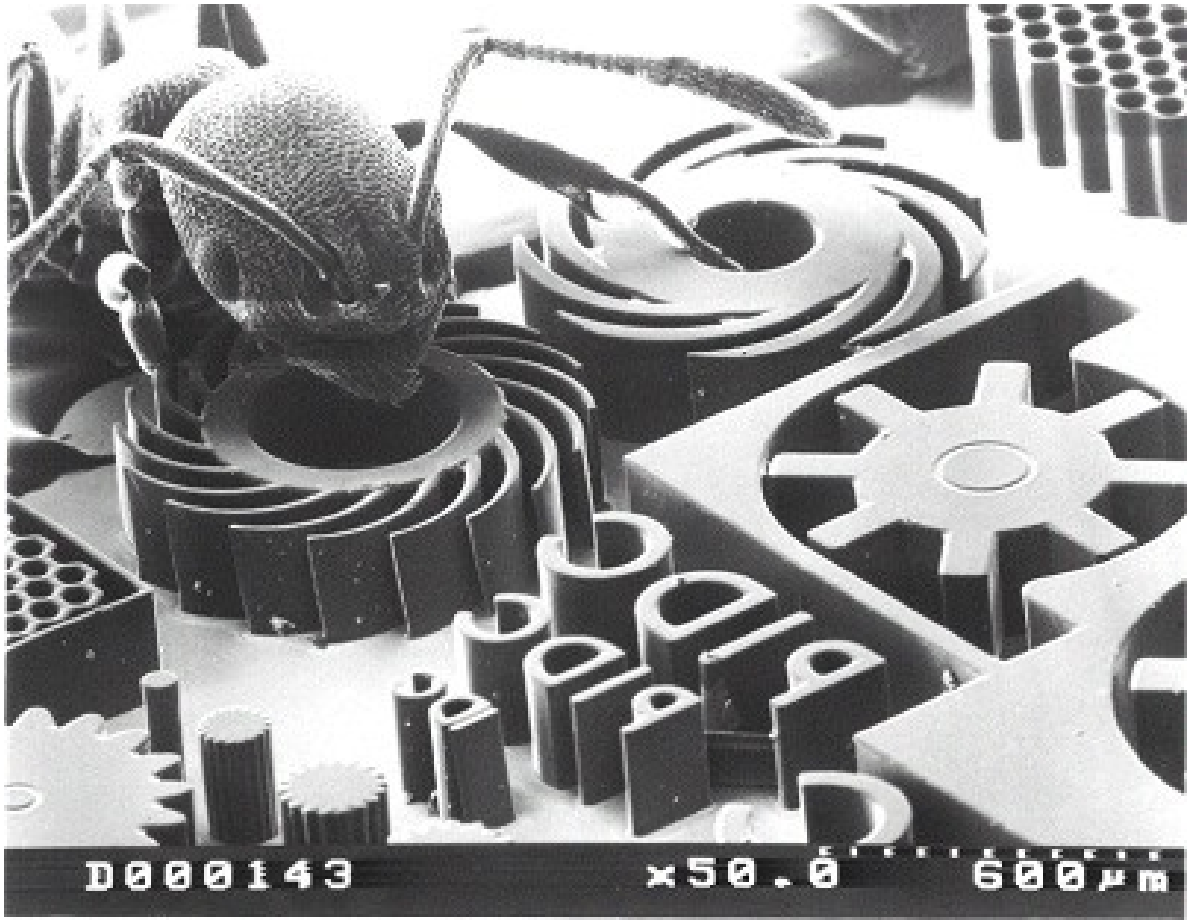
¿A qué nos referimos cuando hablamos de MEMS?

- Sistemas mecánicos de dimensiones micrométricas
- En general estructuras maquinadas con técnicas litográficas

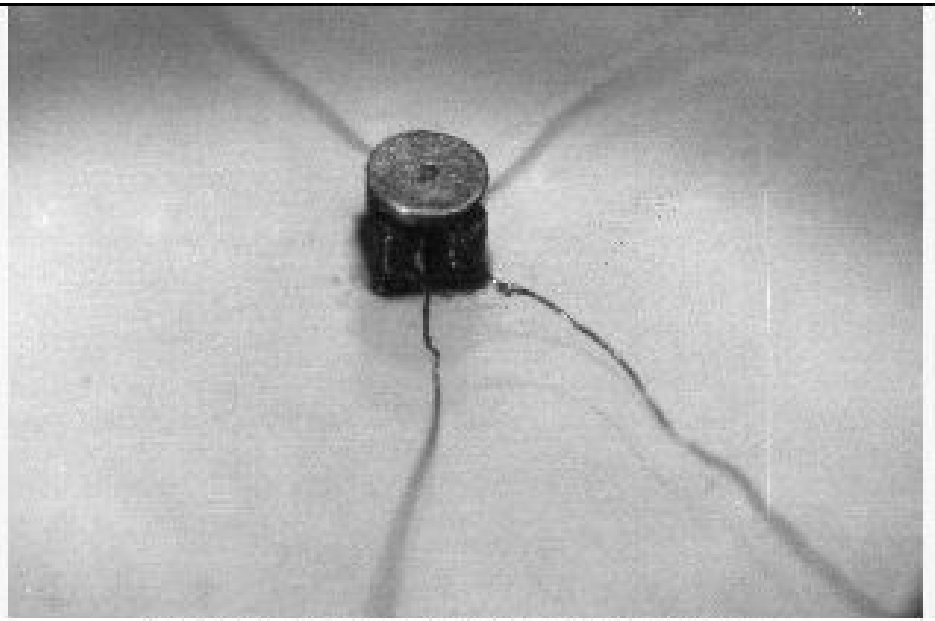


There's Plenty of Room at the Bottom

Richard P. Feynman

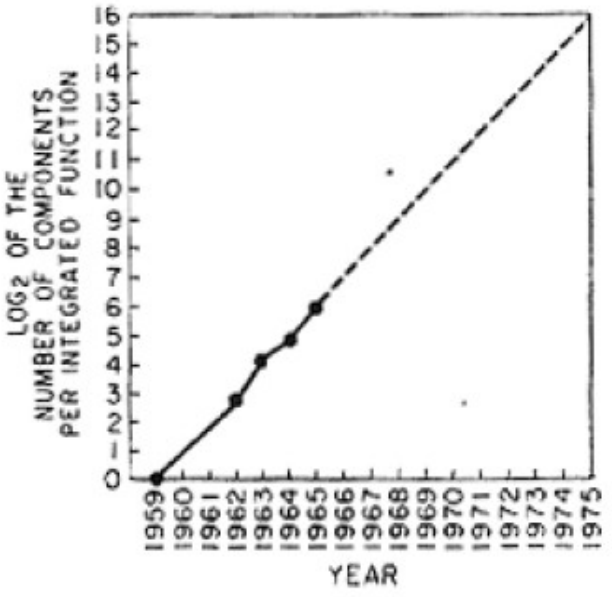
Caltech, APS Meeting
26 de Diciembre de 1959

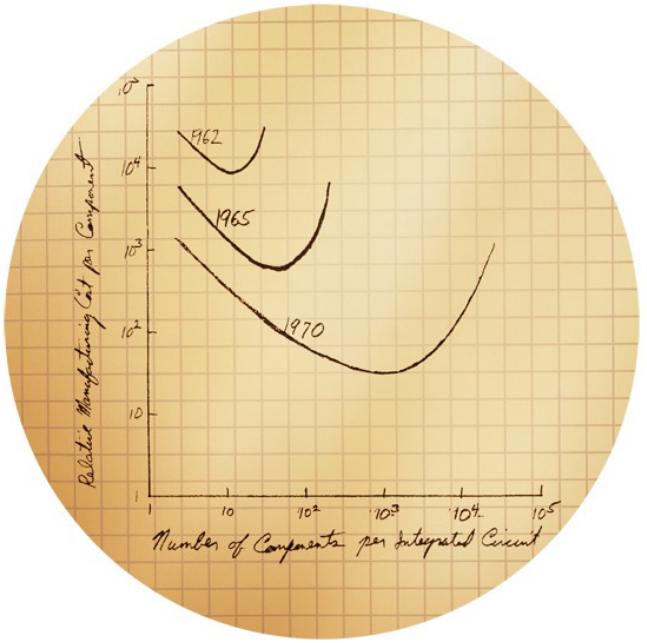
What I want to talk about is the problem of manipulating and controlling things on a small scale.

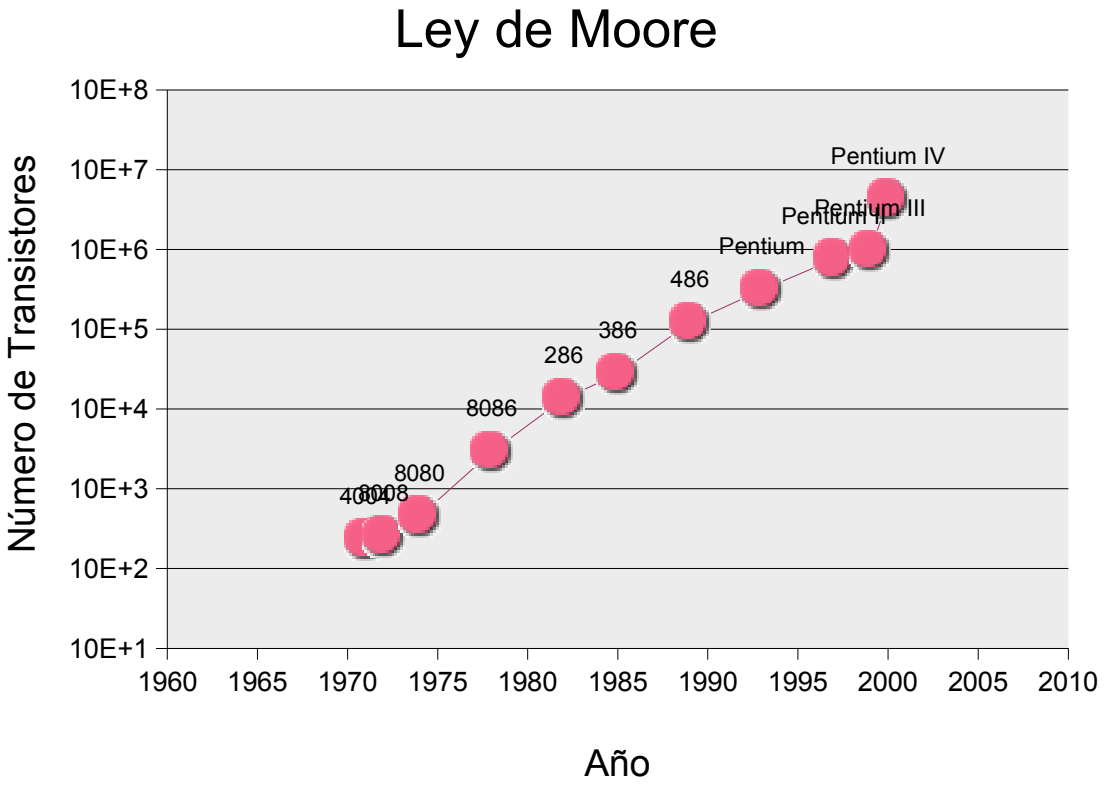


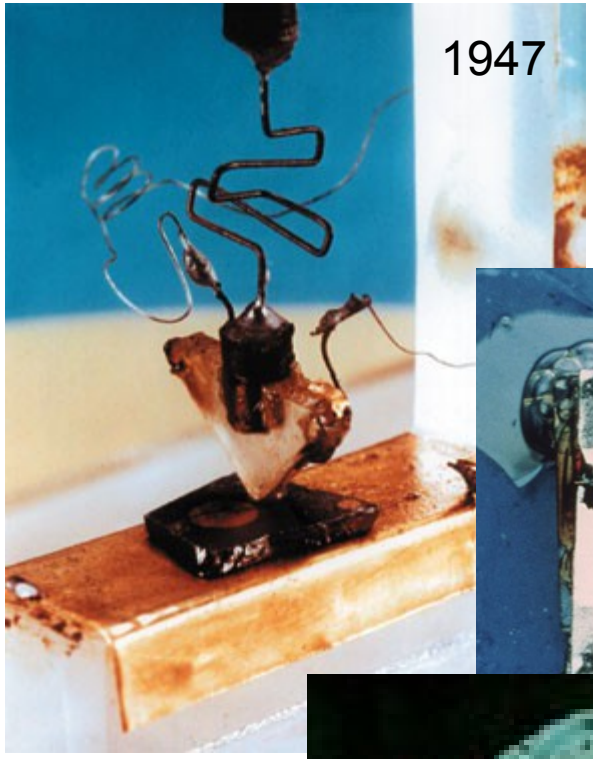
And I want to offer another prize—if I can figure out how to phrase it so that I don't get into a mess of arguments about definitions—of another $1000 to the first guy who makes an operating electric motor—a rotating electric motor which can be controlled from the outside and, not counting the lead-in wires, is only 1/64 inch cube.

