––––Design of Parallel Kinematics with Extremely Small Hyteresis Effects for High Repeatability

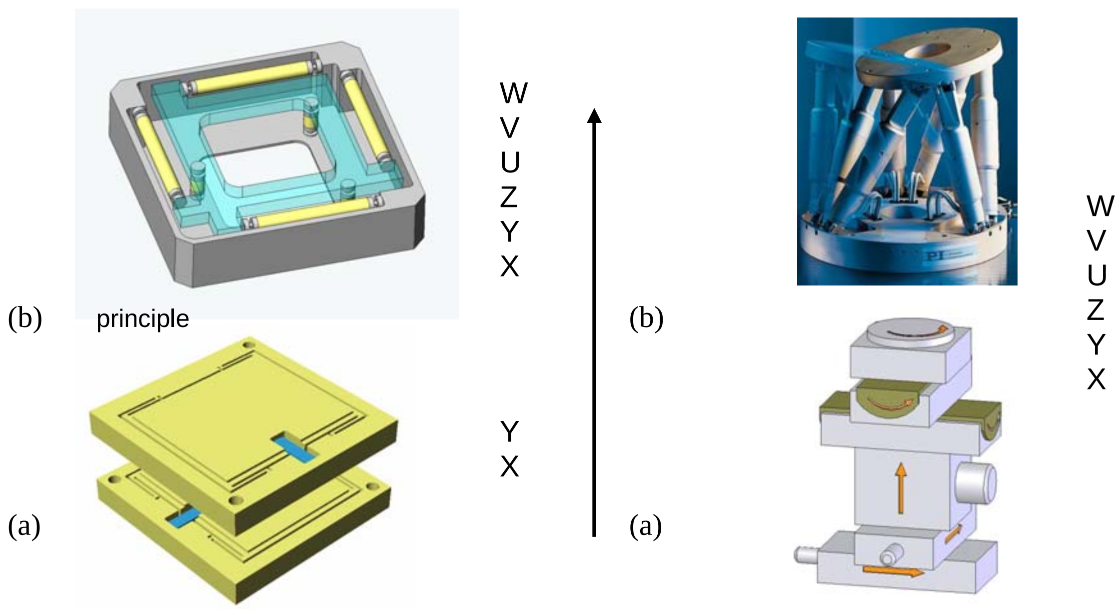
Dr.Rainer Gloess, Physik Instrumente (PI) GmbH & Co.KG, Germany

Ultra-high precision parallel-kinematics structures are used for micro- and nanopositioning applications from surgery to scanning microscopy, fiber alignment, precision machining and micro-handling.

Advantage of PKS

Before Physik Instrumente (PI) started designing submicron precision hexapods more than a decade ago, PI designers had already experience with different parallel-kinematics structures for sub-nanometer precision applications.

Systems like these are used for example in ultra-high-resolution scanning microscopy and in semiconductor mask alignment and metrology applications, where sub-nanometer resolution and sub-millisecond response times are required.



Piezo Nanopositioning Stage Designs ***Motorized System Design***

Fig.1: *Serial (a) vs. parallel (b) PZT-stage and PKS design*

	Piezo Flexure Stage (Nanopositioning Systems)	Motorized Hexapods (Micropositioning Systems)
Actuator resolution	0.000 01 [µm]	0.1 [µm]
Range	10.. 500 [µm]	15..100 *10^3 [µm]
Sensor	7 sensors , stationary (parallel metrology)	6 sensors one per strut
Joints	EDM-cut flexure	Ball or needle bearings Preloaded wire flexures
Power dissipation	Close to zero for static position control, Passive sensor probe & target	Small: Motor power Sensors power

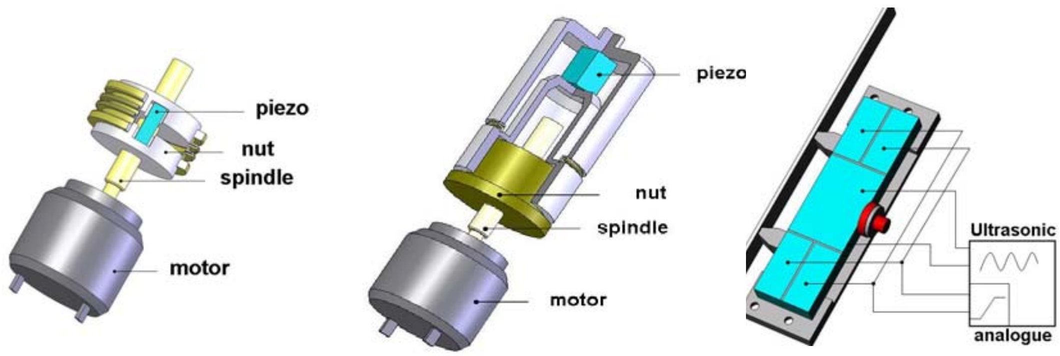
The main difference between the two PKS structures is based on the travel range. For small motion, several microns to several hundreds micron, linear piezo actuators combined with stationary capacitive sensors can be used. The position sensors (not shown) directly measure the common moving centre and indicate the slightest off-axis motion to the controller, which compensates in real time. Another advantage is active trajectory control on a sub-nanometer scale, which is possible when the sensors used in a parallel motion- metrology configuration.

In high-speed nanopositioning applications, one advantage of the parallel-kinematics approach over the stacked or nested serial kinematics systems is the ultra-low inertia resulting in higher resonant frequencies, faster step response and higher scanning rates.

For travel range over 1mm, no stationary 6-DOF sensor with nanometer resolution rae currently commercially available. Therefore the sensors should be designed into the struts (or each drive – for systems witch constant strut length). The system performance will be determined by the precision of the joints, the cable outlet and the power dissipation near the mechanics.
One of the most important features for high accuracy and repeatability is a structure with non-moving cables (no friction).

Hybrid Systems
Hybrid systems consist on the combination of both:

- piezo actuators for extremely fast response and high accuracy and
- motorized drives for long travel range.



(a) Nut with piezo (b) strut with piezo (c) ultrasonic drive with analogue mode

Fig.2: *Hybrid systems (principle)*

We have designed hybrid 3-DOF systems with ultrasonic piezo motor drives for high-speed, long travel motion in combination with piezo actuator driven nanopositioning stages. For the highes over all accuracy, there only should one sensor in the system and based on the sensor input, the controller must decide if the long range or short range actuator needs to be energized.
Promissing solutions for hybrid actuators are the combination of
- Spindle/nut or ultrasonic piezo drives & PZT linear actuators in the strut
- Spindle/ nut & PZT linear actuators in the nut (stack or tube)
- Piezo ultrasonic drives with additional analogue mode

3-DOF Ball Sensor
The sensor uses an optical beam principle to measure the surface contour of a precision ball (d=9mm). This sensor was designed for the measurement of the tool-center-point stability. This sensor is the basic element for a new calibration method. The new method is designated to calibrate systems in a range better than 1µm.

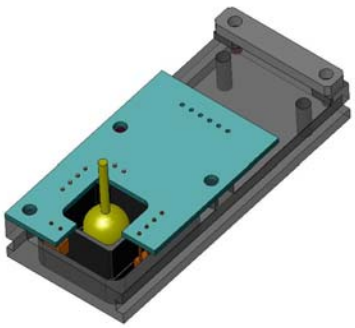


Fig. 3: *3-DOF Ball Sensor*

Parameter

Resolution		0.1µm
Range	x, y, z	300µm
Digital sensor interface		

Reference: S.Vorndran: http://www.parallemic.org/Reviews/Review012.html