MEMS

(Micro Electro Mechanical Systems)

for IR & THz Light Control

by

Hiroshi Toshiyoshi

Takuya Takahashi

with

Research Center for Advanced Science and Technology
The University of Tokyo

also with

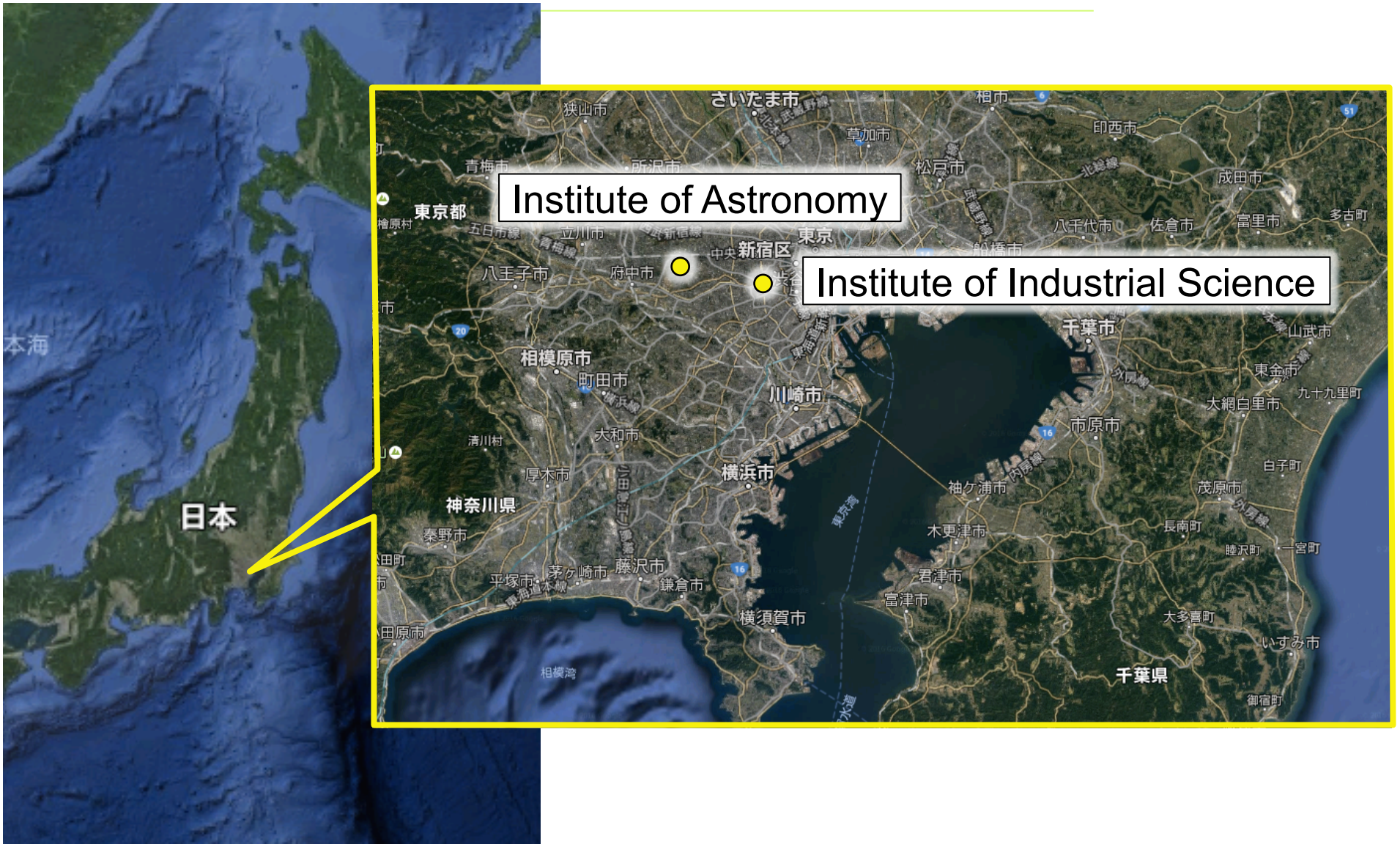
Institute of Industrial Science
The University of Tokyo

Institute of Industrial Science, Univ. of Tokyo

Built 2001

- Since 1949
- Relocated in Roppongi in 1962
- New Komaba Campus in 2001
- Departments 5
- Centers 6
- Faculty 73
- Assistant 70
- Technical Staff 87
- Administrative Staff 61
- Graduate School Student ~650
- Postdoctoral Fellow ~200
- Annual Budget ~9B JPY
- …
- The Largest Research Institute (attached to Universities) in Japan

University of Tokyo & Institute of Industrial Science



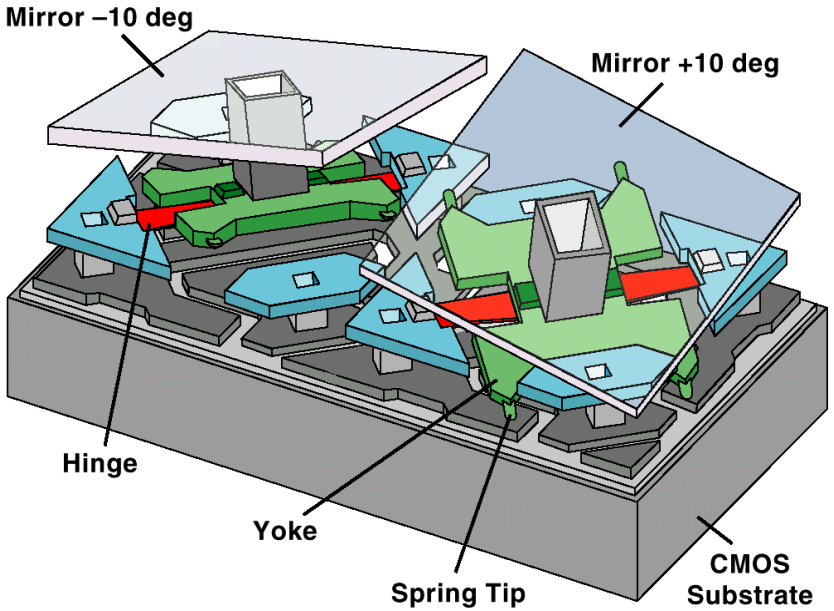
Different Scales …

ϕ > 100k Light Years

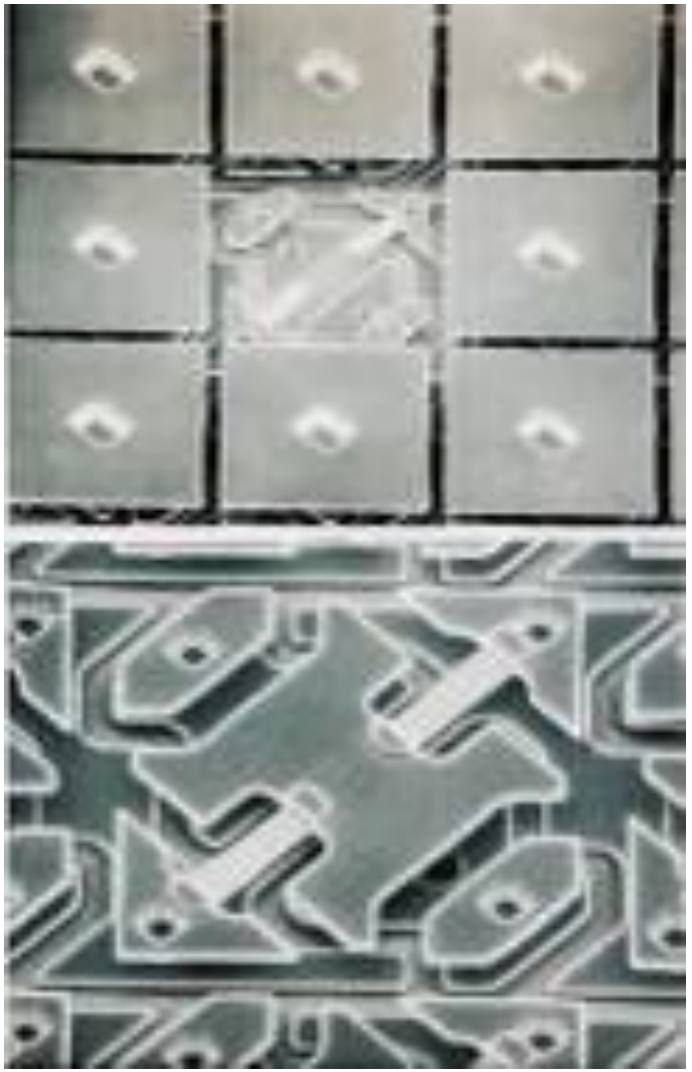
ϕ ~ 100 μm

Example of MEMS Actuator: DMD for Image Display

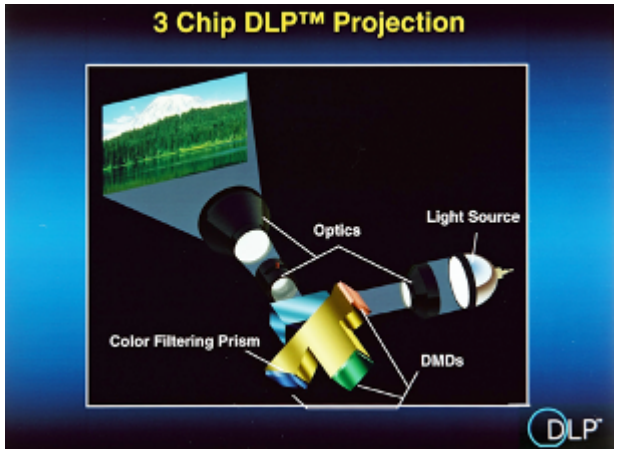
Digital Micro Mirror (DMD), Texas Instruments, US



