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MICRO AND NANO MECHONICS POSITIONING STAGES

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Abstract: The paper presents the results obtained by the research department of mechOnics a.g. in the domain of the piezoelectric micro and nano-positioning equipment. The 1D, 2D and 3D translation stages developed by mechOnics a.g. are presented and their characteristics are provided, in a comparative way. The driving engines, the measuring sensors and the control possibilities are also given. The study is completed with some custom-like equipment produced, especially designed and adapted for particular applications: rotary stages, ultra-low temperatures translation stages.

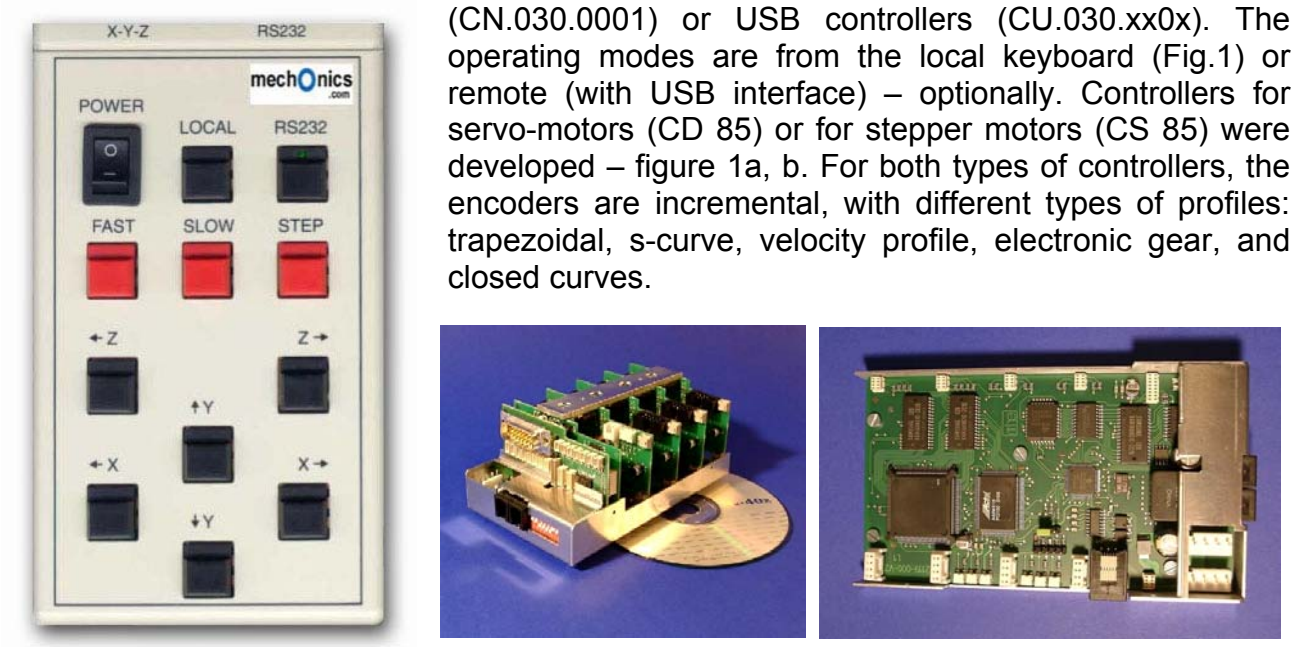
1. Introduction

There are many companies that produce good quality positioning equipments [2], for a variety of requests [1]. In order to answer to the most demanding options, the R&D Department of the mechOnics ag developed, too, a series of piezoelectric micro- and nano-positioners, some of them of general purposes, others with special, increased quality specifications [3]. The philosophy of the company stood for the designing and the manufacturing of the entire positioning system, from the x, xy or xyz stages, to the controllers and to the positioning sensors.

In this paper, a brief overview of the advances made in this kind of equipment will be presented, on the main modules of the positioning systems.

