# Precision Motion for Biomedical Devices: The Use of L1B2 Ultrasonic Motors

**Roman Yasinov, Gal Peled, Nir Karasikov and Alan Feinstein***

Nanomotion Ltd., 3 Hayetsira St., Yokneam 20692, Israel

## Short Communication

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***For Correspondence**

Alan Feinstein, Nanomotion Ltd., 3 Hayetsira St., Yokneam 20692, Israel.

**E-mail:** nano@nanomotion.com

## INTRODUCTION

The scaling down of biomedical devices puts a constraint on the use of standard electromagnetic motors for motion creation. The efficiency of electromagnetic motors scales down with size and power, making 1 $cm^3$ motors barely efficient. Piezoelectric ultrasonic motors can successfully bridge this gap as their efficiency is not size dependent [1]. Originally developed during the 1970s (in response to the semiconductor industry's increasing demand for precise nonmagnetic positioners) [2], these motors are presently applied in a wide range of precise motion applications, including biomedical devices. Among the various design possibilities of ultrasonic motors, the L1B2 type motors (the standing wave linear motor based on the combination of first longitudinal and second bending modes) are well suited to industrial production, combining a robust design with a high dynamic range in velocity and high positioning accuracy. The range of possible applications covers the fields of biomedical devices, semiconductor manufacturing and metrology, electro-optical and aerospace modules [3]. Biomedical use has been demonstrated for surgical robots, operating under an MRI field [4,5] and virtual microscopy applications [6]. The design scope also encompasses zoom capability for small optical devices, precise syringes, small pumps, multi-joint vertebra, etc.

A recently published comprehensive review of the structure and applications of L1B2 piezoelectric ultrasonic motors can be found in reference [7]. In short, they offer both linear and rotary motion axes, with a high stiffness along the motion direction (essential for high precision), linear speeds above 200 mm/s (with a six orders of magnitude dynamic range in velocity), a fast move and settle (with unlimited travel), a sub-nanometer positioning resolution, as well as an extremely low magnetic , compatible for operation under a magnetic field above 5 Tesla. Dedicated resonance drive schemes allow the use of low voltage power sources, allowing battery operation for small sized devices.

The medium sized motors, having a typical size of a few centimeters, can apply forces of several tens of Newtons (for example see Nanomotion HR type motors [8]), fully addressing, for example, the motion requirements for surgery-assisting robots [9]. The small sized motors, having a typical size of less than 1 cm, offer forces up to about 0.5N (for examples see Nanomotion Edge motors [10]) suitable for compact biomedical applications, such as zoom for endoscopy tools (see **Figure 1** for a typical design), small pumps and multi joint vertebra motion. The low magnetic signature of piezoelectric materials allows all of the above applications to operate in the presence of strong magnetic fields (typical motor residual magnetic field is less than 0.1 nT), such as the ones existing inside MRI devices. Additional design data can be found in reference [7].

Available types of motion include linear and rotary motion axes. Those can be combined to produce compound multi-axis devices. An example simple device, shown in **Figure 1**, employs an L1B2 element driving a ceramic ring attached to a rotary motion axis. The axis rotation shifts the position of an objective lens, thereby providing zoom capability to a small onboard camera, located behind the lens. The device is small enough to be incorporated into endoscopy tools, providing high quality zoom capability. Other design concepts include, for example, a small high precision syringe for drug delivery where the lens is replaced by a high accuracy push piston. Similar concepts can be used to produce small pumps and small joints with multiple motion axes, allowing high precision three-dimensional motion.

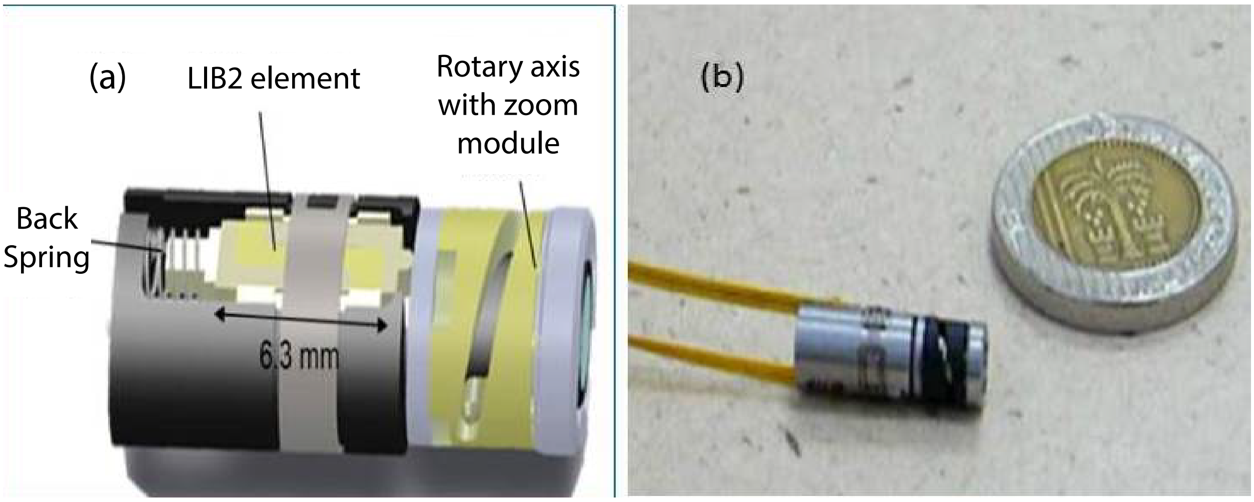


**Figure 1.** Adapted from [7]. Example of an L1B2 motor use in biomedical applications: (a) Schematic drawing of a rotary module designed to provide zoom capabilities for endoscopy tools. (b) An image of the module that is schematically shown in (b).

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