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**United States Patent** [19]

Neukermans et al.

[11] **Patent Number:** 5,629,790[45] **Date of Patent:** May 13, 1997[54] **MICROMACHINED TORSIONAL SCANNER**

[76] **Inventors:** **Armand P. Neukermans**, 3510 Arbutus Ave., Palo Alto, Calif. 94303; **Timothy G. Slater**, 1226-25th Ave., San Francisco, Calif. 94122

[21] **Appl. No.:** 139,397[22] **Filed:** Oct. 18, 1993[51] **Int. Cl.<sup>6</sup>** ..... G02B 26/08[52] **U.S. Cl.** ..... 359/198; 359/199; 359/201; 359/202; 359/203; 359/214; 359/224; 250/234[58] **Field of Search** ..... 359/196-199, 359/201-203, 212-214, 223-226, 230, 290-293; 250/230, 234; 310/15, 36, 40 MM[56] **References Cited****U.S. PATENT DOCUMENTS**

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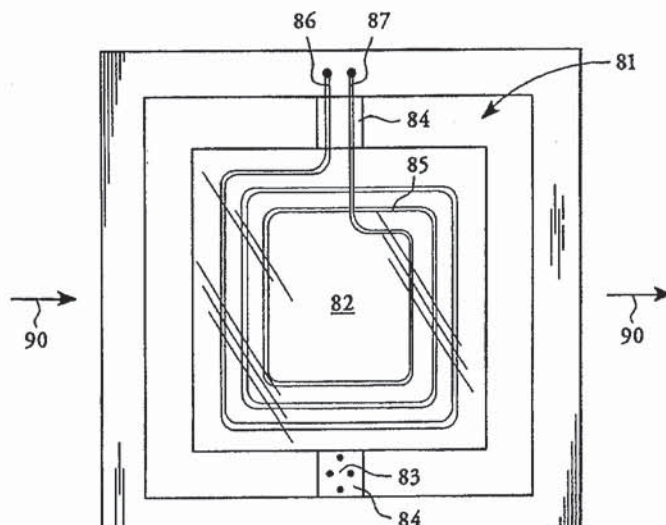
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*Primary Examiner*—James Phan*Attorney, Agent, or Firm*—Donald E. Schreiber[57] **ABSTRACT**

A frequency-locked torsional scanner of the type having a micromachined mirror formed on a surface of a silicon wafer section supported within a larger wafer section by a pair of opposed torsion bars. The principal vibrational frequency of the mirror is selected to be at least 20% higher than other modes of vibration. To prevent breakage, the torsion bars are hardened by conversion of at least a surface layer to silicon carbide or nitride. A pair of scanners with orthogonal torsion bars may be mounted in a vacuum enclosure for two-dimensional scanning at different rates suitable for television display. In alternate embodiments, a detector and a scanner may be built on a plate on the same supported wafer section or two scanners may be independently supported or one scanner and one detector may be independently supported as two plates. The mirror may be driven electrostatically, magnetically, or by both methods.

**41 Claims, 11 Drawing Sheets**

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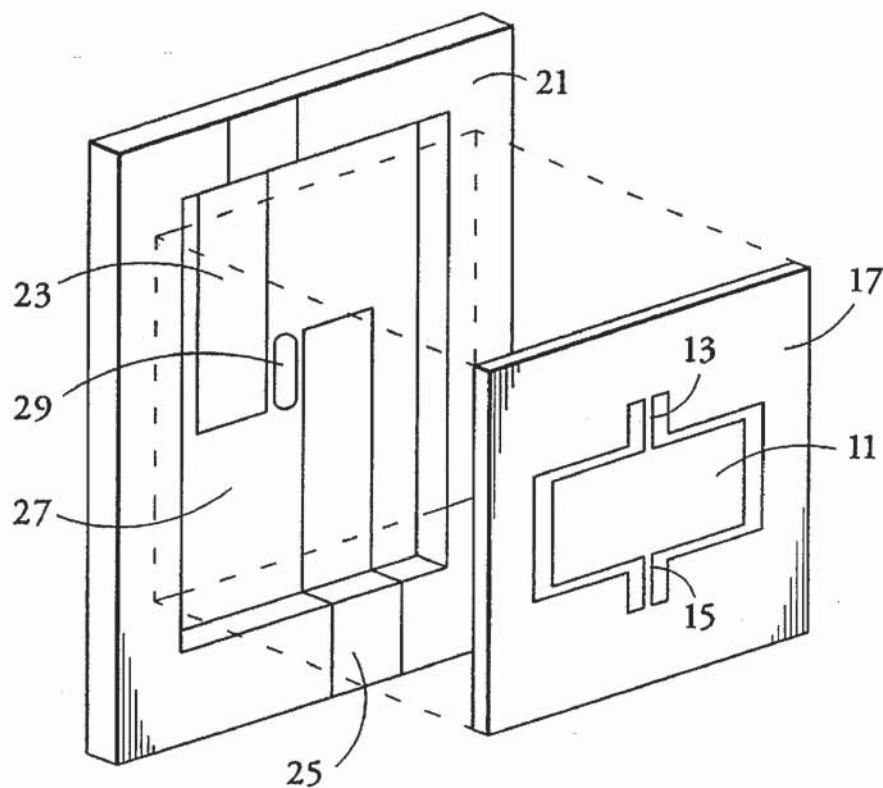


