PI

Piezo · Nano · Positioning
news

Issue 37

OCT: Piezo Motors in Medical Design

Ultrasonic piezo linear drives—new application in non-invasive medical technology

Piezo technology enables fast, compact, high-resolution OCT scanner

In addition to the classic, invasive, punch biopsy technique, there are a number of only partially satisfactory non-invasive procedures in clinical and cosmetic research for properly categorizing skin changes. Those based on ultrasound do not provide good resolution, and confocal microscopy cannot penetrate sufficiently below the epidermis. Now, however, there is a practical alternative: the new SkinDex scanner – developed by ISIS Optronics in Mannheim, Germany – combines the advantages of ultrasound and confocal microscopy.

Continued on page 2

In medical engineering, modern PILine® ultrasonic piezo motor drives are opening up applications which were impossible using classic electric motor leadscrew systems. Due to the piezoelectric effect and the direct creation of linear motion, PILine® drives are not only faster, lighter and more compact than conventional motorized drives, but they can also be made non-magnetic. They achieve resolutions of 20 nm (0.02 µm) and velocities of up to 1 m/s. Their travel range is basically unlimited, and they are available in a number of different integration levels to match the desired (OEM) application. Medical engineering provides an up-to-date example.

Contents:

Continued from page 1

The SkinDex scanner is based on the technology of optical coherence tomography (OCT) and examines the tissue on and under the skin surface non-invasively. The results obtained are extraordinary. The information contained in the 2-D and 3-D sectional images is comparable to that of a histological examination.

OCT uses the basic transparency of skin together with the interference fringes obtainable with white light. The optical paths are made up of optical fibers.

Exact positioning for precise results

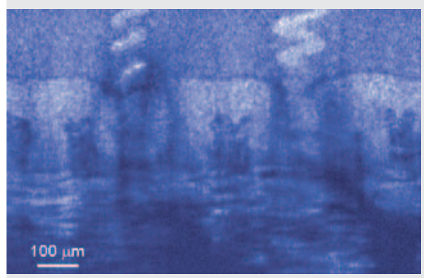
To enable creation of 2- and 3-dimensional images from interference patterns, the optical fibers must be moved both axially and laterally during the scan. This task requires positioners capable of the highest precision. Ultimately, it is the performance of the drives which determine the system resolution and hence the quality of the images.

A PILine® P-661 OEM motor is used to position the reference-arm mirror (depth parameter). This motor was chosen primarily because of its compact design and, considering its size, its high force capacity of 2 newtons (0.5 lbf). Total travel is 2 mm, the position resolution in this application 30 nm (0.03 µm, 1.18 micro-inch).

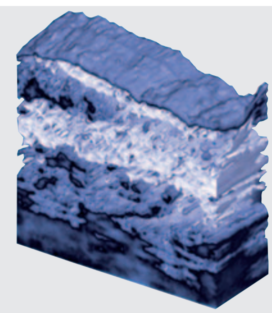
As the images are recorded sequentially, the high speed and excellent dynamic response of the drive is a great advantage. As a result, the SkinDex needs only a few seconds to generate its highly informative images. The lateral motions of the optical fibers in the sensing arm executing the surface scan are also performed by a PI drive.

In this case it is a PIHera® P-622.2CD, a flexure-guided, 2-axis, piezo nanopositioning system, which provides a resolution of 1 nm (0.001 µm, 0.04 µ-inch) and covers an area of 250 x 250 µm. Piezo-motor drives have thus again contributed to an innovation from which many people will benefit in the future.

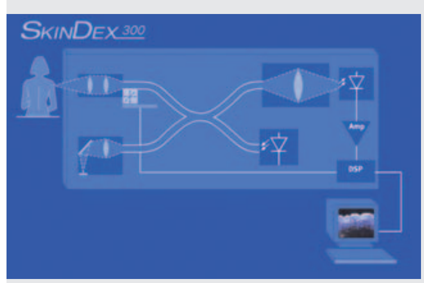
The SkinDex scanner based on OCT technology for non-invasive but reliable examination of the tissue on and under the skin surface (photo ISIS Optronics).