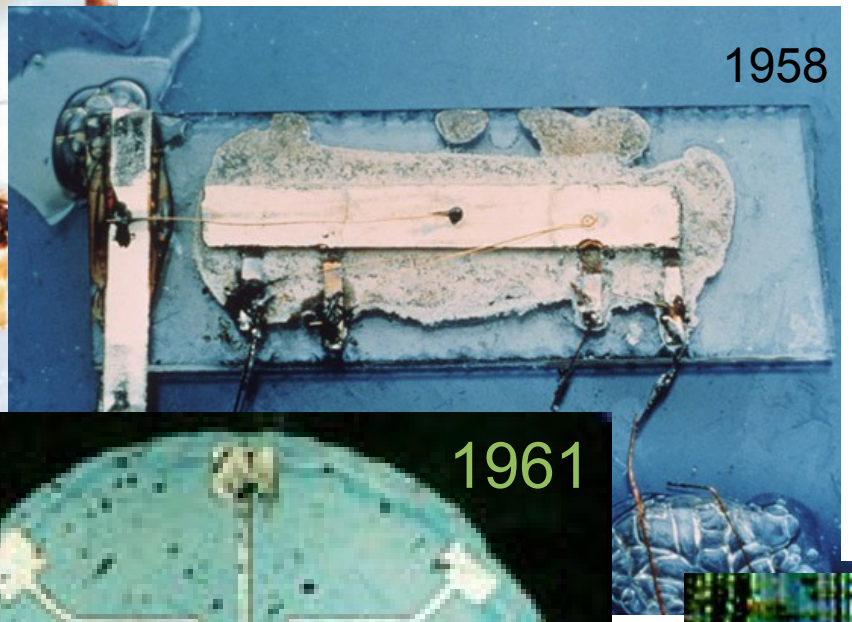
I do not expect that such prizes will have to wait very long for claimants.[1]

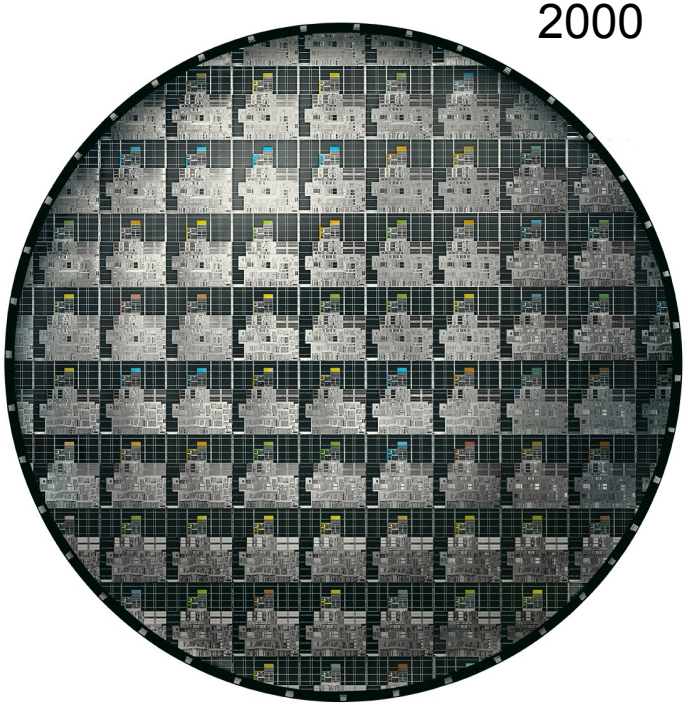

LOG2 OF THE NUMBER OF COMPONENTS PER INTEGRATED FUNCTION
YEAR
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975

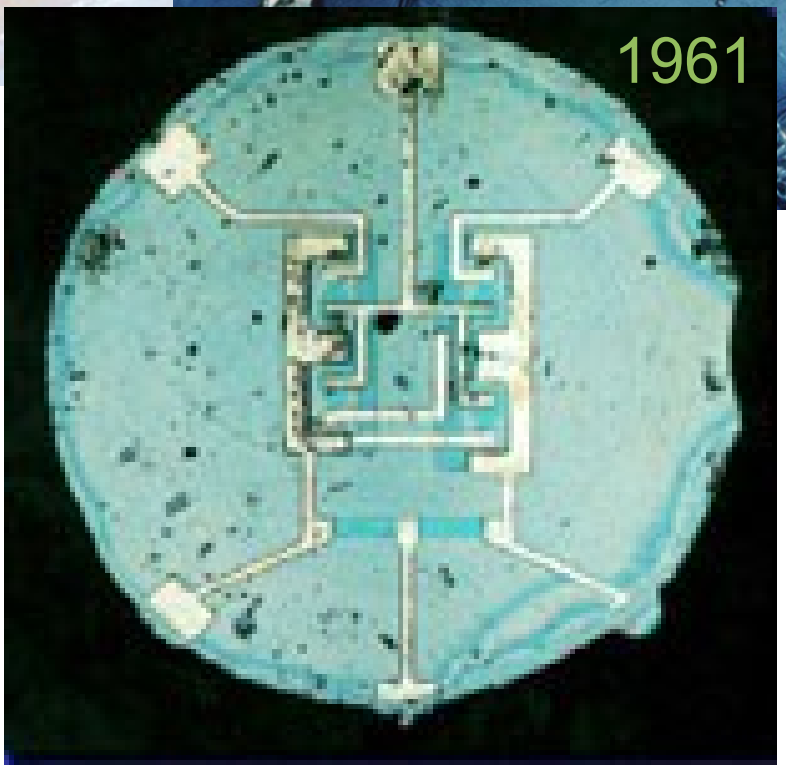

1962
1965
1970
Number of Components per Integrated Circuit

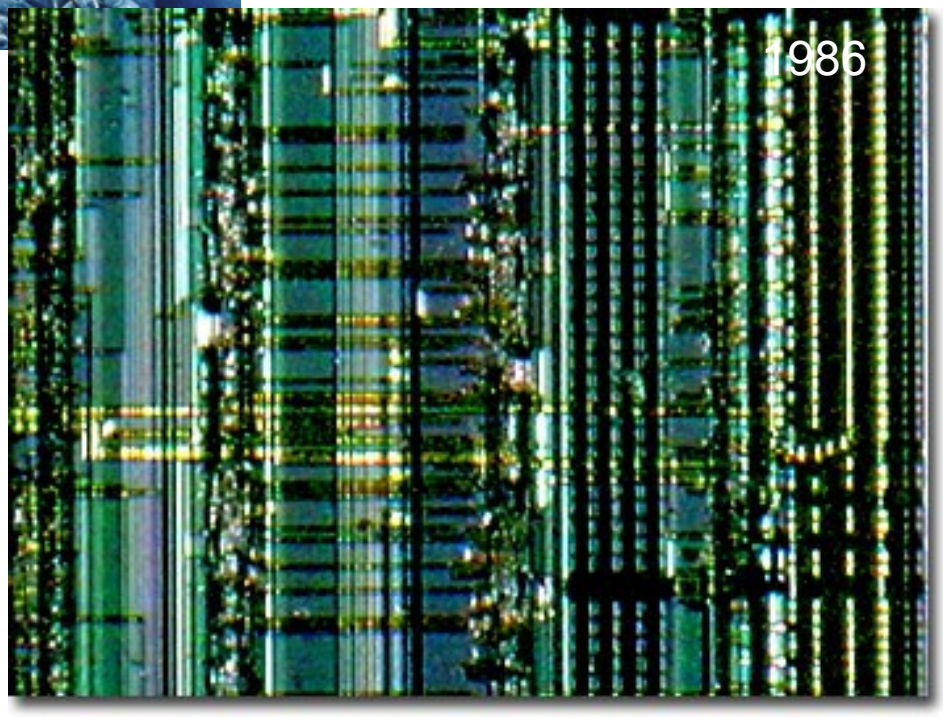

Ley de Moore
Número de Transistores
Año
10E+1
10E+2
10E+3
10E+4
10E+5
10E+6
10E+7
10E+8
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
4004
8008
8080
8086
286
386
486
Pentium
Pentium II
Pentium III
Pentium IV


1947


1958


2000


1961

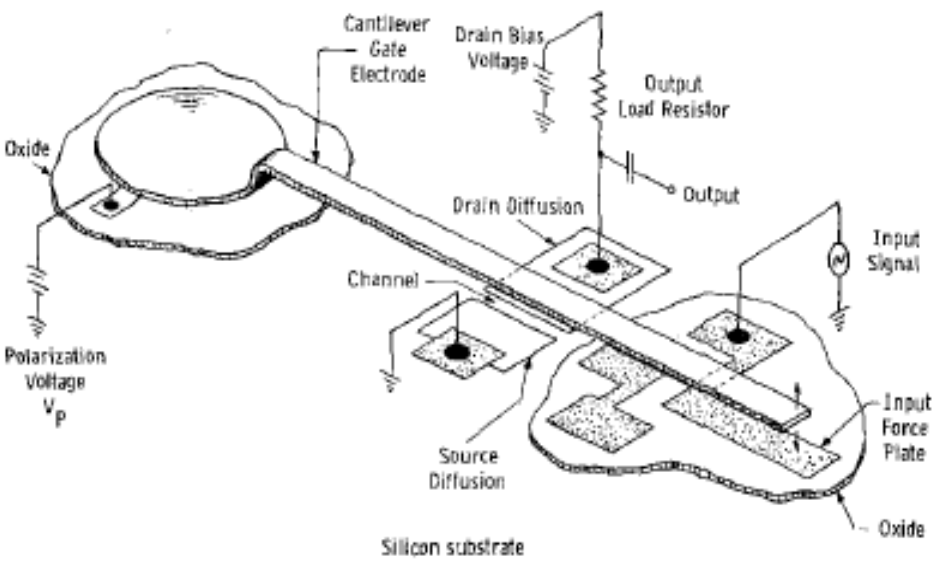

1986

The Resonant Gate Transistor

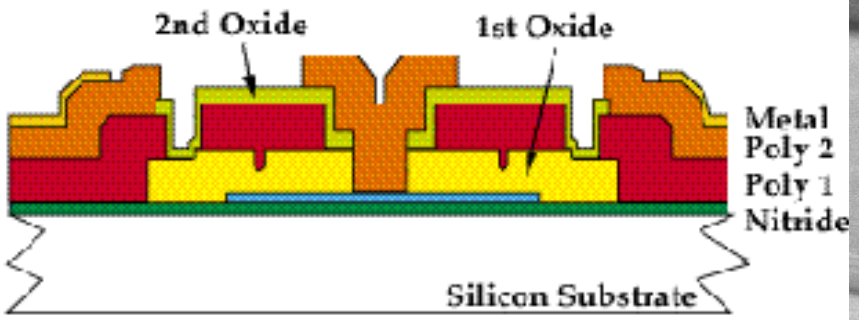
HARVEY C. NATHANSON, MEMBER, IEEE, WILLIAM E. NEWELL, SENIOR MEMBER, IEEE,
ROBERT A. WICKSTROM, AND JOHN RANSFORD DAVIS, JR., MEMBER, IEEE

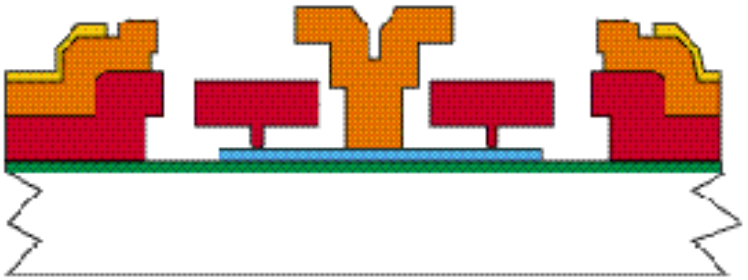
Abstract—A device is described which permits high-Q frequency selection to be incorporated into silicon integrated circuits. It is essentially an electrostatically excited *tuning fork* employing field-effect transistor "readout." The device, which is called the resonant gate transistor (RGT), can be batch-fabricated in a manner consistent with silicon technology. Experimental RGT's with gold vibrating beams operating in the frequency range 1 kHz $< f_0 <$ 100 kHz are described. As an example of size, a 5-kHz device is about 0.1 mm long (0.040 inch). Experimental units possessing Q's as high as 500 and overall input-output voltage gain approaching +10 dB have been constructed.

