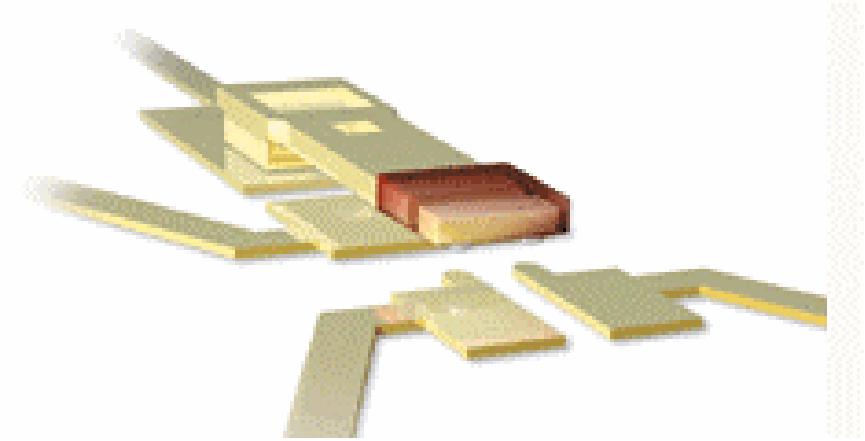


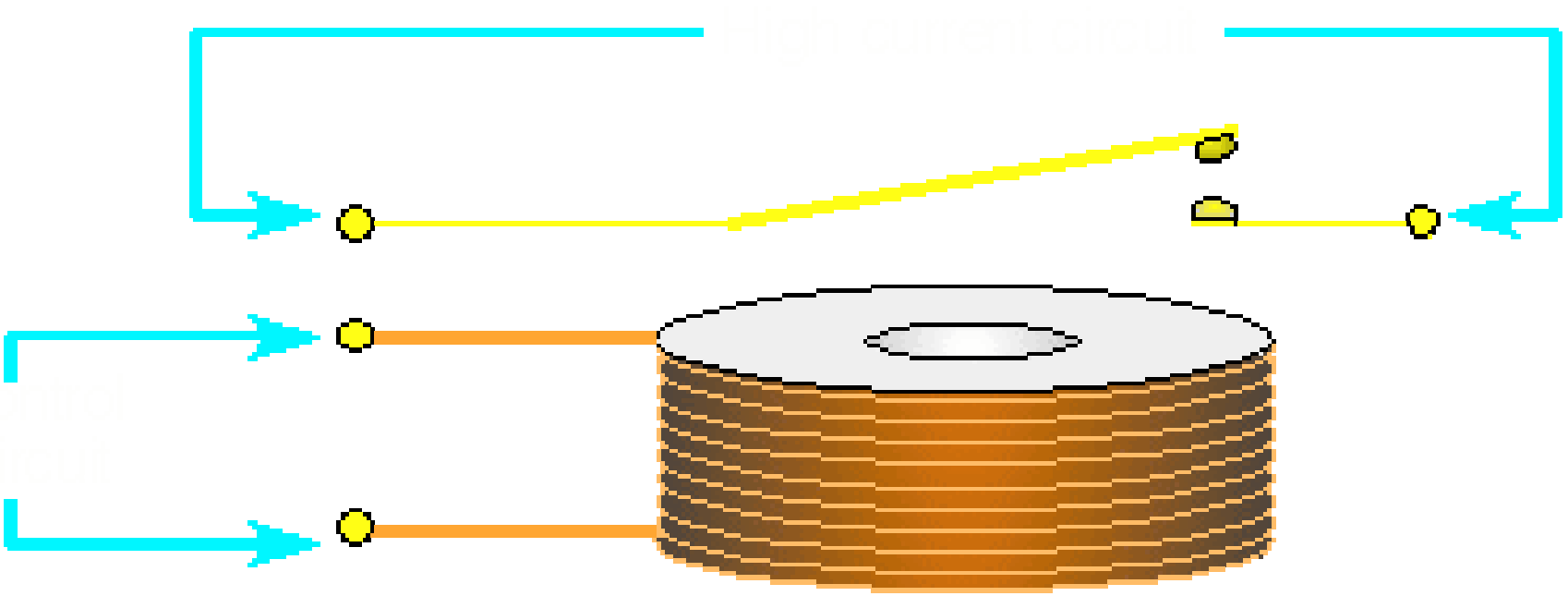
Micromachined Switches and Relays

Chang Liu
Micro Actuators, Sensors, Systems Group
University of Illinois at Urbana-Champaign

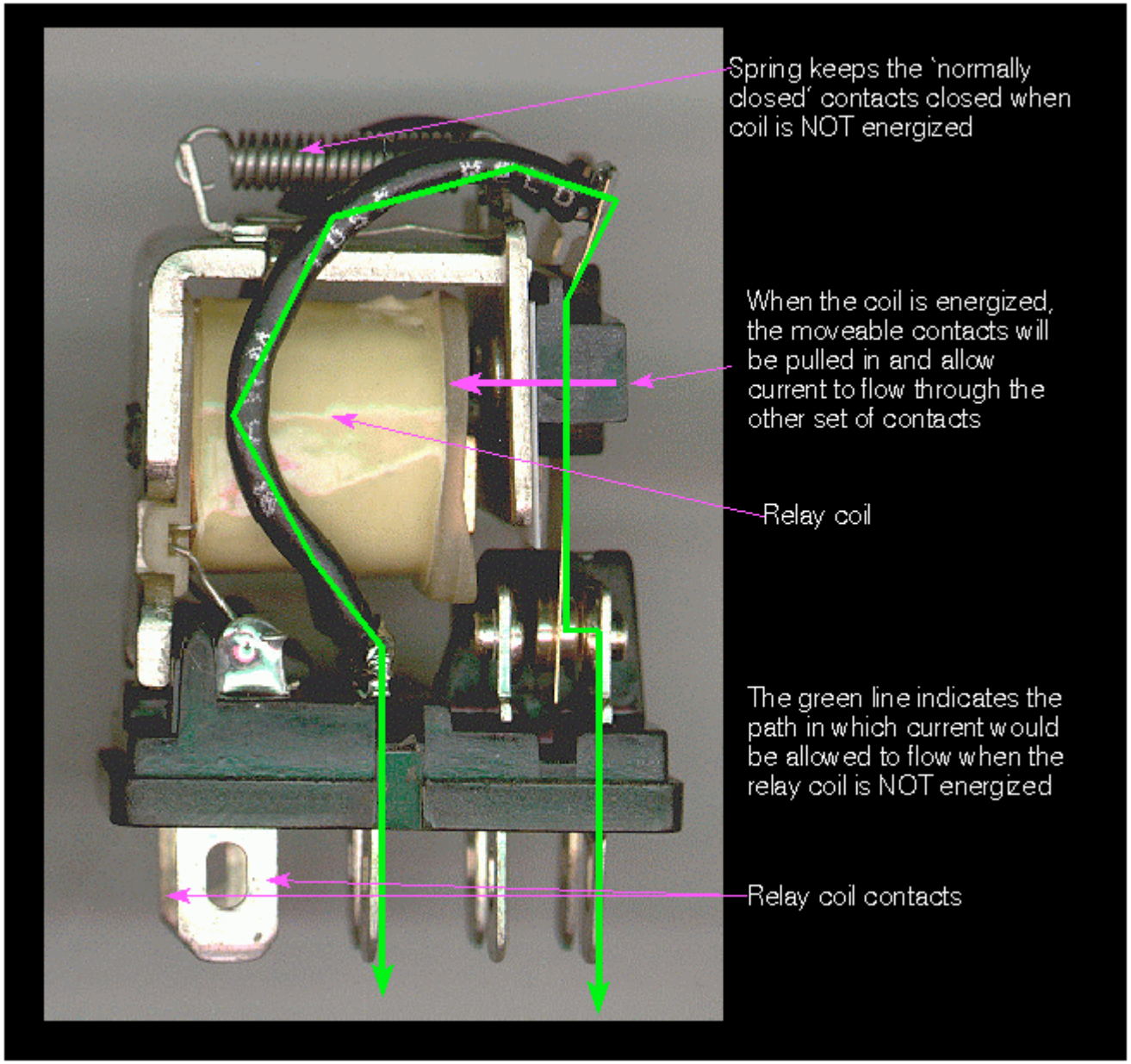
Outline

- Motivation
  - Relays: for low frequency signals
  - Switches: for low and high frequency signals
- Embodiment of micro switches and relays
  - Electrostatic actuation
  - Electromagnetic actuation
  - Thermal bimetallic actuation

