BUYING a positioning system

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A positioning system consists of a mechanic or mechatronic motion device for linear, rotary or combined motion plus motion control electronics. It moves objects with micro-, nano- or even sub-nanometer precision. Many photonic applications and optical devices or inspection systems require high positioning accuracy, especially in microscopy, nanolithography and interferometry.

Today's microscopes are often equipped with piezo stages that offer up to six degrees of freedom, thus allowing for rapid, high-precision scanning. For example, an objective or sample scanner based on piezoelectric actuators can provide high-speed Z motion for fast and throughput optimized autofocusing tasks with high precision.

The exact speed and accuracy depend largely on the choice of control electronics and how they match in terms of parameter setting. This choice must be made in consultation with the user.

Positioning systems can be divided into two main families, according to their degree of accuracy (micro- or nanometer range).

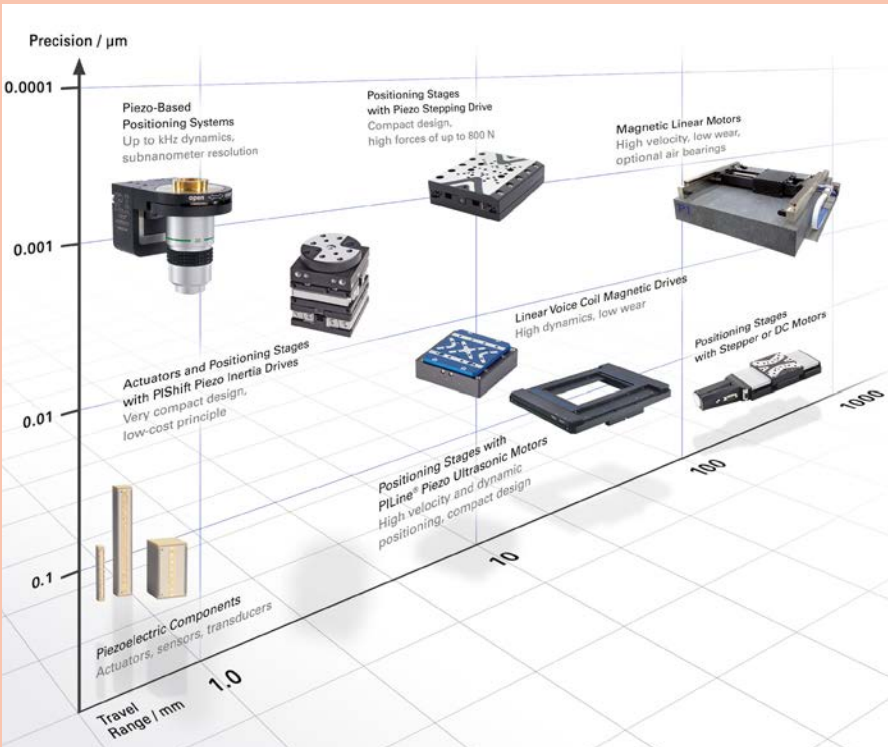

Figure 1. Product Roadmap. The choice of the drive system strongly depends on the demands for travel range and resolution.

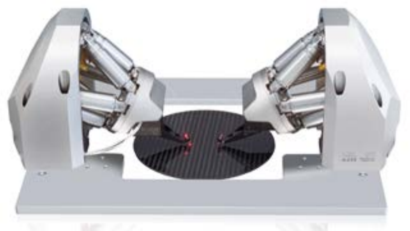

Figure 2. Multi-channel fiber alignment system for silicon photonics device testing.

Micropositioning systems

Micropositioning systems offer travel ranges of between several millimeters and several meters, and are accurate (e.g. for repeatability) in the range of 0.1 to 10s of microns. Linear or rotary stages can be fitted with a range of drive and bearing concepts such as DC motors or stepper motors with spindle drives, magnetic direct drives or piezoelectric drives. In terms of precision, mechanical guiding systems such as ball bearings are sufficient.

When choosing a micropositioning system, a large number of factors need to be taken into consideration. They generally include the number of degrees of freedom, available travel range, resolution or minimum motion increment, positioning repeatability, or accuracy. Precision criteria will dictate the type of position sensor that is considered (e.g. linear encoders) and the guidance quality to be selected (e.g. flatness, pitch and yaw, wobble and eccentricity). For many applications, it must be possible to parameterize the speed of travel. Lastly, the nature of the system's components determines both its lifespan and the environments in which it can be used (e.g. vacuum, magnetic).

Nanopositioning systems

With nanopositioning systems, the precision is even better than with micropositioning systems; they provide repeatability in the range of 10 down to 0.1 nanometers. In this class of precision, the choice of system components is limited! As mechanical friction needs to be avoided, possible drive concepts are magnetic direct drives and piezoelectric actuators. Recent developments in piezoelectric motors and control electronics mean that it is also possible to have piezo motion with travel ranges of up to several millimeters at nanometer precision. Besides the proper drive, stages for nanopositioning use flexure bearings for small and air bearings for large travel ranges. Non-contact sensors are either optical or capacitive ones.

Many factors need to be considered when choosing a nanopositioning system, and they depend directly on the final application. If, for example, the main requirement is speed (i.e. dynamics), it requires a system with a high resonant frequency and high-bandwidth electronics. The setting of these dynamic parameters is therefore crucial – as is the payload the system will be expected to bear.

By contrast, if the main requirement is extremely high precision or resolution, it is important to opt for a system with one or more position sensors (capacitive or strain gauge) and to adjust the control electronics parameters according to the nature of the sensor(s) and the payload. The choice of a nanopositioning system should therefore always go hand in hand with the choice of control electronics. Only an appropriate combination of the two will guarantee the best possible performances in terms of the target application.

Figure 3. Piezoelectric motors are built into miniaturized positioning stages – the image shows versions with a width of only 22 mm. Stages like these are used inside micro manufacturing applications and for photonic alignment tasks. They are also available for ultra-high vacuum applications, where space is limited.

Selection criteria

Positioning systems have many technical parameters. Here, we will limit ourselves to those that concern actuators and positioning stages or systems, leaving the control electronics aside.

The accuracy of a positioning system is defined as the difference between the actual versus desired positions.

- Resolution corresponds to the smallest measurable position increment. It is important to distinguish open-loop resolution from closed-loop resolution, which is achieved using a position sensor coupled with a controller.
- Repeatability is the ability to return to a given position from any other position. It is limited by hysteresis and backlash.
- Speed: piezoelectric actuators provide sub-millisecond response times, but it is important to define each system's functional requirements (*XY scanning*, description of periodic patterns).

Attention also needs to be paid to the other parameters, namely resonance frequency (stiffness), load (maximum weight the system can withstand), maximum travel range (from several micrometers to several hundred millimeters), compactness (system's overall volume), and lastly the ability to operate in a vacuum or at cryogenic temperatures. ■

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