FIG. 1  
(PRIOR ART)

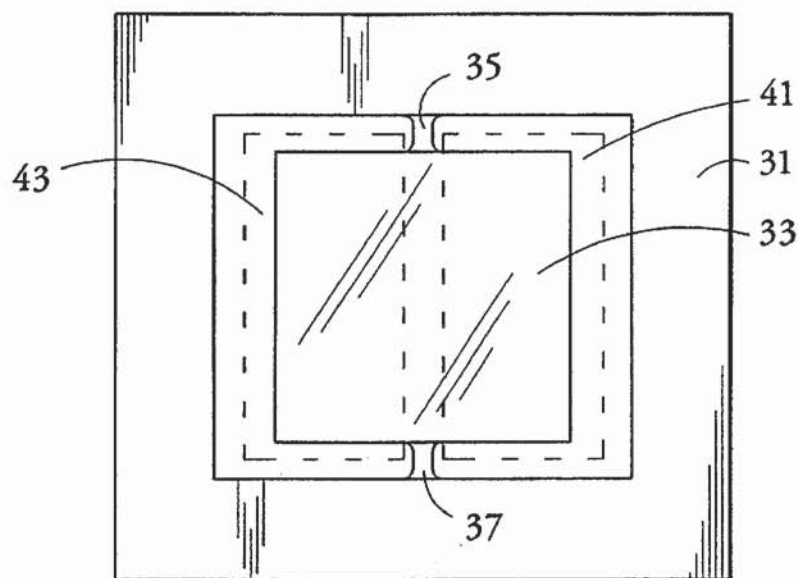


FIG. 2

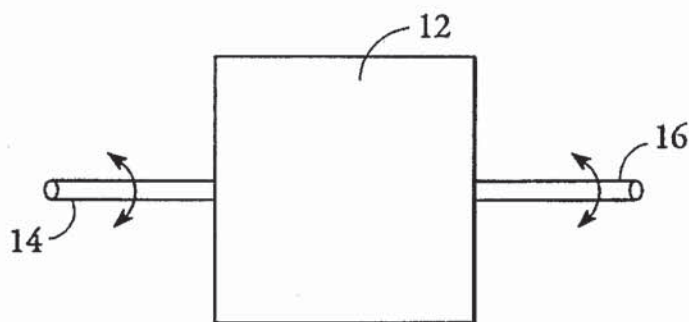


FIG. 1a

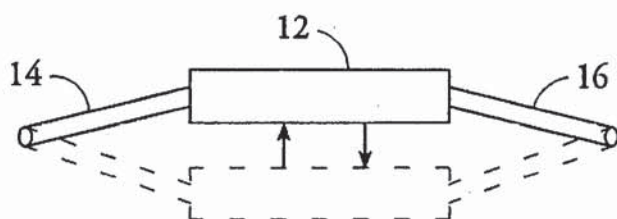


FIG. 1b

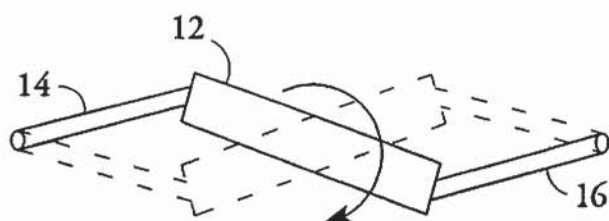