Conventional Electromagnetic Relay

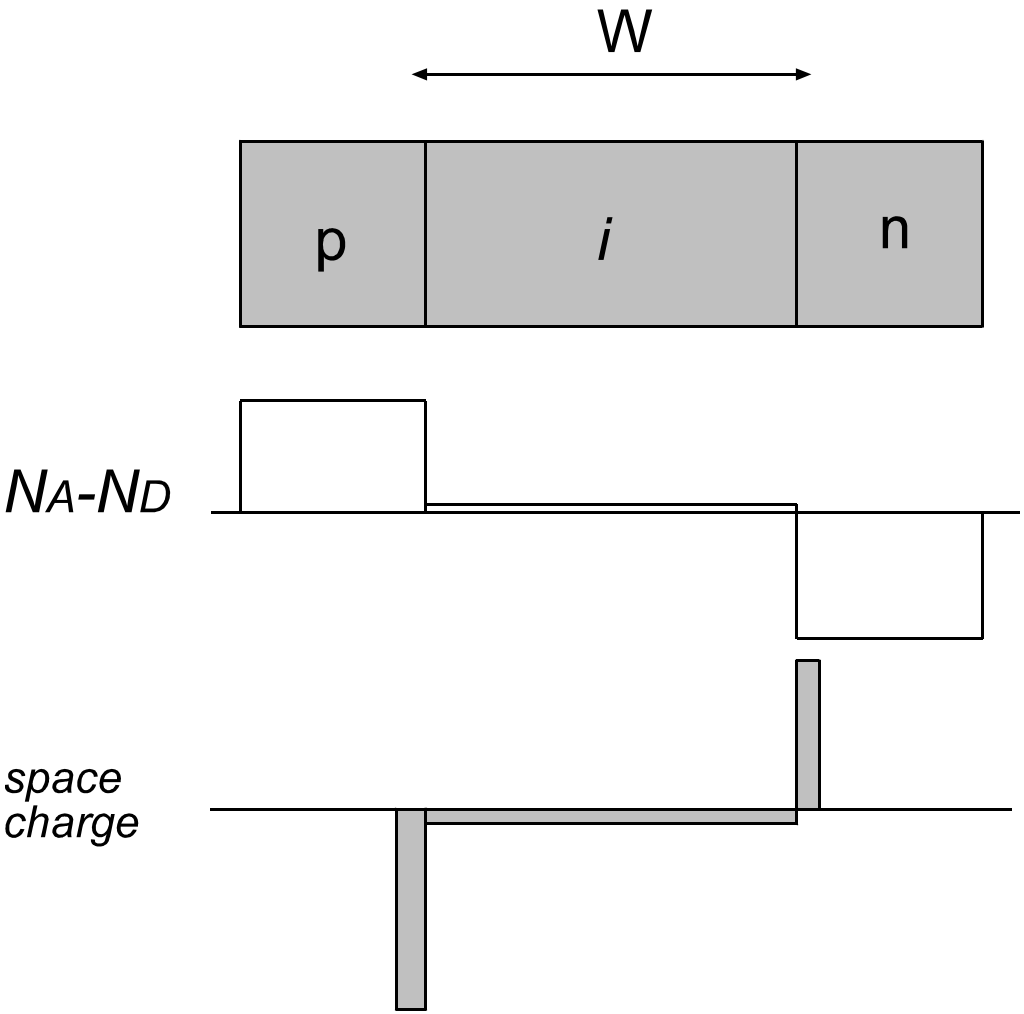


Macro Relay


Spring keeps the 'normally closed' contacts closed when coil is NOT energized
When the coil is energized, the moveable contacts will be pulled in and allow current to flow through the other set of contacts
Relay coil
The green line indicates the path in which current would be allowed to flow when the relay coil is NOT energized
Relay coil contacts

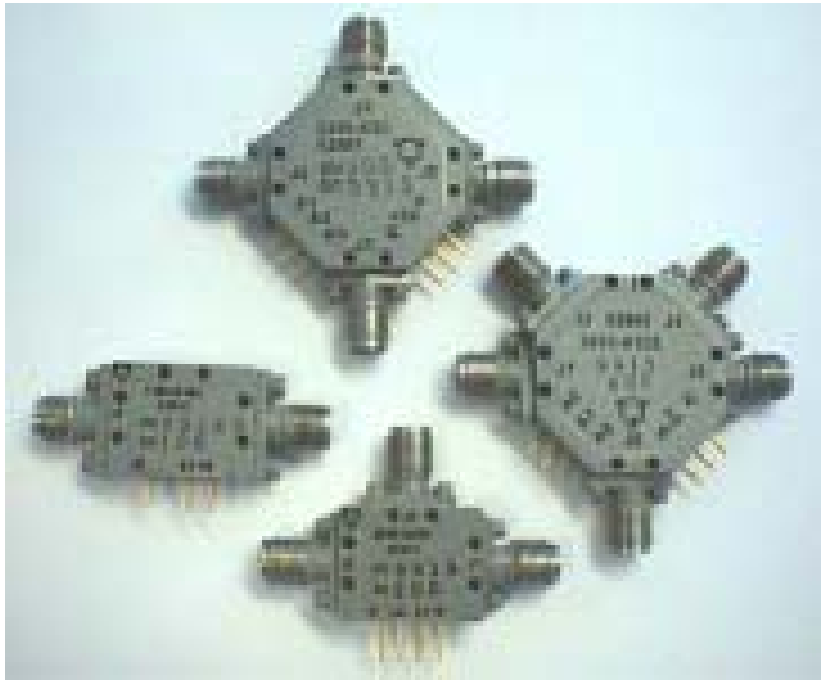
P-I-N diode

- Advantage for RF switching
  - Constant capacitance
  - High power handling capacity
  - High speed
    - $W/2v_s$
    - V_s being the saturation velocity of minority carriers in the intrinsic region



Motivation for Micro Mechanical Switches

- High degree of integration with IC
- Increased on/off impedance ratio
- Reduced power consumption



Shortcomings of Conventional Relays and Switches

- Performance
  - High loss at on-state
  - High leakage at off state
    - Especially important for phase array phase shifters
  - Response speed slow
- Volume, weight and power consumption

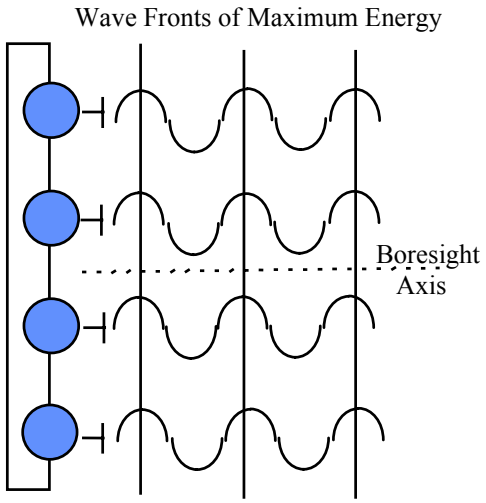
Requirement of Military Radars

Reduce aerodynamic drag associated traditional dish radar
Increase response speed of weapon deployment and foe detection
Planar configuration for realizing low radar cross-section.