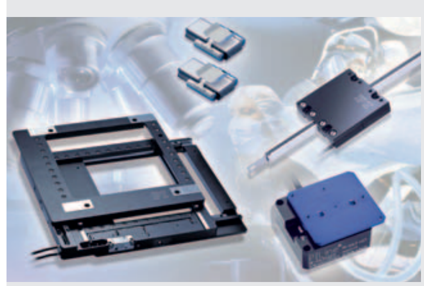
A look under the skin of the ball of the thumb. Even the untrained eye can recognize the spiral-shaped sweat-gland ducts.



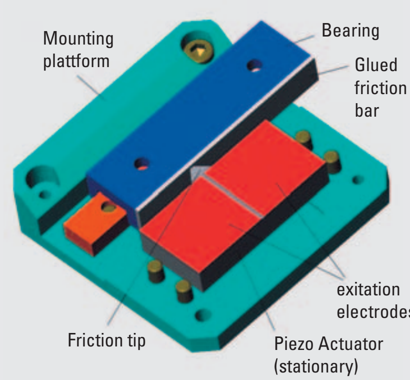
3-D OCT image: Individual laminar and cylindrical structures such as larger blood vessels are visible under the rough skin surface.



White-light interferometry is the basis of OCT. Using optical fibers, light is divided into a sensing and a reference beam. After being reflected by the target (i.e., a cutaneous structure) and the reference mirror respectively, the beams are recombined and enter the detector. An interference signal pattern results (photo: ISIS Optronics).



Integration levels in PILine® ultrasonic piezo motor technology: from 8-mm drives, through the successful Rod-Drive linear drive, to integrated multi-axis systems.



Working principle of an ultrasonic piezo motor drive.

Actuators for Micro Pumps & Valves

Precision Dosing of Small Volumes

Variety of piezoactuators and lever-amplified systems

Miniaturized Technology

Displacement pumps are used worldwide in many diverse branches of industry. Increasing miniaturization means the market for their smaller "relatives" is also growing: Microdispensers take on distribution and dosing tasks where small volumes in the milliliter or microliter range have to be controlled

Wide Range of Applications for Promising Technology

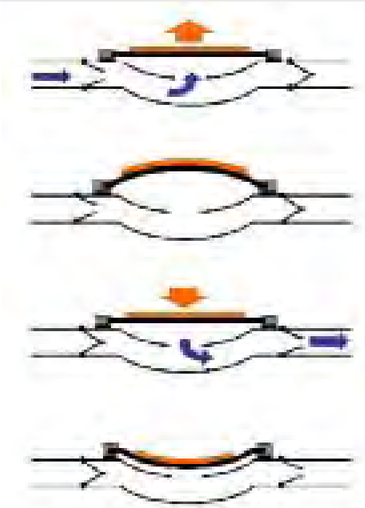
In laboratory and medical engineering, biotechnology or chemical analysis, tiny dispensers accurately dose active substances or medicines. Micropumps take care of the removal of reaction gases in closed processes. Industrial machines benefit from the possibility of using micro-valves to apply lubricants such as oils or grease in a decentralized way at the point where they are required – in an economical, precise and automated way.

Piezo is the Driving Force

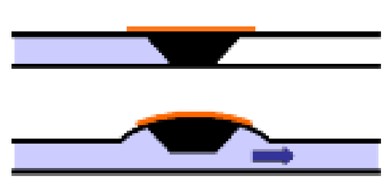
The design is based on the familiar principles of diaphragm pumps and valves and also makes use of the peristaltic principle. The miniaturized drives are based on piezoelectric actuators in various shapes and degrees of integration.

Adapted for Precision & Force

The properties of the pump media – viscosity and drop size, for example – determine the different forces which have to be applied and hence the size of the piezo actuator used. The piezo displacement is a variable parameter which controls the dosing volume. With micropumps, the frequency also determines the flow rate that can be achieved.



Micro-diaphragm pumps operate in a similar way to piston pumps, but the medium to be transported is separated from the drive by a diaphragm. Passive inlet and outlet valves control the pumping direction. Piezo elements in disk form which are mounted directly onto a metal disk make ideal drive systems for micro-diaphragm pumps: This drive solution occupies extremely little space, and the piezo displacement can be very finely adjusted, allowing the pumped volumes to be very precisely defined.

