Imaging Methods in Medical Technology

PIEZO ACTUATORS FOR PRECISE POSITIONING SYSTEMS AND SCANNERS
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Introduction

A number of imaging techniques are now increasing efficiency in medical research, diagnostics and therapy. Optical metrology is often the cradle of familiar methods, especially those used in automated processes, e.g. interferometry or microscopy.

Ultrasonic and magnetic resonance techniques are ideal for a variety of visualization tasks. The various methods have one fundamental thing in common: They need fast, precise drive systems.

If the application so requires, they must also be as compact as possible or operate reliably even in strong magnetic fields. Piezoelectric drives, scanners and positioning systems are a safe bet here.

Properties of Piezo-Based Drives and Drive Systems

Piezo-based drives and drive systems are fast and compact; they are not affected by magnetic fields nor do they have any effect on such fields. Since the motion is based on crystalline solid-state effects, motions down to single figures in the nanometer range can be resolved. What is more, there are no moving parts in the conventional sense and thus no need to worry about mechanical wear and tear.

The actual size and power of the drives, the travel range and positional resolution can vary depending on the design (Fig. 1). The deciding factors are the object to be moved and the distance it must cover: Piezo actuators can cover scanning ranges of a few 10 µm with frequencies of up to several thousand hertz.

Fig. 1 Piezoceramic actuators have features which make them ideally suitable for many common imaging tasks in medical technology (PI (Physik Instrumente))

For large travel ranges, especially when high speeds are also required, ultrasonic linear drives (Fig. 2) are used. They can produce resolutions of up to 50 nm (0.05 µm) and are therefore an interesting alternative to the conventional combination of electric motor and spindle. And the drives are much more compact. Moreover, there is no need for mechanical coupling elements which otherwise usually translate the rotary motion into a linear one.

Ultrasonic linear drives have high driven velocities of up to 600 mm/s or so and are thus suitable for fast scanning cycles. The typical travel ranges are between one and several 100 mm. If comparably large loads have to be moved, the obvious solution is to use so-called PiezoWalk drives, where individual actuators “step” along a moving runner. They combine forces of up to 600 N, high resolution in the nanometer range and unlimited travel.

It is thus possible to find a tailor-made, piezo-based drive solution for practically all types of imaging application in medical technology, as the examples briefly described below illustrate.

Fig. 2 Miniaturized ultrasonic linear drives can be integrated directly into the optics (PI (Physik Instrumente))
Two-Dimensional Images: Image Resolution, Stability or Focusing

Medical research and diagnostics often require imaging techniques with high resolution and stability. One tried and tested method is so-called microstepping, which involves moving the image sensor (e.g. the CCD element) backwards and forwards very quickly in the area of one pixel as the image is being recorded. Fast, piezo-based two-dimensional scanners are ideal here.

The piezo drives used operate with the necessary velocities in the video frequency range and cover the required travel ranges between the individual pixels of a sensor chip with scanning ranges of up to several 10 µm. The image information can thus be interpolated and superimposed. This produces an image with higher resolution (Fig. 3).

Fig. 3 Microstepping: The image sensor is moved backwards and forwards very quickly in the area of one pixel as the image is being recorded (PI (Physik Instrumente))

If an image is to be enlarged or focused, the imaging elements, i.e. the mirrors and lenses, must be moved and adjusted accordingly in the respective recording instrument.

With automated processes, the important criteria are the precision and usually the speed as well. A typical application is to be found in pharmaceutical research for the screening of large numbers of samples.

For high throughput and low reaction times the optics must be focused on the surface of the samples within a very short time. The low settling times in the millisecond range are the main reason why piezo-based nanopositioning systems have the upper hand here.

Scanning the Depths: Three-Dimensional Imaging Techniques

Many fields of medical technology rely on three-dimensional imaging techniques, to investigate structures or layers, for example. Confocal microscopy (Fig. 4) is used in diagnostics to produce virtual sections through the tissue structure, or to detect the structure of the sample surface through the shift of the focal plane, for example.

This method is also used in ophthalmology, as well as in quality assurance for implants or cell diagnostics. These applications require that the imaging optics be moved with precision in the direction of the optical axis to adjust the focal plane, or in the plane at right angles to this for the area scan.