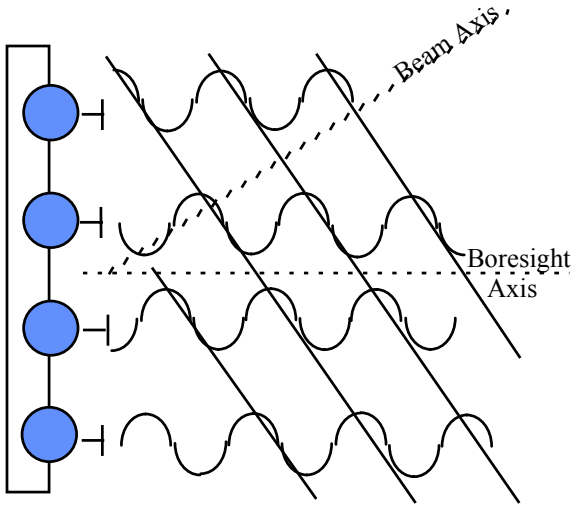
Electronics Scanning and Phase-Array Radar

- Increased data rates
- Instantaneous beam positioning
- Elimination of mechanical errors
- Multi-mode/Multi-target capability

- Refer to attached paper by Elliot Brown

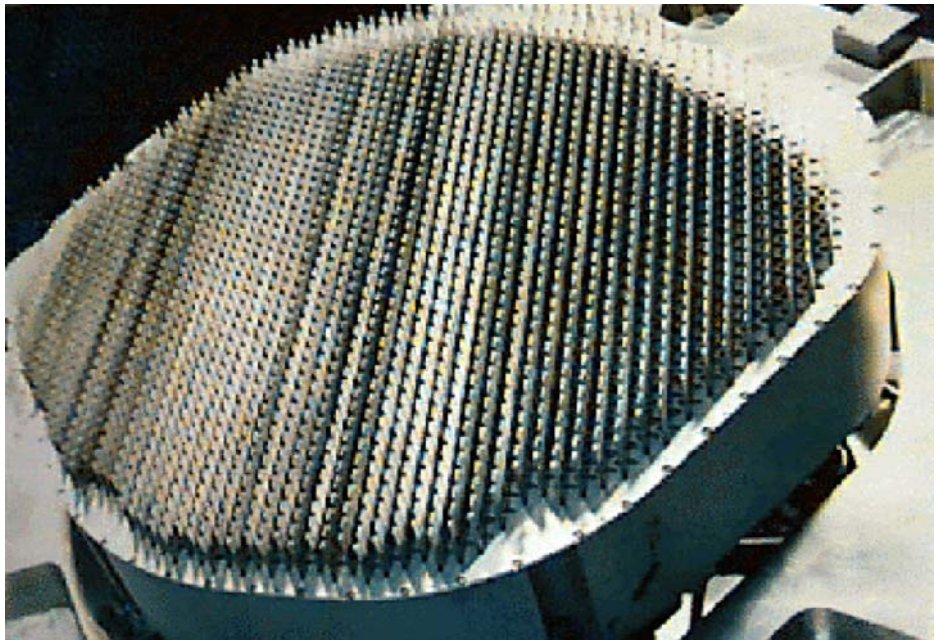


Radiating in Phase

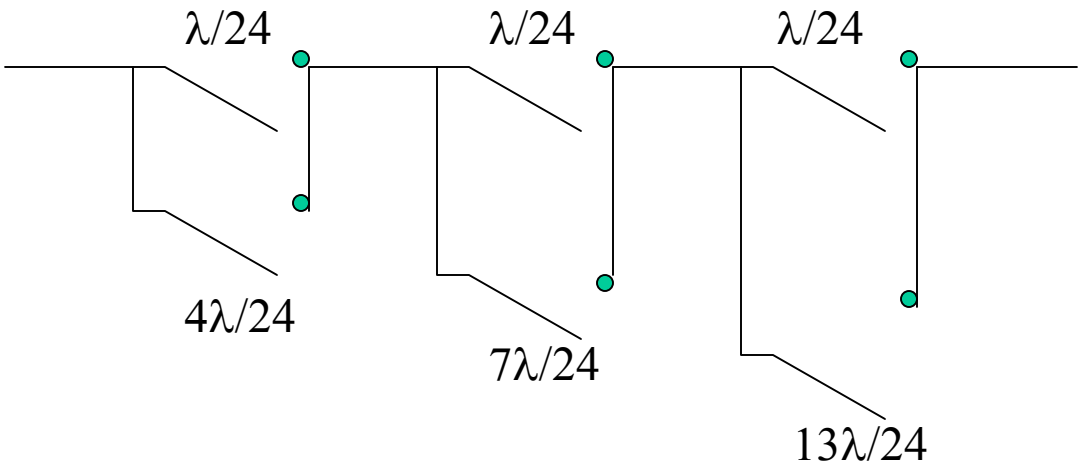


Altering the Phase to
Change the Axis

2D Arrayed Phase Array Radar



Micro Switch Phase Delay (Coarse)

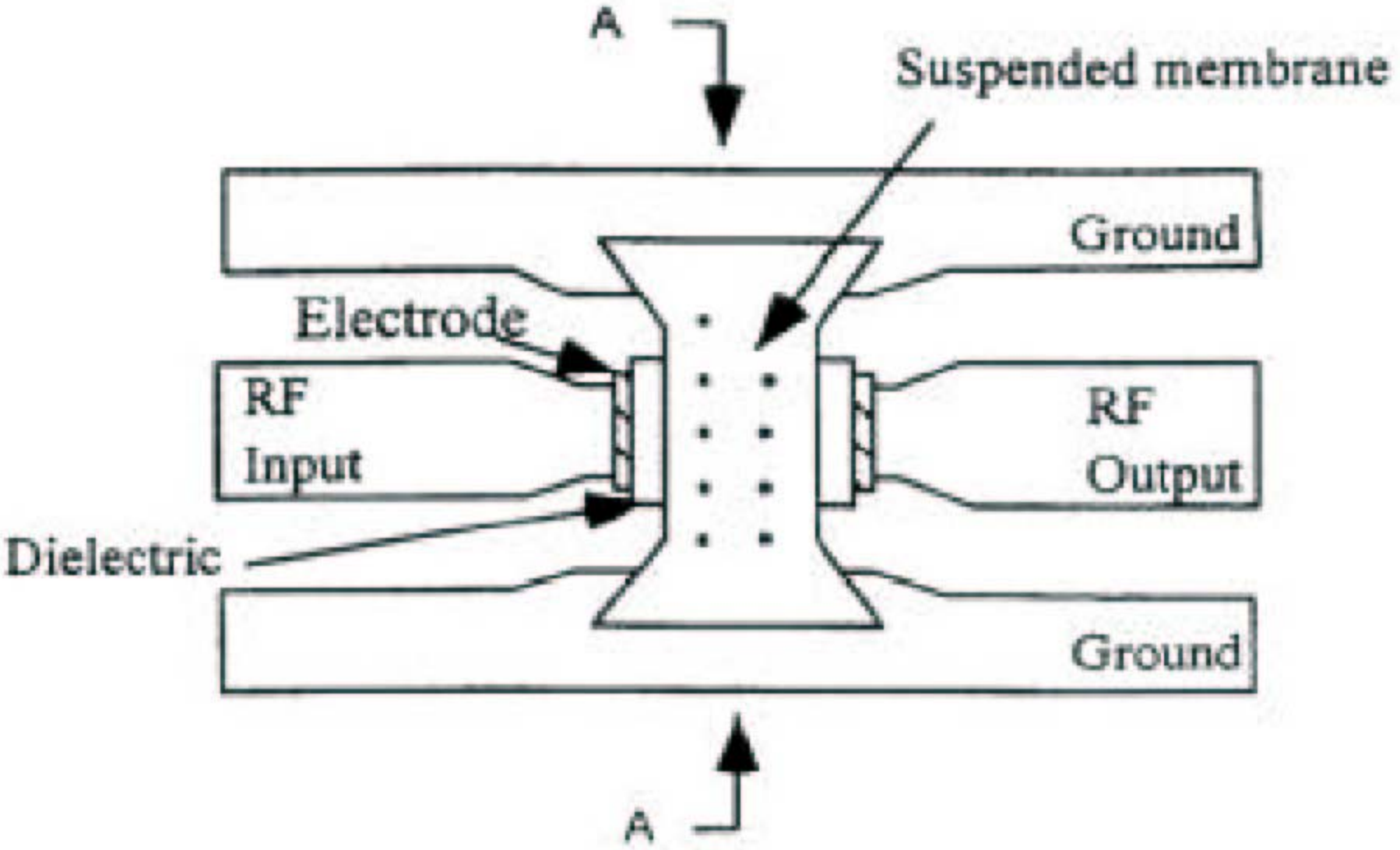


- Schematic diagram of time-delay phase shifter in which N different binary loops are connected in series to provide 2^N possible delays.
- Following delays are possible for N=3
  - 3λ/24, 6, 9, 14, 15, 18, 21, 24.