FIG. 1c

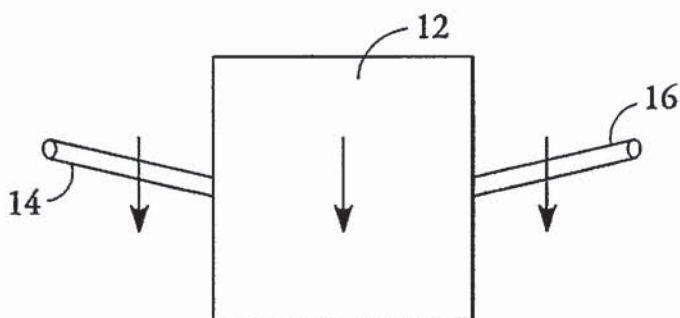


FIG. 1d

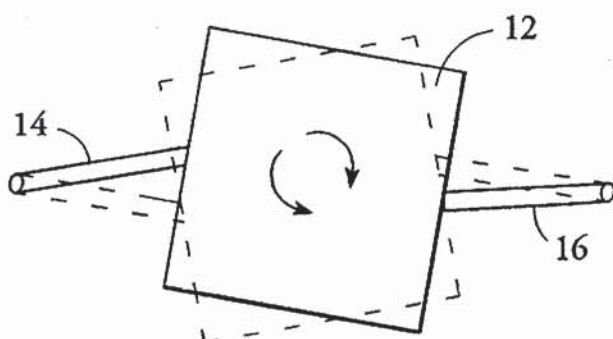


FIG. 1e

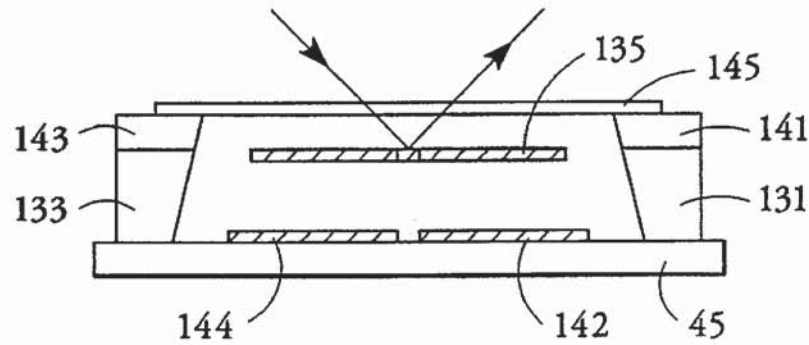


FIG. 2a

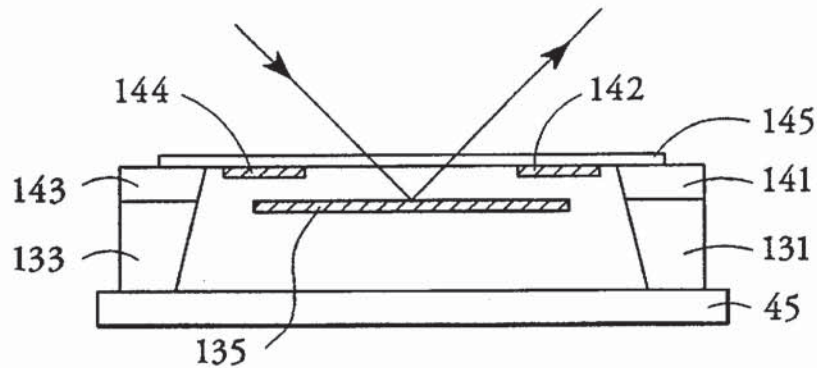