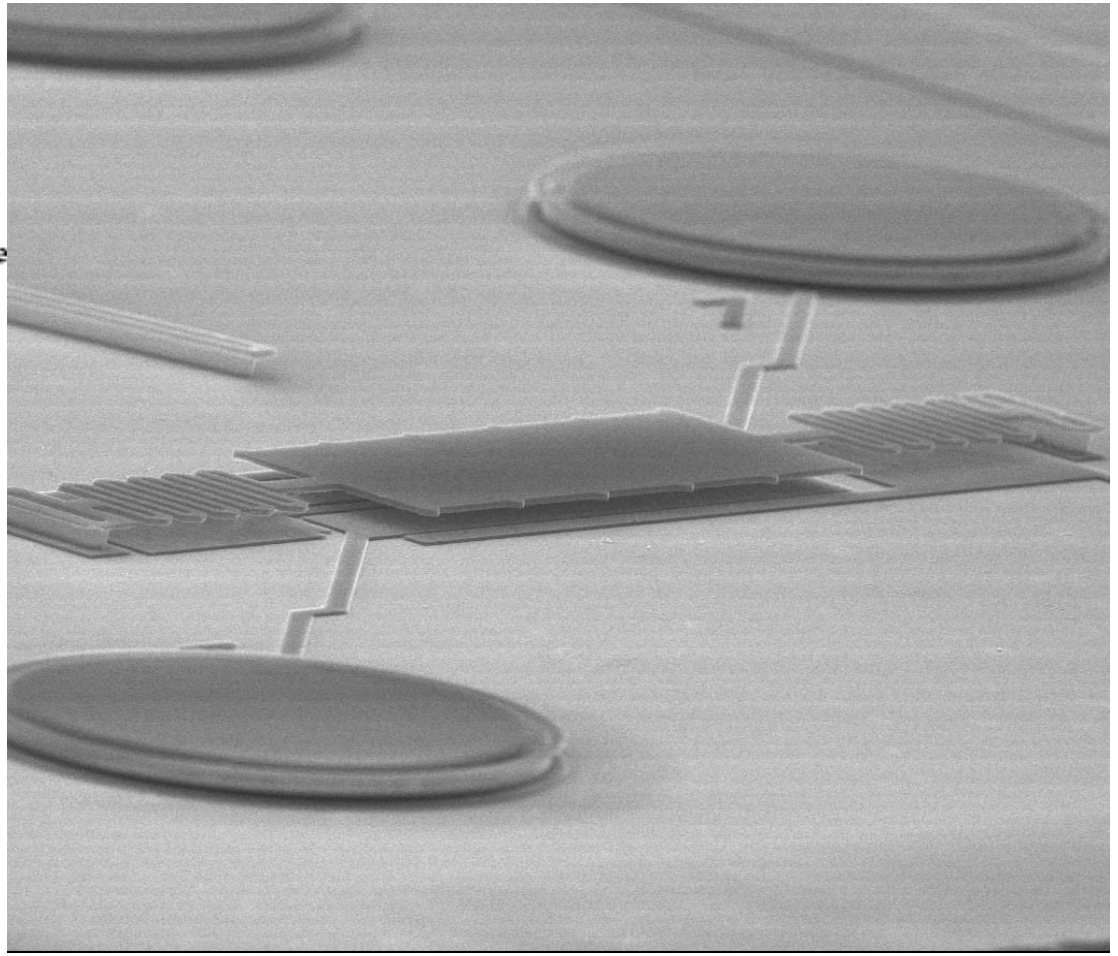
The mechanical and electrical operation of the RGT is analyzed. Expressions are derived for both the beam and the detector characteristic voltage, the device center frequency, as well as the device gain and gain-stability product. A batch-fabrication procedure for the RGT is demonstrated and theory and experiment corroborated. Both single- and multiple-pole pair band pass filters are fabricated and discussed. Temperature coefficients of frequency as low as 90–150 ppm/°C for the finished batch-fabricated device were demonstrated.



Para hacer estructuras “tridimensionales” es necesario realizar muchas etapas sucesivas.



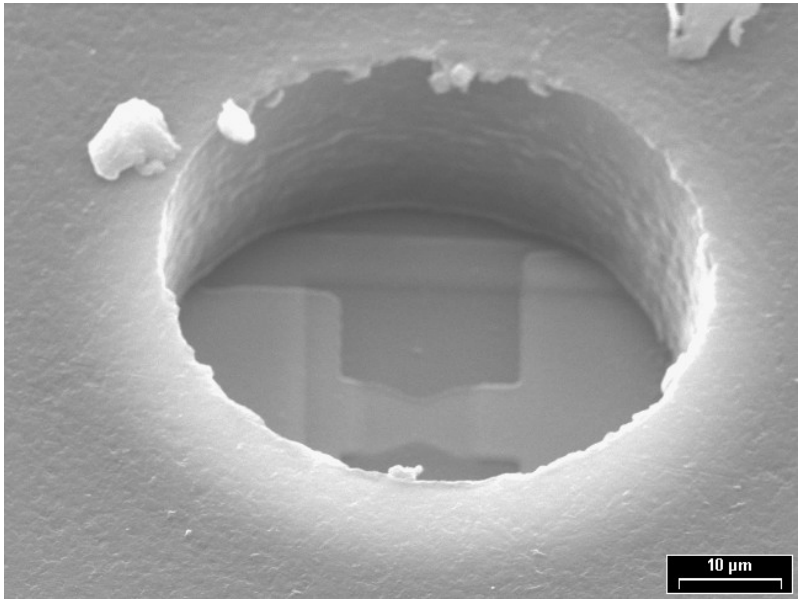


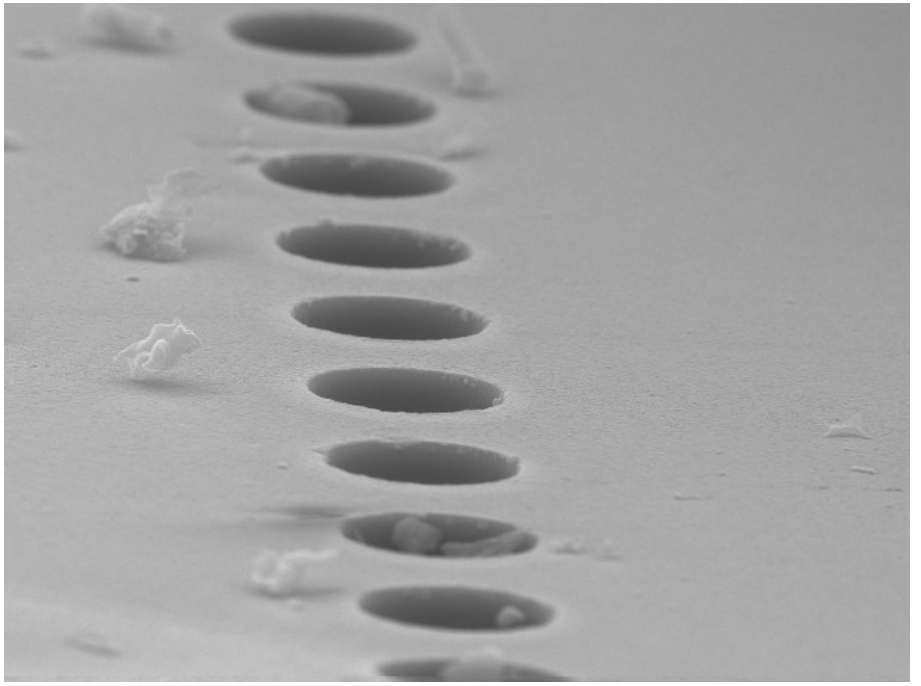


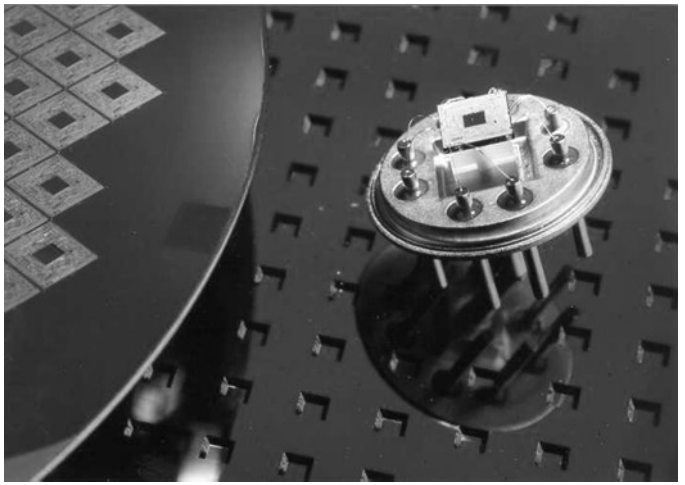
Algunos atributos de MEMS

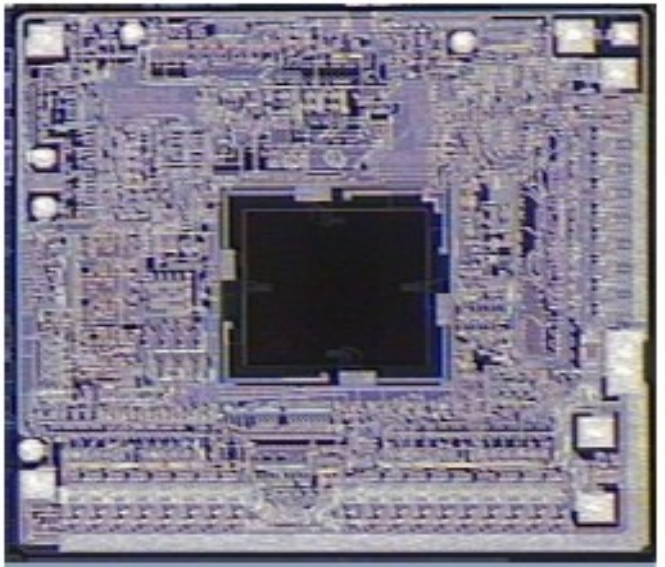
- Son chicos y baratos de hacer
  - ≅ Utilización de tecnología establecida en IC
    - Fácil replicación
    - Integración con electrónica
  - ≅ Baja disipación
- Robustez

Ejemplos:







