Introduction to Microsystem

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Outline

- What is Microsystem technology?
- Why is it so popular? $$$
- History overview
- Current and future applications
- Micro pressure sensor, accerolerometer micro mirror arrays, inkjet printhead
- Microfabrication
- Microscience
- Summary and Conclusion

What's in a name?

- MicroSystem Technology (MST) popular in Europe
- Micro-Electro-Mechanical Systems (MEMS) widely used in United States
- Microengineering sometimes used in UK
- Micromachines, マイクロマシン used in Japan
- 微機電系統 in Chinese

MEMS definition

MEMS is a study of making machines in micro scale with the fabrication technique in Integrated circuit (IC) industry. The size ranges from micrometer to milimeter (10^{-6} ~ 10^{-3} m)

MEMS are the systems that integrate

- **sensing**
- **actuation**
- **computation**
- **control**
- **communication**
- **power**

Size Does Matter

10^{7}

10^{6}

10^{5}

10^{4}

10^{3}

10^{2}

10^{1}

10^{0}

10^{-1}

10^{-2}

10^{-3}

10^{-4}

10^{-5}

10^{-6}

10^{-7}

10^{-8}

10^{-9}

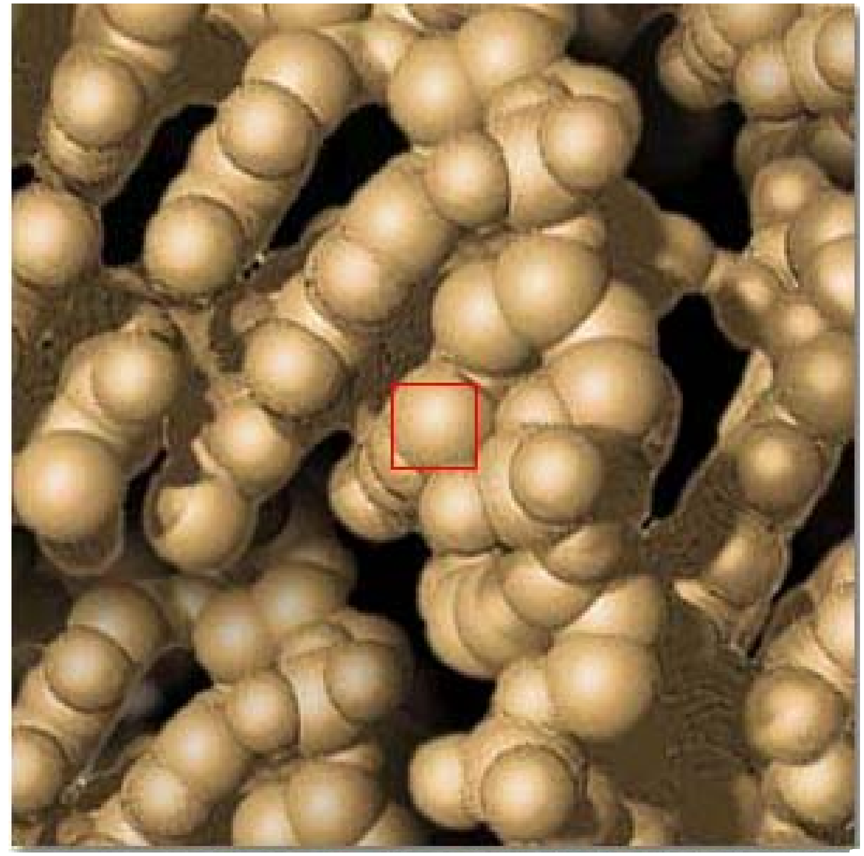
Science

Traditional Engineering

MEMS

Nanotechnology

Biomedical

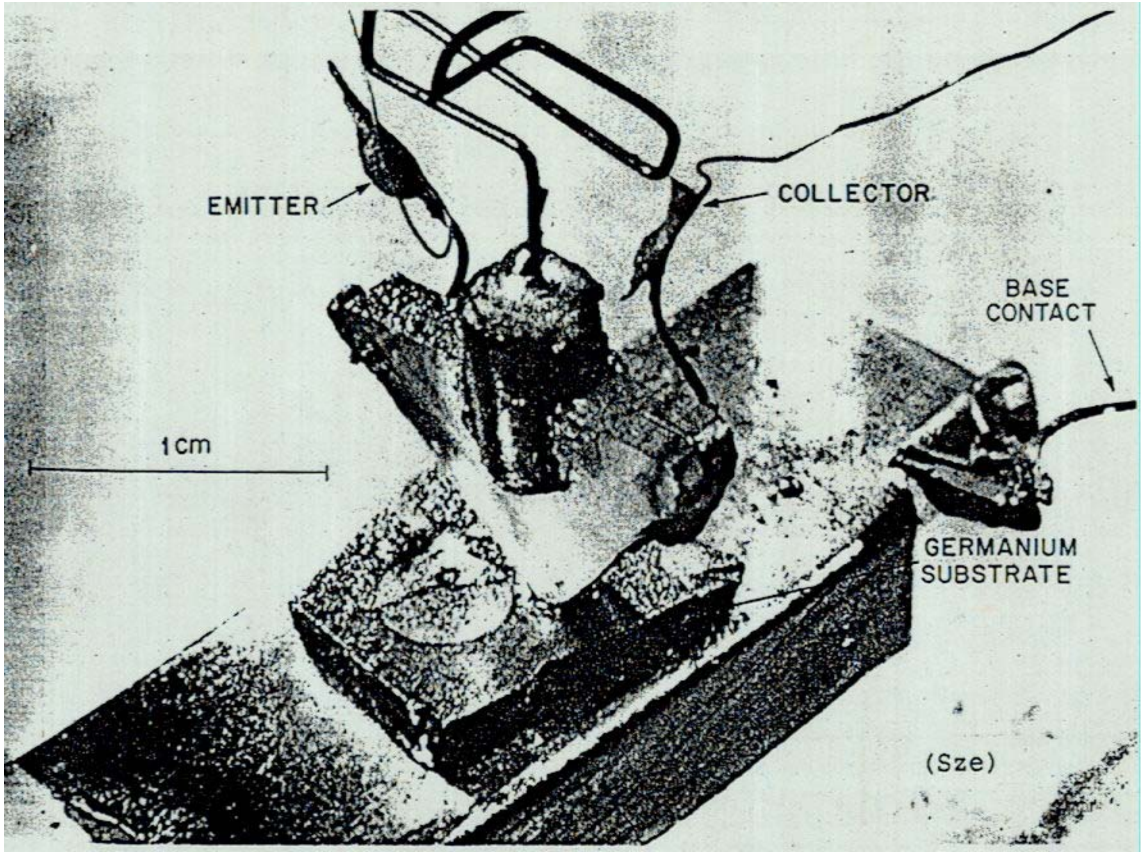


Unit : Meter

A brief history of MEMS

- 1947 invention of the transistor (made from germanium)
