Implementation of Nanosecond Time synchronization capability on wireless smart devices

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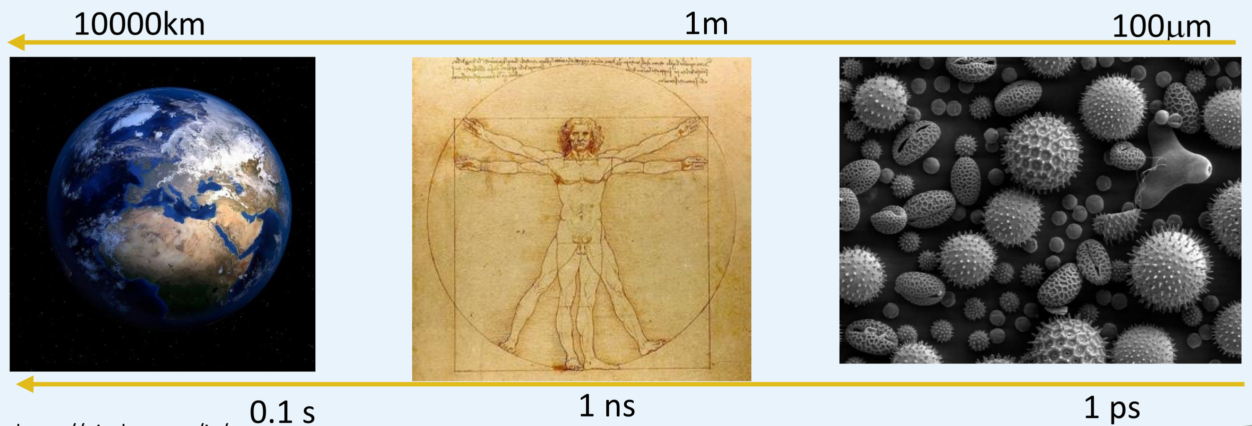
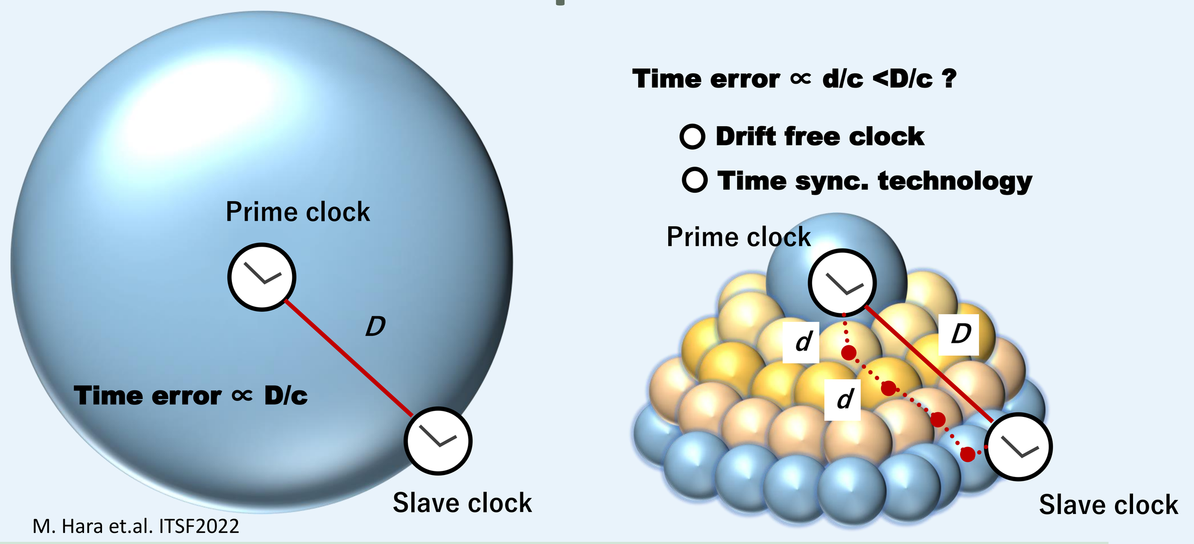
CONCEPT <Share the "Just-now"!>