http://www.dlp.com/

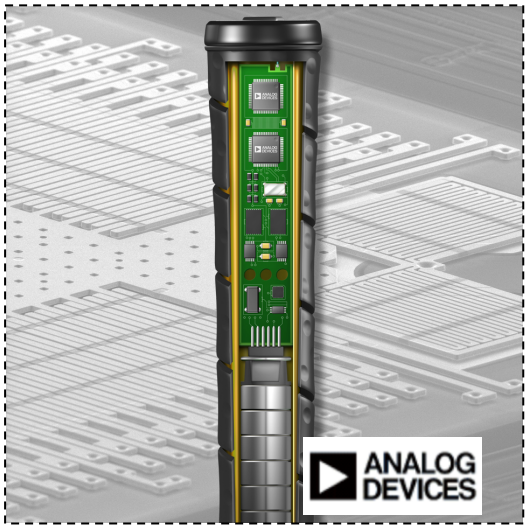


http://www.dlp.com/



http://www.dlp.com/

Example of MEMS Sensor : Accelerometers



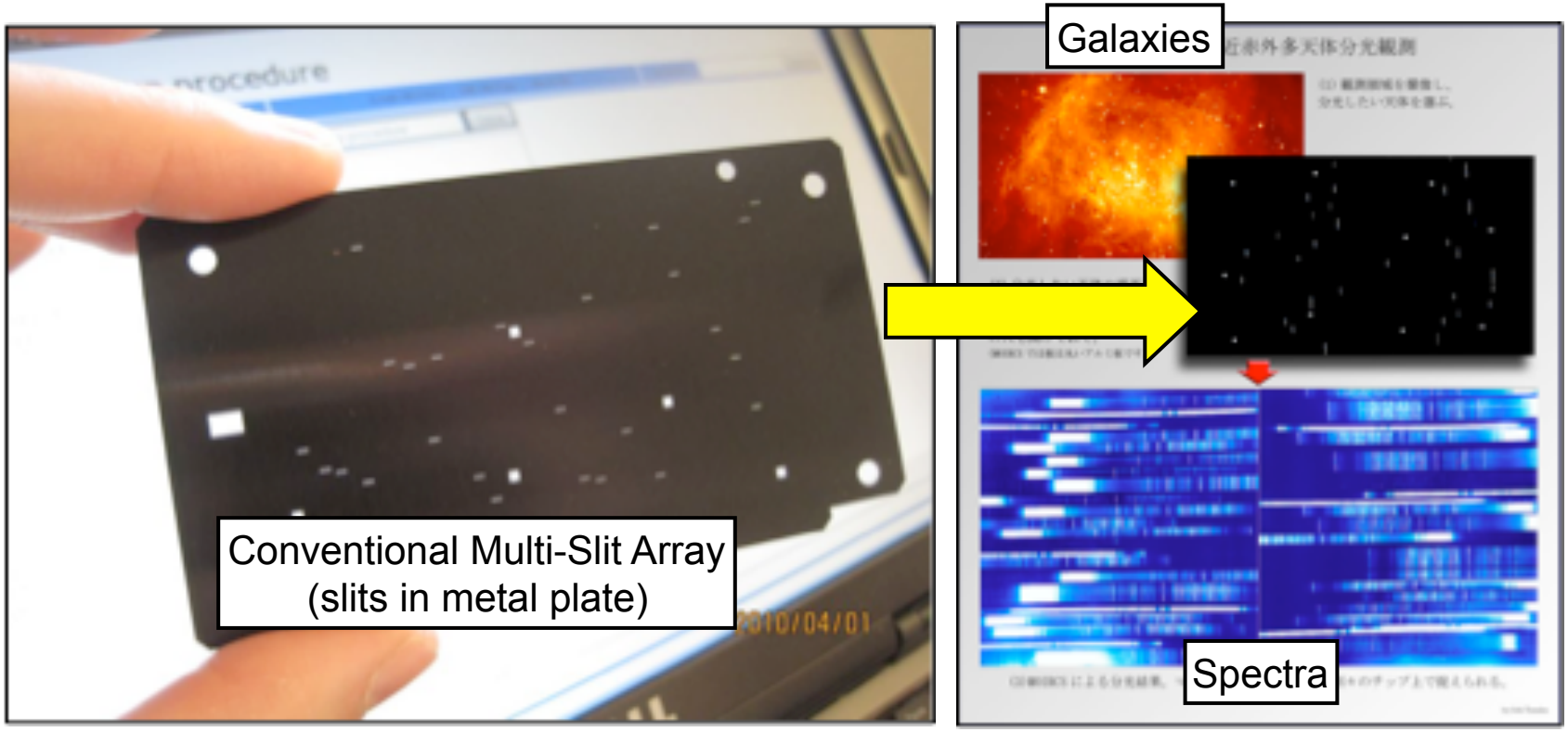
MEMS
(Micro Electro Mechanical Systems)
for IR & THz Light Control

by
Hiroshi Toshiyoshi

with
Research Center for Advanced Science and Technology,
The University of Tokyo

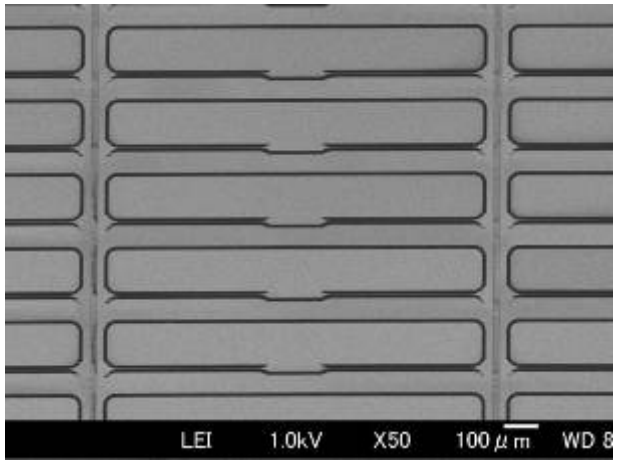
Univ. Tokyo Atacama Observatory (TAO) in Chile