- 1958 silicon strain gauges commercialized; first integrated circuit (TI: Jack Kilby)
- 1961 first silicon pressure sensor demonstrated (Kulite)
- 1967 Invention of surface micromachining (Nathanson, Resonant Gate Transistor)
- 1970 first silicon accelerometer demonstrated (Kulite)
- 1977 first capacitive pressure sensor (Stanford) Prof James Angell
- 1979 first thermal inkjet printer (HP lab)
- 1980 Petersen, K.E., "Silicon Torsional Scanning Mirror"
- 1982 disposable blood pressure transducer (Foxboro/ICT, Honeywell, $40)
- 1982 active on-chip signal conditioning
- 1984 First polysilicon MEMS device (Howe, Muller); HP ThinkJet
- 1988 Rotary electrostatic side drive motors (Fan, Tai, Muller)
- 1989 Lateral comb drive (Tang, Nguyen, Howe)
- 1990 BIACORE microfluidic chip
- 1991 polysilicon hinge (Pister, Judy, Burgett, Fearing)
- 1992 Grating light modulator (Solgaard, Sandejas, Bloom), DARPA USD$80M/yr
- 1992 MCNC starts MUMPS
- 1993 First surface micromachined accelerometer sold (Analog Devices, ADXL50)
- 1996 Digital micro-mirrors array commercialized, DMD (Texas Instrument)
- 2001 Micro optical switch for internet backbone commercialized

Early Semiconductor Fabrication



J. Bardeen, W.H. Brattain, "*The first transistor, a semiconductor triode*", Phys. Rev. **74**, p.230,1948

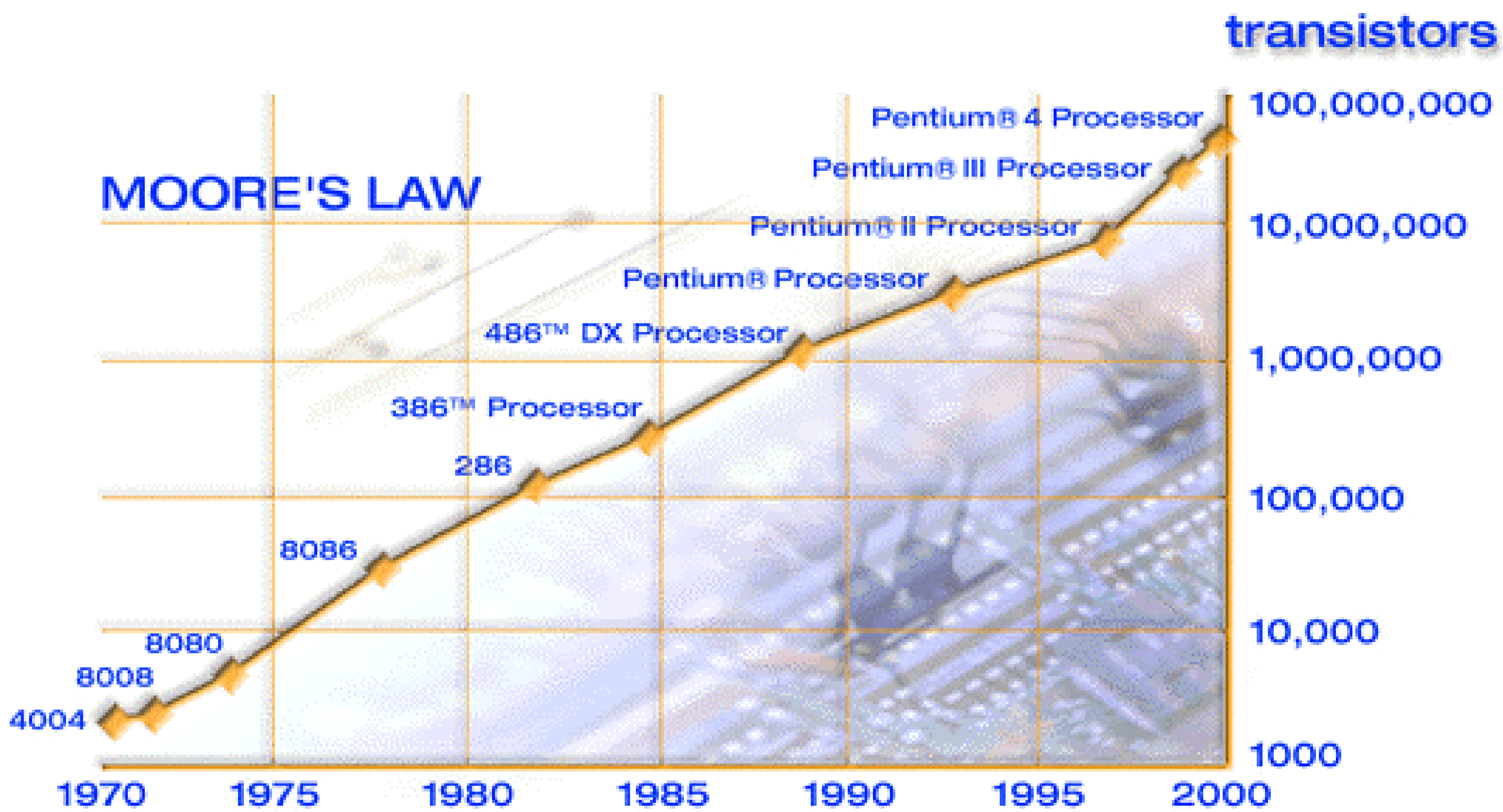
State-of-the-art Integrated Circuit Chip