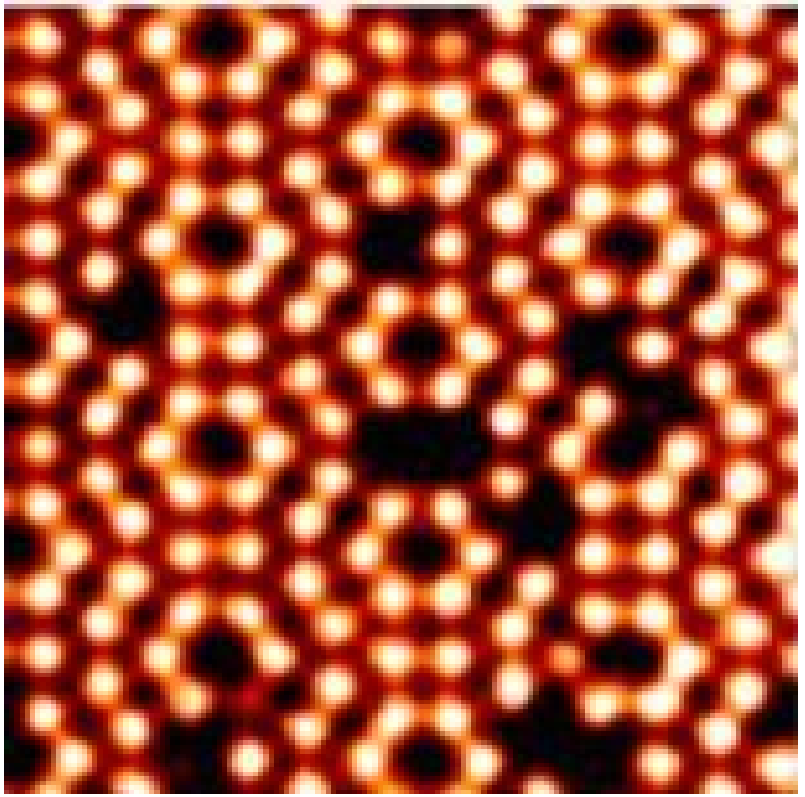


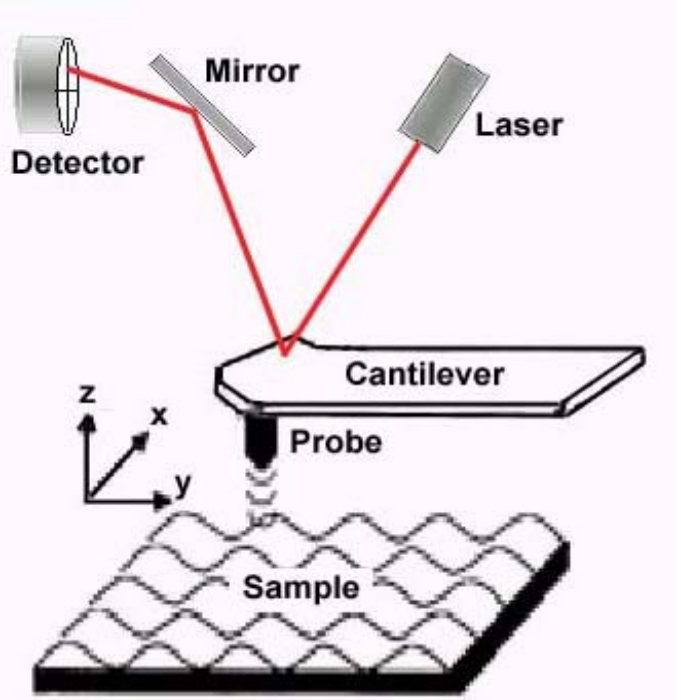
SMD085

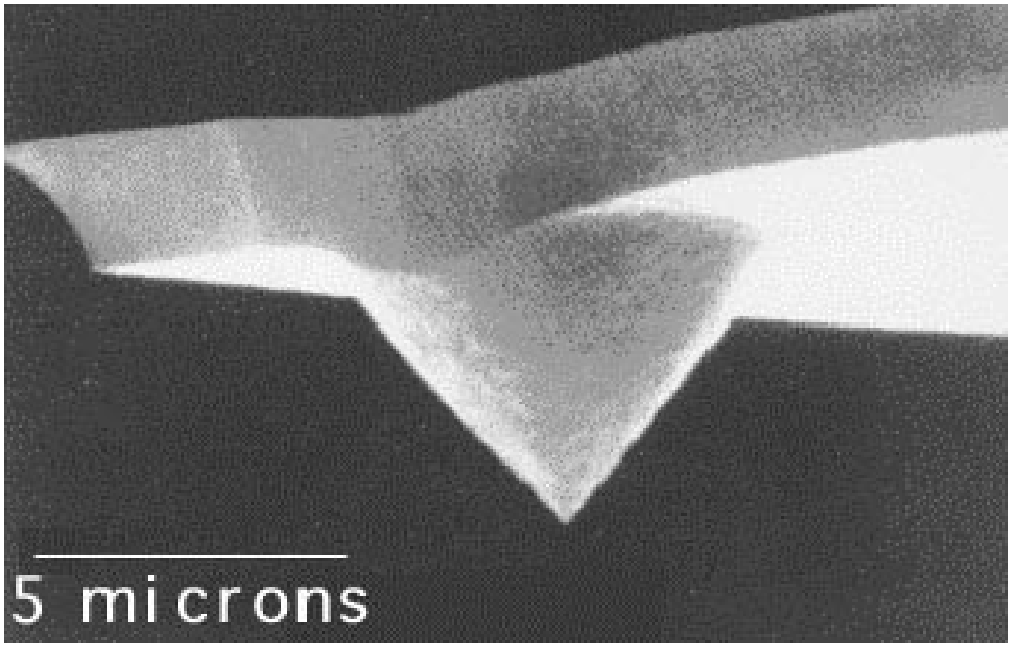
Introduction

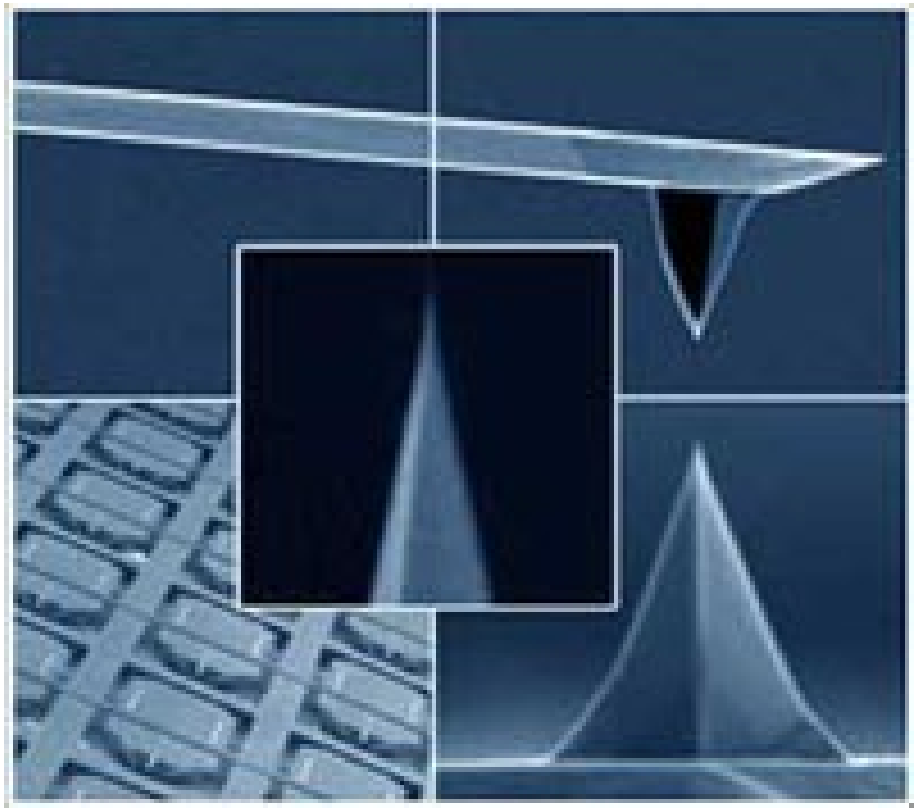
Bosch is the world market leader for pressure sensors in automotive applications. The SMD08x are a new family of a wide range of micromachined pressure sensors. They are one of the first pressure sensors for barometric air pressure which comes in an SMD package. It is easy to equip in standard assembly lines.

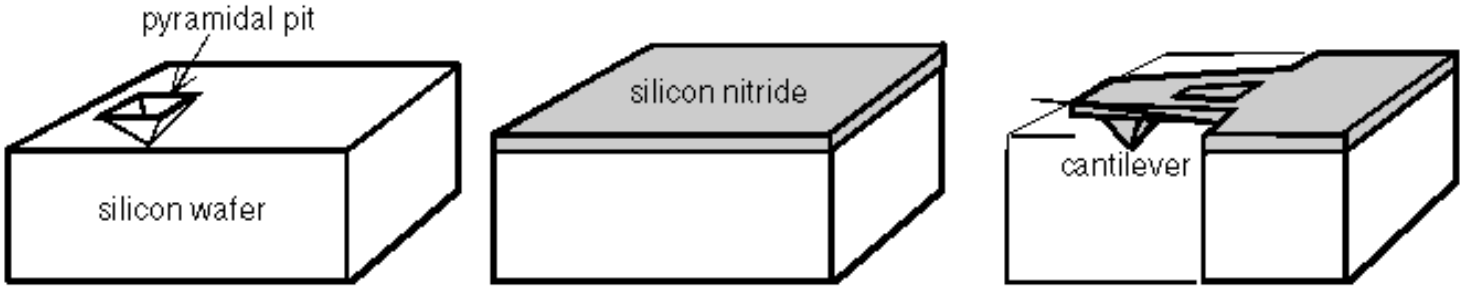
Microscopio de fuerza atómica






5 microns




pyramidal pit
silicon wafer
silicon nitride
cantilever

De nuevo Feynman...

Infinitesimal Machinery

Richard Feynman

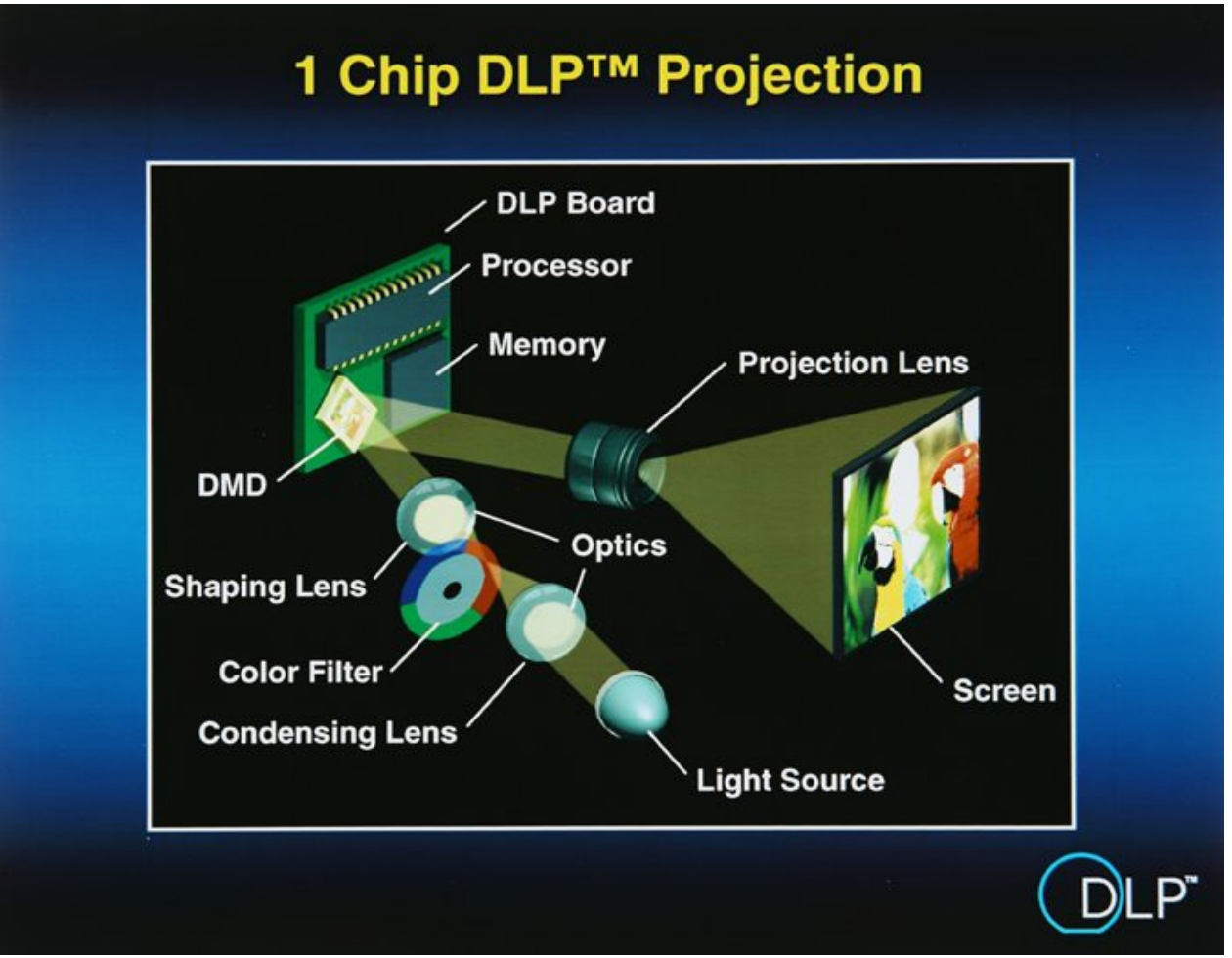
Revisiting "There's Plenty of Room at the Bottom"