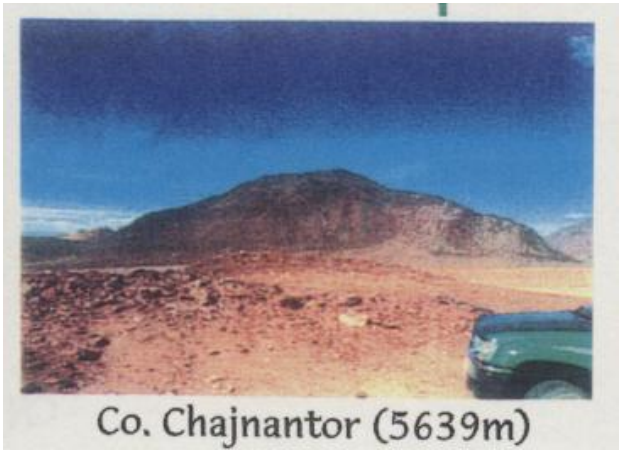
Conventional Multi-Slit Array

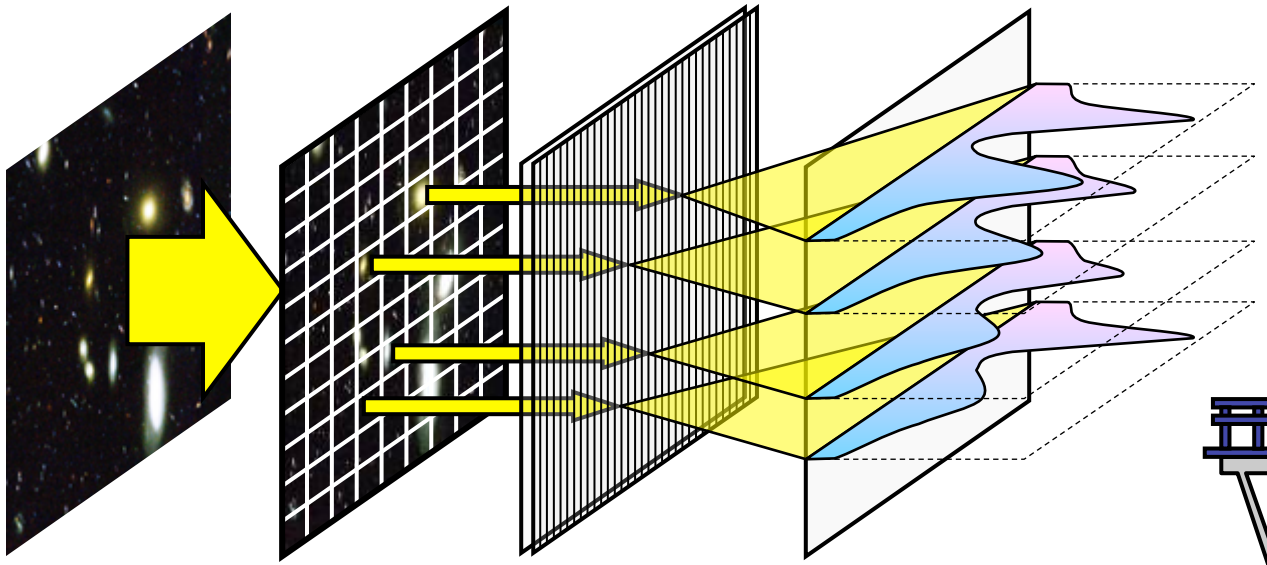


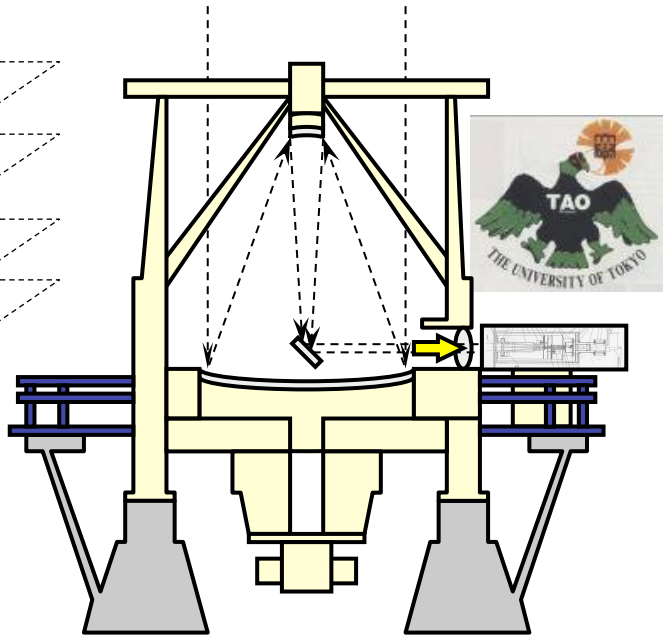
Multi-Slit Array for Observatory

TAO in Atacama（5639 m）



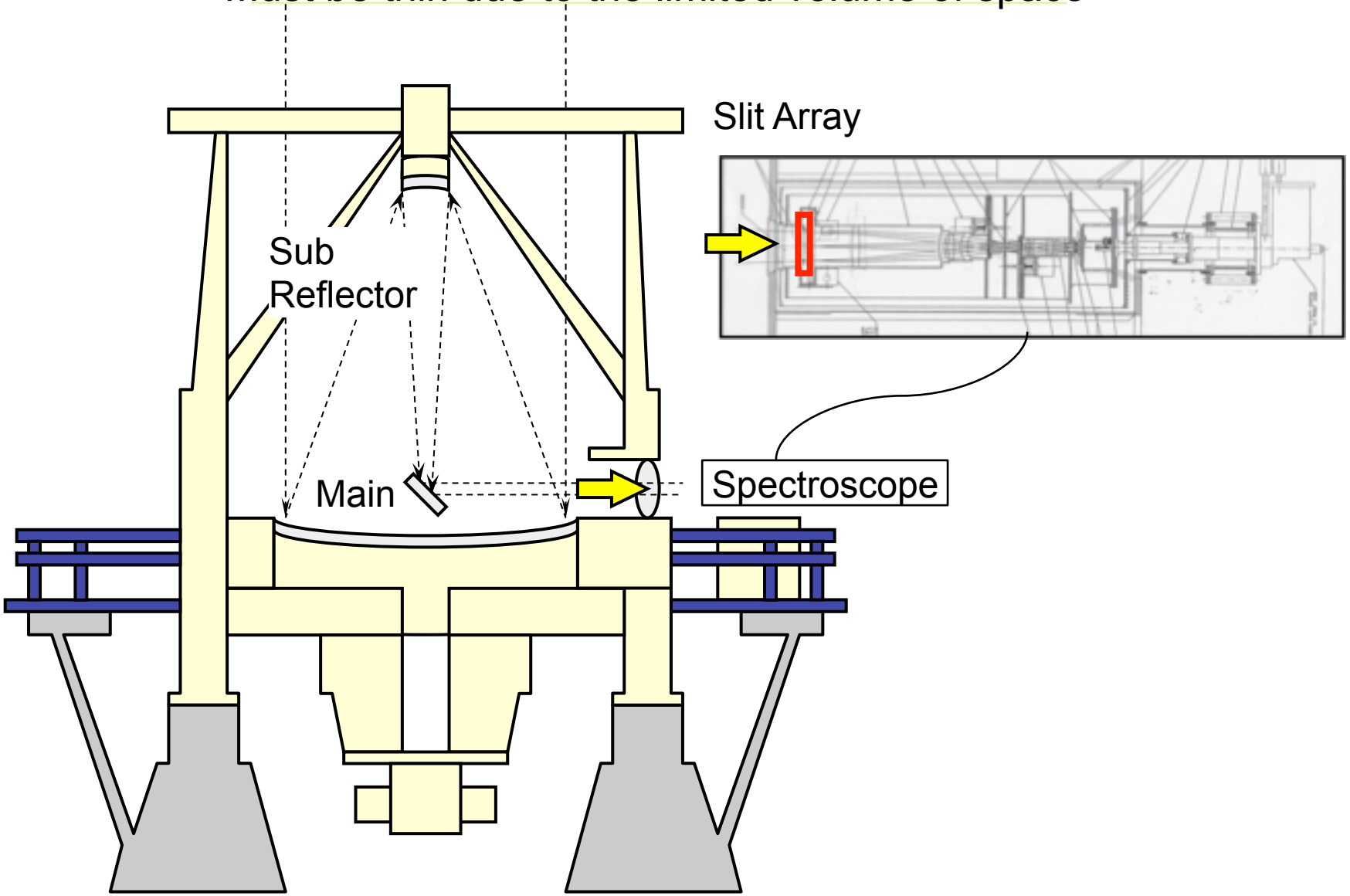






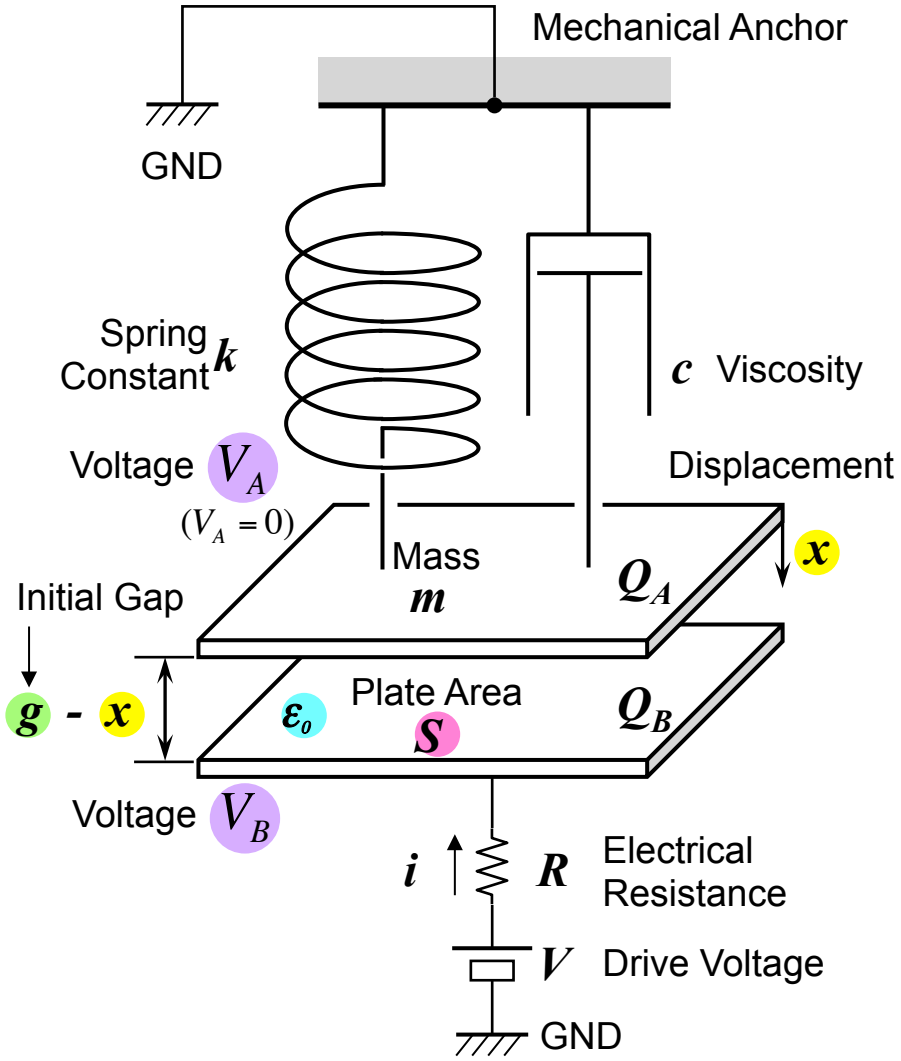
Multi-Slit Array for Observatory

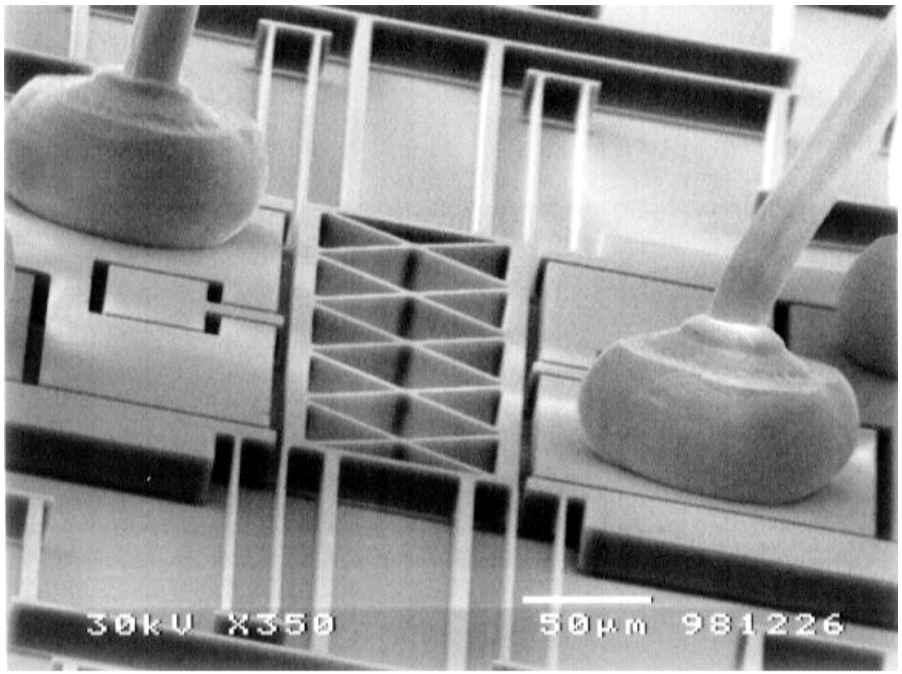
Must be thin due to the limited volume of space



Electrostatic Actuation Principle

Electrostatic "Pull-in" Analysis

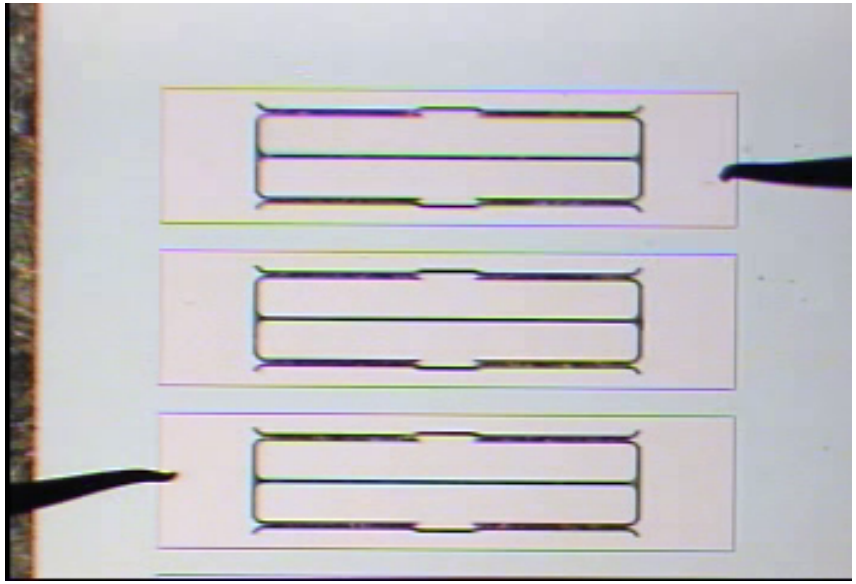


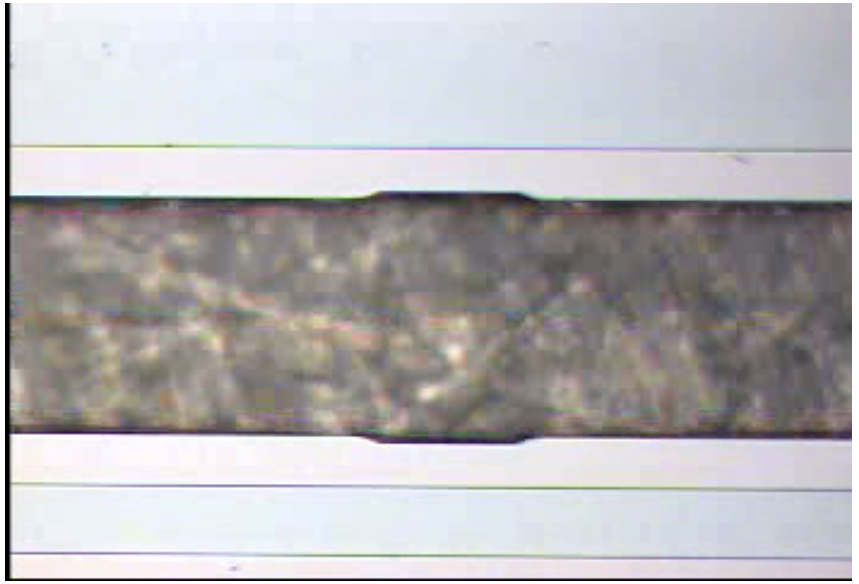


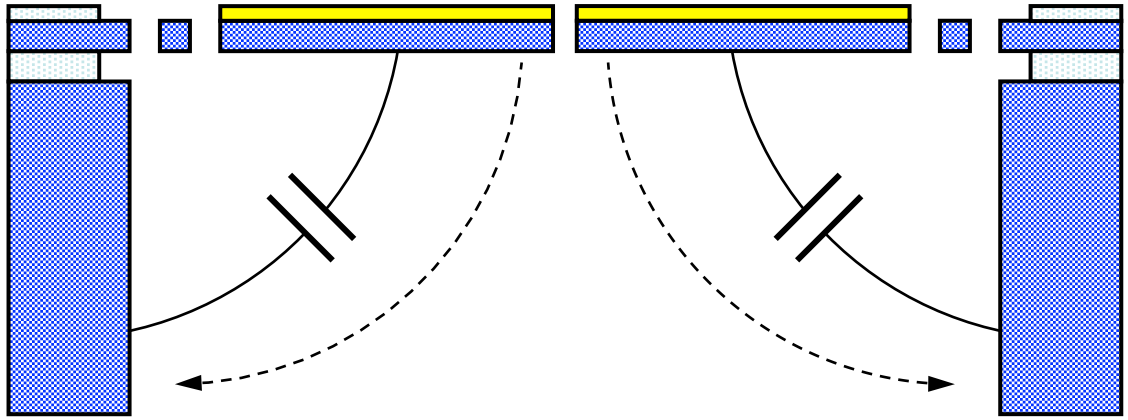
Electrostatic micro actuator (bi-directional)