Intel@
Pentium 4
Processor

42 million transistors
0.18 micron
lithography
2001

http://www.tomshardware.com/cpu/01q2/010423/p4-01.html

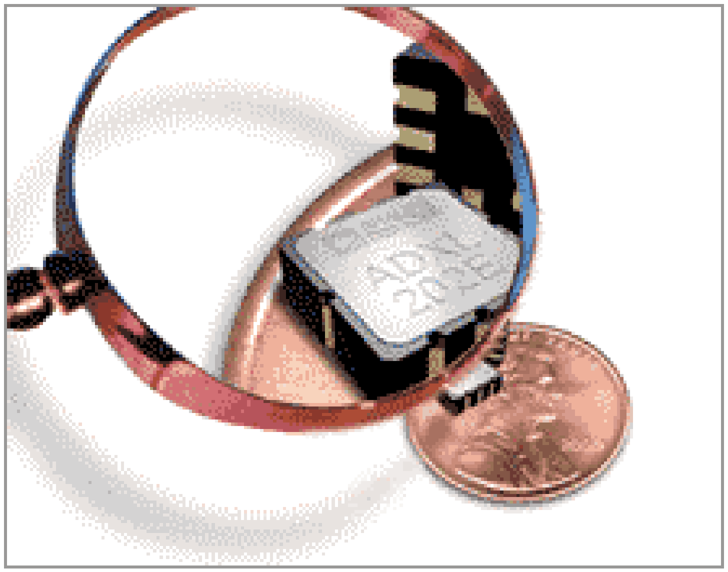
Moore's Law for IC Chip



CPU power doubles every 18 months

How about MEMS?