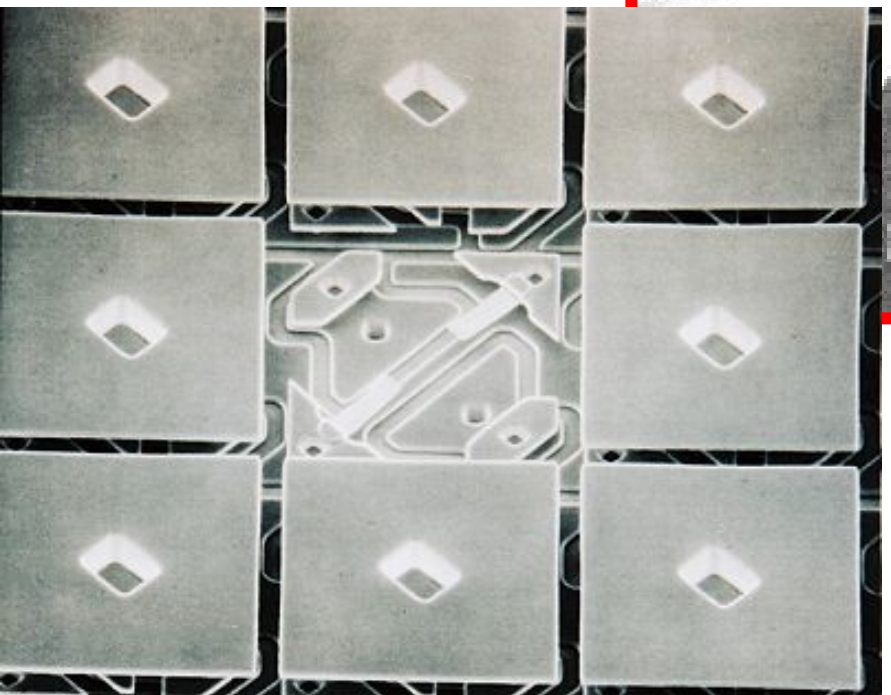
Jet Propulsion Laboratory
23 de Febrero de 1983

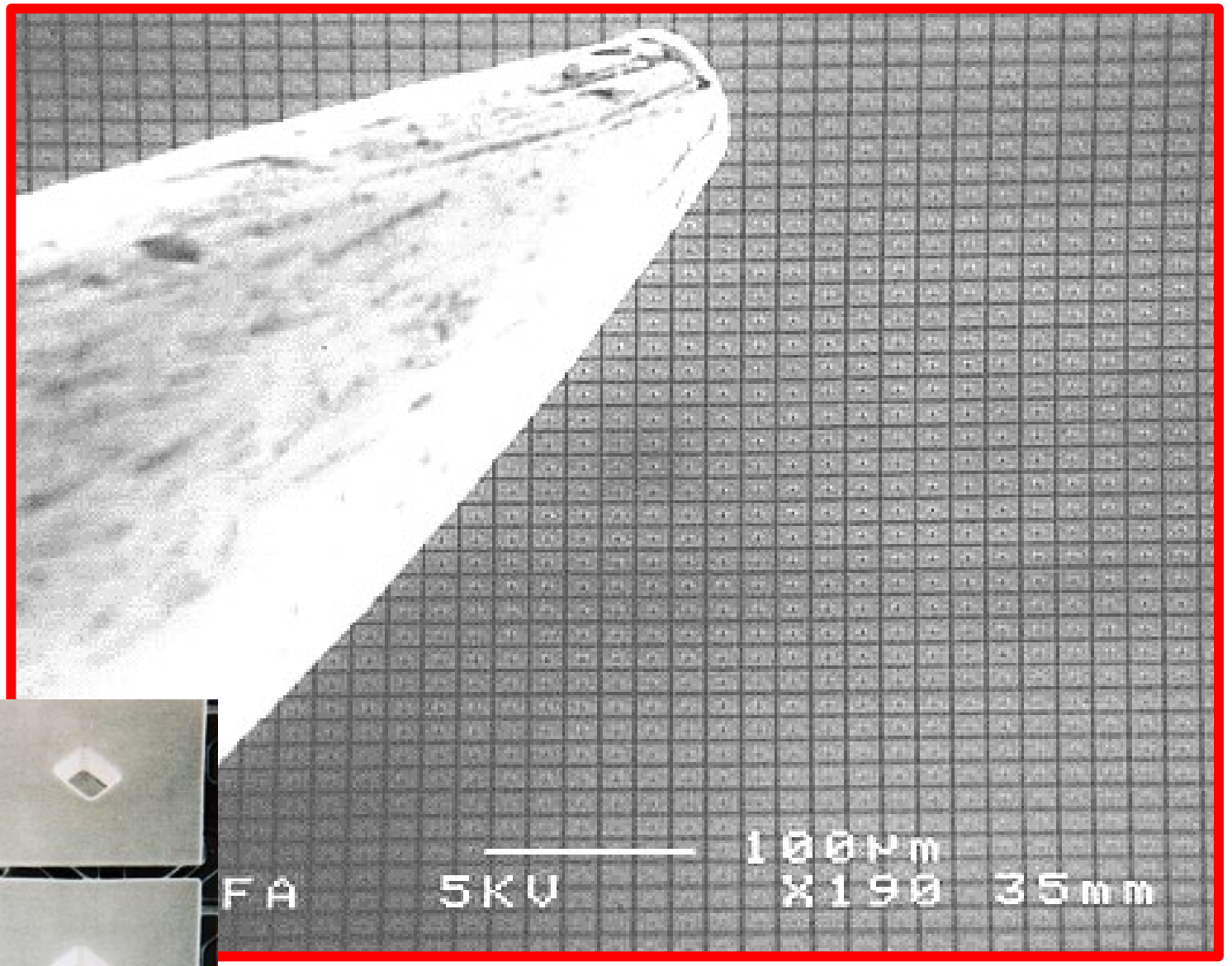
had a closed area and a half wheel that you turned underneath, you could open and shut a hole to let light through or shut it out. And so you have light valves. But because these tiny valves could be placed all over an area, you could make a gate that would let through patterns of light. You could quickly change these patterns by means of electrical voltages, so that you could make a series of pictures. Or, you could use the valves to control an intense source of light and project pictures that vary rapidly—television pictures. I don't think projecting television pictures has any use, though, except to sell more television pictures or something like that. I don't consider that a use—advertising toilet paper.

...Y entonces tenemos válvulas de luz. Pero como estas diminutas válvulas pueden ser puestas por toda un área, podemos hacer una puerta que deje pasar "patrones" de luz. Podríamos rápidamente cambiar estos patrones por medio de voltajes eléctricos y así hacer una serie de dibujos. O podriamos usar estas válvulas para controlar una fuente intensa de luz y proyectar imágenes que varien rápidamente, imágenes de TV. Sin embargo, yo no creo que la proyeccion de imagenes de televisión tenga algún uso, excepto para vender más imágenes de TV o cosas como esas. Yo no considero eso un uso (como tener papel hgénico con propaganda)...