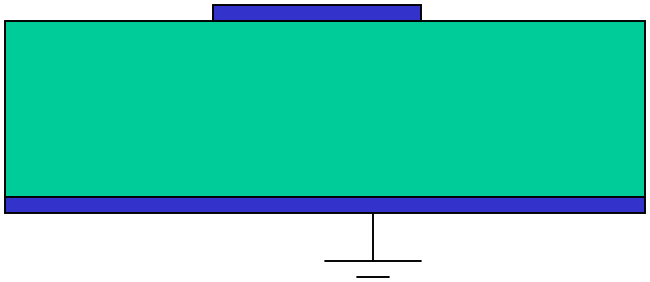
Electrostatic Actuation Switch

- Simple configuration
- Easy to control

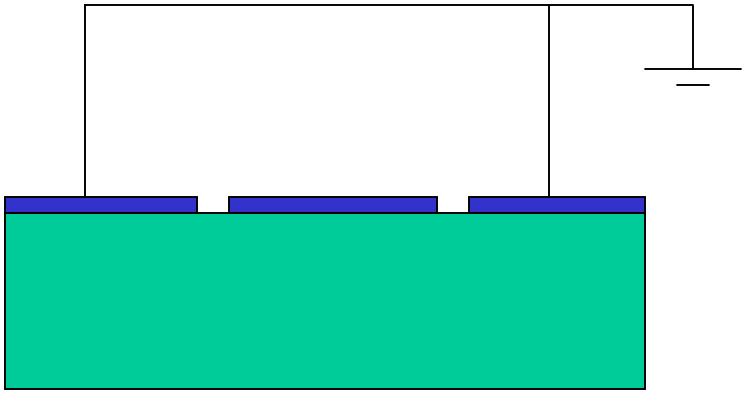
- May require voltage outside of the IC power supply range
  - I.e. greater than 5 V.


