Inchworm Motor Technology

Inchworm Motors Assure Precise Positioning

Only Burleigh™ Inchworm® systems from EXFO Burleigh Products Group[1] provide true linear motion, nanometer resolution and a range of motion over hundreds of millimeters.

Inchworm motors aren't steppers or servos so there's no backlash or mechanical drift, and no rotational motion, gearboxes or hydraulic lines. Inchworm motors are solid-state linear positioning devices that provide a superior motion profile with no loss of resolution at high speeds or any loss of force or smoothness of motion at low speeds.

Patented in 1974, Inchworm technology has set the standard for ultra-high resolution positioning. Inchworm motors use compact piezoelectric (PZT) ceramic actuators to achieve nanometer-scale positioning steps over hundreds of millimeters. You won't find this capability anywhere else.

The Technology Behind Burleigh Inchworm Systems

The Genesis of Inchworm Motors

During the 1970s, Burleigh engineers developed expertise in PZT technology because of the wide use of PZT materials in its optical instruments. For instance, Burleigh's Fabry-Perot interferometers require that mirrors be positioned with nanometer resolution. This nanopositioning task could be accomplished only with PZT technology.

We developed the patented Inchworm motors as a result of the growing need to position objects on the nanometer scale over many millimeters of continuous motion. They harness the highly precise positioning capabilities of PZT materials and use them over a linear range of motion previously available only with leadscrew-based or linear electro-magnetic motors (Figure 1).

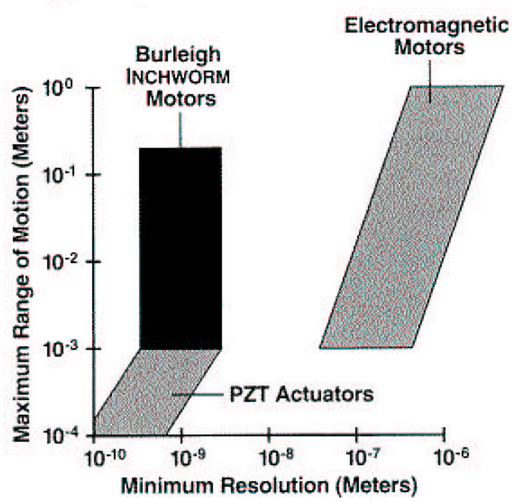

Figure 1

How PZT Actuators Work

A PZT actuator is an electro-mechanical device that undergoes a dimensional change when voltage is applied (Figure 2). The conversion of electrical energy into mechanical motion takes place without generating any significant magnetic field or the need for moving electrical contacts. Dimensional changes are proportional to the applied voltage and therefore can be adjusted with extremely high resolution.

PZT actuators can be operated over millions of cycles without wear or deteri-

[1] Formerly Burleigh Instruments Inc.

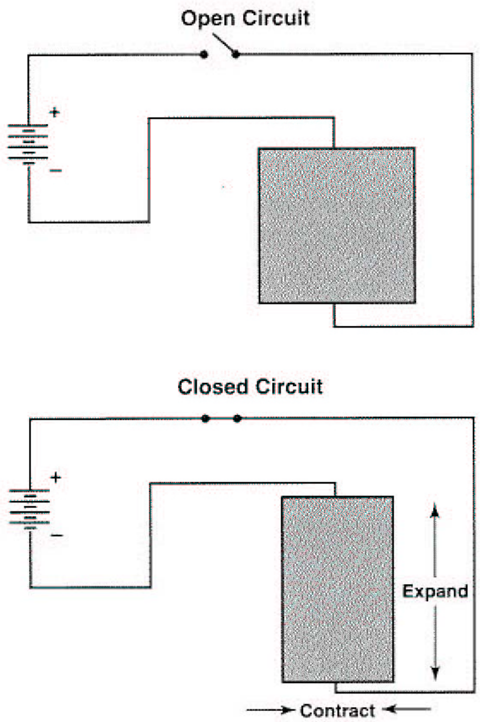

Figure 2

oration. Their high response speed is limited only by the inertia of the object being moved and the output capability of the electronic driver. Virtually no power is consumed or heat generated when maintaining a PZT actuator in an energized (holding) state.

The maximum dimensional change of a PZT actuator, however, is on the order of 0.1% of its total length (even with the application of hundreds of volts). This means considerable design and manufacturing expertise is required to use PZT actuators as useful positioning devices. EXFO Burleigh Products Group has more than 31 years of experience using PZT actuators for ultra-high resolution positioning.

The Principle of Operation for Inchworm Motors

EXFO Burleigh Products Group offers different families of Inchworm motors with a variety of application-specific performance characteristics, but the basic operating principle is the same for all models.