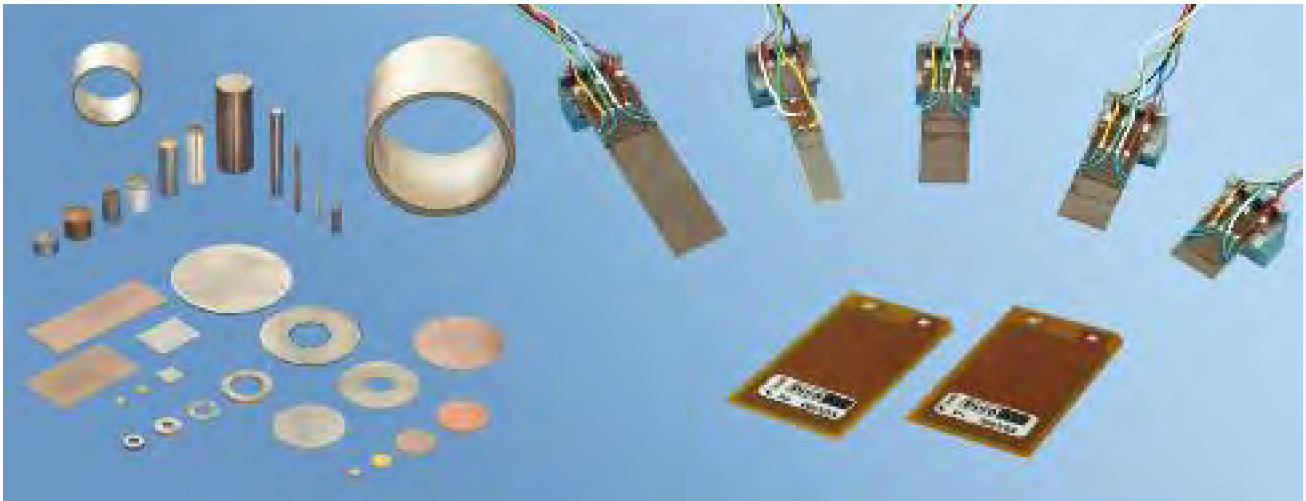


Working principle of a diaphragm valve. Usually, valve applications require higher forces than pumps.

The principle of peristaltic pumping makes directional valves obsolete; the pumping direction in this case is specified by the order in which the individual actuator elements are driven.

Piezo Advantage: Fast, Compact, Long Life

Piezoceramic Elements Drive Micropumps



PI offers a large selection of different piezoelectric components: disks, tubes, benders, patches...

Reliable and Fast

The special properties of the piezo ceramics permit flexible flow rates of a few tenths of a microliter to several hundred milliliters per minute at pumping frequencies up to the kilohertz range accompanied by high dosing accuracy. The switching times of a few microseconds are significantly faster than those of magnetic designs. The piezo drives have the power and stiffness values required to also work against pressures of up to tens of bars and are thus also suitable for use with more viscous media.

Piezo ceramics are fundamentally very simple to use and integrate; their compact size even makes them suitable for integration into so-called labs-on-a-chip.

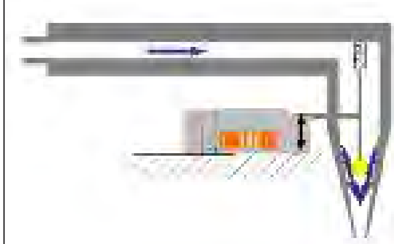
Variable Shapes, Different Forces

Simple piezo ceramic disks or rings are mounted onto a metal or silicon disk and, as the most compact bender element, thus control the opening or closing of diaphragm pumps or valves.

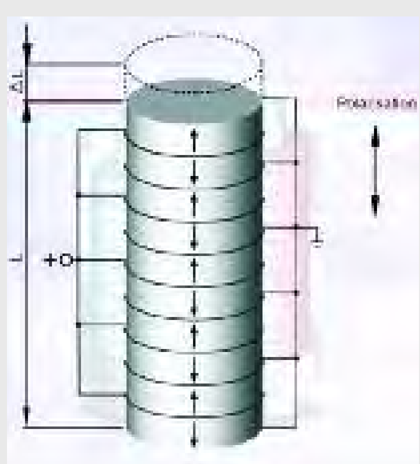
An alternative is to use piezo bender elements, which PI Ceramic can manufacture in almost all shapes and forms.

