main shaft 800 mm It is integrated with a 20x20 mm stainless steel mechanical bidirectional coupling coupling with 2 mm pitch in length. Al alloys (alloys) used in the system are 6063 and 7075. All mechanical parts are covered with black static paint because of this; high power laser measurements are color sensitive. The color factor directly affects the optical measurement values. For this reason; All mechanical parts are painted black for more accurate optical measurements. The entire weight of the mechanical system, including the servo motor, is 16.65 kg (Artkin, 2017).

Figure 4. The image of the system in the manufacturing lab. in Hereke V.S. after the assembly is completed.

Prototype 001-2005

The first system produced belongs to 2005. The opto-mechanical system, in which the measurements are taken, consists of the scanner, stepper motor and the mechanical parts that connect them, connected by shafts and bearings. Such assemblies include apparatuses of various types and sizes that are vital in the field of optics.

Opto-mechanical mechanism equipments can be manufactured by various companies, these mechanisms can be used according to their intended use; it is produced in different grades, it is quite expensive to buy directly; The experimental setup we used in the experiment is a completely original system; It is a system that is different from all systems with similar dimensions and connection mechanism. The technical drawings of the opto-mechanical system used in the experimental setup are shown below.

This system can also be used for academic studies, especially in the z-scan experimental setup, which is an experimental application of non-linear optics that enables measurements that require precise position change in optics. Precise position change for this system can be realized thanks to the designed mechanical design.

Motion Basics and Standards is first important parameter for mechanical systems. The function of a stage is to constrain motion to a desired direction. For a linear stage, the desired motion is along an ideal straight line. Prototypes 001-2005 system in total weighs 8,5 kg. Scanning distance of Prototype 001-2005 is 379 mm. and movement resolution of 001-2005 is 2.11×10^{-3} mm.

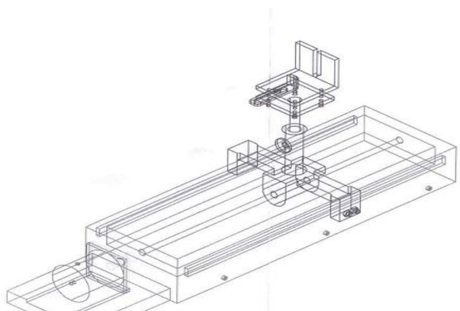


Figure 5. Three Dimensional Technical drawing for the opto-mechanical system designed in 2005, isometric view of the system

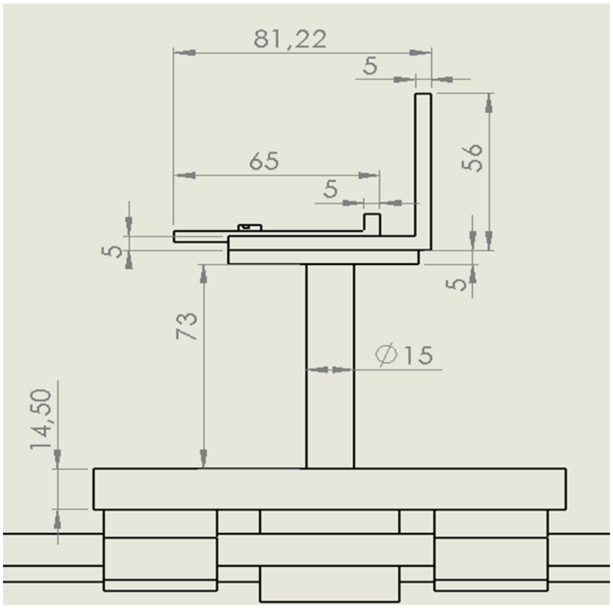
Figure 6. Prototype 001-2005 photos from different angles in optical measuremet lab in Gebze Technical University in 2005.

Prototype 002-2014

The system designed in 2014 is as follows. As seen in the technical design; The optical holder is designed for inspecting liquid and transparent materials. The scan distance for the material to be tested is a net 266 mm. The motion resolution for each signal of the system is 1.42×10^{-3} mm. This system includes roller bearings, shafts, aluminum alloy parts, plastic holders and rolling bearings.