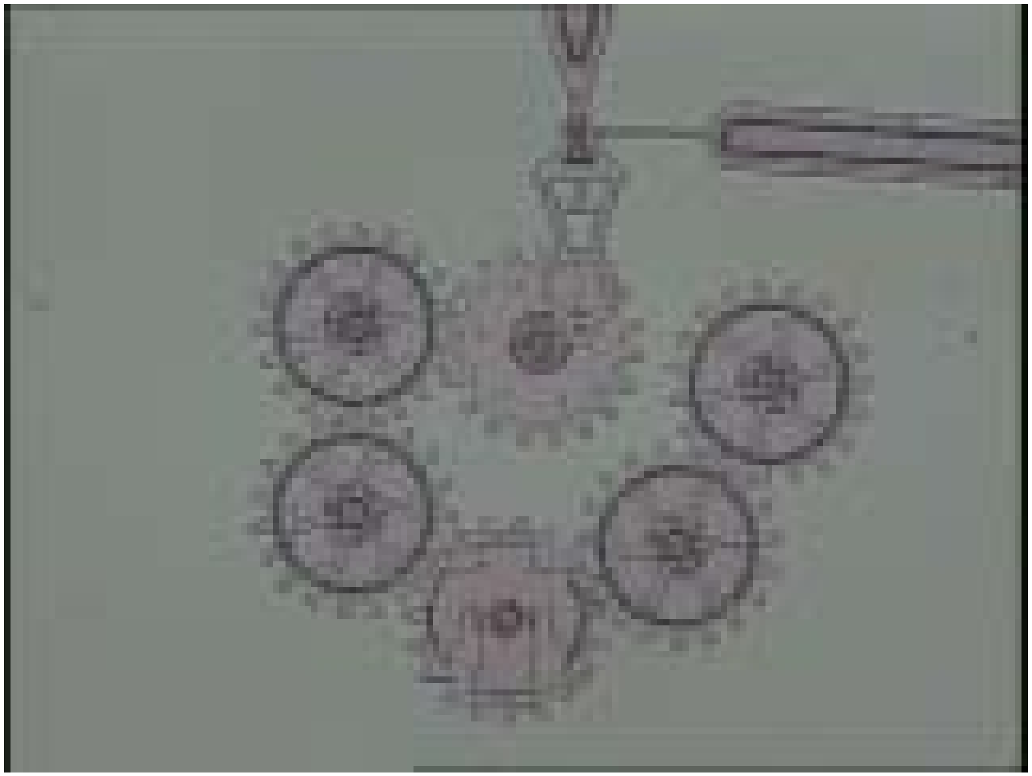
State-of-the-art MEMS Chips



Analog Devices
ADXL202
micro-accelerometer

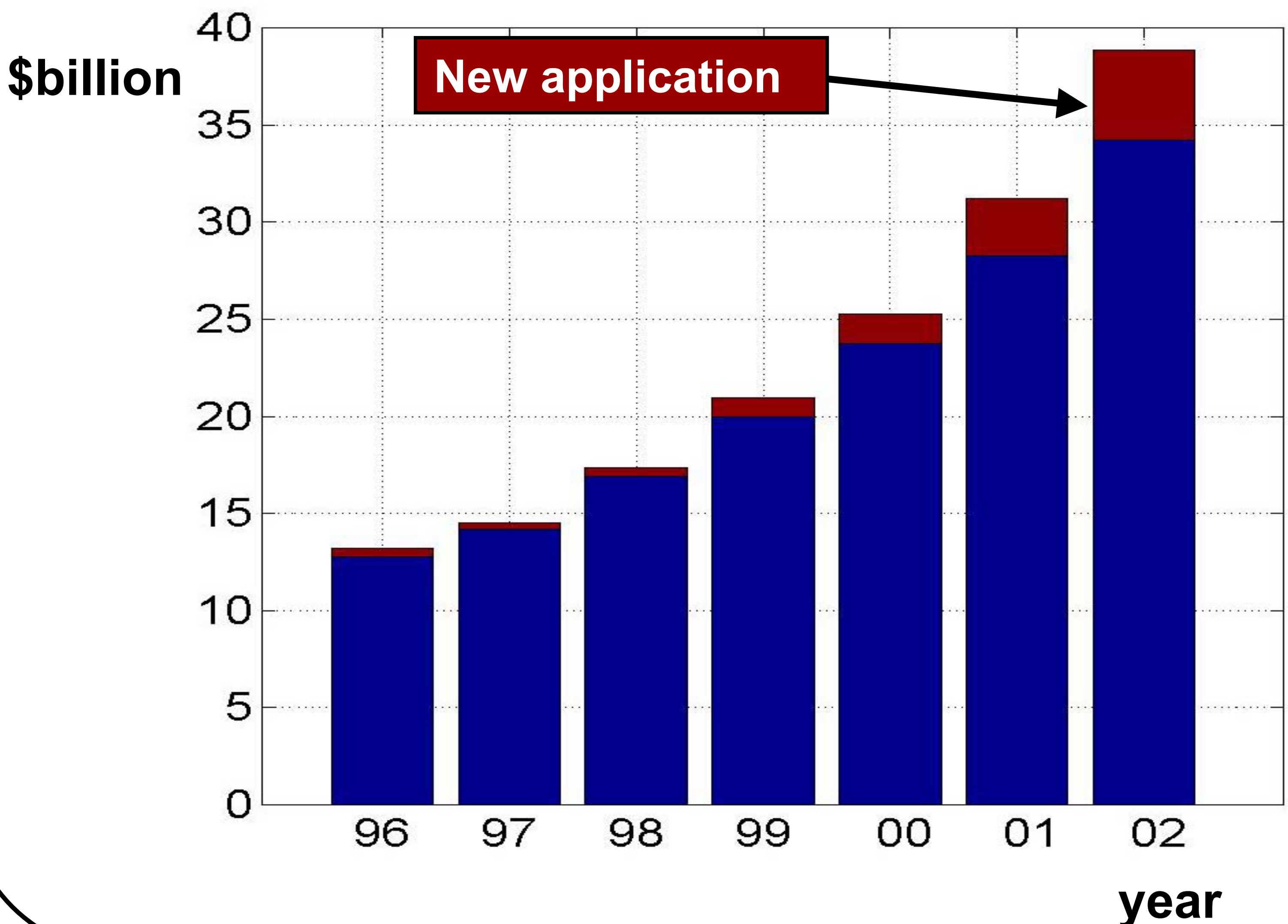
Texas Instrument
Digital light processing
~ 1 million mirrors