Small piezoelectric tubes have also been used for a long time for the drop-on-demand method as used in ink-jet-printing, for example. Piezo patches or, for greater forces, piezo stack actuators operate peristaltic pumps.

The corresponding drive electronics are compact and can even be used in portable instruments – for dosing medication, for example.



In micro-valves, particularly where viscous liquids are processed with higher pressures, translational actuators with and without prestress can be used. Where larger strokes of the valve tappet are required, the actuator stroke can be amplified by levers.



Piezo Actuators: Fast, Reliable and Easy to Integrate

Piezo actuators convert electrical energy directly into mechanical energy and vice versa. Travel ranges of up to one millimeter can typically be achieved with resolutions down to the nanometer range. High dynamics with frequencies of up to several kilohertz are also achievable. The movement is based on crystalline effects and so there are no rotating parts and no friction; piezo actuators are therefore maintenance-free and non-wearing and, because no lubrication is required, they are vacuum compatible. They can move large loads and have a very compact design.

Medical Engineering News: Driven by Piezo

Piezo elements from PI Ceramic. The broad spectrum of standard products is supplemented by custom engineered products, with the shortest-possible time-to-market

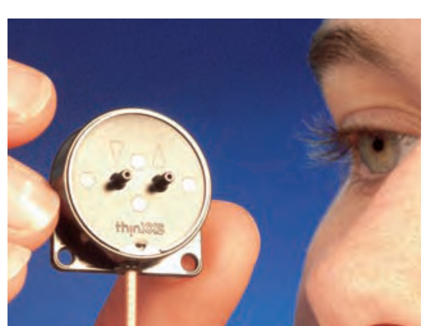
The continuing miniaturization in medical engineering places ever increasing demands on the components. Piezo drives are the solution for many motion control applications; the piezo effect efficiently generates fast and precise motion while requiring very little space.

Efficient Aerosol Generation with Piezo Elements

The treatment of respiratory diseases often involves medications being administered directly with atomizers. One method of atomization is to generate very fine droplets with the aid of ultrasonic piezo ceramics.

Specially shaped piezo disks excite a stainless steel diaphragm with several thousand holes to execute ultrasonic oscillations at more than 100 kilohertz: this produces particularly homogenous aerosols, allowing the medications to be dosed accurately and administered in a more targeted way.

An annular piezo disk serves as an ultrasonic transducer to produce the aerosol in the atomizer head of the eFlow® rapid Electronic Nebulizer series.
(source: Pari Pharma GmbH)



Custom piezo disks precisely dose liquids and gases in the ThinXXS micropump.
(source: thinXXS Microtechnology AG)

Moreover, the piezo technology reduces the time required to atomize medications by up to 50 % compared to conventional systems increasing the quality of life for patients with chronic diseases.

Piezo ceramics meet the special hygiene requirements in medical engineering; the aerosol generators can be sterilized at high temperatures, even in autoclaves. The ultrasonic operation is soundless for humans, and the low power consumption of the piezo components allows battery operation.

Piezoelectric Drives in Microfluidics

Piezo-driven microdispensers, i.e. micropumps and microvalves, can dose minute volumes down to the microliter range with very high accuracy. Disk-shaped piezo elements mounted directly onto a metal microdiaphragm provide the highly dynamic drive for precision miniature liquid or gas pumps. Due to the separation of drive and medium through the diaphragm, interference with the pumped media is completely avoided.

Lab-on-a-chip applications are made possible by the minute dimensions.

Othodontic Research: Hexapod Speeds up Biomechanical Test & Measurement

From Christoph Bourauel and Ludger Keilig–Department for Orthodontics at the Rheinischen Friedrich-Wilhelms-Universität, Bonn.

Dental biomechanics deals with the interactions between dental materials, treatment instruments or dentures and the reaction of teeth, biological tissues, etc. to mechanical stresses. A wide spectrum of force systems occur here with masticatory forces exerting loads to 380 N and torques to several Nm.

