first and second sets of comb fingers **712**, **702** may be in a substantially co-planar interdigitating engagement in the absence of biasing force.

Several different types of biasing elements are depicted schematically in FIG. **7** for the sake of example. The rotating device **700** may include any or all of them or combinations where the biasing elements are linked. Such biasing elements may exert a constant biasing force to pull the first and second sets of comb fingers out of alignment. Alternatively, the biasing element may exert a time varying force that rotates the rotatable element. By way of example, the biasing element may include a magnetic material **731** and/or a current carrying coil **732** formed on the rotating element **720**. A current source **742** may provide electric current to the coil **732**. The magnetic material **731** and/or coil **732** may interact with an external magnetic field B produced by an external coil **744** and/or magnetic material **746**. A current source **748** may provide electric current to the external coil **744**.

Alternatively the biasing element may include a pair of gap-closing electrodes **752**, **754** coupled respectively to the rotating element and the substrate **701**. A voltage source V' coupled between the two gap closing electrodes **752**, **754** may provide a voltage for driving the rotating element **720**. In another embodiment, the biasing element may include third and fourth sets of comb fingers **714**, **704** coupled respectively to the rotating element and the substrate **701**. A voltage source V" may be coupled between the third and fourth sets of comb fingers to provide a voltage for driving the third and fourth sets of comb fingers **714**, **704**.

Finally, the biasing element may be an actuator **760** coupled to the rotating element **720** and the substrate **701**. The actuator **760**, which is represented schematically in FIG. **7**, may be a mechanical actuator such as a spring loaded element, a stress bearing material carrying a residual stress gradient, a piezoelectric element or a thermal bimorph actuator.

Alternatively, the rotational flexure **711** may provide a torsional bias and thus act as the biasing element.

It must be stated that the torsion biasing force can be time varied with application of combdrive electrostatics to modify device damping ratio and resonant frequency device characteristics.

The rotating device **700** may optionally include a position sensing means other than the first and second sets of comb fingers **712**, **702**. For example, the sensing means may be the gap closing electrodes **752**, **754**, which may optionally be coupled to a capacitance sensor C' to provide a means for sensing the angular position of the rotating element **720**. Furthermore, the sensing means may include the third and fourth sets of comb fingers **714**, **704**. A capacitance sensor C" may be coupled between the third and fourth sets of comb fingers **714**, **704** to provide a means for sensing the angular position of the rotational element **720**. Finally the device **700** may include a sensor element **770**, shown schematically in FIG. **7**, such as a piezoresistive strain gauge or piezoelectric sensor mechanically coupled between the rotational element and the substrate **701**. Alternatively, the device **700** may include an optical sensor **772**, e.g., that senses a change in an optical signal from an optical source **774** to sense a change in the angular position of the rotating element **720**.

Where the first and second sets of biased comb fingers are used to drive the rotational element **720**, the position sensing means, e.g., any or all of the capacitance sensors C, C', C" or the sensor element **770** may be coupled via a feedback element **780** to the voltage source V that drives the first and second sets of biased comb fingers **712**, **702**. Where the first and second sets of biased comb are used to sense the angular position of the rotating element **720** the capacitance sensor C may be coupled via the feedback element **780** to the biasing means, e.g., either of the current sources **742**, **744**, either of the voltage sources V', V", or the actuator **760**. Of course, if the first and second sets of biased comb fingers **712**, **704** are used to both drive the rotational element **720** and sense its angular position, the capacitance sensor C may be coupled to the voltage source V via the feedback element **780** in a feedback control loop. The feed back control element **780** may be implemented in hardware, software, firmware, or some combination thereof.

The various embodiments of the present invention provide a novel class of biased combdrive actuators and position sensors that employ self-aligned combdrives and a biasing means for generating a constant and/or time-varying angular displacement. Such self-aligned combdrive devices can rotate uni-axially or bi-axially, so as to provide for one-dimensional and two-dimensional scanning devices.

An important advantage of the self-aligned rotating combdrive and position sensor devices according to embodiments of the present invention is that the first and second comb fingers may be fabricated in a single layer of a substrate and hence substantially interdigitated according to a predetermined engagement. This significantly simplifies the underlying fabrication process. Another important advantage of the present invention is that because the first and second comb fingers begin from a substantially co-planar and interdigitated engagement, non-linear rotational effects that are inherent in the prior art combdrive actuators are substantially reduced. Furthermore, since the rotating devices of the present invention may be self-aligned, instabilities that arise from misalignment between the first and second combs in the prior art can be avoided. The self-aligned rotating combdrive actuators and position sensors thus produced provide more predictable and reliable performance. Further advantages of the self-aligned combdrive rotating actuators and position sensors of the present invention are manifest in their simple design, compact size, low cost, and versatile performance.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions, and alterations can be made herein without departing from the principle and the scope of the invention. Specifically, it must be stated that the methods of operating a combdriven actuator by application of a torsion force, sensing the position of the actuator and controlling torsion force and/or comb-finger voltage in response thereto, may apply to any combdrive as well as the self-aligned combdrive of the present invention. It must also be stated that the position sensor element may operate on principals other than capacitance and that the bias force may be applied mechanically, non-mechanically and through manipulation of electromagnetic energy. Accordingly, the scope of the present invention should be determined by the following claims and their legal equivalents.

What is claimed is:

1. A method of operating a rotating comb-drive actuator, comprising:

a) providing a first plurality of first comb fingers and a first plurality of second comb fingers, wherein said second comb fingers are interdigitated with said first comb fingers in an engagement;

b) mechanically coupling a rotating element to said first comb fingers, wherein said rotating element is attached to a rotatable flexure disposed along an axis;