Microgears driven by a microengines

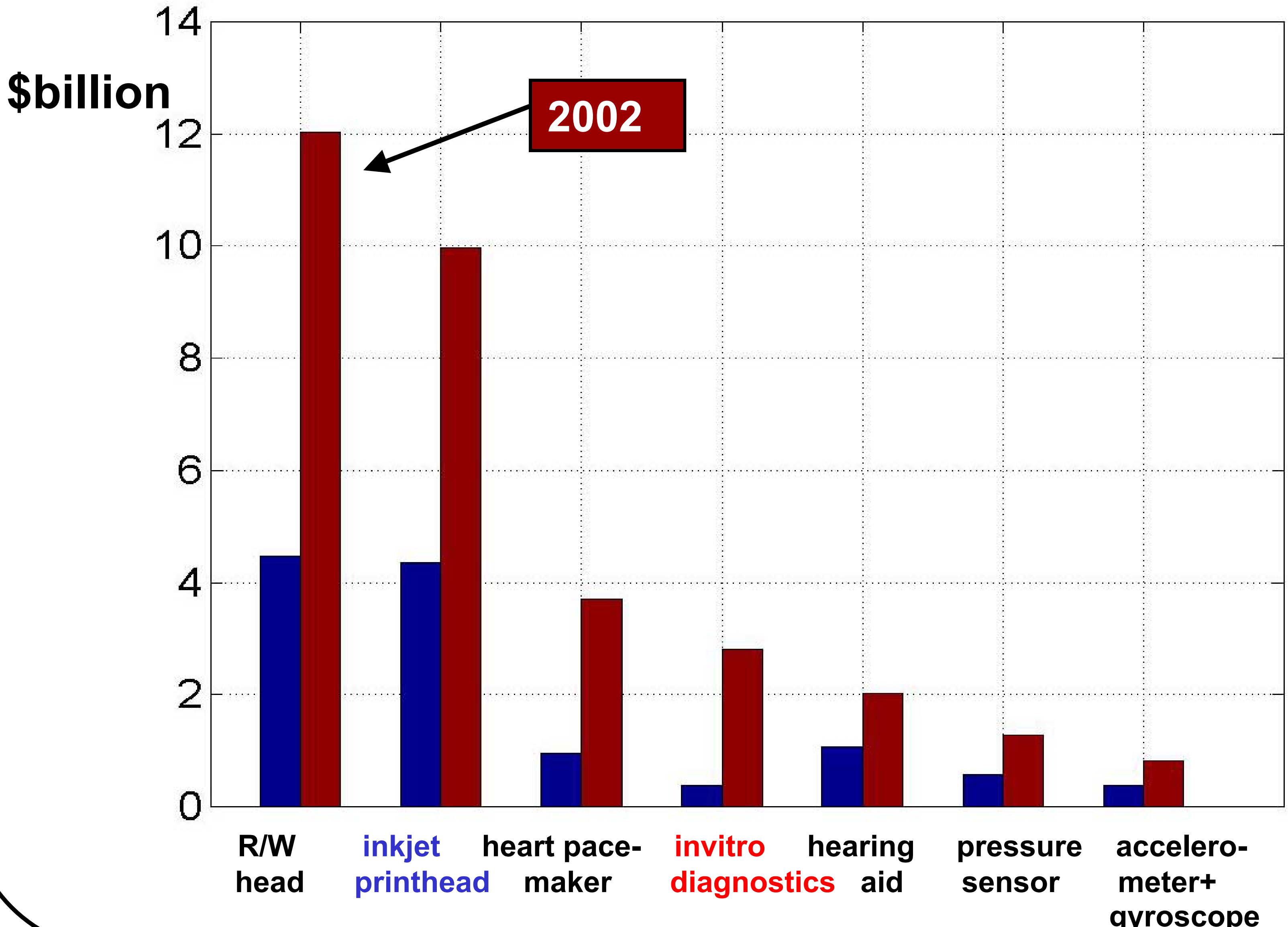


US Sandia National Lab MEMS project for nuclear weapon security

MEMS market analysis by NEXUS



MEMS market volumes in 1996 & 2002



Current MEMS applications

- Pressure sensors, disposable blood pressure
- Accelerometers, air-bag deployment
- Ink-jet printer heads
- Digital micromirrors for computer projectors
- Portable clinical analyzers
- DNA microarray

More applications

- Inertial guidance microdevices: microgyroscope
- Active magnetic head for ultra high density hard-drive
- Optical switches for internet backbone system
- Flow control, drag reduction
- Bio-chemical lab-on-a-chip
- Communication components:
  micromechanical filters, RF-switches & relays
- Power MEMS:
  microfuel cells, micro generators
- Military MEMS:
  micro NBC (nuclear, baterial and chemical) detectors

Traditional Uses of MEMS

Airbag deployment

MEMS accelerometer

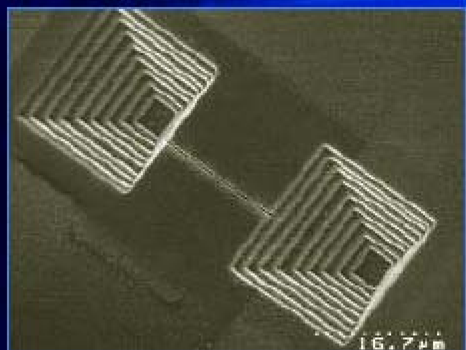
Stability Control System

MEMS micro-gyro

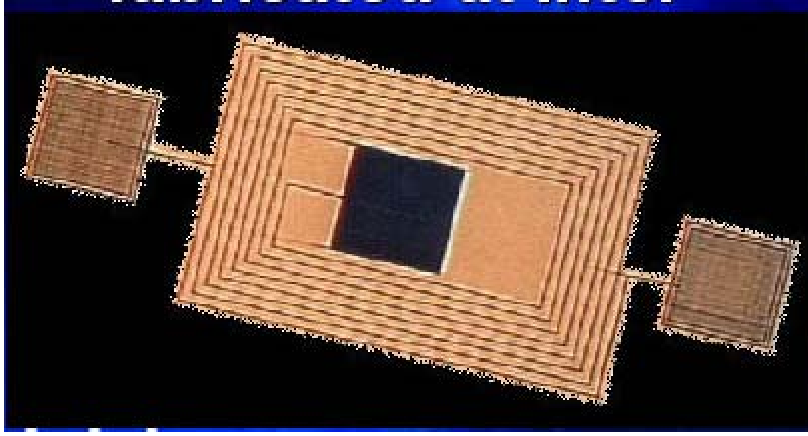
MEMS Pressure Sensor

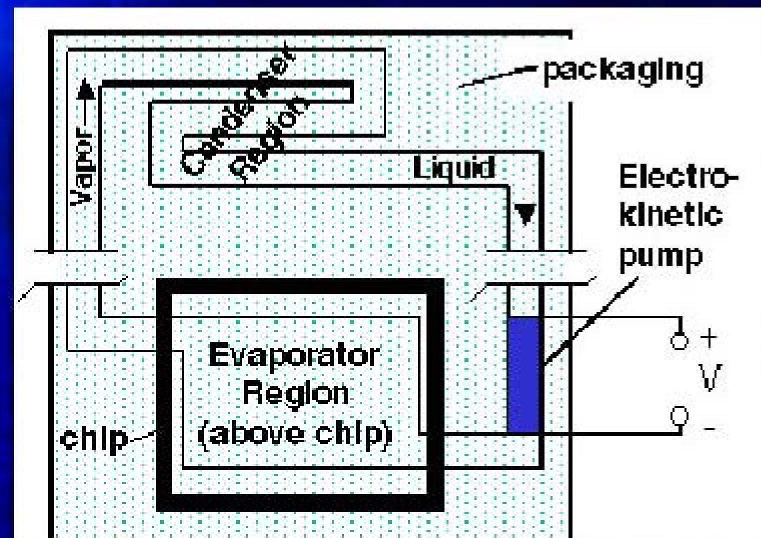
Future Potential Uses of MEMS

Potential for Chip Cooling, BioMEMS



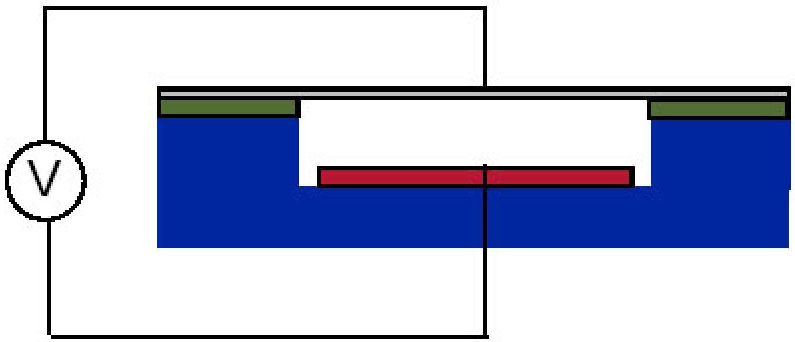
Micro-fluidics devices fabricated at Intel