A
Suspended membrane
Ground
Electrode
RF
Input
RF
Output
Dielectric
Ground
A

Types of Waveguides

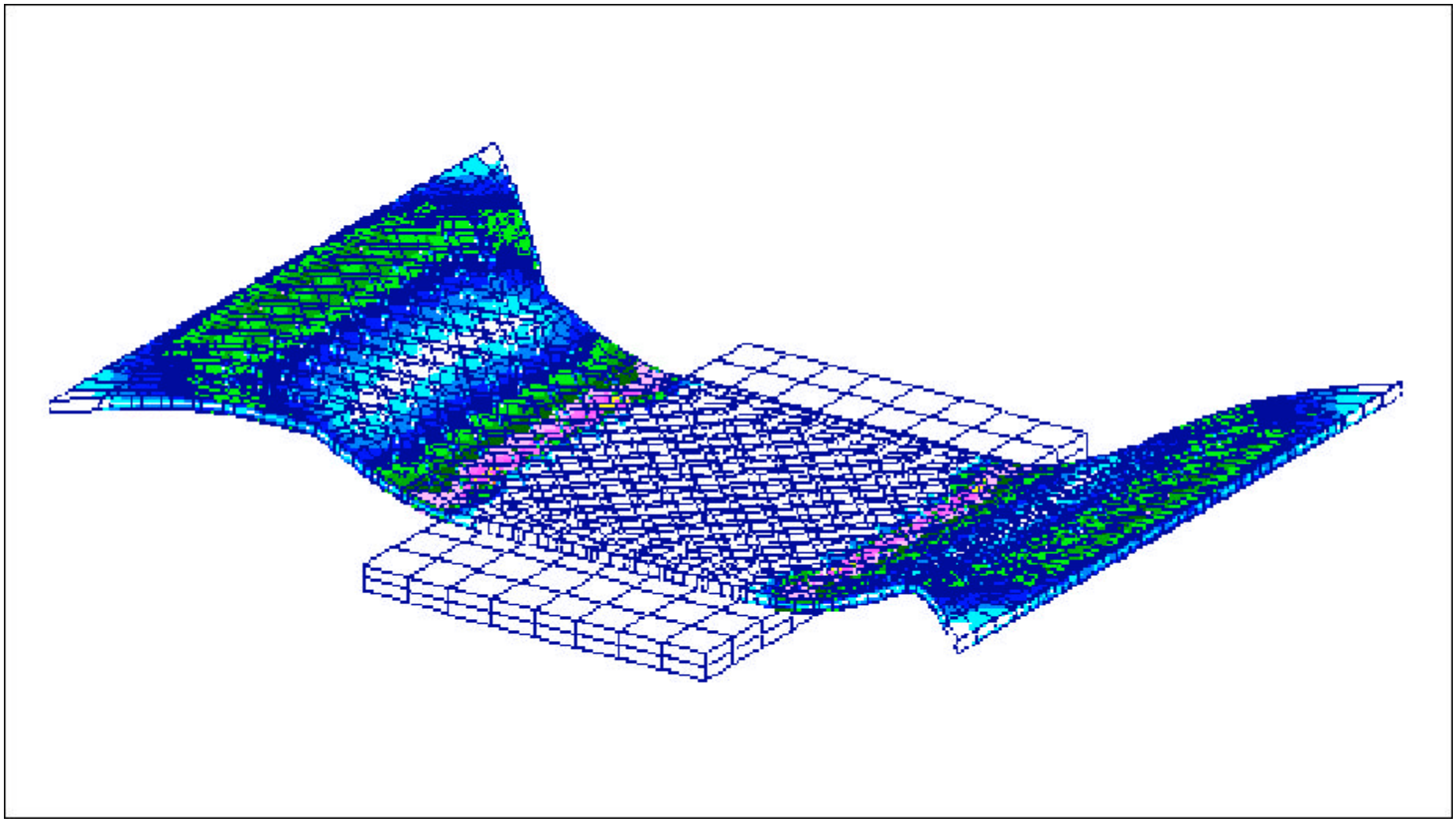


Micro strip waveguide

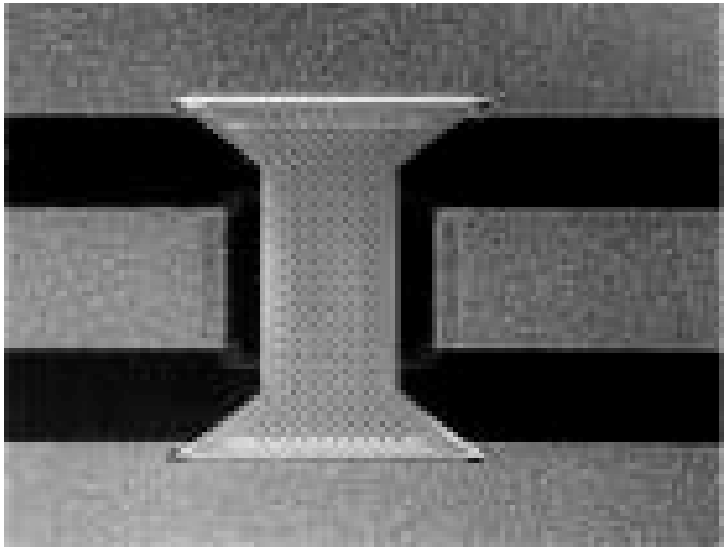


Co-planar wave guide

Electrostatic Simulation Results

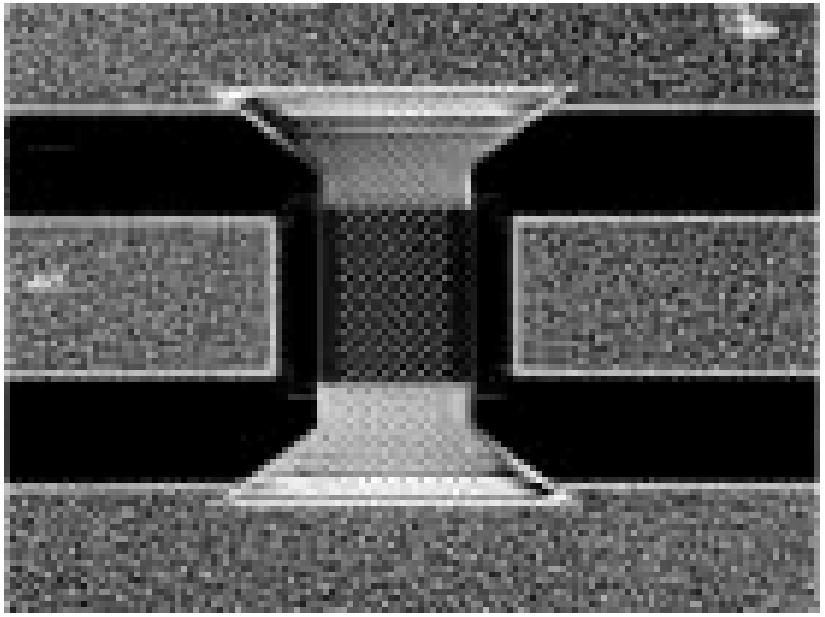


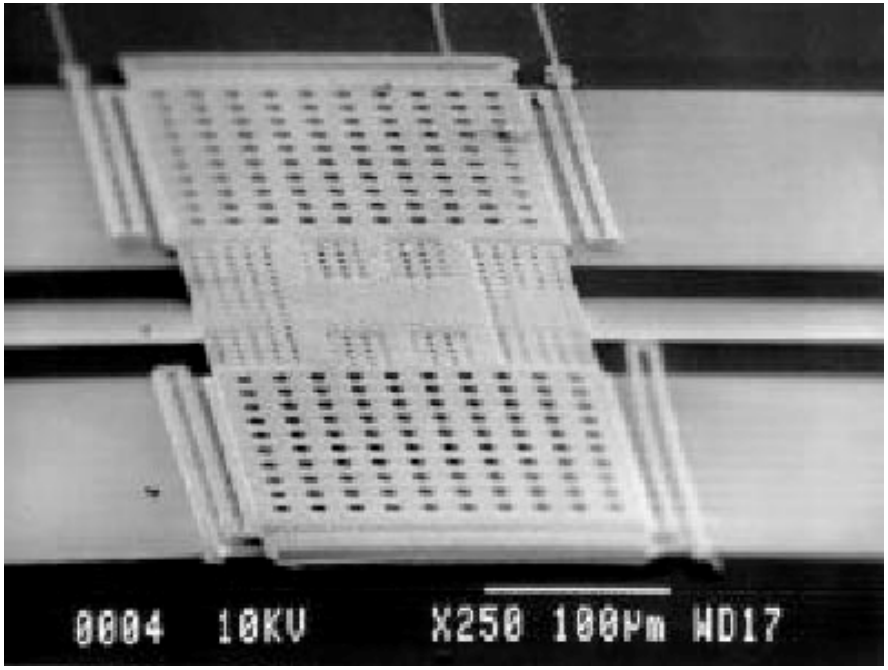
Photos of Switch at On and Off Positions