Optical MEMS Shutter Array at UTokyo

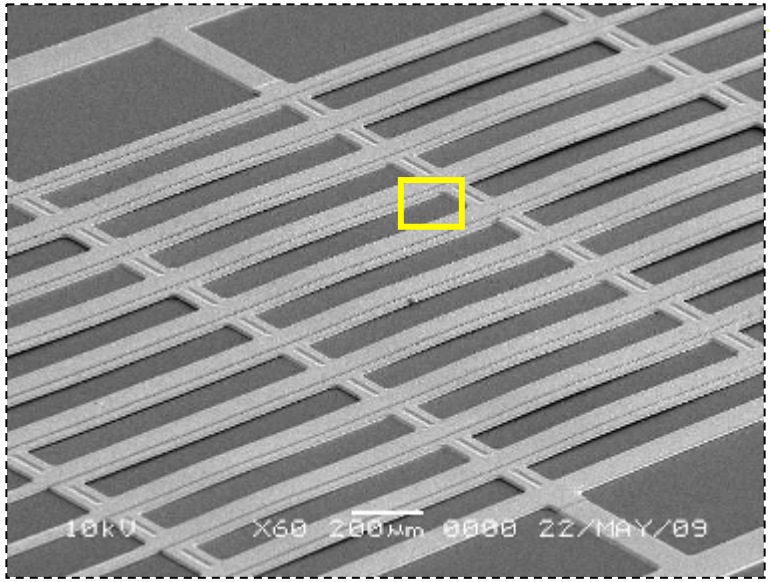
W 100 um x L 1000 um

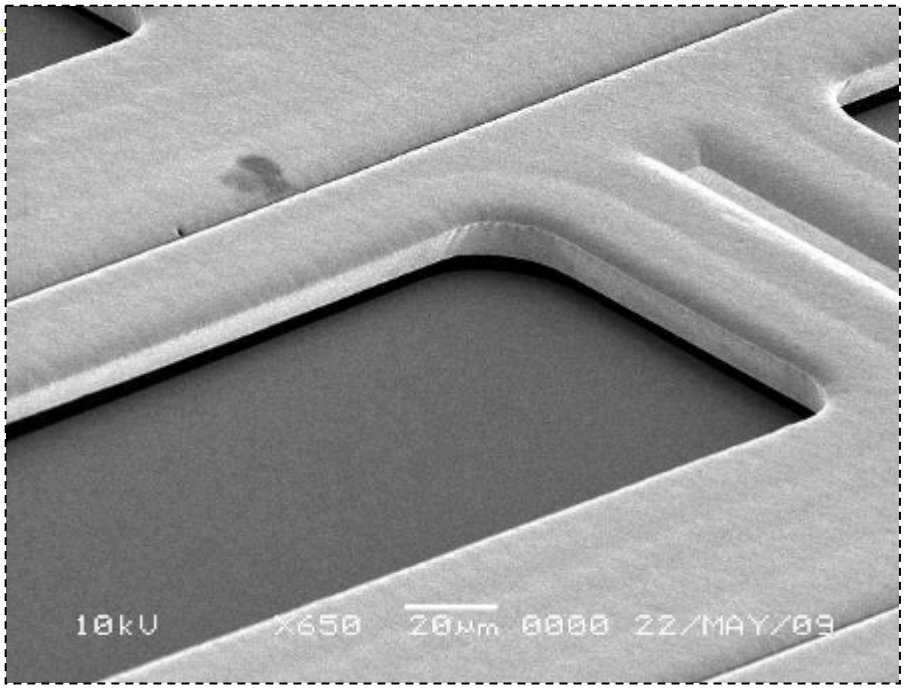


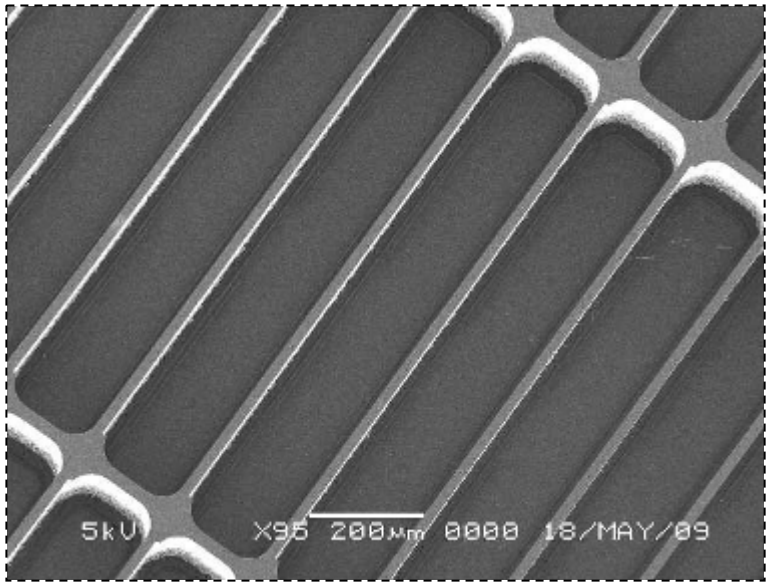


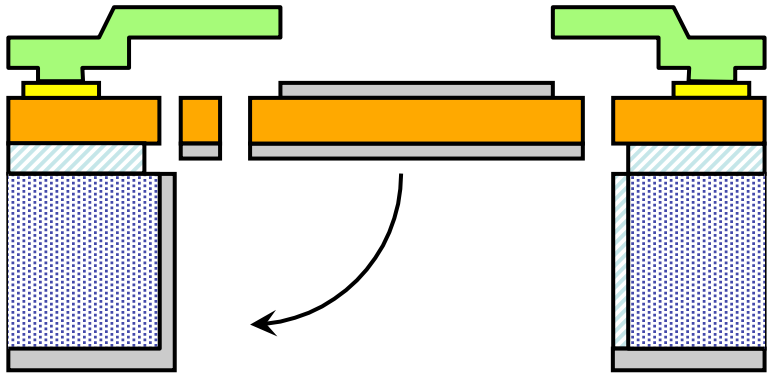


MEMS Shutter Array with Visors to Block Stray Light



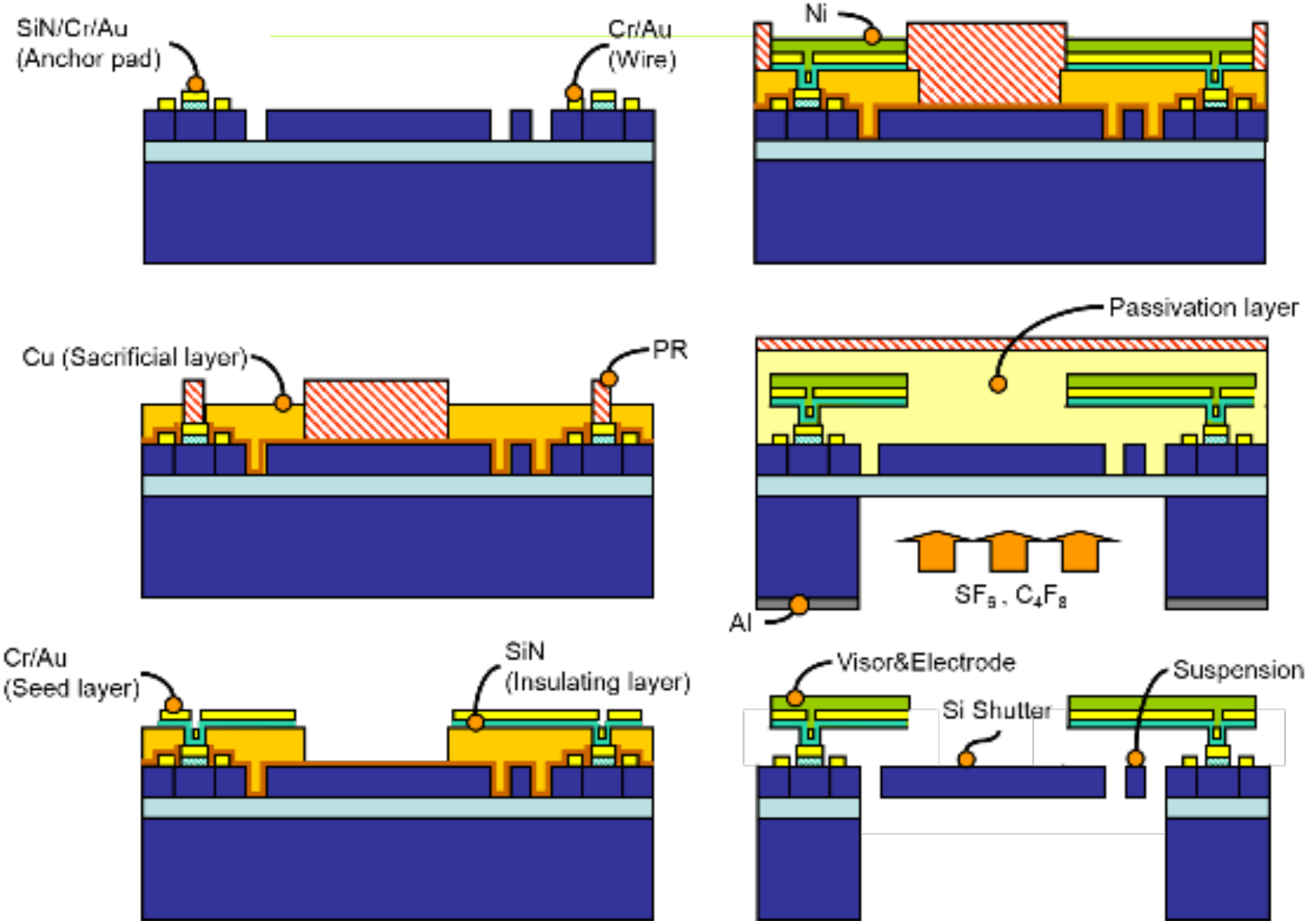