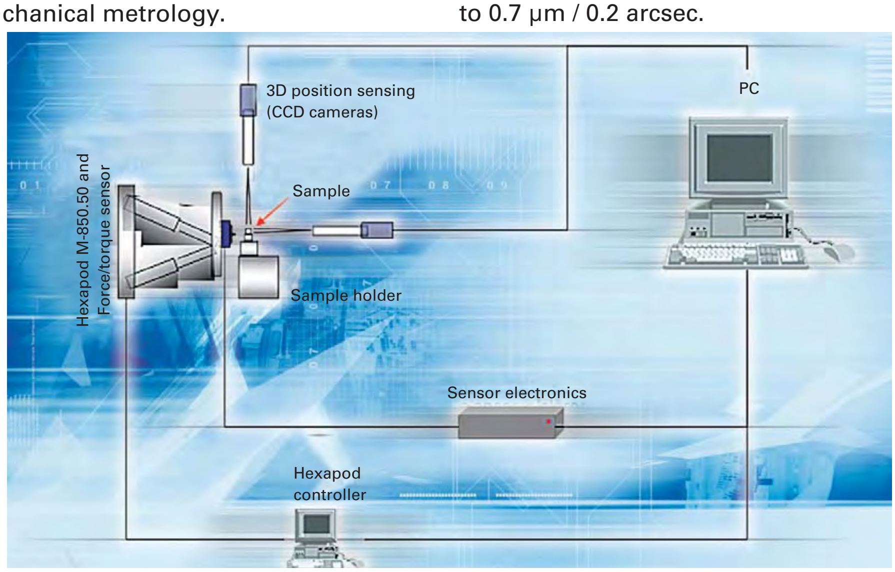
At the same time, movements of several orders of magnitude are involved: orthodontic equipment can change the position of teeth by up to several mm, whereas—during mastication—teeth are deflected by less than 100 µm and implants by as little as a few microns or less. These combinations of small forces with large deflections, on the one hand, and large forces and extremely small deflections on the other , represent a challenge with respect to the biomechanical metrology.

To deal with this challenge, the Dental Clinic of the University of Bonn designed the HexMeS (Hexapod Measuring System) based on the M-850.50 Hexapod. The ability to move in 6 degrees of freedom and the combination of small dimensions, very high stiffness and resolution of less than 1 µm (1 arcsec) were the key reasons for choosing the M-850 system.

HexMeS also features two 6-component force/torque sensors for the Hexapod with measuring ranges of 12 N (120 Nmm) and 130 N (10 Nm) respectively and an optical detection system equipped with 3 CCD cameras.

Because of its high stiffness (100 N/µm), sample deflections can usually be calculated directly from the Hexapod motion.

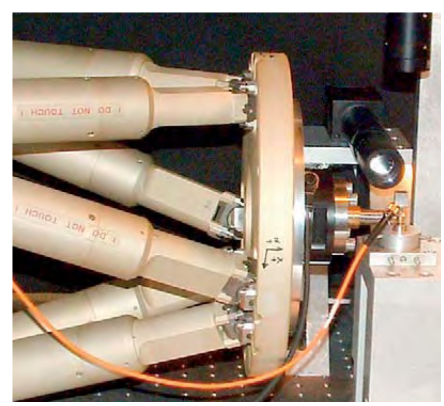
For high-load testing—simulations of mastication in the 100 N range—the optical portion of the HexMeS is used. It resolves sample deflections to 0.7 µm / 0.2 arcsec.



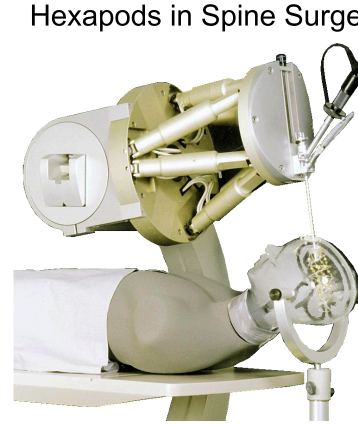
HexMeS block diagram.

The M-850-based HexMeS currently represents one of the most flexible measuring systems in the field of dental biomechanics. Its efficiency and the broad spectrum of its application have been demonstrated in a whole series of experimental investigations into dental implants, telescope crowns and orthodontic prostheses.