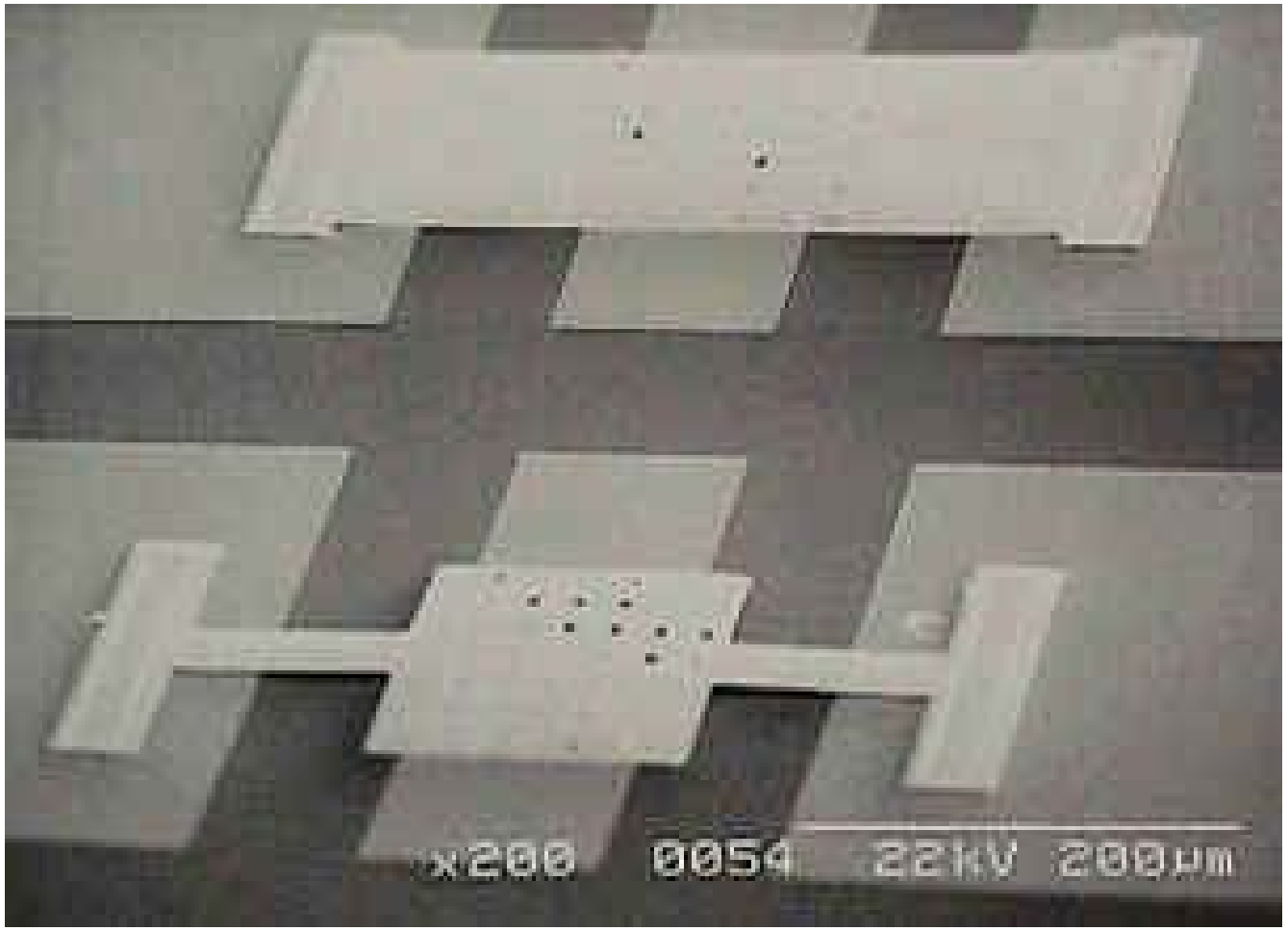


ON

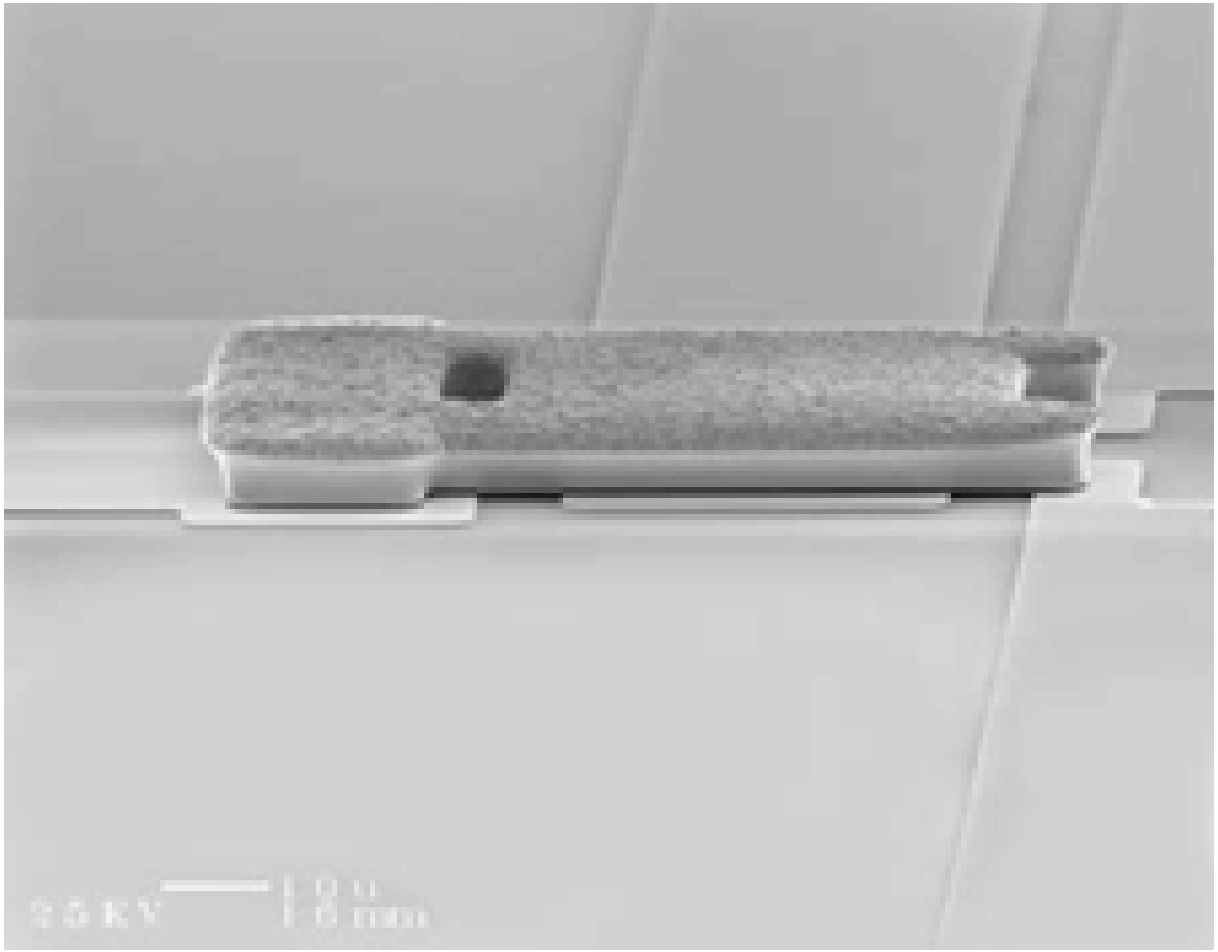
OFF




0004 10KV X250 100µm WD17


x200 0054 22kV 200µm

Electroplated Ni Switch



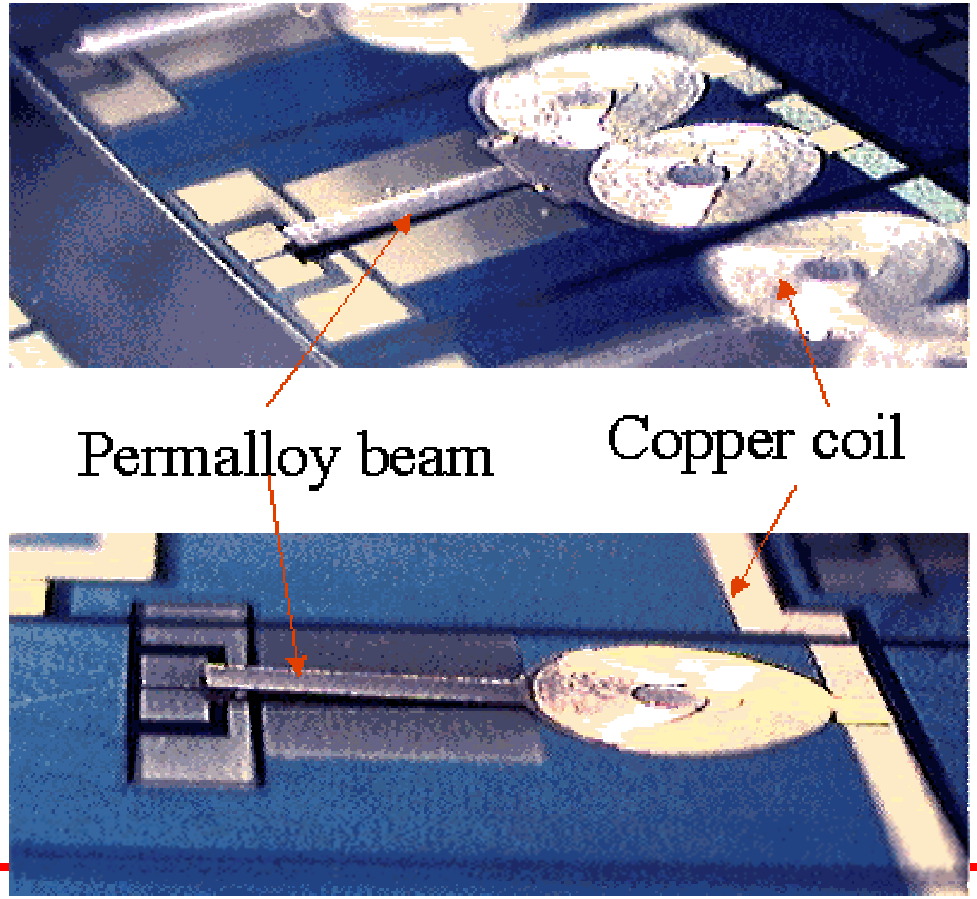
Electromagnetic Micro Relay

- High force, stable contact
- Possibility of achieving latching
- Low voltage, compatible with IC

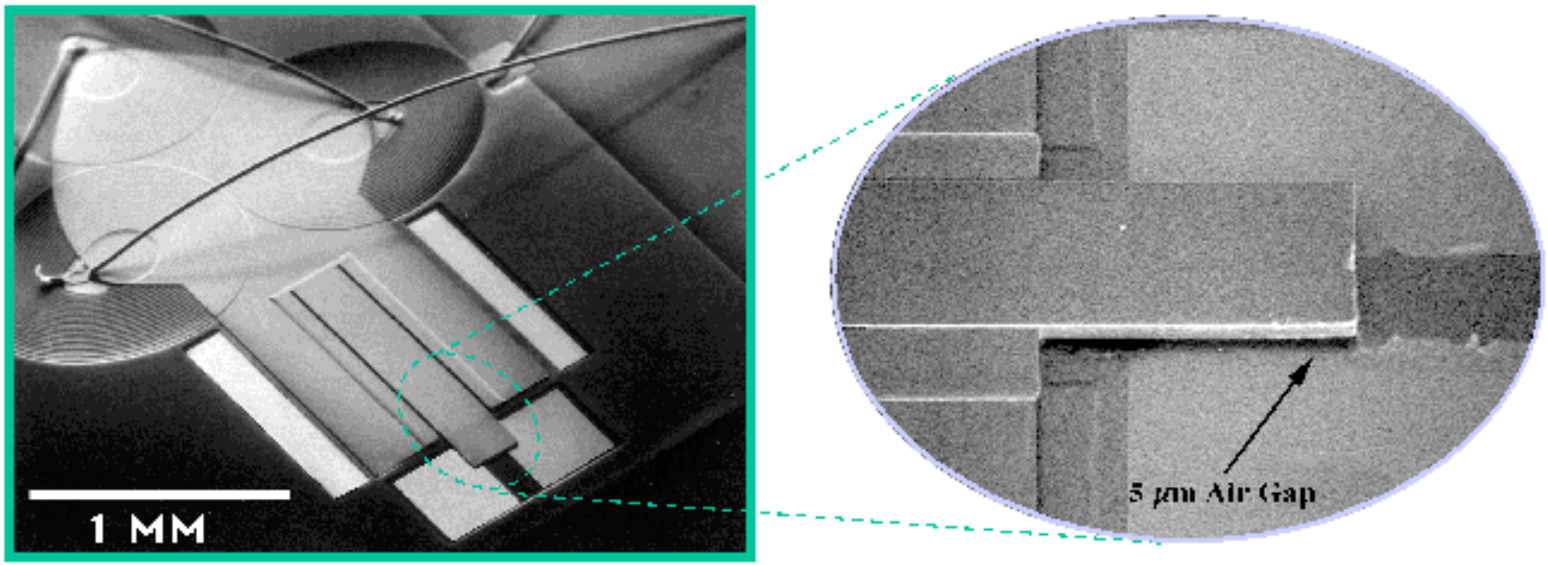
- Current driving, power hungry.