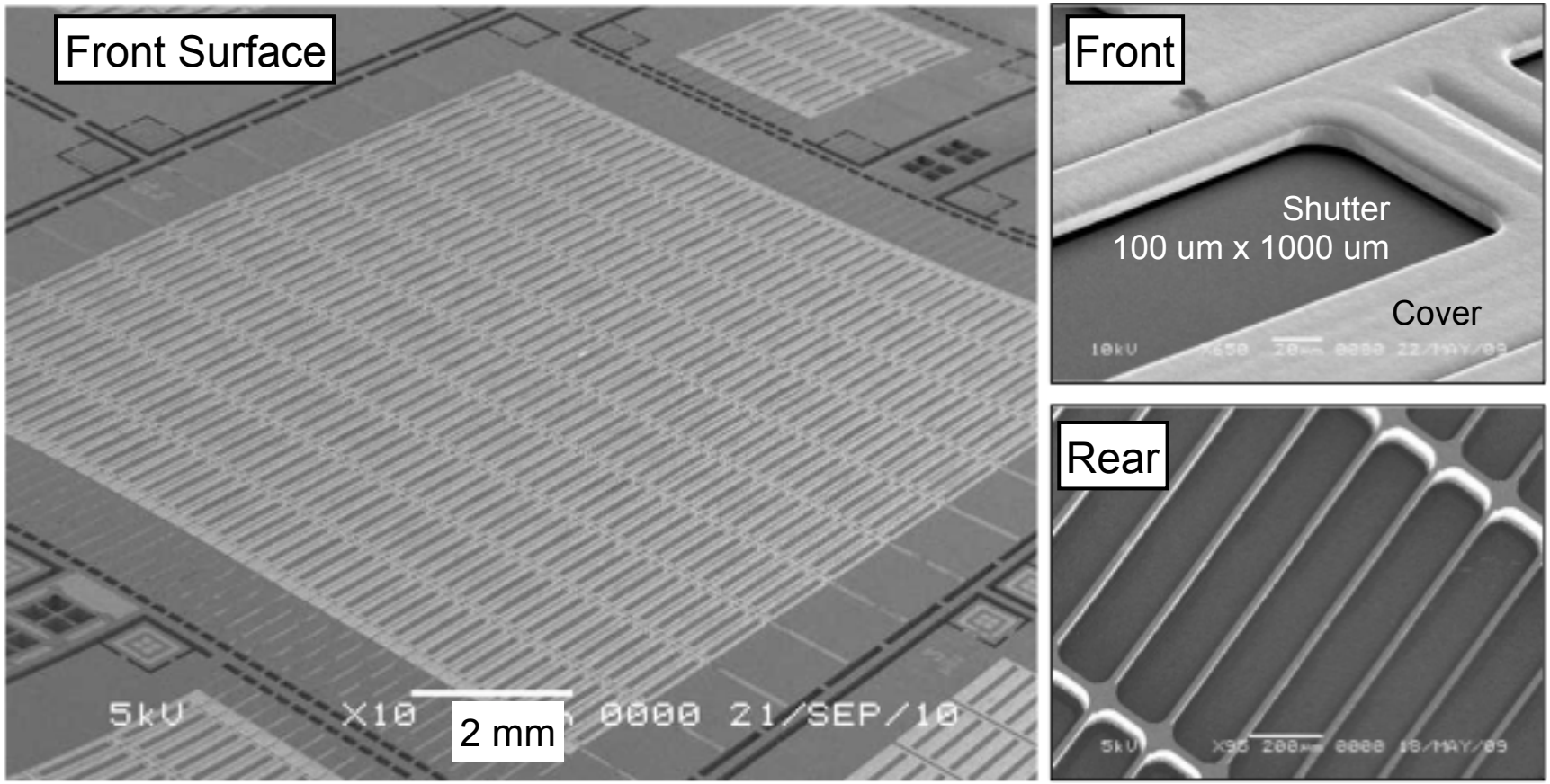


Hiroshi Toshiyoshi © 2016, <hiro@iis.u-tokyo.ac.jp>, IIS, Univ. of Tokyo, http://toshi.iis.u-tokyo.ac.jp/

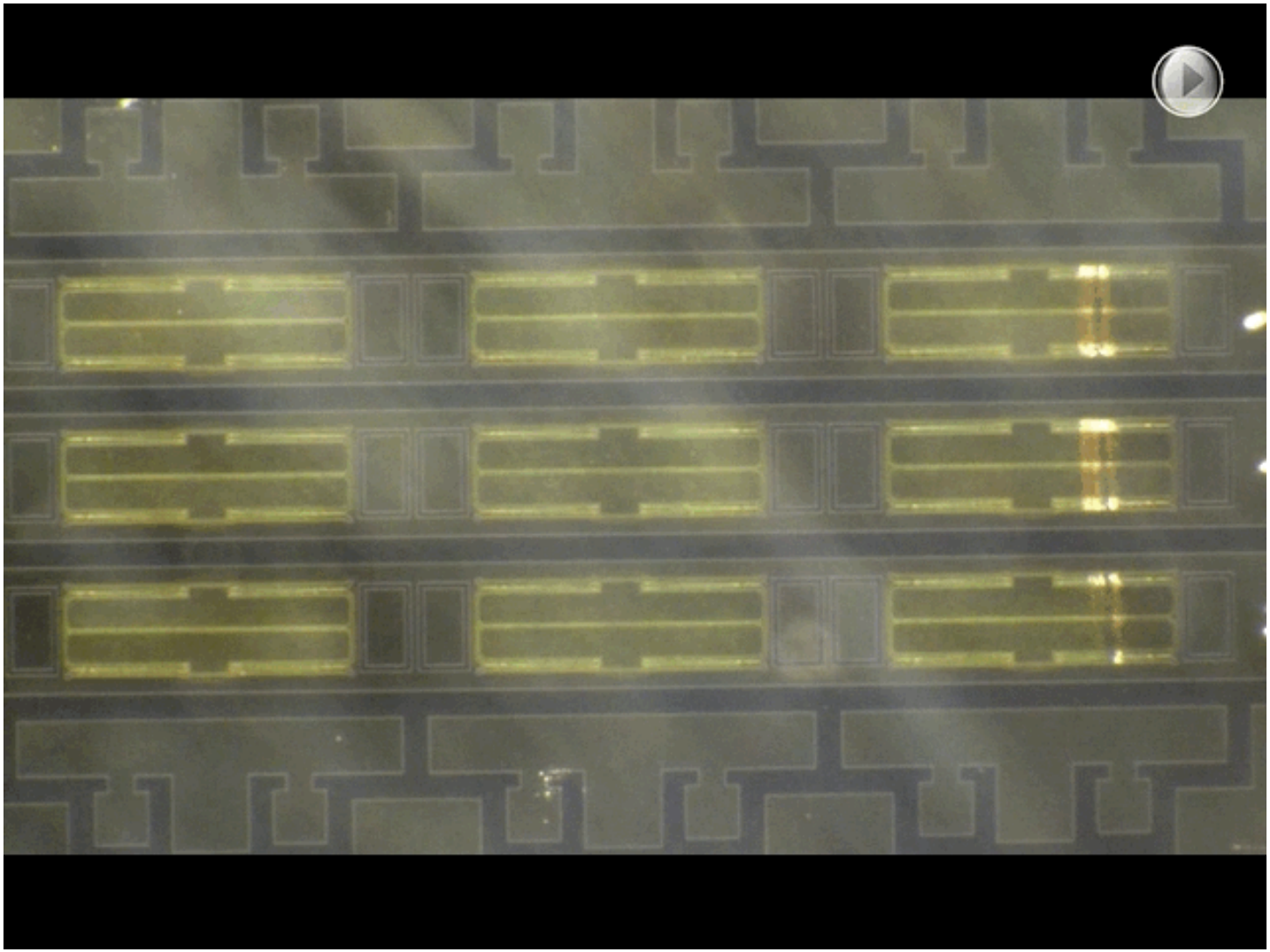
Micromachining Profess for MEMS Shutter Array



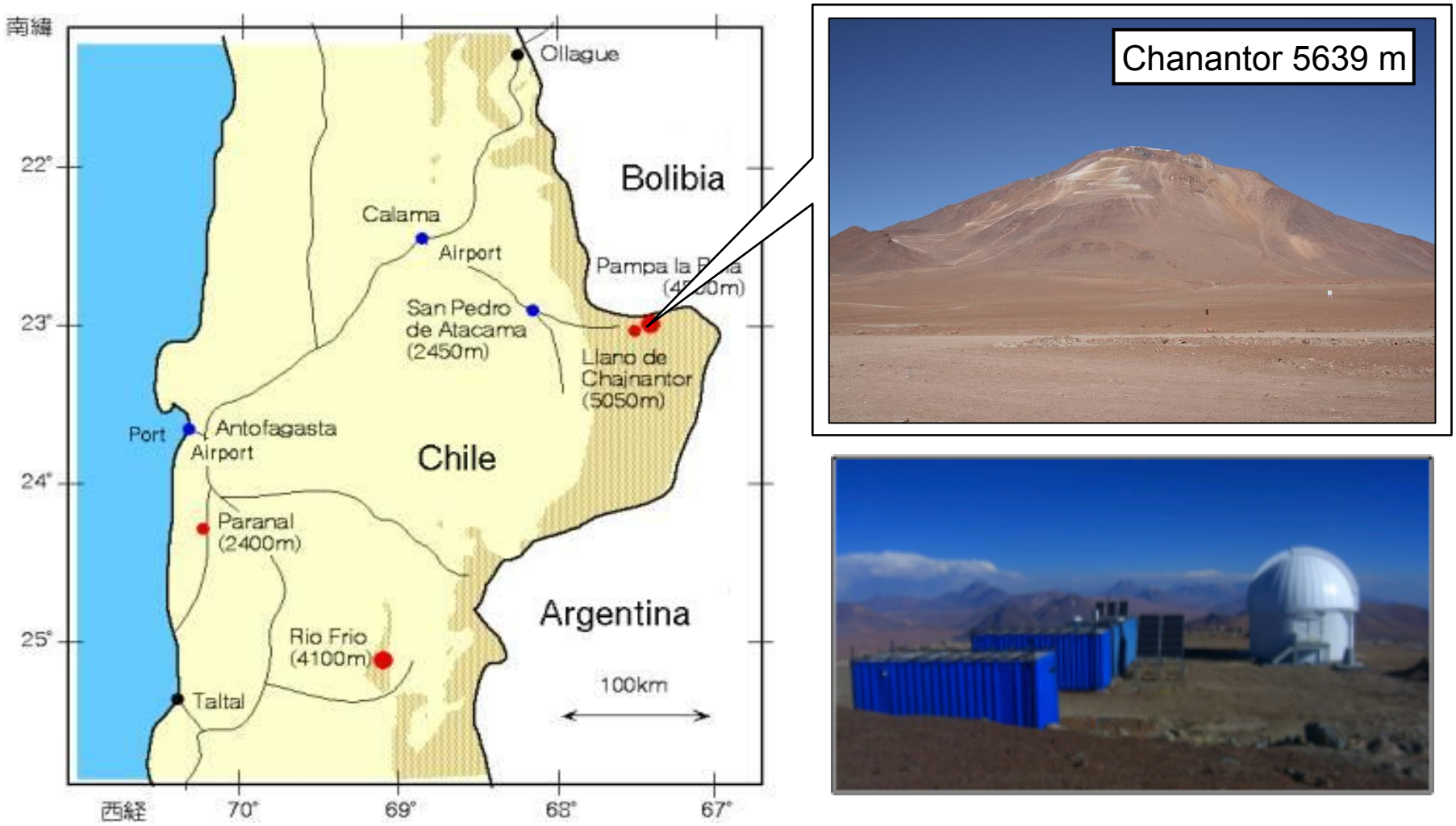
Optical MEMS Shutter Array (400 Elements)



Electrostatic Shutter Operation (in Vacuum)