2. Motor controllers

The micro-positioners are driven by hand-held (CN.030.0001) or USB controllers (CU.030.xx0x). The operating modes are from the local keyboard (Fig.1) or remote (with USB interface) – optionally. Controllers for servo-motors (CD 85) or for stepper motors (CS 85) were developed – figure 1a, b. For both types of controllers, the encoders are incremental, with different types of profiles: trapezoidal, s-curve, velocity profile, electronic gear, and closed curves.



a) *b)* *c)*

Fig.1. Motor controllers: a) CN 30 command keyboard; b) CD 85; c) CS85 controller

In figure 2, the USB controllers for piezo-electric inertial drives are presented. They can be used without sensor or in closed loop for one axis (Fig.2a) or (up to) 3 axis (Fig.2b).

a) *b)*

Fig.2. Piezo controllers: a) CU 30 – USB-driven; b) CU 30 CL – closed loop

Each of these devices can control up to 4 motors and allows for the acceleration and velocity change during motion, with user-friendly and self-instructional commands. The monitoring functions are window selectable for the error limit and for the position errors. A comparator function, as well as the simultaneous tracing of different parameters during the motion are possible.

The suitable softwares to be used for PC are: DOS, Win 95, Win 2000, Win XP and Win NT. Specialized programs may be written in Borland Pascal or in DLL for Windows; in DLL for LabView, they are in preparation.

3. Micropositioners

In figure 3, two of the micro positioning stages for uni-dimensional (1D) displacements are presented. In table 1, the functioning, characteristic parameters of three xyz devices, obtained as a combination of the 1D devices, are compared.

Regardless of their type, each of these devices has some common, essential working features, such as: a) low hysteresis of the piezo-driven step motor; b) they hold reached position without current; c) positioning accuracy better than 50 nm; d) guidance accuracy (without load) for 8mm travel: yaw angle < 20 arc sec, pitch aangle <60 arc sec, vertical/lateral deviation < 1/2µm; e) customized designs possible; f) vacuum preparation optionally (to 10^{-6} or 10^{-9} mbar); g) no limit switches necessary; h) open or closed-loop application.

a) *b)*

Fig.3. Set of mechOnics 1D micropositioners: a) MS 30; b) MS 38

mechOnics miniature translation stages *Table 1*

Type / Parameter	MS 30			For ultra low temperatures ML 17	xyz positioners MX 25	
Travel [mm]	8	18	30 (max. 48)	5	2 in xyz	10 in xyz
Maximum velocity	2			1.5	2	
Mass [g]	32	38	54	25	46	76
Torque M_x, M_y, M_z [Nm]	0.5			M_x 3.0 M_t, M_z 1.5	0.15	
Force F_x [N]	4.5 – blocking force			4.5	< 2	
Forces F_y, F_z [N]	30			5	F_y < 2 F_z > 3	
Resolution [nm] (calculated)	Double step[1]:		400			
	Single step[2]:		200	200	200	
	Half step[1]:		100	-	100	
	1/16 step[2]:		15	15	15	
Remarks	CNC-machined aluminum body; Precision ball bearings guides			CNC-machined steel body; Precision linear bearings	CNC-machined aluminum body	

[1] with CN 30 controller; [2] with CU 30 controller

a) *b)* *c)*

Fig.4. Set of mechOnics 3D (xyz) micropositioners:
a) MS 30; b) ML 17 – for low temperatures; c) MX 25

Using the uni-dimensional stages, bi- and tri-dimensional stages are obtained. In figure 4, three of the micro-positioning tables for tri-dimensional, xyz displacements, are represented, where the xyz combination of ML 17 is a 3D micro-positioner for ultra-low temperatures (~ 4 K).

Several solutions for special laboratory applications were developed, in order to meet high-performance specifications: advanced vacuum or / and low temperatures (~4K).

Due to the required applications, besides the translation stages, kinematical mirror or prism tilting stages with piezoelectric inertial drives were developed (Fig.5) – characteristics in Table 2.

MT 25 Tilting Stage – characteristic parameters *Table 2*

Angular adjustment	Max. velocity	Optical height	Mirror mount	Free opening	Mass	Resolution (calculated) [µrad]		
						1/16 step [1)]	Half step [2)]	Single step [1)]
(6 ± 3)°	25 mrad/s	11.5 mm (on rod); 12.5 mm (in plate)	Diameter ½inch	Diameter 9 mm	46 g	~ 1	~ 7	~ 14

[1)] with CU 30 controller; [2)] with CN 30 controller

4. Position sensors

The miniature translation stages are equipped with linear measuring systems (Fig.5), with measuring lengths of 8; 18; 30 mm (Table 1) and resolutions of 1; 0.5; 0.1; 0.05 µm (which means, from standard to excellence). The linear expansion coefficient achieved is 23.8×10^{-6} grd^{-1} (operating temperature 0 -55 C), with an accuracy class of ±1µm/m.