Motion is created through sequential activation of three PZT components (Figure 3). The outer two PZT elements (numbers 1 and 3 in the figure) act as clamps. The central PZT element (number 2) expands and contracts along the motor shaft when voltage applied. Though all three PZT elements operate independently, they are physically connected.

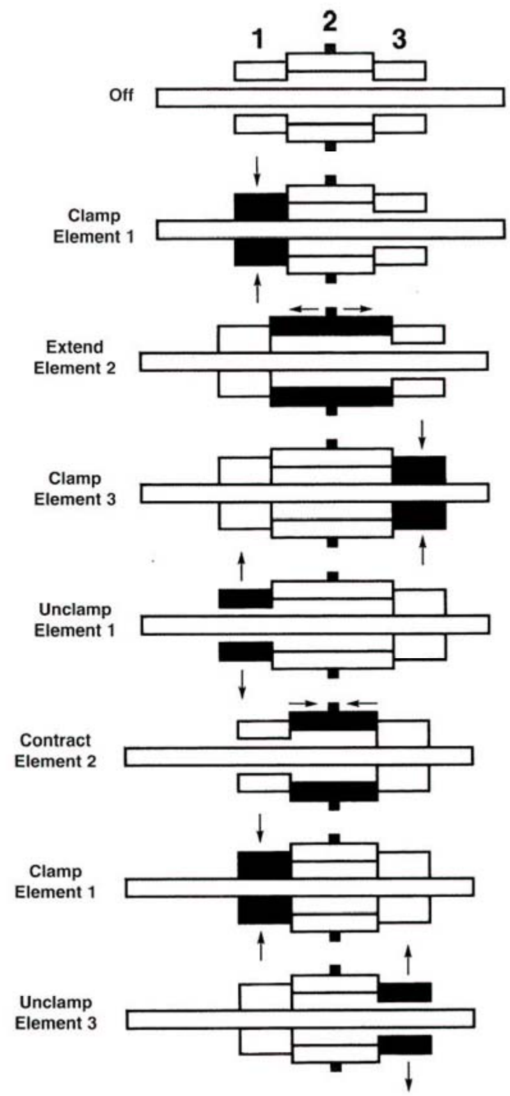

Figure 3

When a voltage is applied to PZT element 1, it clamps the shaft. Then a variable-rate staircase voltage is applied to PZT element 2, causing it to change length in discrete steps on the order of nanometers. The staircase takes hundreds of steps from its lower to upper limit and may be stopped or reversed at any point on the ramp. Since these steps are controllable, it is the ultimate resolution of any positioning system using an Inchworm motor (Figure 4).

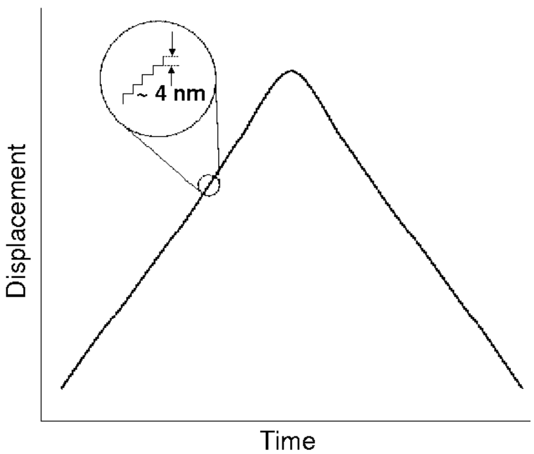

Figure 4

At the end of the staircase ramp, a voltage is applied to PZT element 3, causing it to grip the shaft. Voltage then is removed from PZT element 1, releasing it from the shaft. The staircase starts downward until it reaches its lower limit, at which point PZT element 1 is reactivated, PZT element 3 is released and the staircase begins again.

This sequence can be repeated any number of times, resulting in a total range of motion limited only by the length of the motor shaft. In general, the motor is mounted in the middle of PZT element 2 to provide the smoothest and most symmetric motion profile.