Univ. Tokyo Atacama Observatory (TAO) in Chile



MEMS
(Micro Electro Mechanical Systems)
for IR & THz Light Control

100 GHz – a few THz
or Millimeter Wave

by

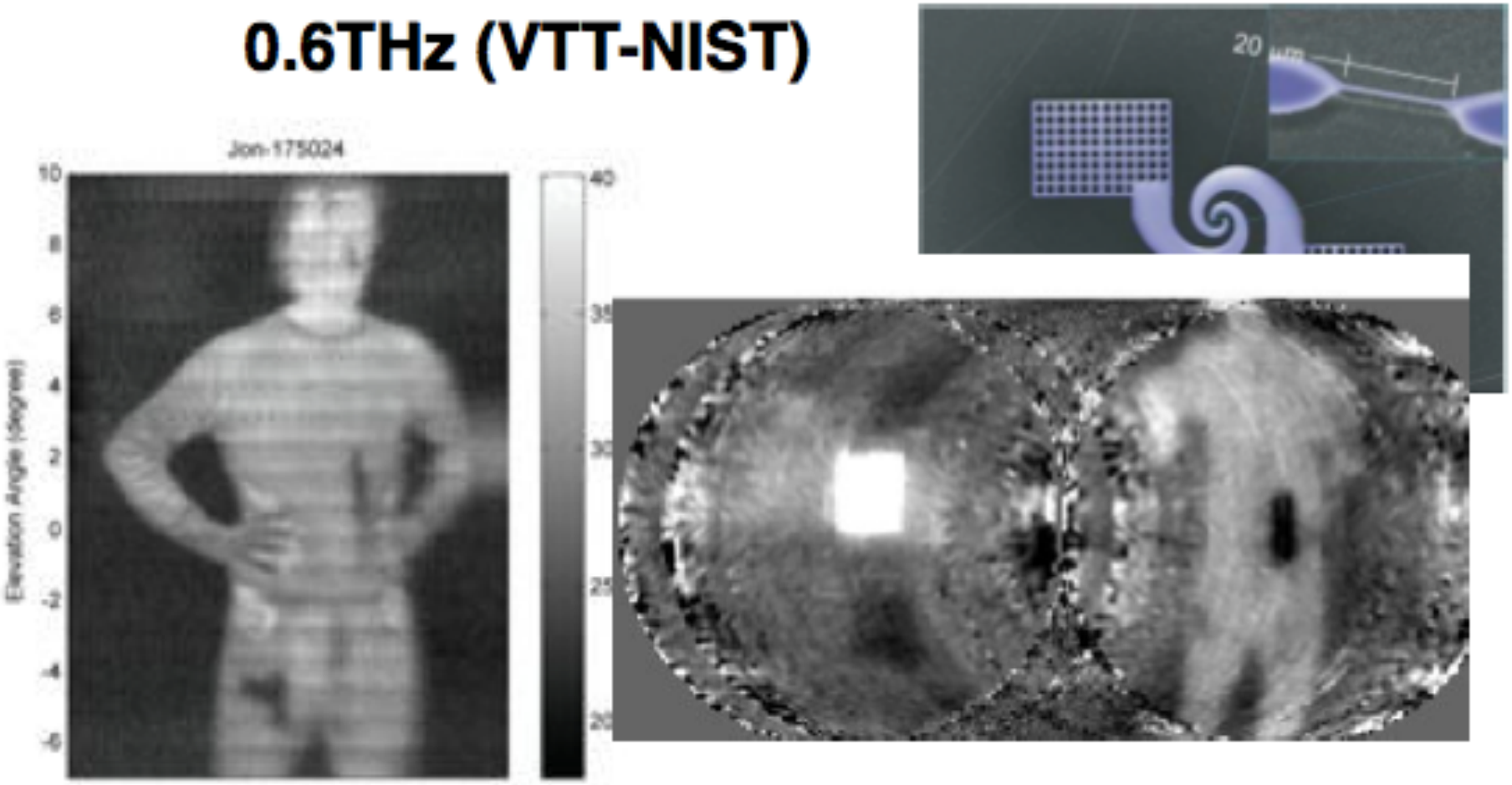
Hiroshi Toshiyoshi

with
Research Center for Advanced Science and Technology,
The University of Tokyo

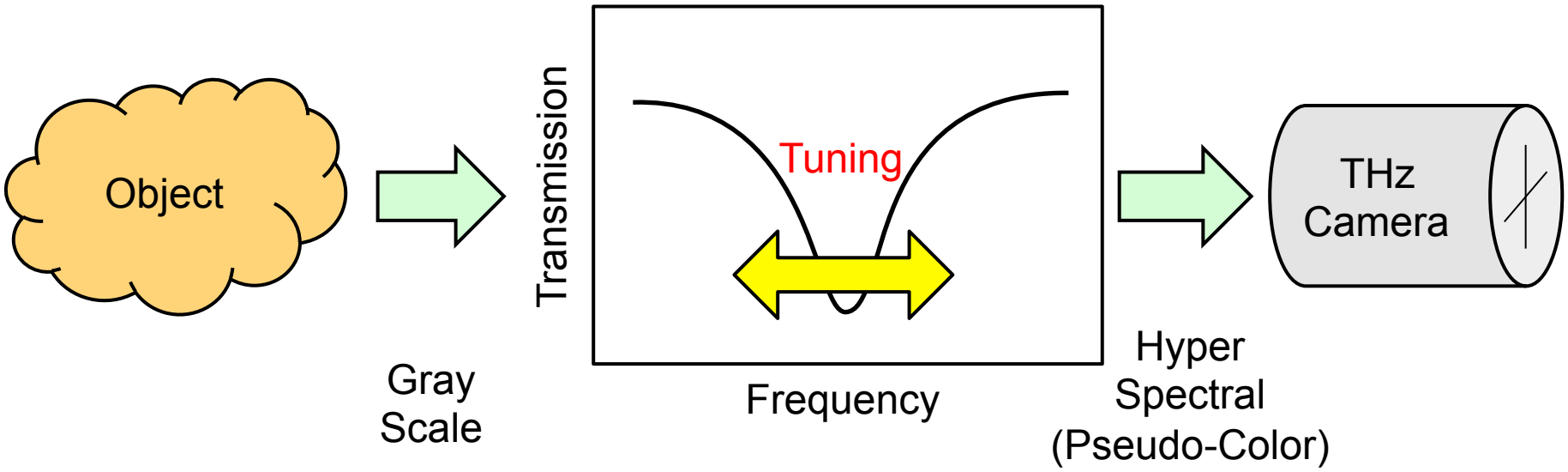
Making Gray Scale THz Image into Color ?

0.4 THz ~ 0.8 THz

- **4K NbN bolometers at 0.6THz (VTT-NIST)**

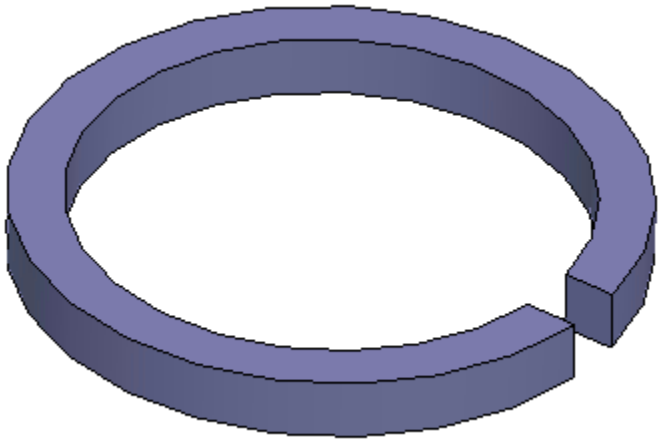


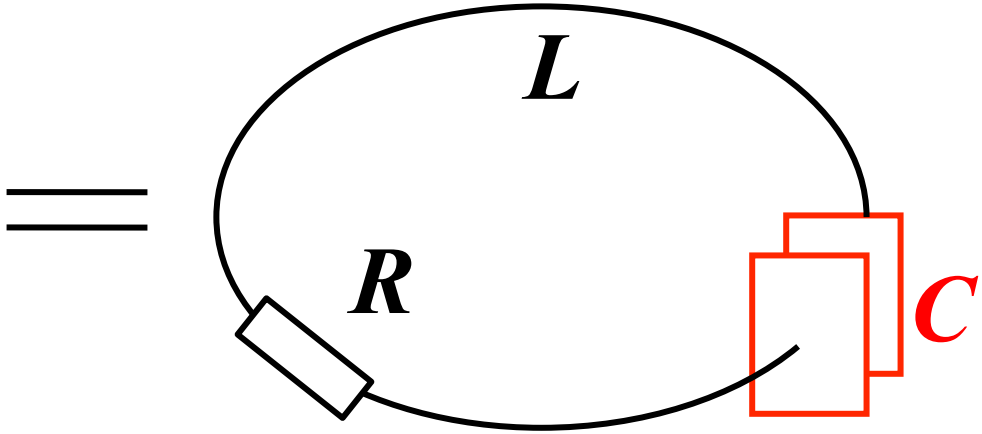
Hyper-spectral Imaging through Tunable THz Filter

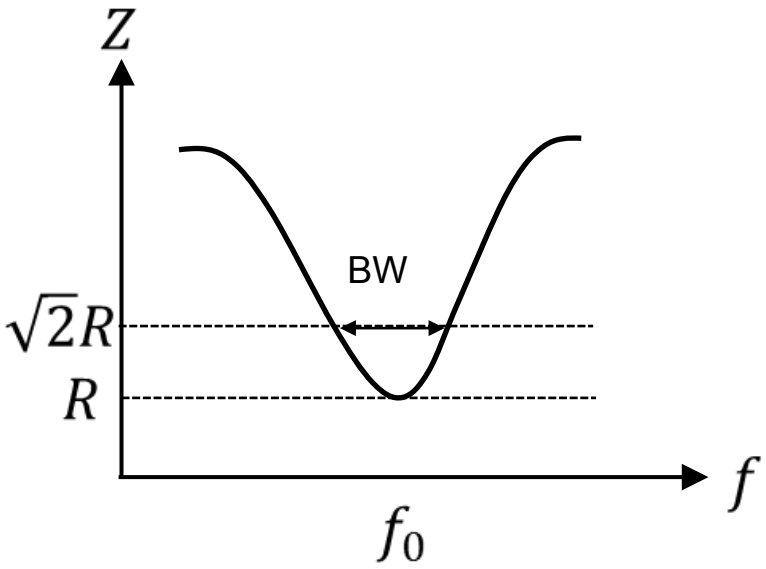


Tunable THz Filter Principle

Split Ring Resonator (SRR)



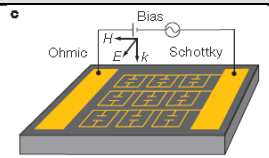
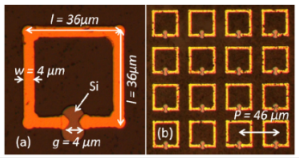
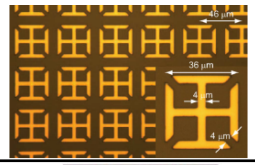
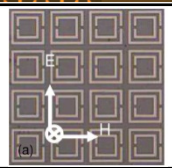
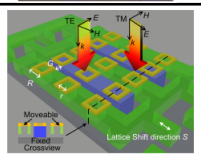
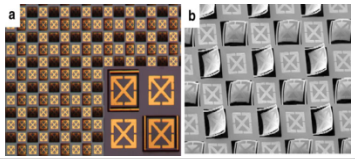
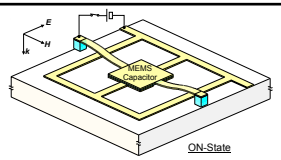