Electromagnetic Active Micro Relay

Integrated Micro Relay



First Variable Reluctance Actuator

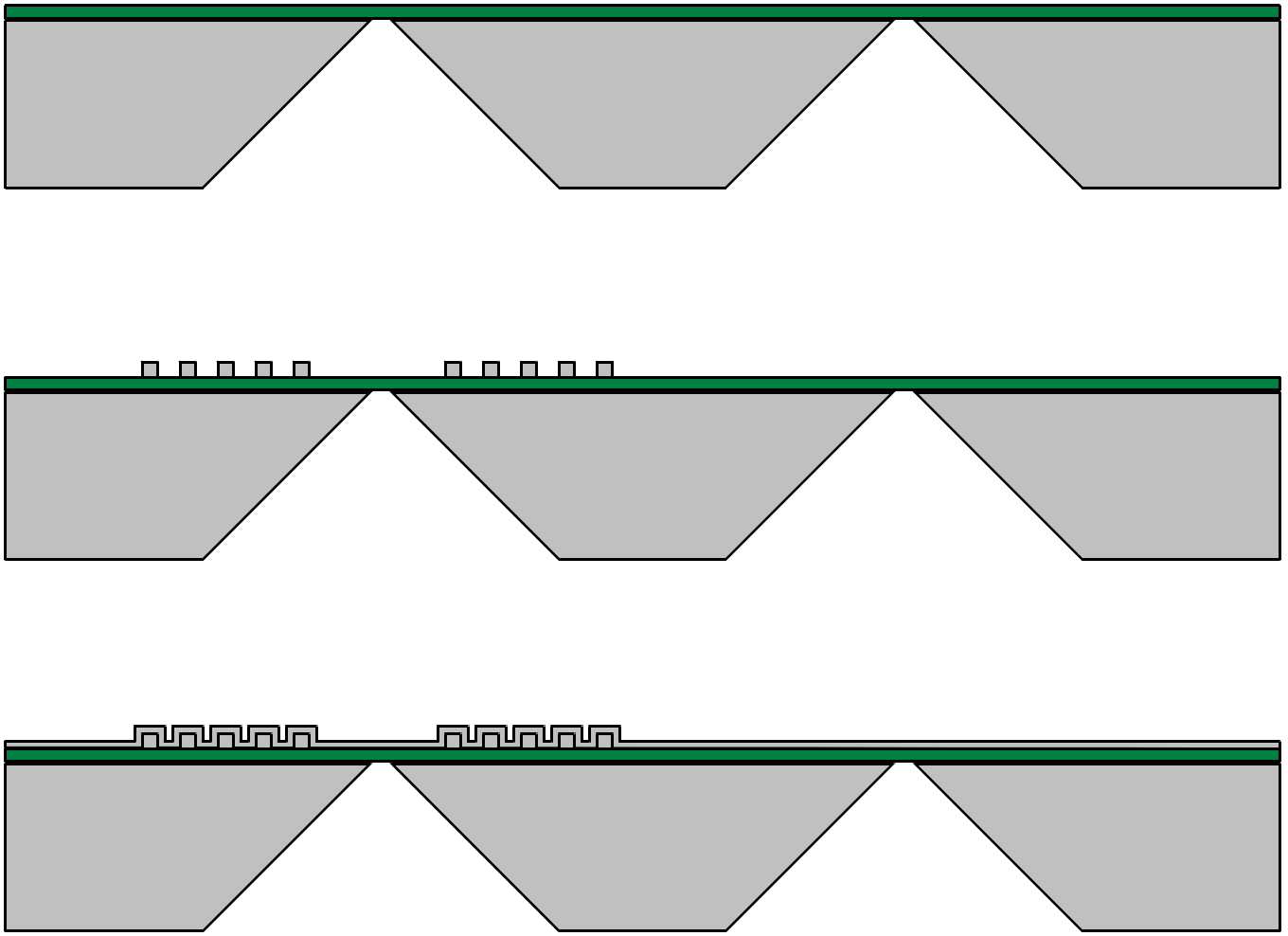


Deflection: 5 μm to 10 μm

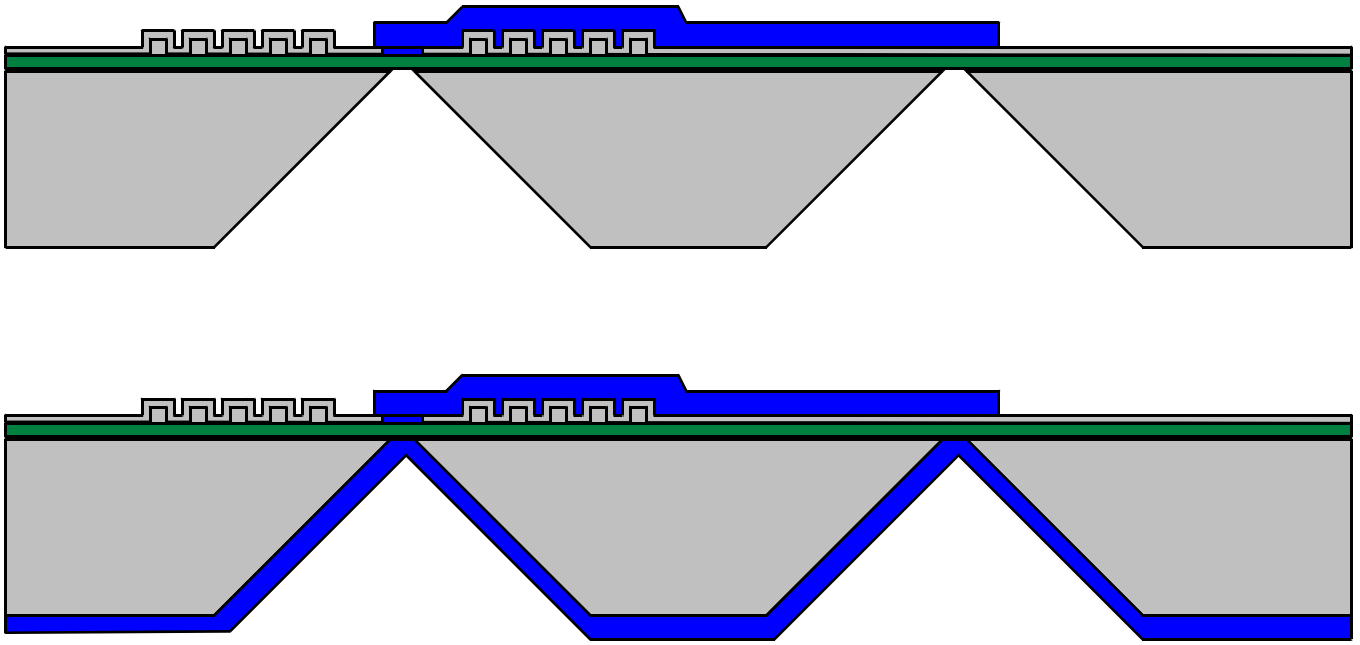
Coil Current: 20 mA to 500 mA

Closing Force: 10 μN to 1 mN

Fabrication Process



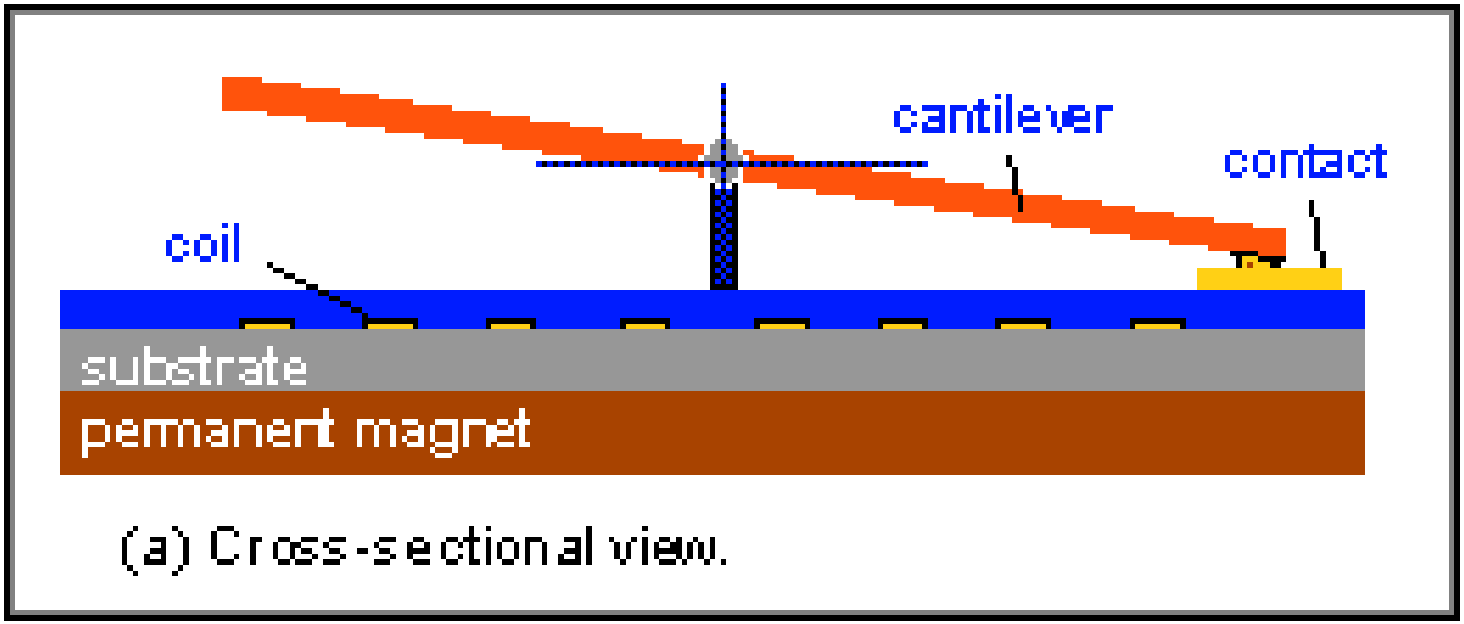
Fabrication Process (continued)



