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(54) **TWO-DIMENSIONAL GIMBALED SCANNING ACTUATOR WITH VERTICAL ELECTROSTATIC COMB-DRIVE FOR ACTUATION AND/OR SENSING**

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(58) **Field of Search** 385/16, 18; 359/196-199, 359/223, 224, 226

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,648,618 A 7/1997 Neukermans et al. 73/862.08
5,723,353 A 3/1998 Muenzel et al. 437/51
5,726,073 A * 3/1998 Zhang et al. 438/20
5,753,911 A 5/1998 Yasuda et al. 250/306

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

DE 296118818 12/1996 G02B/6/35
DE 19757181 A 7/1997 G02B/6/35
DE 19644918 A 4/1998 G02B/6/35
EP 0907076 A2 4/1997 G01N/27/00
EP 0911952 A2 4/1999 H02N/1/00
EP 0911952 A3 4/2000 H02N/1/00
EP 0907076 A3 10/2000 H01J/37/63
FR 2732467 A1 4/1996 G01P/15/08

OTHER PUBLICATIONS

“A Flat High-Frequency Scanning Micromirror”; Robert A. Conant, Jocelyn T. Nee, Kam Y. Lau and Richard S. Muller; Berkeley Sensor & Actuator Center, University of California, Berkeley.

“Electrostatic Comb Drive For Vertical Actuation” A.P. Lee et al., Proceedings of the SPIE, SPIE, Bellingham, VA, vol. 3224, Sep. 29, 1997, pp 109-119.

(List continued on next page.)

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(57)

ABSTRACT

A two-dimensional scanner consists of a rotatable gimbal structure with vertical electrostatic comb-drive actuators and sensors. The scanner's two axes of rotation may be controlled independently by activating two sets of vertical comb-drive actuators. The first set of vertical comb-drive actuator is positioned in between a outer frame of the gimbal structure and the base, and the second set of vertical comb-drive actuator is positioned in between the inner part of the gimbal structure and the outer frame of the gimbal structure. The inner part of the gimbal structure may include a reflective surface, and the device may be used as a mirror. Furthermore, the capacitance of the vertical comb-drives may be measured to monitor the angular position of the mirror, and the capacitive position-monitoring signal may be used to implement closed-loop feedback control of the mirror angle. The two-dimensional scanner may be fabricated in a semiconductor process. Two-dimensional scanners may be used to produce fiber-optic switches.

51 Claims, 7 Drawing Sheets