Resonance $$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

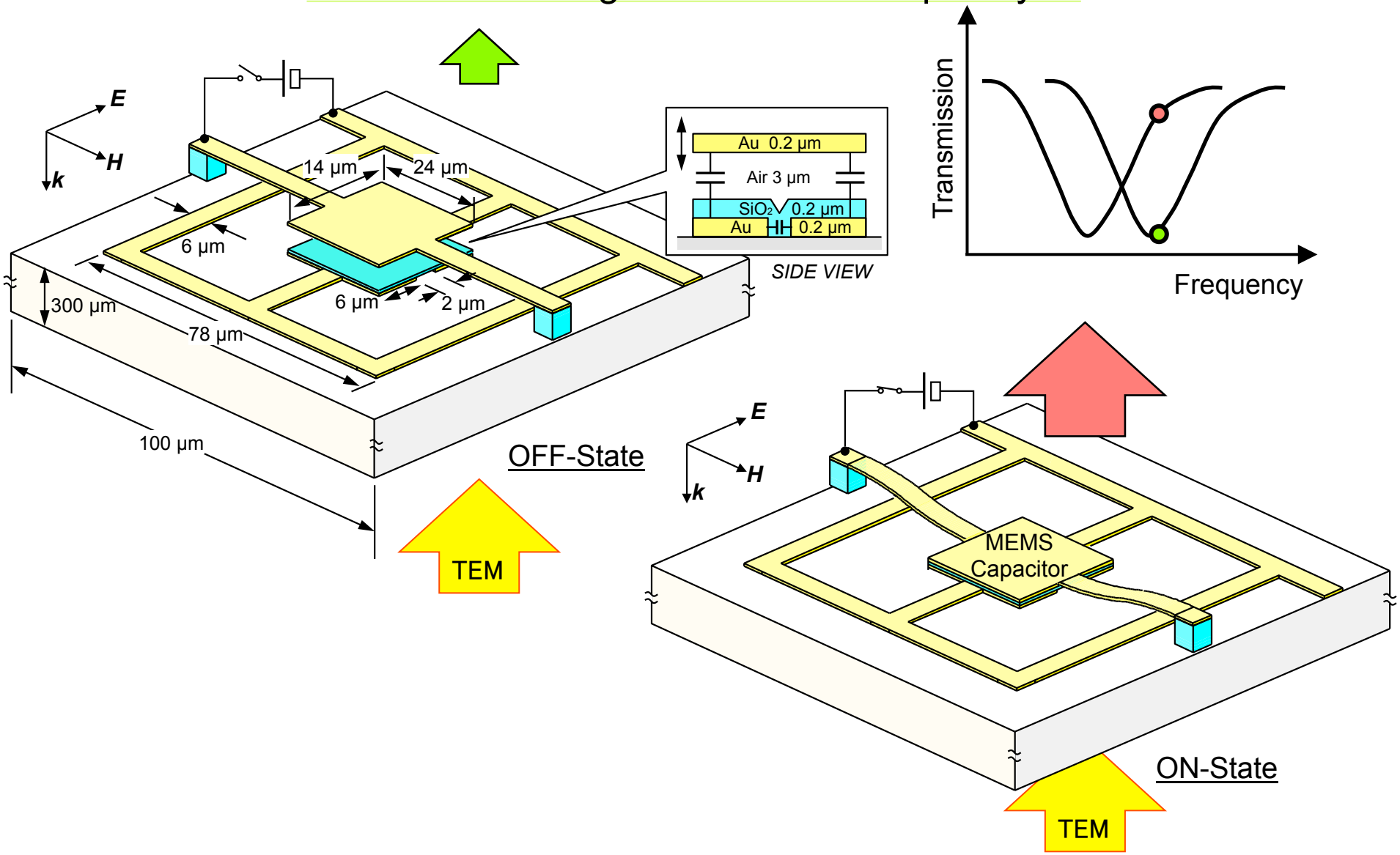
Q factor $$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Terahertz Control Methods

Control	Mechanism	Device	Reference
Electric Field	Carrier Density		H.T.Chen, Nature, 2006
Photo Excitation			D.R.Chowdhury, APL, 2011
Temperature	Permittivity		R.Singh, Opti. Lett., 2011
Magnetic Field	Metal Properties		B.Jin, Opti. Expr., 2010
Mechanical Displacement	EM Coupling		W.M.Zhu, APL, 2011
Mechanical Tilt Angle	Polarization		H.Tao, Infrated Milli Thz waves, 2011
Reconfiguring SRR Element	Tunable Capacitor		This work

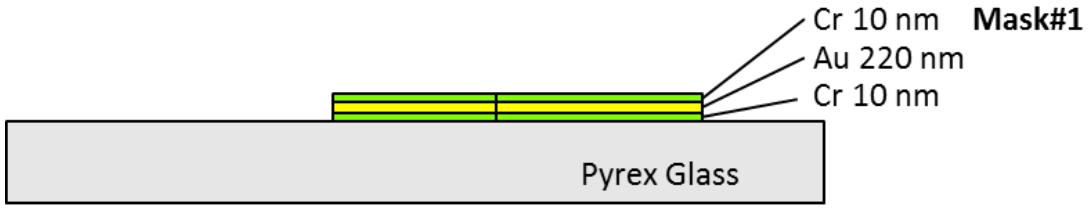
Tunable Capacitor in Split-Ring Resonator

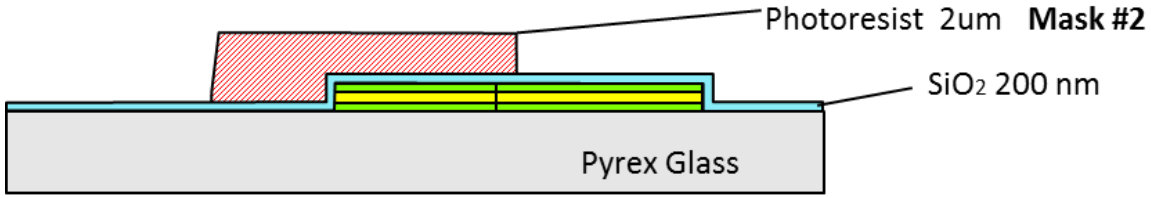
Tuned C changes Resonant Frequency

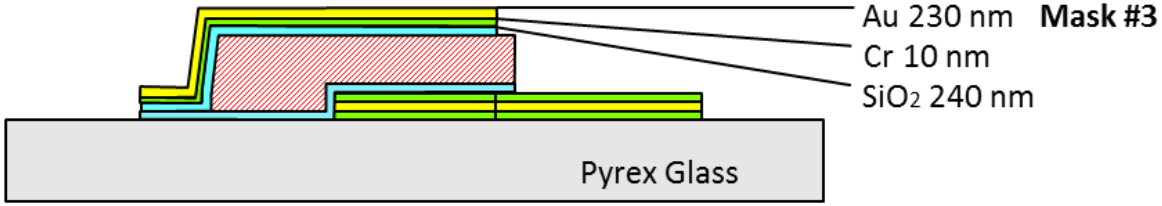


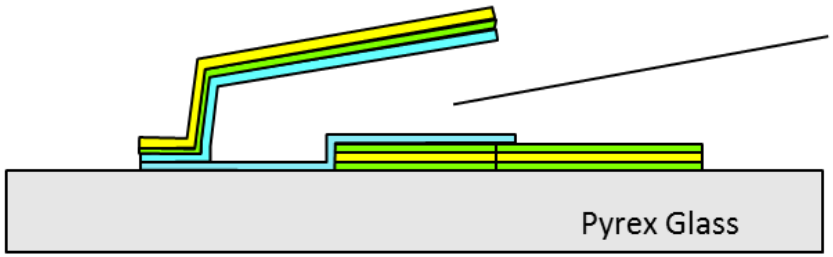
Surface Micromachining Process

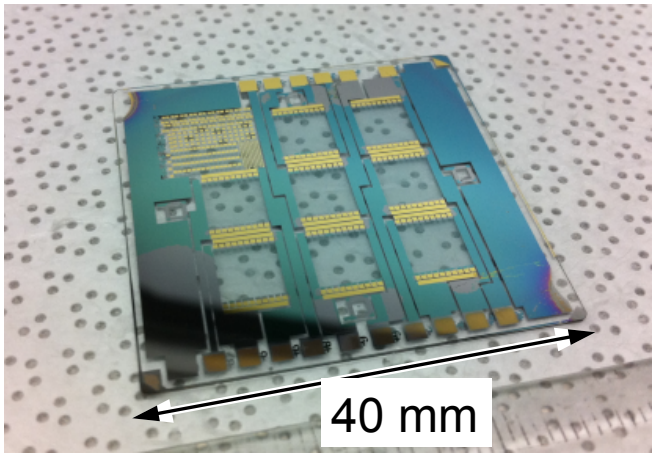
Cr / Au as Structure, Al as Sacrificial Layer