Micro-refrigerator (Research at Stanford University)

Micro pressure sensors

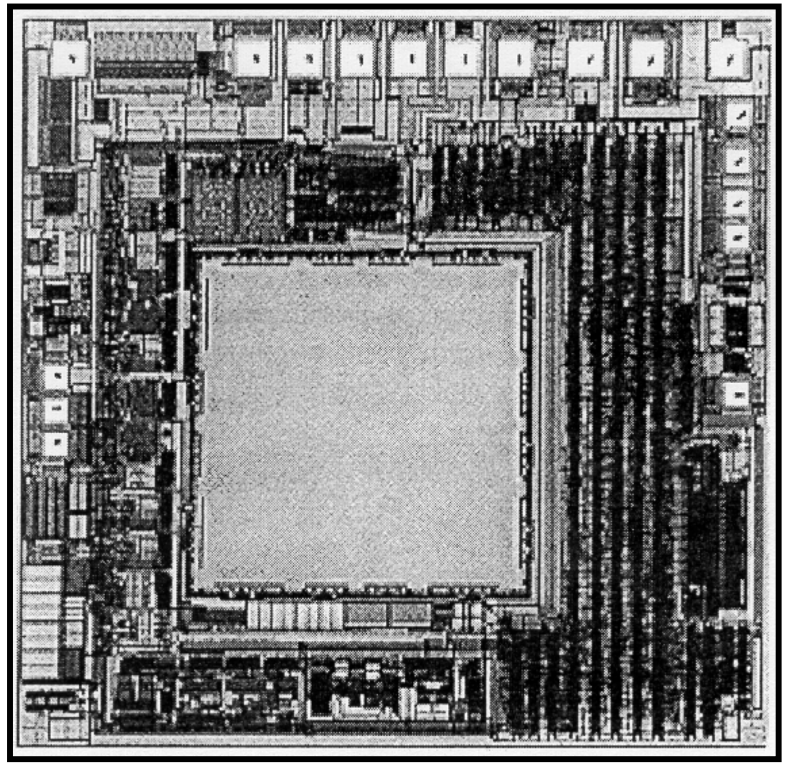


Capacitive sensing

Piezoresistive sensing

Integrated Pressure Sensors

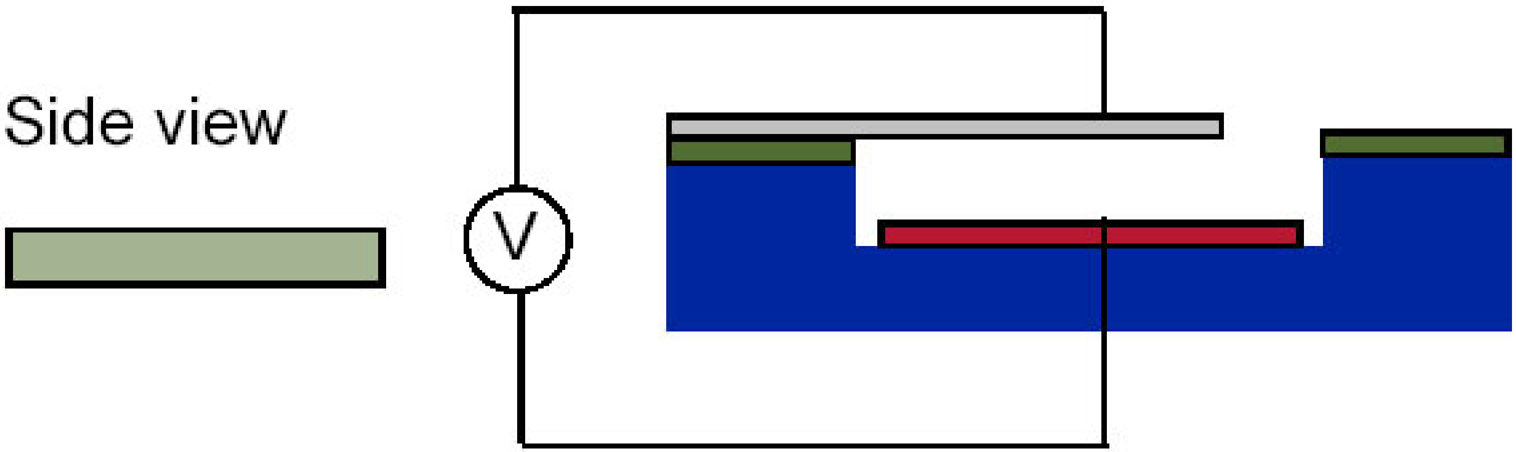
- Silicon pressure sensors have been on the market for over 30 years
- First integration attempt
  - late 1970's
- Over 100 million units are now produced every year
- A significant portion of which has on-chip integration ranging from
  - Passive trim elements only
  - Analog signal conditioning
  - Digital signal conditioning