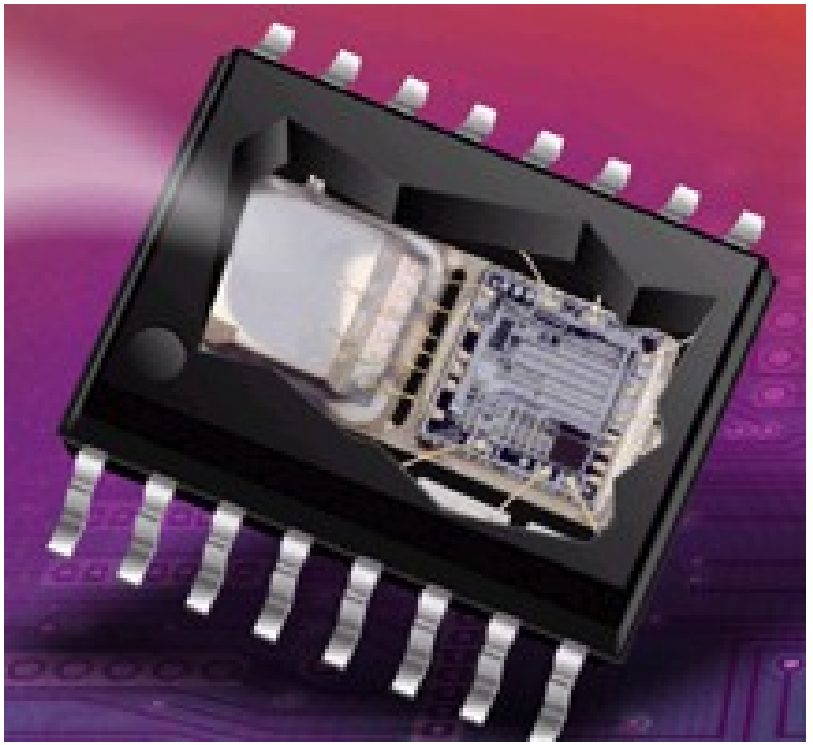
Texas Instruments DMD MEMS Array





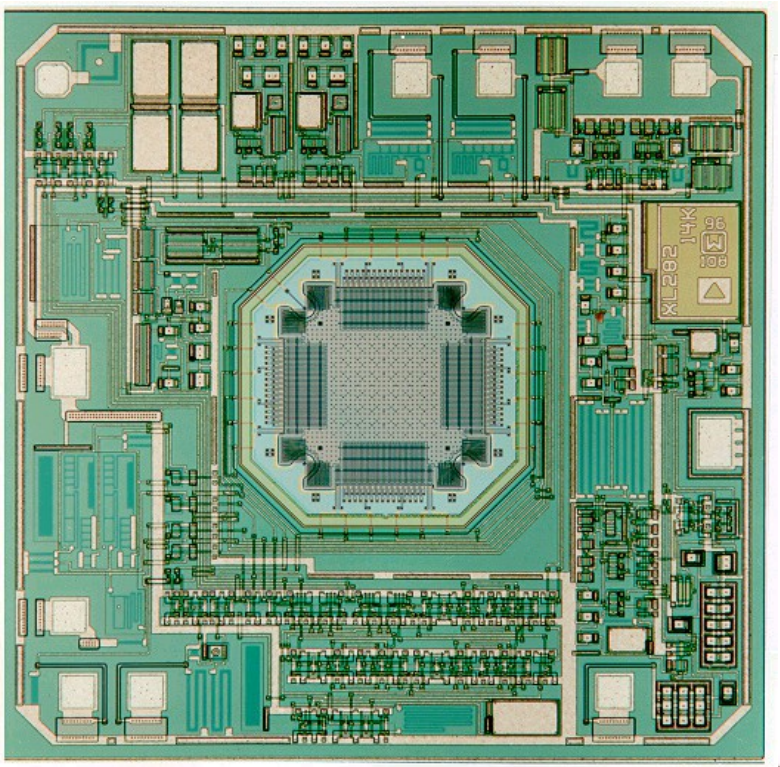

100µm
FA 5KV X190 35mm

Integration at Different Levels



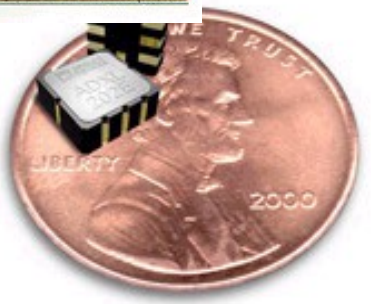
Multi-Chip

Integration in Package



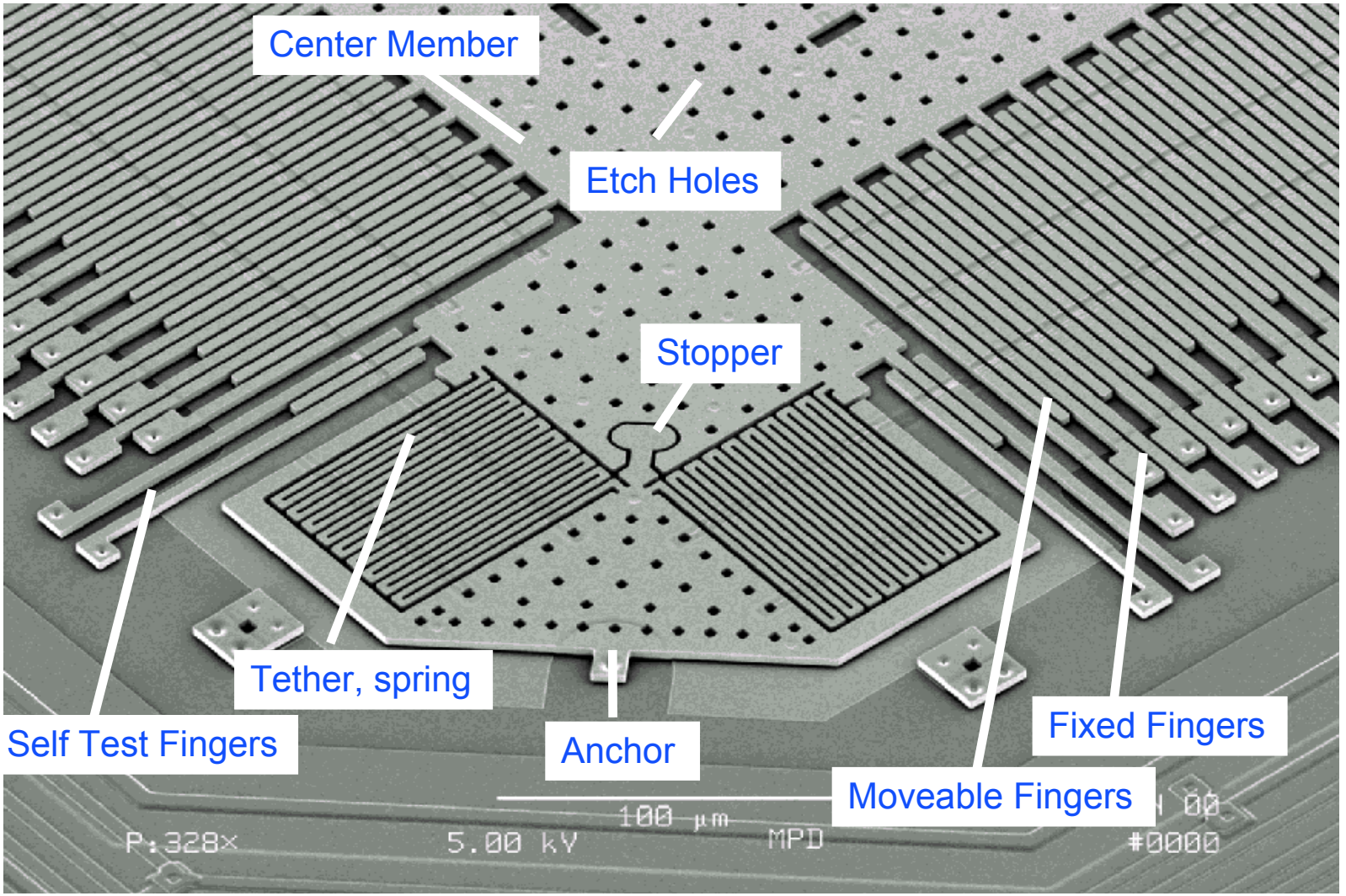
Single Chip

Integration on Chip



*i*MEMS® Technology

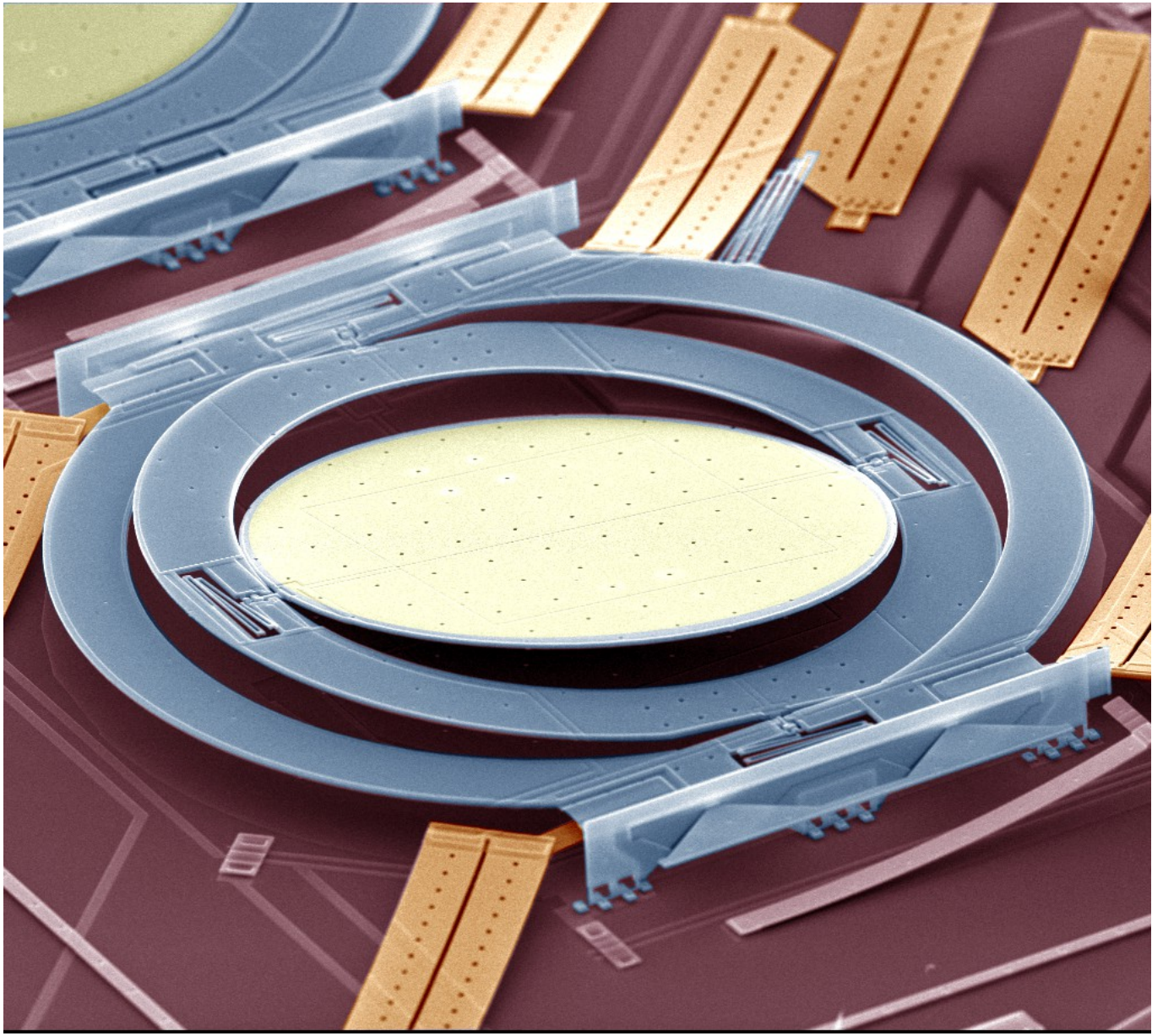
Accelerometer beam (ADXL202, one corner)



2-axis Beam-Steering Surface-Micromachined Mirror

Lucent Technologies
Bell Labs Innovations

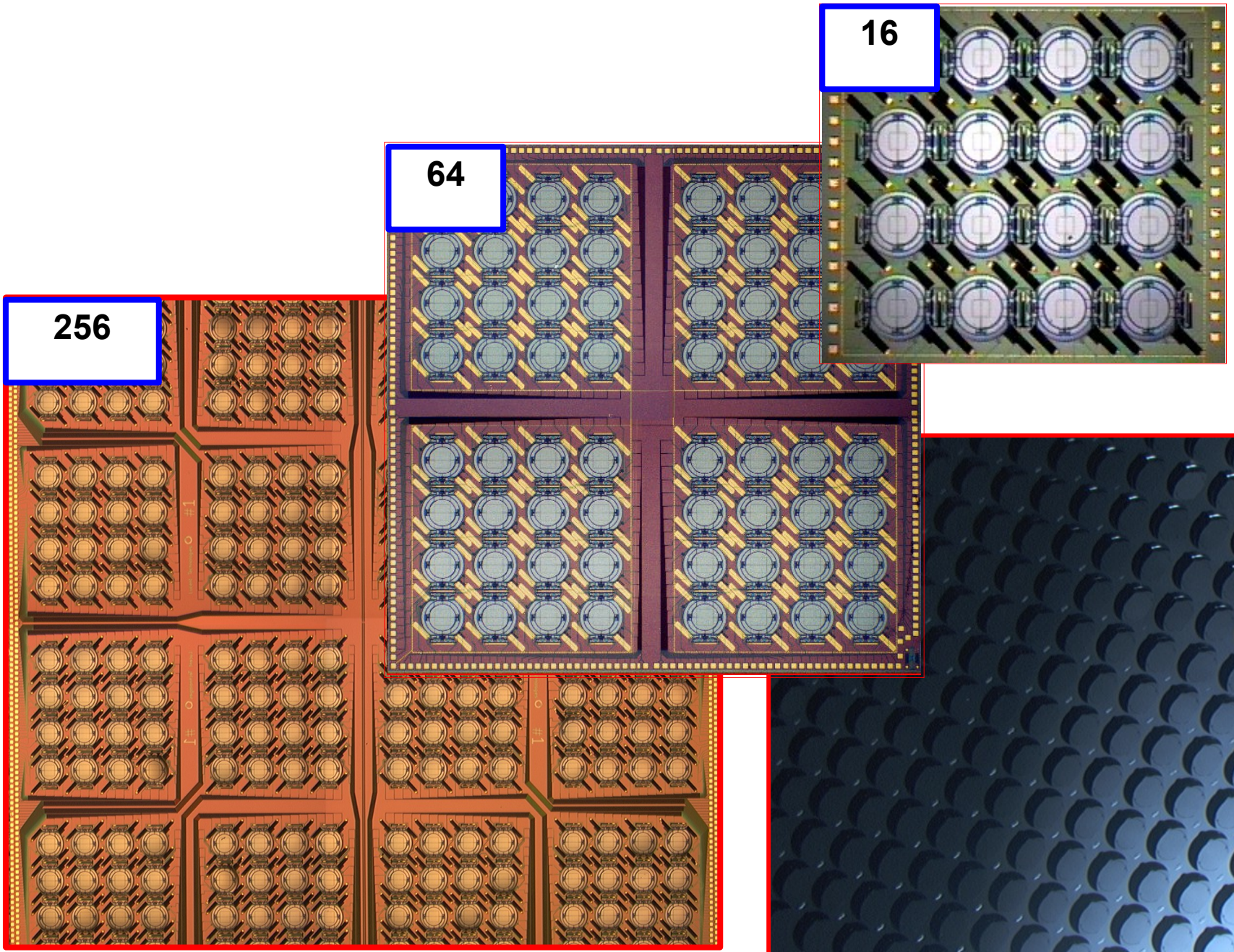
- raised frame for ±9° angles with 500um reflector
- self-assembly mechanism to lift and lock the frame
- gimbal mount with four serpentine springs
- electrostatic actuation with electrodes under device
- < 170V drive voltage to capacitive load
- < 5msec switching time
- gold reflector



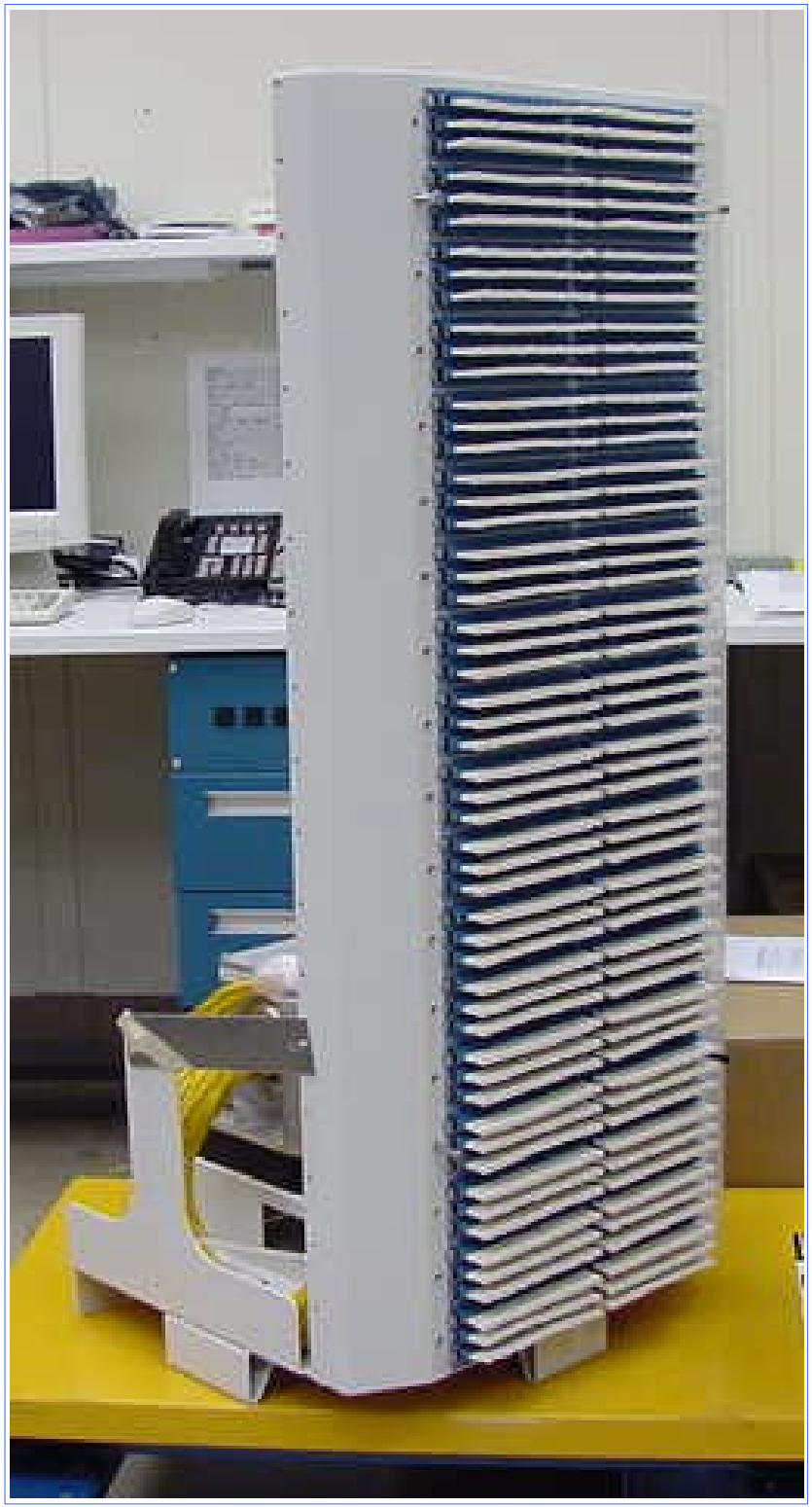
V.A. Aksyuk et. al. Proc. SPIE v.4178 2000