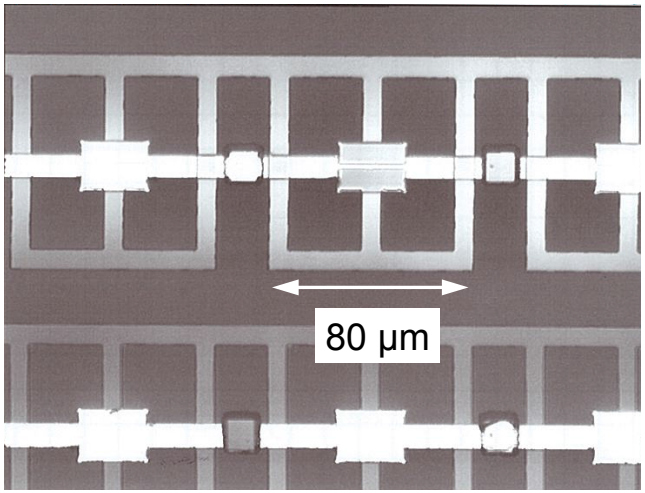






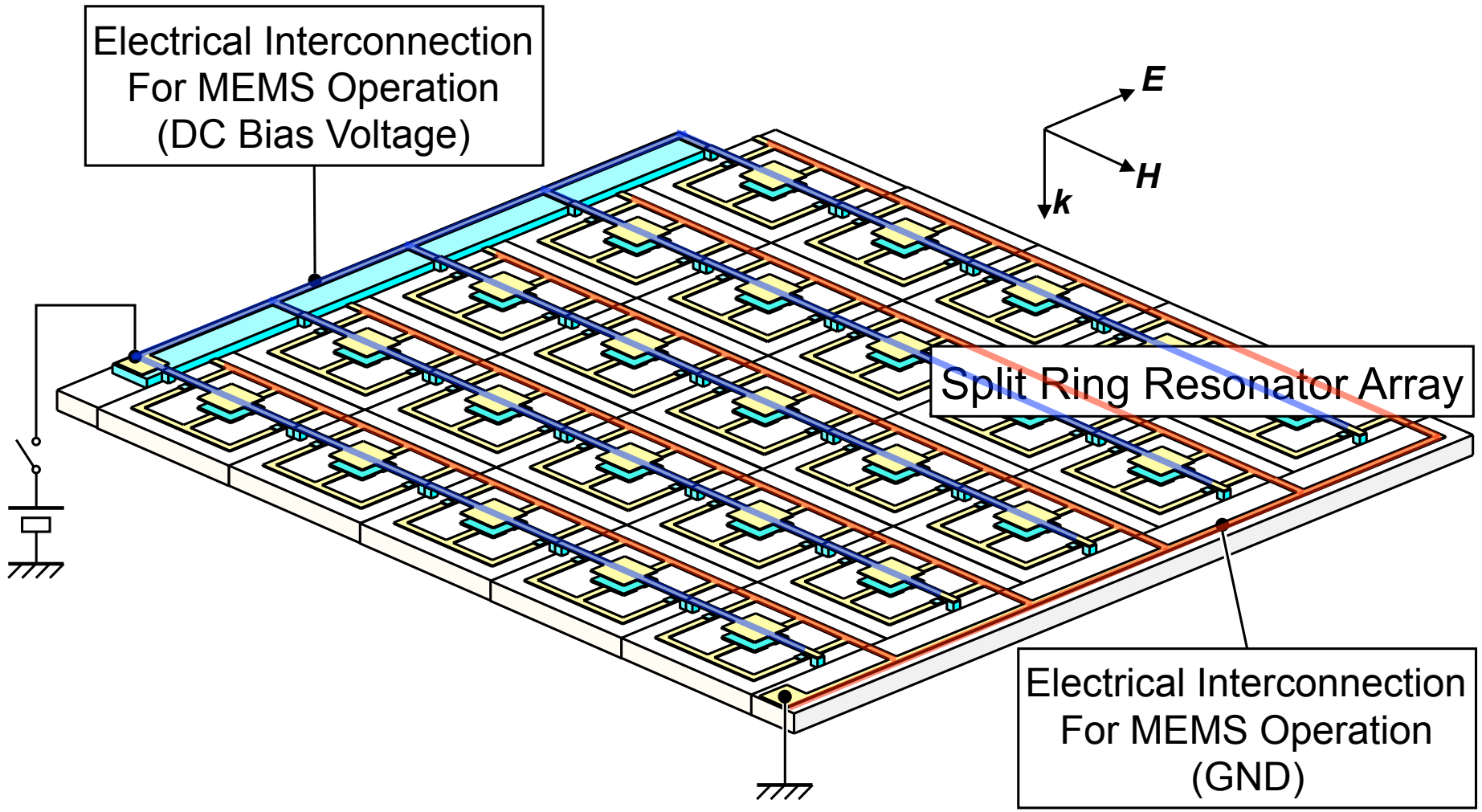






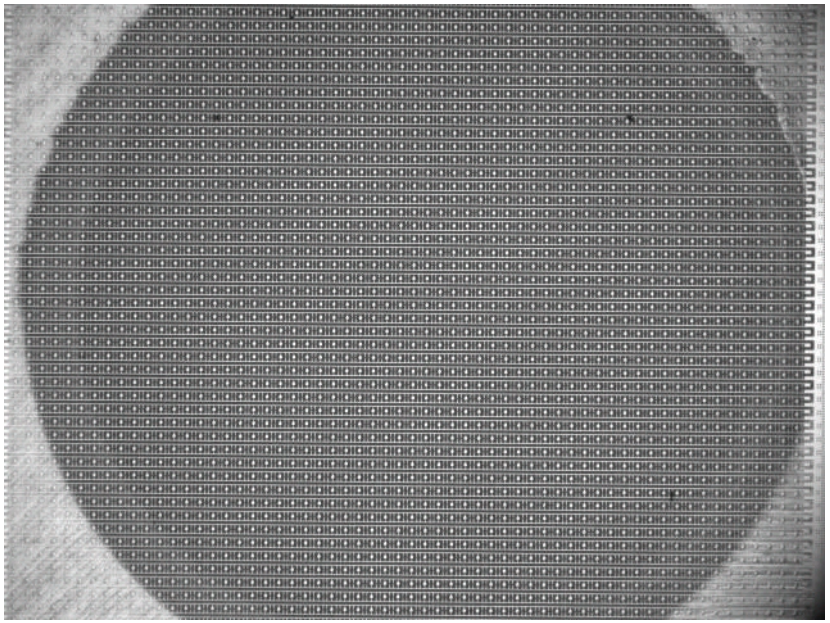
Electrical Interconnection via Ladder-Chained SRRs

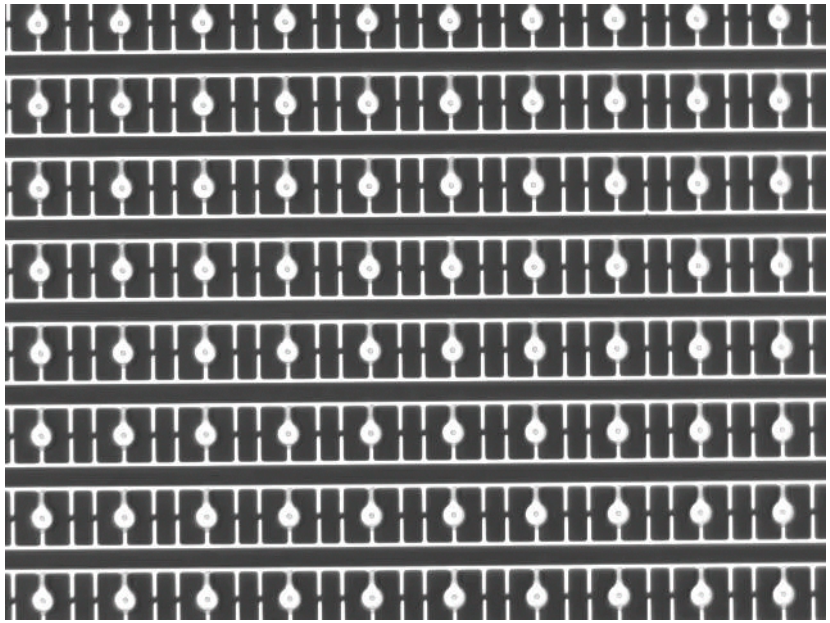
DC / RF Decoupled



High-Speed Video Camera

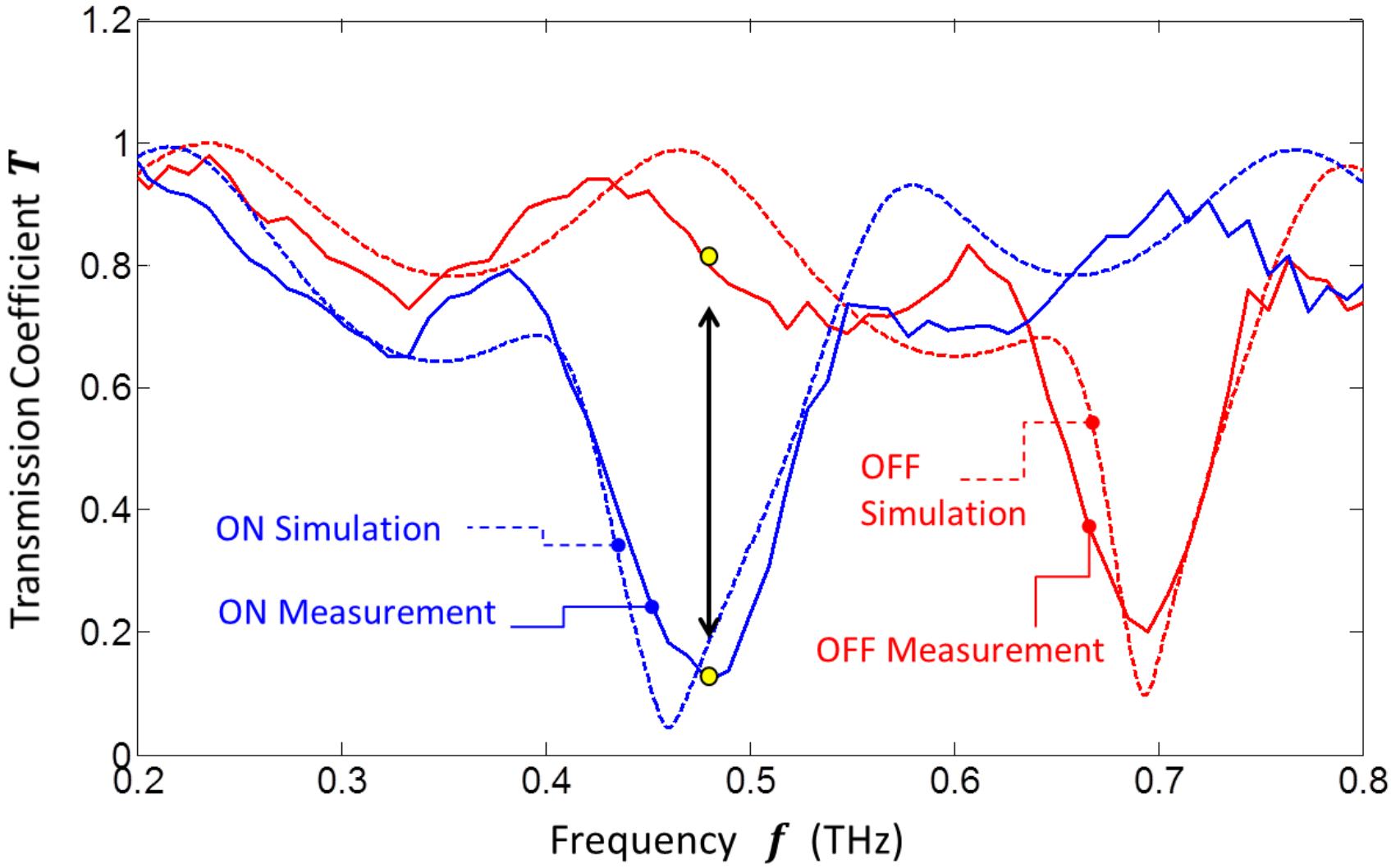
Electrostatic Operation 10 V, a few tens kHz speed





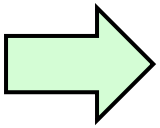
Transmission Control by MEMS-SRR

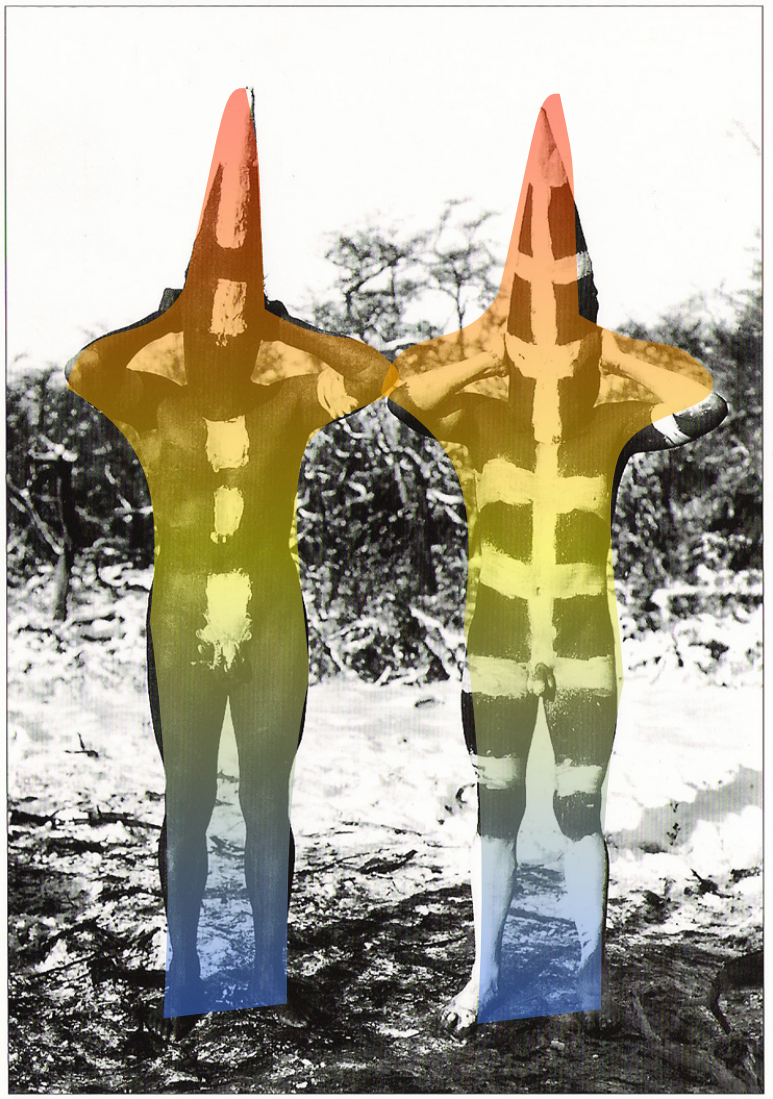
Tunable Band-Stop Filter (Transmission) between 0.45 and 0.7 THz



We will be seeing something like this …

Pseudo Hyper-spectral THz Imaging

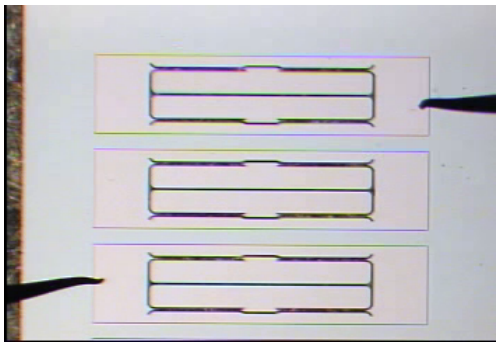




Summary

1. MEMS is an enabling technique to play with light due to free-wavelength transparency, large contrast of modulation, and high fidelity in linear response. In particular, electrostatic operation has high compatibility with device integration.

2. MEMS shutter array is under development for potential use as a reconfigurable micro slit array in infrared observatory.



3. MEMS can also be used in tunable THz filter, in particular to make pseudo-color (hyper-spectral) THz imaging.