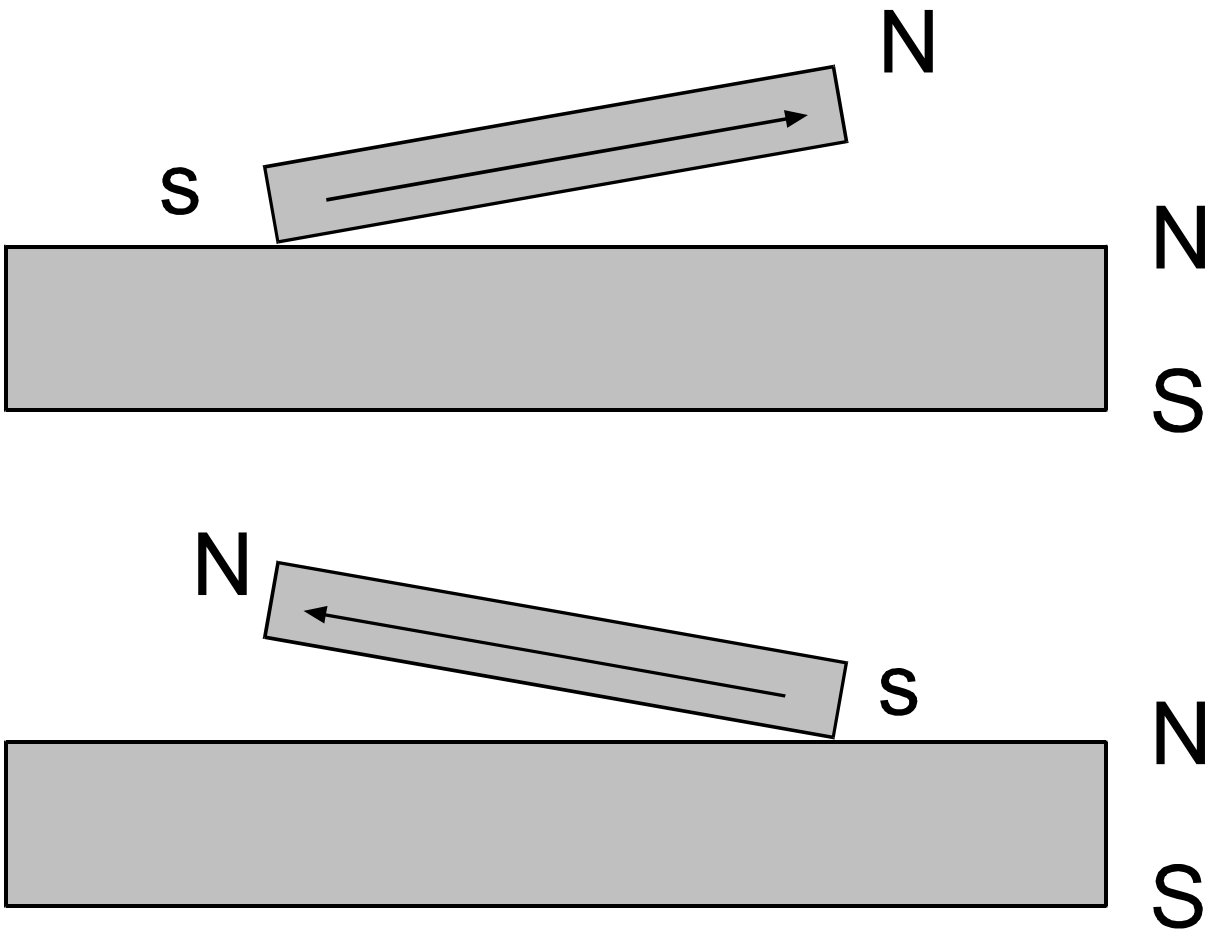
- http://www.memsindustrygroup.org/instat02.htm
- http://www.memagazine.org/backissues/jan01/features/reraces/reraces.html

Electromagnetic Latching Switch

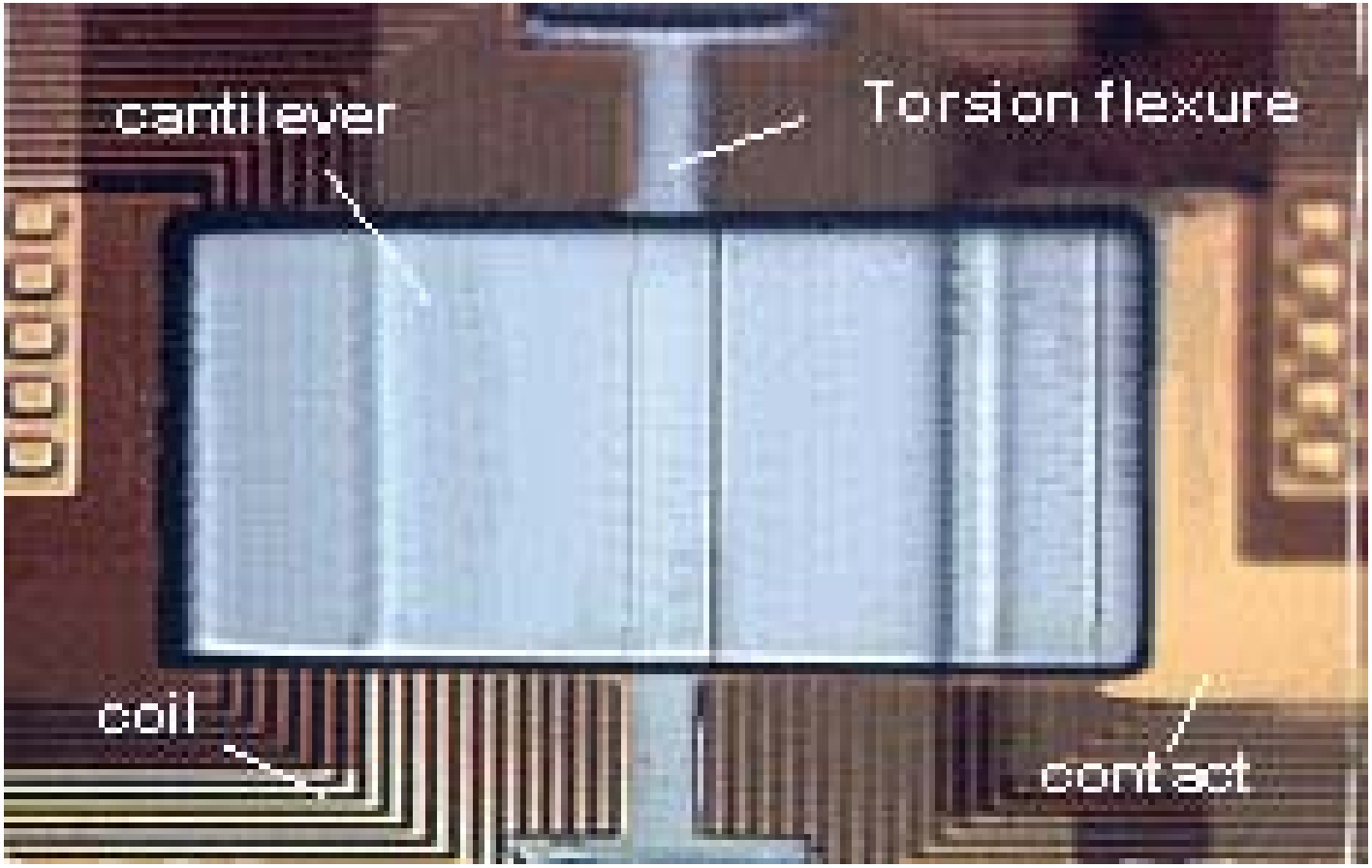
- Invented by Arizona State University Professor J. Shen
- Basis for MicroLab, a start up backed by 4.5 Million funding.
  - http://www.microlab.net/paperBody.html



Two Stable Positions



SEM



Chang's Secret Sauce to Get Tech-Rich

- A "brilliant" idea
  - best ideas are always simple ideas!
  - *Don't fool yourself*.
  - Career wise, always place your self in a good position to generate a good idea.
    - A faculty member, a research group leader, a department head
- Turn it into an iron-locked patent
  - uniqueness + good lawyers
  - why? Prevent others from competing
- Find good investment
  - All dollars are not created equal.

Thermal Actuator

- Thermal Actuator offers unique control modes
- Thermal actuation requires high power, so latch is required at steady state.