Load testing of a double crown.



Click here for Article on Hexapods in Spine Surgery



Piezo Dispenser Drive for Bio-Handling

PI is increasingly employing PILine® piezo ultrasonic drives in its positioning stages as an alternative to motor/leadscrew designs – particularly when the stages must be small and fast. They achieve positioning accuracies of up to 0.1 µm and speeds of up to several 100 mm/s.

Small and fast is not only a requirement in classical micropositioning technology, however. Piezo ultrasonic motors are also extremely well suited to applications where the accuracy requirements are not quite so demanding – in the range between 5 and 100 micrometers for example, which is usually sufficient for industrial automation and handling tasks.

PI has developed the low cost M-664KCEP dispenser drive with PILine® piezo ultrasonic motors for this kind of application. Eight or more of these drives stacked together can move pipettes vertically and independently of each other in order to dispense liquids into well plates. A single actuator is only 9 millimeters wide to match the standardized sample holder.

The M-664KCEP covers the travel range of 50 millimeters in less than 250 milliseconds and generates forces of up to 4 N. The resolution of the positioning sensor is matched to the application and amounts to 5 micrometers.

Stack of 8 M-664KCEP linear actuators, shown with well plate. The integrated ceramic piezomotor provides high speeds of more than 200 mm/sec.

Movement in Micropositioning Technology

Low Cost PI Drives for Automation and Handling

Setting valves, adjusting components, pick and place ...

The specifications for these types of motion control applications differ from those PI is used to dealing with in only two respects: Not one nanometer but 10 micrometers and more are sufficient for the positioning accuracy. The price plays a much more important role, however.

Good quality and good service are two things which customers do not want to forego, which is why PI has recently received many requests from the market segments mentioned.

These requests have led to the development of the M-228 and M-229 linear actuators. These have travel ranges of 10 or 25 mm and use classic stepper motors – with either a compact (motor + gearbox) or cubic (direct drive) configuration. Despite the low prices, the user need not forego useful features such as mechanical position display, a non-rotating spindle or safety limit switches.

M-228 Stepper Mikes offer a low-cost alternative.

M-228 and M-229 are characterized by the following data:

- bi-directional repeatability: 5 µm
- unidirectional repeatability: 2 µm
- resolution 80 nm (with C-663 Mercury™ Step controller)
- backlash: 5 µm
- speed: 2 mm/sec
- positioning accuracy: 10 µm

The compact M-810 is smaller in diameter than a CD, but offers long travel ranges in six axes with excellent position resolution

Six Degrees of Freedom in a Small Package

New Ultra-Compact Miniature Hexapod

The new M-810 miniature Hexapod combines all advantages of PI's other proven parallel-kinematic systems in the smallest of packages. With a diameter of only 10 cm and a height of 11.8 cm, the M-810 offers travel ranges of up to 40 mm in the XY plane and 13 mm in the Z-direction. Despite of its small size, the hexapod can reliably position loads of up to 5 kg at velocities of 10 mm/s.

The limited space necessitated the usage of new tec hnologies for encoders, motors and limit switches. Nevertheless, control is 100 % compatible to previous standard PI Hexapods.

As with other parallel-kinematics positioners from PI, the six high-resolution actuators are connected directly to a single moving platform. The user is able to define the center of rotation (pivot point) independent of platform motion with a simple software command.

In contrast to conventional, stacked, multi-axis systems, there is no accumulation of guiding and lever-arm errors.

Click here for Article on

Hexapods in Spine Surgery

Physik Instrumente (PI) GmbH & Co. KG

Auf der Römerstraße 1
D-76228 Karlsruhe

Tel. +49 721 4846-0
Fax +49 721 4846-100
info@pi.ws
www.pi.ws

PI USA

PI (Physik Instrumente) L.P.
16 Albert St.
Auburn, MA 01501
Tel: +1 (508) 832 3456
Fax: +1 (508) 832 0506
info@pi-usa.us
www.pi-usa.us

PI Ceramic GmbH

Lindenstraße
D-07589 Lederhose

Tel. +49 36604 882-0
Fax +49 36604 882-25
info@piceramic.de
www.piceramic.de