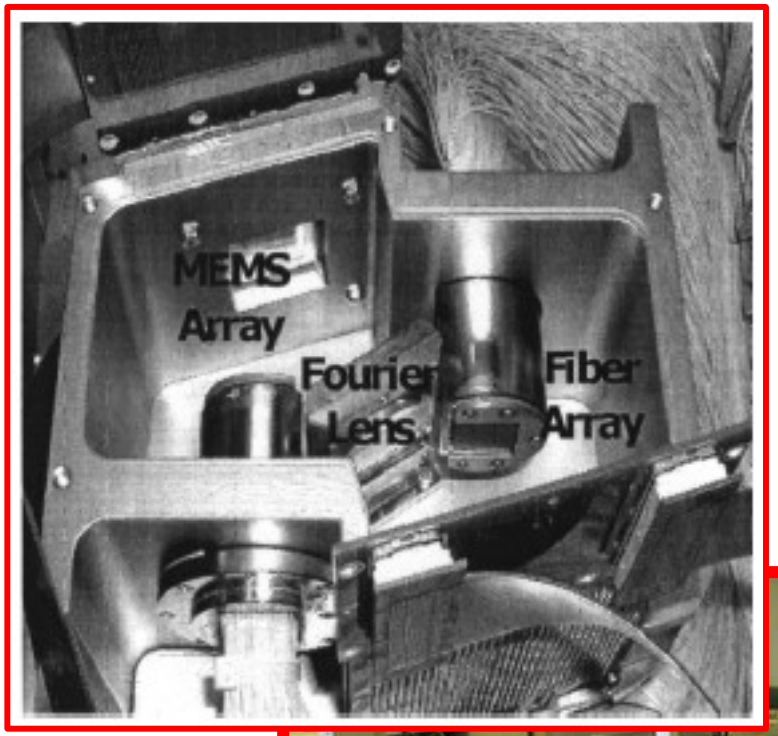
Micromirror Arrays

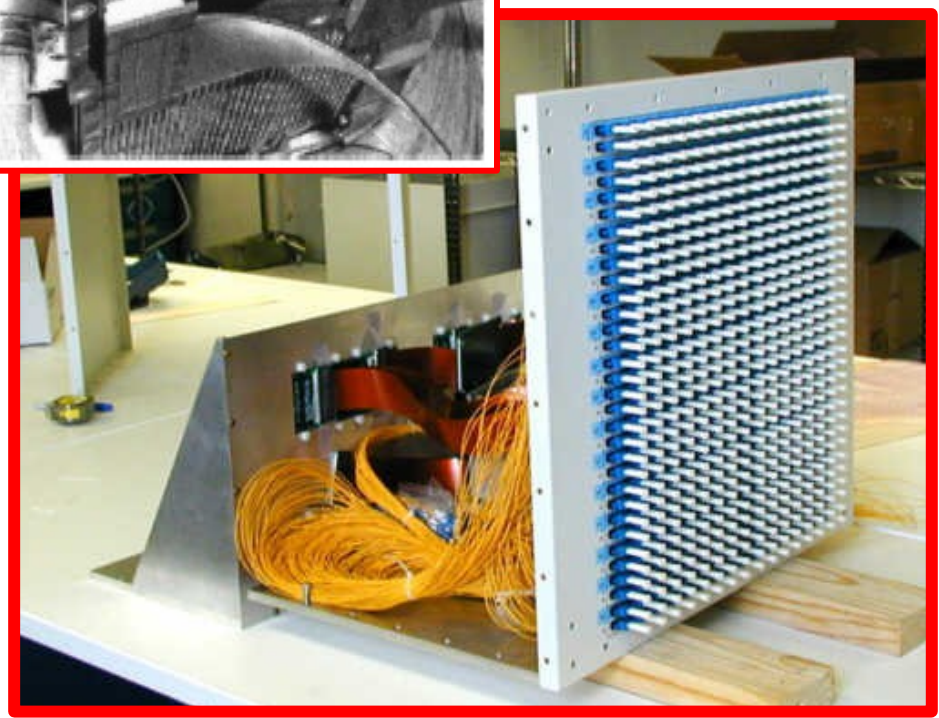
Lucent Technologies
Bell Labs Innovations