As it was seen in technical design; it has been designed for examining optical holder, for liquid and transparent materials. Repeatability is the tolerance to which the controlled mechanical system can be repeatedly positioned to the same point in its travel. Repeatability is generally less than system resolution, but somewhat better than system accuracy. Linear systems are available with resolutions measured in microns (Artkin, 2014).

The 2D and 3D images of the opto-mechanical system, originally designed using solid Works for the 'Z-Scan test apparatus', are as follows. The cost of the system with the optical holder is around 300 Euros, market prices for similar systems vary between 1600 Euros and 3000 Euros.



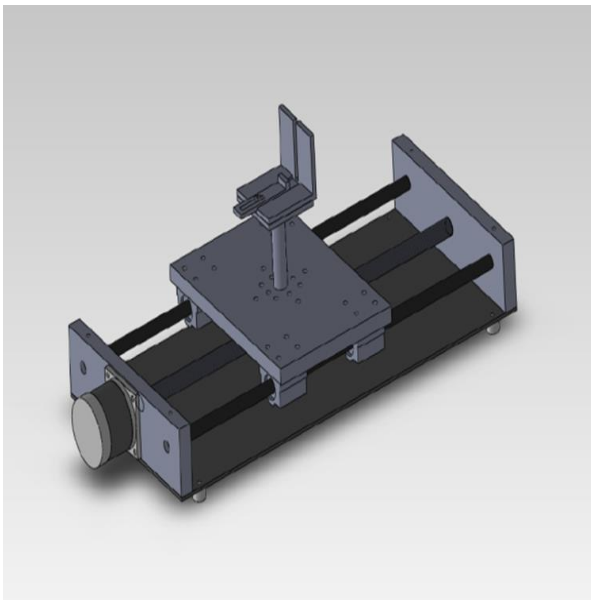


Figure 7. Solid Works isometric picture of opto-mechanical system with optical holder designed in 2014, on the right, detailed dimensioned technical drawing side view of optical holder specially designed for the system and some photos of the Opto-mechanical system designed in 2014.

Table 1. Comparison of some parameters for the designed prototypes of opto-mechanical systems.

Designed Opto-mechanical Systems for Z-Scanning	Weight (kg)	Scanning Distance (mm)	MovementResolution (mm)
The Last System	16.65	650	1.21×10^{-3}
Prototype 002-2014	4.2	266	1.42×10^{-3}
Prototypes 001-2005	8.5	379	2.11×10^{-3}

Result and Conclusion

This system, which includes servo motor and automation units, some of which mechanical parts are processed with CNC Lathe and Universal Milling located in Hereke Asim Kocabiyik Vocational School manufacturing laboratory, is a successful vocational technical application; At the same time, it can be used successfully to determine the optical properties of some materials with precise position control. The designed system is a unique system. High-end applications of this system can be used in Furniture, decoration benches, CNC Router benches (z), mini CNC router (y) workbench, Polyfram cutting machines and similar systems.

All kinds of operations in machinery and automation systems are provided with repetitive circular and linear movements. Whatever the procedure is, it must be in an axial guide and bedding so that the renewed movement can be deployed in a healthy and stable manner. In all kinds of loading and speed applications, there should be no wear in order to maintain the bedding precision and tolerance values. For this reason, the bearing elements must be made of hardened and ground special steel. The bearing surfaces are covered with a felt shield and protective bellows for lubrication purposes, providing long-lasting working quality. Linear motion systems should be designed in accordance with the desired working environments and the loads to be applied. Moment and drive alternatives required in axial movements should be created according to the units they are used in, bedding elements mounted on specially designed aluminum profile bodies are both practical and do not burden the system with unnecessary weights. The channel structures on the existing sections enable all kinds of additional parts to be connected to the process and facilitate adjustment. In linear motion systems, it is possible to control axial coordinate movements according to the desired process by integrating different motors. These systems can offer axial solutions within multi-option classes.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the author.

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