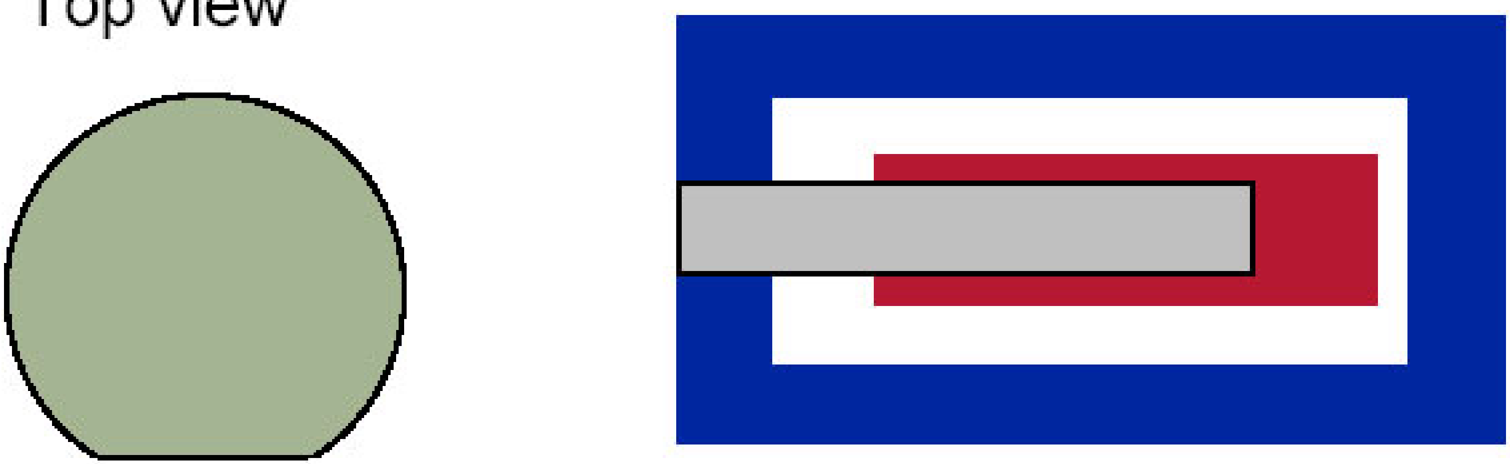
Motorola's latest Automotive Pressure Sensor with DSP

