MEMS Positioning Stages

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1. **Description:** Nanoscale positioning and registration are fundamental to manufacturing at the nanoscale. Current nanomanufacturing processes are limited by a number of factors:
   - It is difficult to transfer a dimensional scale with nanometer precision
   - Existing tools have limited real estate – sensors and transducers are difficult to integrate into active areas
   - Current processes require isolated and enclosed process chambers and spaces that are difficult to access
   - Scaling of sensors and actuators to have large scale parallelism is not possible with existing sensors and positioners

The Center is developing MEMS scale positioning stages based on silicon-on-insulator (SOI) technology for the nanoscale precision, speed and control needed for manufacturing integration of e-jet, direct ink write and other Center processes. The Center is developing controllable X, Y and Z stages and self-calibrating dual axis positioning systems.

Above: Design details. Below: SOI fabricated parallel kinematic monolithic XY MEMS-scale stage
The Center has developed an innovative method of simultaneous actuation and sensing the displacement produced by a capacitive or electrostatic actuator. This is achieved by a dual separation frequency control approach in which a high frequency (much higher than the mechanical cut-off frequency of the actuated structure) is superimposed on the actuation signal.

2. **Motion range:** 10 to 50 microns
3. **Geometric capabilities:** 2-axis and 3-axis capacitive activated systems
4. **Resolution:** < 1 nanometer
5. **Band width:** 1,000 Hz
6. **Uniqueness:**
   a. Simple
   b. XYZ positioning precision not possible via other processes
7. **Competition:**
8. **Limitations:**
   a. Stages expensive to manufacture
   b. Only 3 axis stages currently developed
9. **IP Status:** Patented
10. **Applications:**
    a. Center-developed E-jet Printing, Direct Ink Write, S4, and other Center-developed processes
    b. Mechanical manufacturing platforms requiring nanoscale positioning and manipulation
11. **Current Research Focus:**
    a. Integrated multi-axis systems
    b. Self-calibrating multi-axis positioning systems
12. Examples

a. Details of parallel kinematic XY MEMS stage concept and fabrication with comb drives.

b. Other XY stage designs
c. **XYZ MEMS-scale positioning stage:** This advanced stage incorporates a cantilever that is actuated by a parallel-plate capacitive drive in the z-direction. This allows for controlling the cantilever tip motion in the X, Y and Z directions of about 25 x 25 x 6 microns. The entire stage fits in a 5mm X 5mm square and the device has a bandwidth exceeding 1.5 kHz.

Details of MEMS stage with z-direction cantilever (left). Displacement characteristics of X and Y axes (top) and the cantilever (bottom), measured at the parallel plate drive.