Optical Switch Fabrics

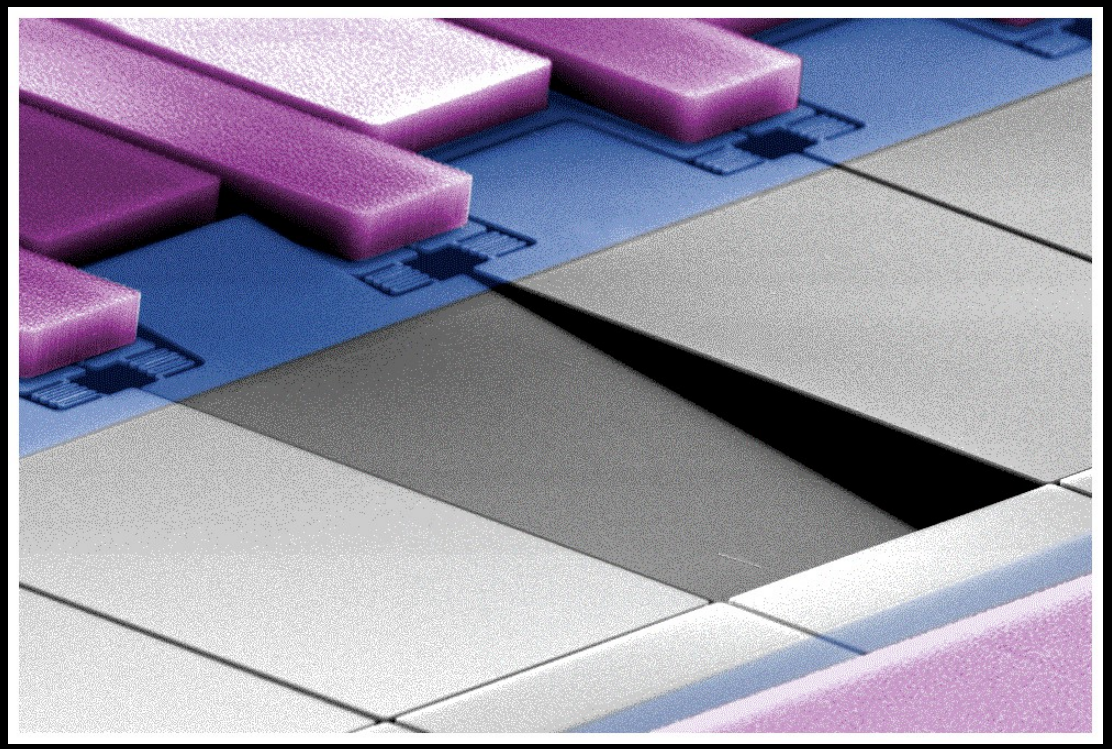


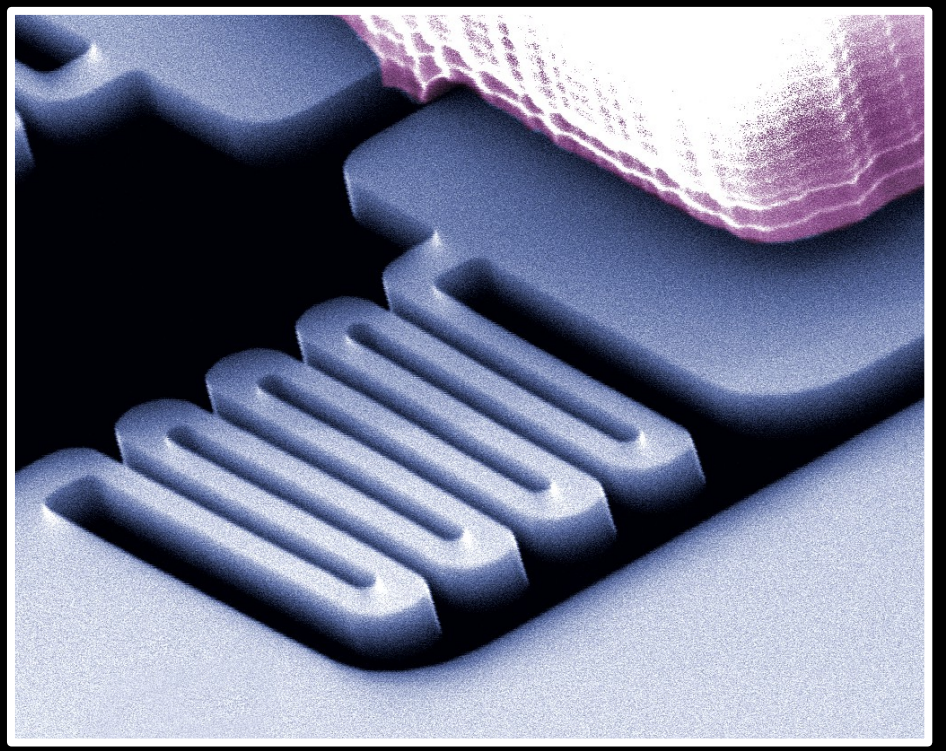




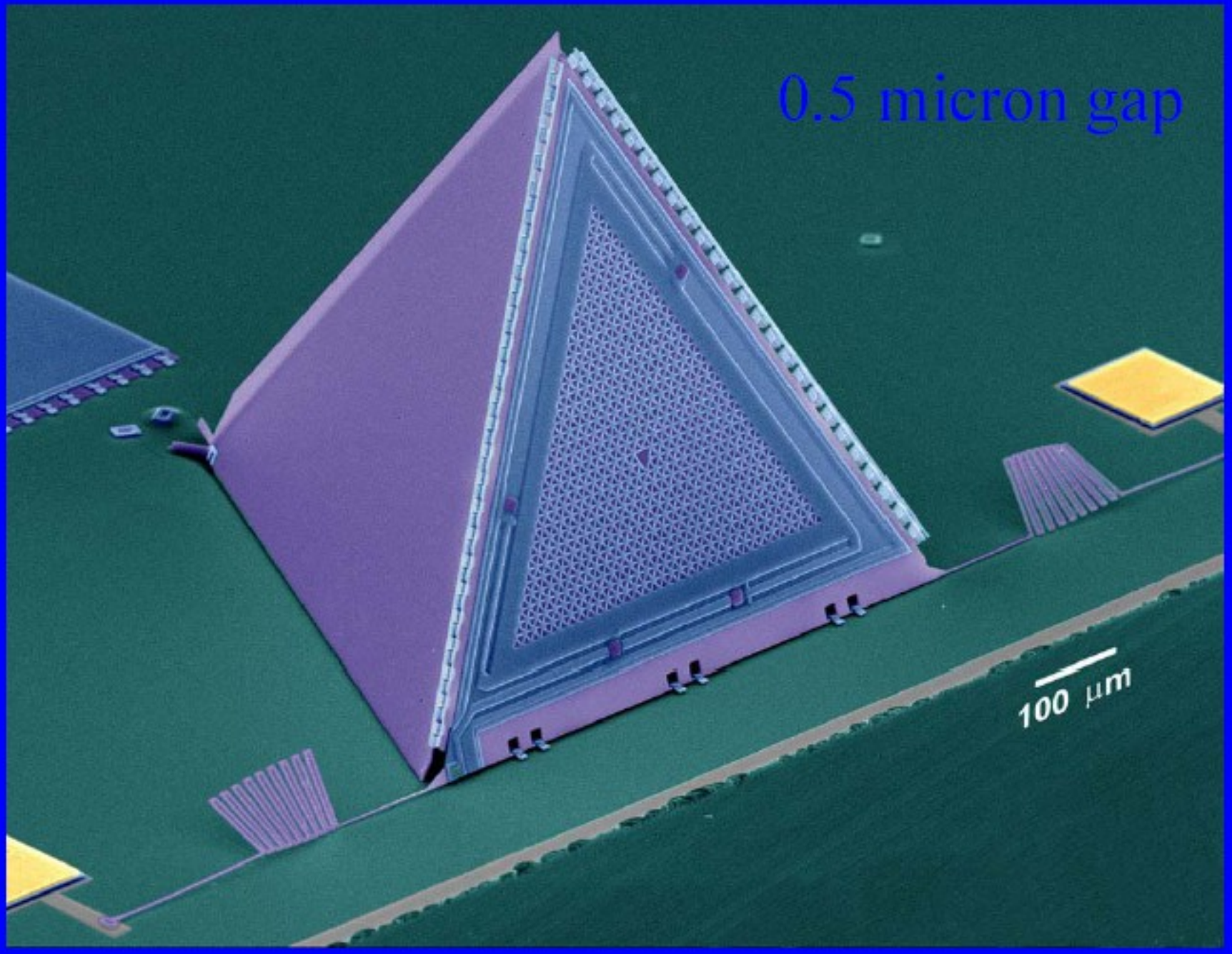
Monolithic Fringing-Field 1xN Switch

Surface-micromachined devices II

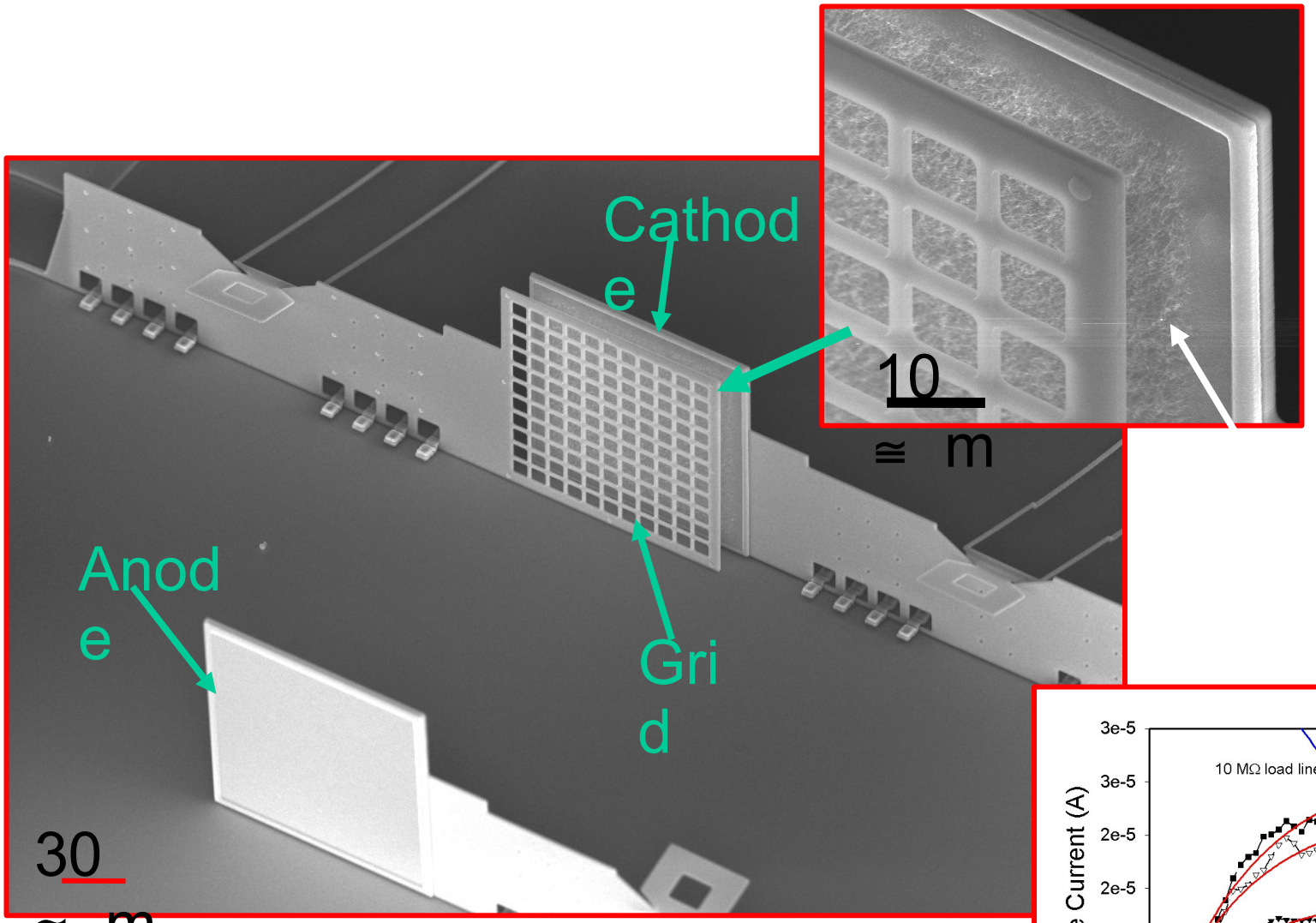


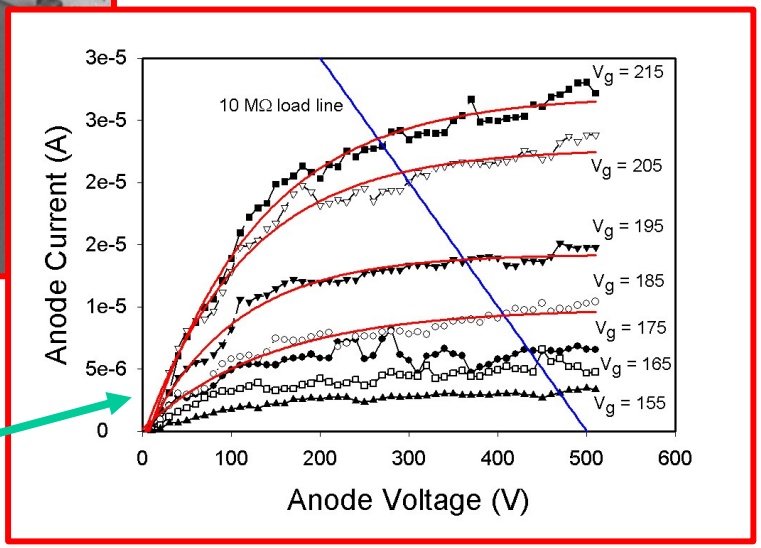


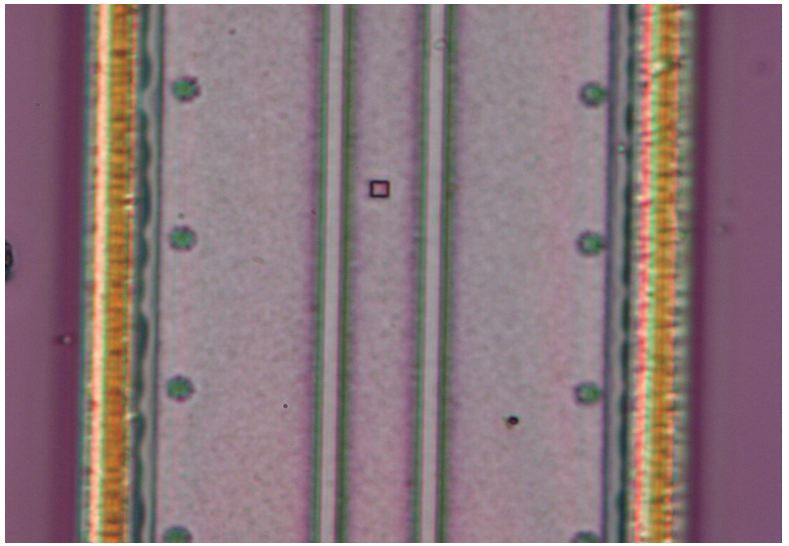
Bell Labs "Tent" all-surface machined microphone

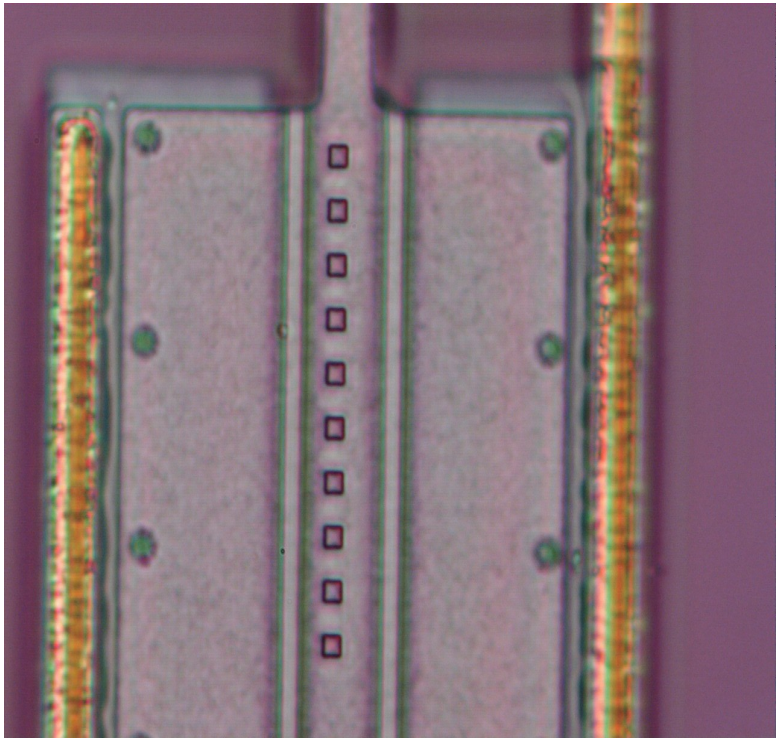


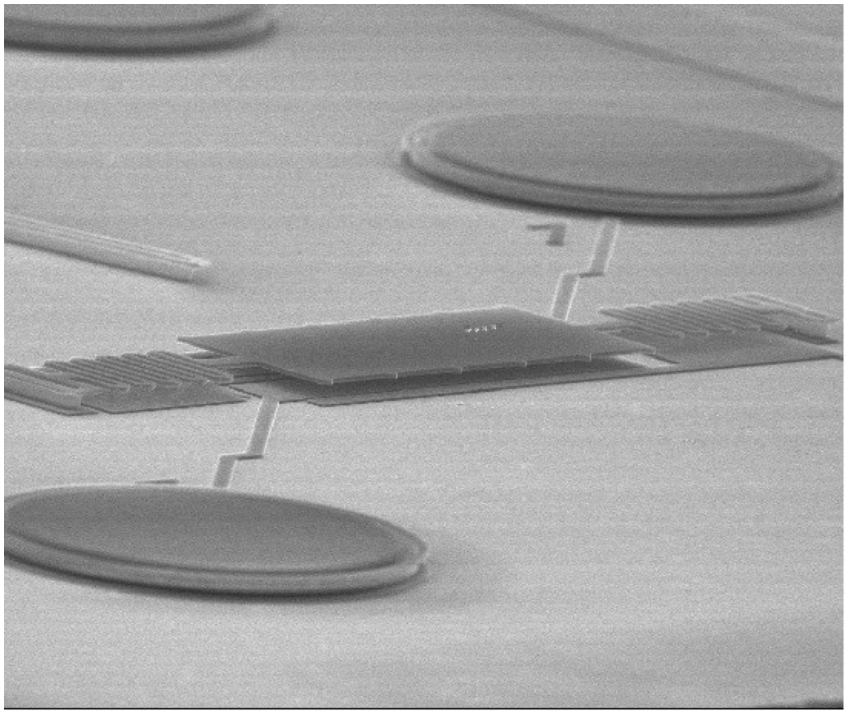
MicroTriode-MEMS Vacuum Tube











$2 \times 2\,\mu\,m^2$ Pb squares
on MEM oscillator