In figure 6, an xyz micro-positioner of MS 30 (up to 48 mm travel) with PS 30 positioning sensors is presented (standard resolution 1µm; on request, better than 50nm).

Fig.5. MT 25 kinematical mirror tilting stage

Fig.6. xyz module with MS 30 and PS 30

5. Applications

Some applications were selectively chosen and they are presented in figures 7-10:

- xyz module (MS 30 and PS 30) with CU 30 CL piezo controller (Fig. 7);
- linear positioner for an aperture with 7 mm travel in the x direction; 1 mm travel in the y direction; positioning accuracy better than 1 μm; vacuum preparation for 10^{-6} mbar; non-magnetic materials (Fig.8);
- miniature monomode coupler MK25 with piezoelectric inertial motor with low hysteresis that holds reached position without current; it is provided with two types aspherical lenses with different NA (aperture numbers), around 0.40, depending of the ; 2 mm travel in xyz with a step width of 200 nm (single step) and a minimum 1/16 step of 15 nm; positioning accuracy better than 100 nm; velocity up to 0.5 mm/s;
- xyz positioner for ultra low temperature microscope with 3 mm travel in xyz; 250 step width; working temperature 4.2K; vacuum preparation (10^{-6} mbar) – figure 10;
- z positioner for low temperature (Fig.11).

A **fully operational mechOnics positioning equipment** (the first one in Romania, so far) is installed in the Mechanism and Mechanical Systems Laboratory of the Faculty of Engineering of the Aurel Vlaicu University of Arad. The system, property of the SC Tehnica SRL Arad, consist of the following **modules**: a) linear stages MS 30, 8mm travel and MS 30, 17.5mm travel (these two can be used together, one for x, the other one for y-displacements); b) xyz stage MS 25; c) mirror tilting stage MT 25; d) CN 30 handheld piezocontroller – figure 12.

Fig.7. CU 30 CL piezo-controller with xyz module with MS 30 and PS 30 (xyz stage)