The voltage applied to the clamp elements has two levels: on (clamped) and off (un-

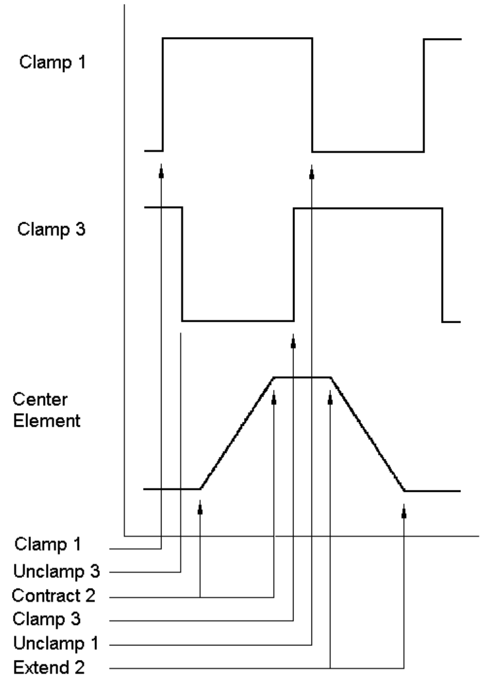

Figure 5

clamped). The center element receives a positively or negatively sloped ramp voltage (staircase) for smooth motion between clamp changes. The slope of these ramp signals coordinated with the clamp change frequency determines translation speed (Figure 5).

EXFO Burleigh Products Group offers three-channel electronic controllers to output these voltage waveforms. These controllers are designed to maximize resolution, speed and push force by optimizing the signal voltage, current and noise. The timing between the three channels also has been optimized using the appropriate delays and overlaps.

During the clamp-unclamp part of the Inchworm cycle, both clamps grip the shaft simultaneously and the shaft is nominally stationary. However, the clamping action does produce small axial and lateral motions.

The axial motion (parallel to the shaft) is an alternating forward and backward motion called "glitch" that nominally sums to zero. EXFO Burleigh Products Group guarantees that the peak-to-peak glitch of the standard Inchworm motor is less than 50 nm (Figure 6).

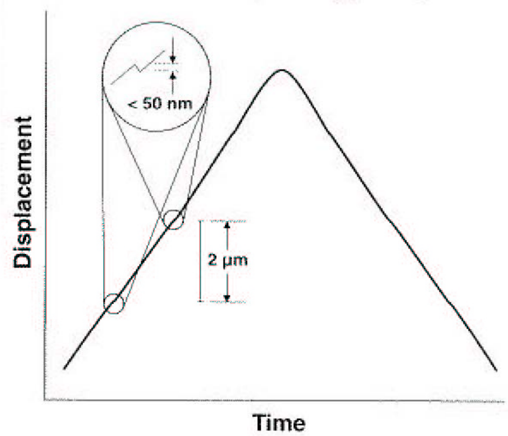

Figure 6

The glitch of the UHV Inchworm motor typically is 1 µm with the net motion of the glitch always backward when the shaft is moving in the "controlled approach direction" (Figure 7). This feature is useful for scanning probe microscope applications, where a probe must be positioned very close to a surface without risk of contact.

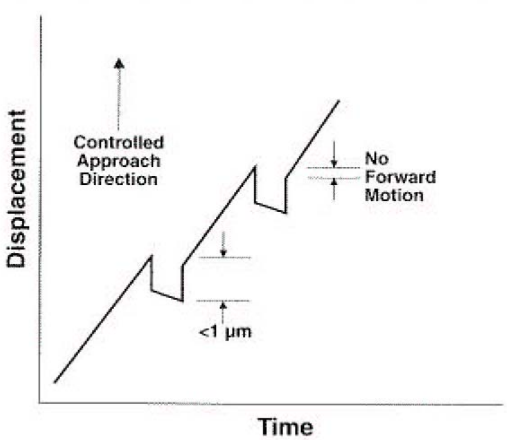

Figure 7

In addition to forward and backward motion, lateral motion (orthogonal to the shaft) is produced during each clamp change. This motion is on the order of 1 µm. EXFO Burleigh Products Group offers a lateral stability option (LSO) for some Inchworm models that reduces lateral motion to ± 0.2 µm (Figure 8). Inchworm stage systems incorporate a flexure coupling to isolate lateral shaft motion from the stage bearings.

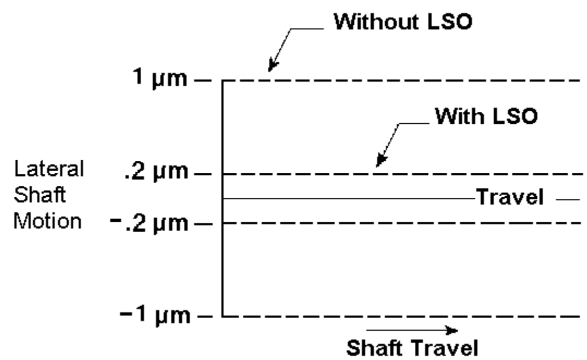

Figure 8

For more information on Inchworm technol-ogy or products, contact us at 585-924-9355 or info@burleigh.com

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