FIG. 2b

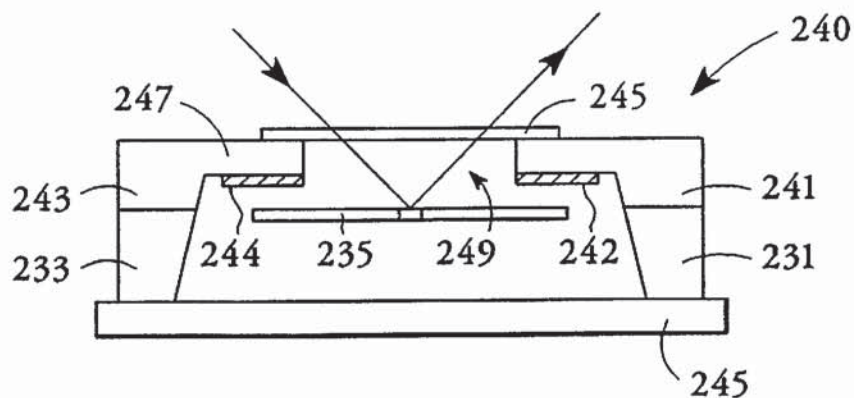


FIG. 2c



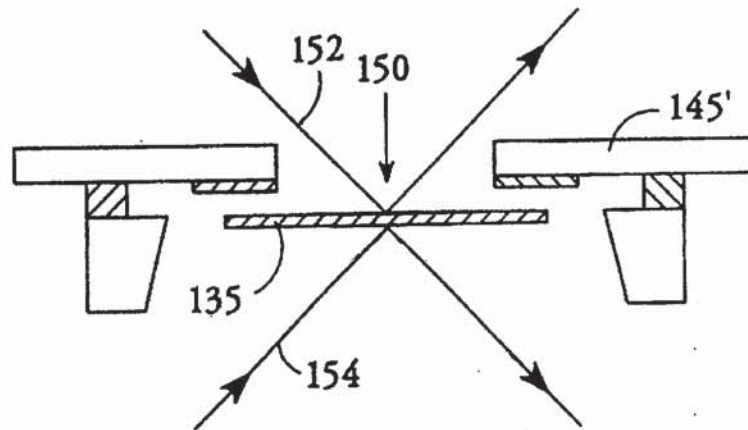


FIG. 2d

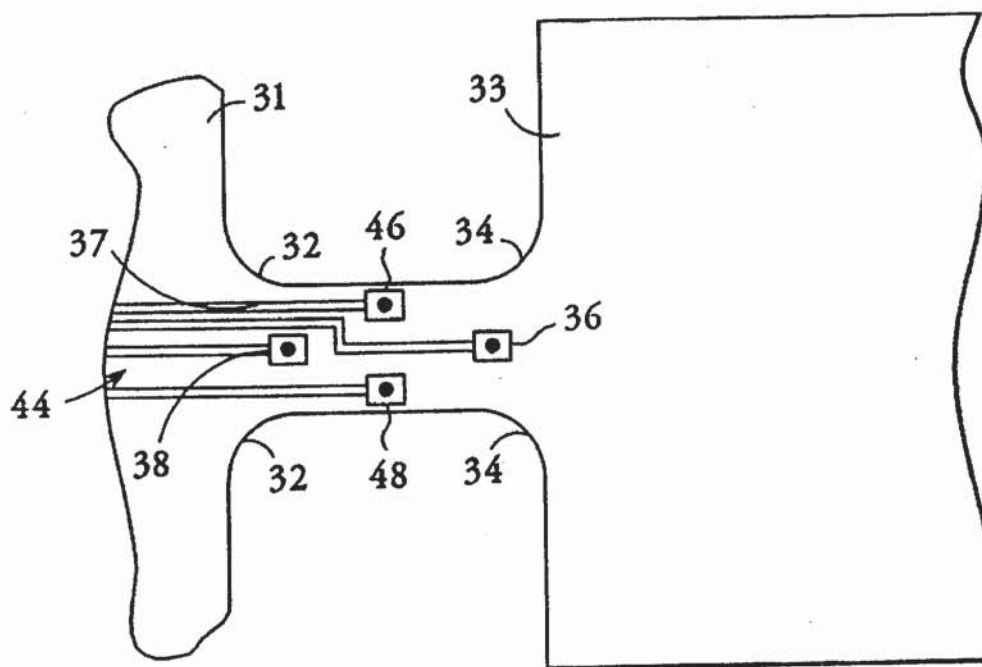


FIG. 3

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