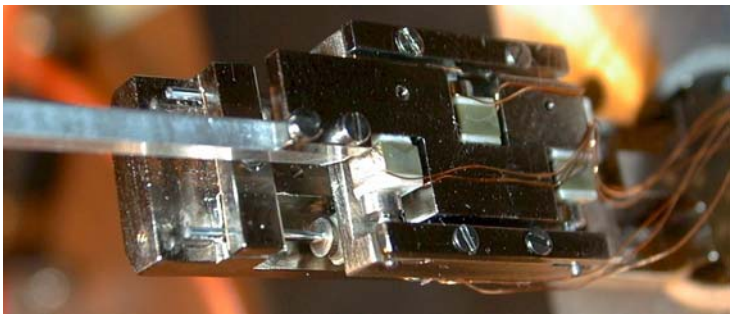


Fig.8. Motorized aperture for REM

Fig.9. Monomode coupler MK25

Fig.10. xyz positioner for low temperature

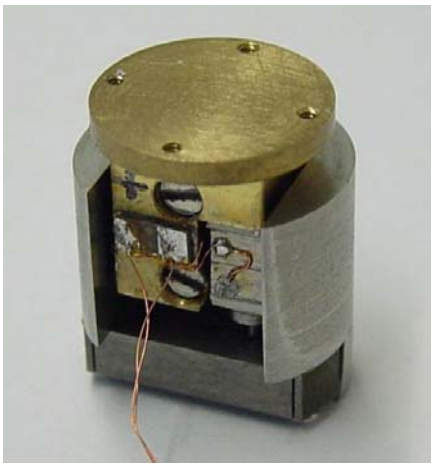


Fig.11. z-positioner for low temperature

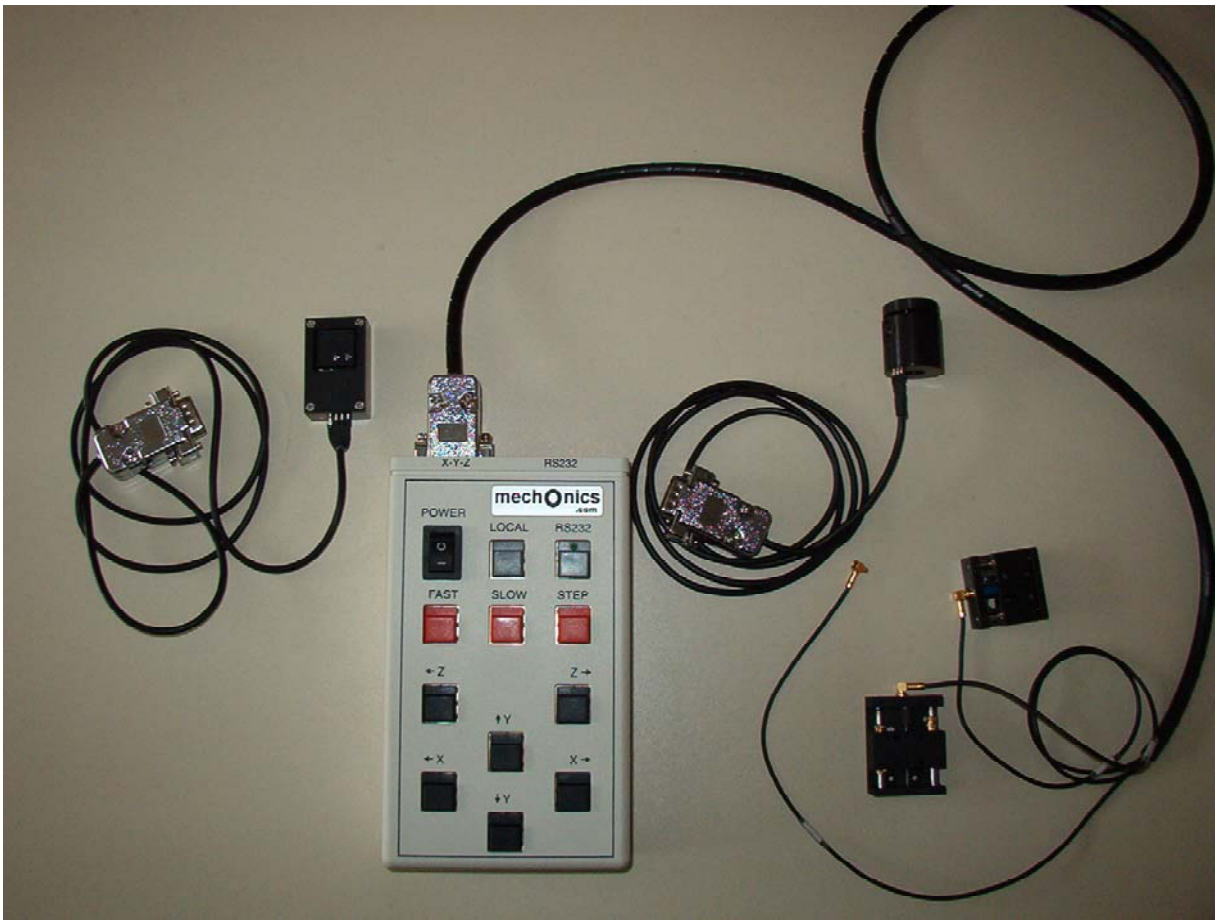


Fig.12. mechOnics positioning equipment
in the Mechanism Laboratory of the Aurel Vlaicu University of Arad

6. Conclusions

In a comparative look with similar items, the mechOnics positioning equipment prove to have an excellent quality-cost balance. They demonstrated that the specialized profile of a small, yet dynamic company focused on but one type of mechatronics systems,

allows for the development of on-request equipment, specially designed and manufactured to meet the most sophisticated demands. An R&D that places the need of a specific, well-defined scientific or technical application, proved to be the best approach. Various application domains are of high interest for the equipment developed, as presented in the examples in this paper: in micro/nano technology, bio-technology, microscopy, quality control, metrology.

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