Fig. 4 Confocal microscopy is used in diagnostics to produce virtual sections through the tissue structure, or to detect the structure of the sample surface through the shifting of the focal plane (PI (Physik Instrumente))
The other possibility is to move the object accordingly. Piezo-based positioning systems are ideal for both options. The choice is again determined by the travel and resolution required and also by the space available. Miniaturized ultrasonic linear drives, for example, can be integrated directly into the optics (Fig. 2, s. S. 3).

**Determination of Distances and Surface Topologies**

Interferometric methods are the means of choice to measure distances or determine surface topologies (Fig. 5). Optical coherence tomography (OCT) can be used to examine layers under the surface of the skin and create three-dimensional images of the skin’s structure, which are used in diagnostics to detect cancer, for example. This requires precise adjustment of the optics in order to compare the wavelengths of measurement and reference beam. Here as well, the exact choice of piezo linear drive again depends on the object to be moved and the travel range it must cover. Precision and positional stability are guaranteed in all cases.

**Radiotherapy and Magnetic Resonance Tomography**

So-called multi-leaf collimators are used in radiotherapy to achieve the best possible distribution of the dose. This involves arranging individual leaves so that the healthy tissue has optimum protection from the radiation. Ultrasonic linear motors make suitable drives for the leaves. They are fast, compact and generate the relatively high forces required.

![Fig. 5 Schematic of the white light interferometry used for OCT applications. The shifts in the interference pattern can be evaluated (Polytec GmbH)](image)

Similar tasks are also to be found in other fields of application. 3-D images are likewise produced in ophthalmology to examine the back of the eye, or in orthodontics to obtain an accurate image of the oral cavity so that dentures can be fitted.

![Fig. 6 Magnetic fields do not affect the operation of piezo drives. Linear drives or positioning systems can therefore be used for high loads in strong magnetic fields (PI (Physik Instrumente))](image)

Magnetic resonance tomography is one field of application in medical technology where images are recorded without the use of optical methods. The drives which move the sensing probes to match the coils, the samples or the diaphragms must operate in strong magnetic fields of up to several tesla (Fig. 6).

Piezo drives are the right choice here. They are the only drives whose operation is not affected by strong magnetic fields, nor do they themselves become a source of interference. There is therefore no need to have expensive encapsulation and shielding. Since the drives can also operate in a vacuum and at extremely low temperatures, they can be located directly on the cooling system of the tomograph without further ado.
Conclusion

Piezoelectric actuators are common where high-dynamics motion over short distances must be performed very precisely and economically. For travel ranges over one millimeter, there are a number of piezo linear drive concepts which cover a wide spectrum of load and dynamics requirements.

High-resolution metrology and production techniques are pushed forward in the semiconductor industry and in biotechnology because of the rapid technological development. Medical technology can draw on these existing drives and techniques.

For this purpose, PI (Physik Instrumente) offers a whole range of piezo drives and the possibility to adapt these specifically to the respective requirements.

More information on piezo actuators and und positioning systems in in medical engineering is available at:

http://www.pi-medical.ws

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Company Profile

Physik Instrumente (PI) GmbH & Co. KG is market and technology leader for precision positioning systems whose accuracy is far below one nanometer. When PI introduced piezoelectric nanopositioning technology more than 40 years ago, typical customers were research labs and universities working on laser cavity tuning, Fabry-Perot interferometers and filters. Few foresaw that whole industrial sectors would become dependent on progress in nanopositioning.

Today PI delivers micro- and nanopositioning solutions for all important high-tech markets: semiconductor technology, optical metrology, biotechnology and medical devices.

PI follows a vertical integration strategy designed to develop and maintain all key technologies in-house. We supervise each and every step from design to delivery in the following areas: software, precision mechanics, digital and analog control electronics, sub-nanometer capacitive position sensors, piezo ceramics and piezo actuators. This assures the highest quality and reduces cost.

As a privately run company with a healthy growth rate, over 500 employees and a flexible, vertically integrated organization, PI can meet the most diverse requirements in the area of innovative precision positioning and supply customers anywhere in the world with outstanding products. Therefore PI has established subsidiaries for sales and service in the most important local markets.

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