Micro accelerometer

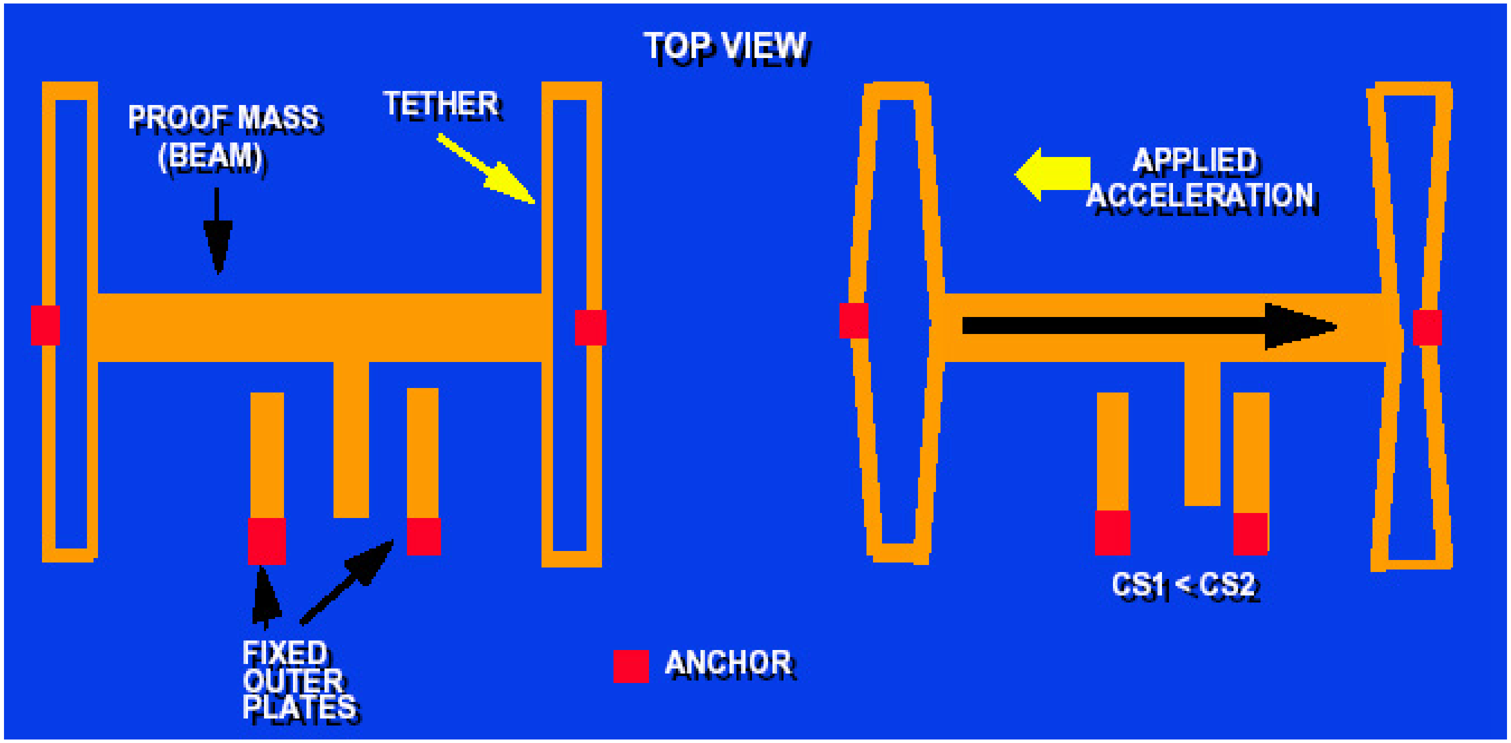
Side view



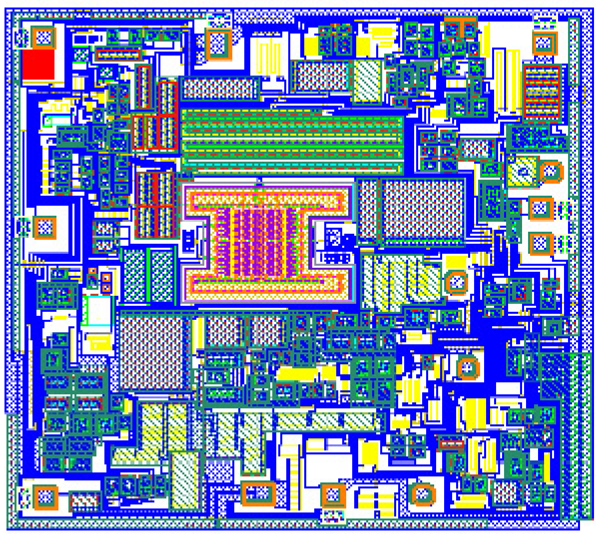
Top view



Micro accelerometer practical design

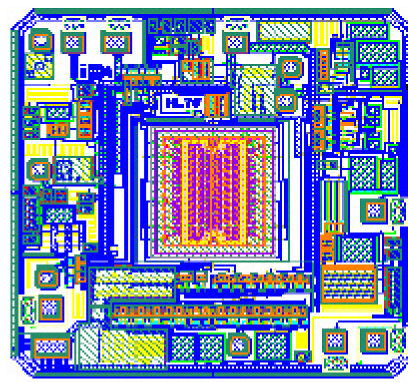


ADI Automotive Accelerometers



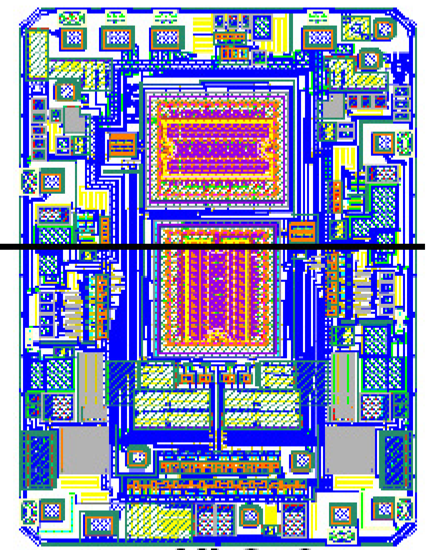
XL50
Original

1993



XL150
New

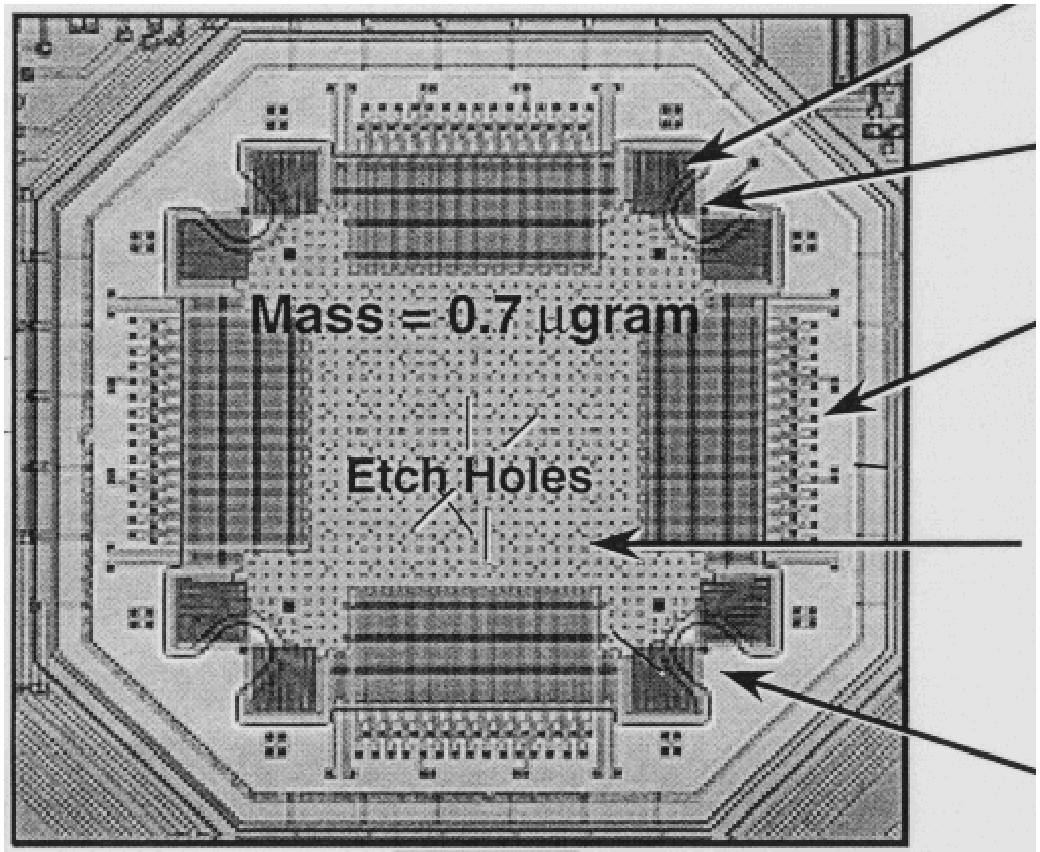
~1996



XL250
2 Channel New

~1997

ADXL202 Beam structure



Tether (Spring)

Anchor point

30 sensing cells per axis
1.2µm gaps,
1µm feature size

2µm thick polysilicon structure suspended 1.6µm above substrate

10kHz resonant frequency

Deflection due to 2*g* acceleration = 5nm = $250 \cdot 10^{-18}$F

Minimum resolvable deflection = 0.04A = $90 \cdot 10^{-21}$F