Uncertainty principle on time and space



<Break the uncertainty through! >
Time cluster concept



NOTE

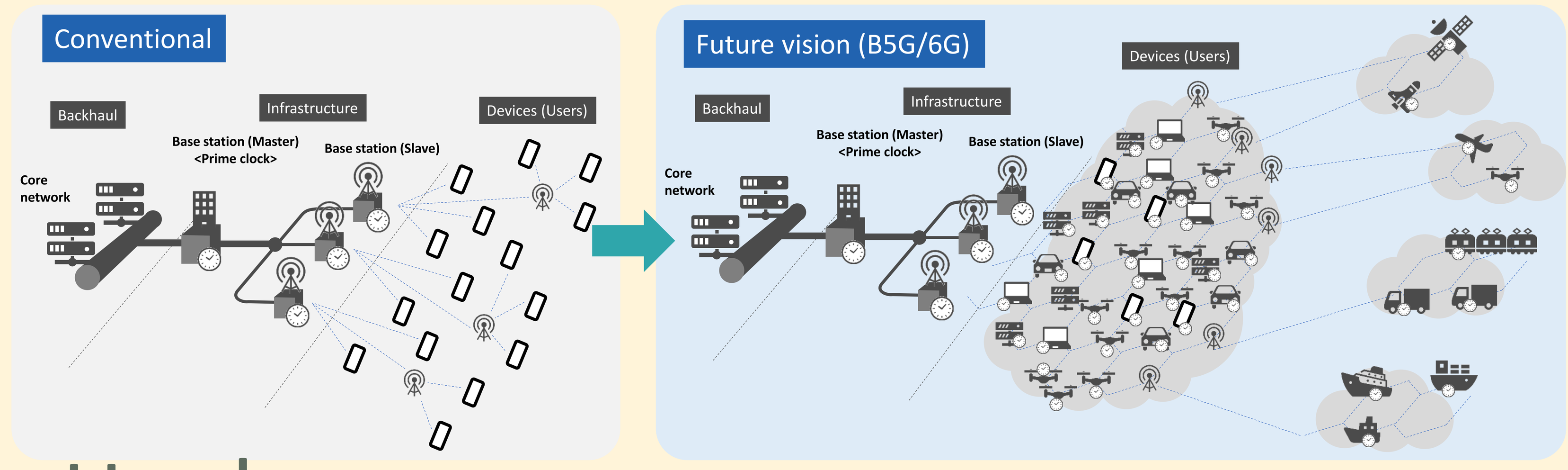
The time shared in the cluster is standard time, not absolute time, which is denied by the theory of relativity and is elusive on a global scale.

The same standard time is shared with accuracy on the order of nanoseconds beyond that of the global scale, but verification of time on a global scale necessarily requires subsecond order.

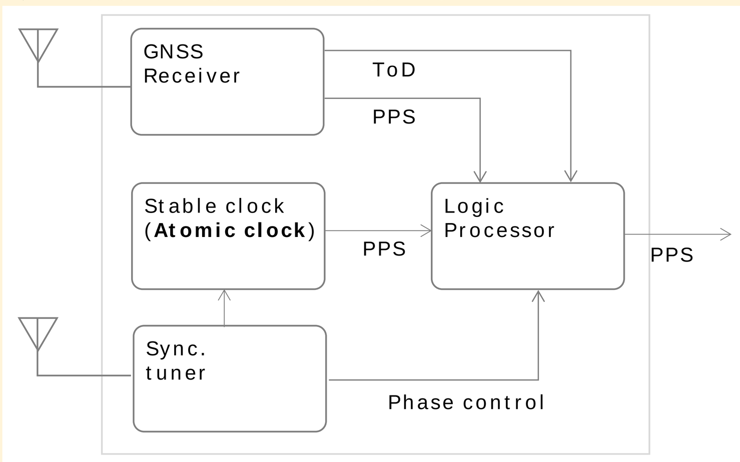
In other words, we allow sub-second delays, the processed data can be reliably tracked in cyberspace with time accuracy of nanosecond class and space accuracy of meter class

Implementation

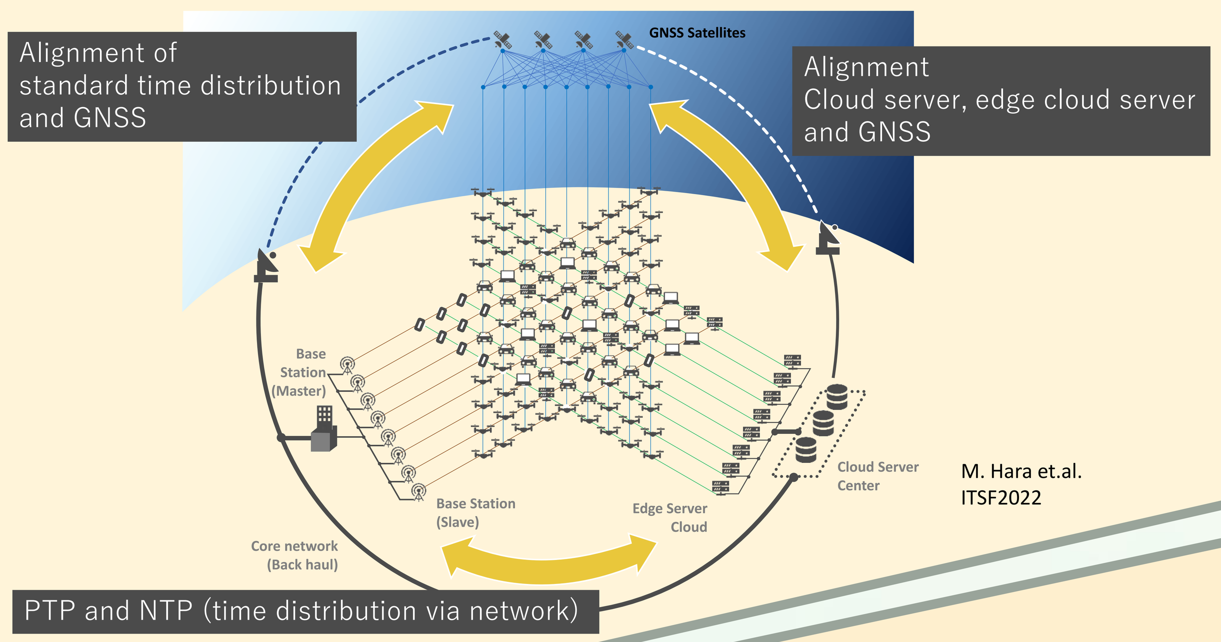
- Diversification of wireless devices
- Mesh networking with any wireless devices for time synchronization



➡ Current trend



Ex) Google spanner
Ex) Meta Timecard



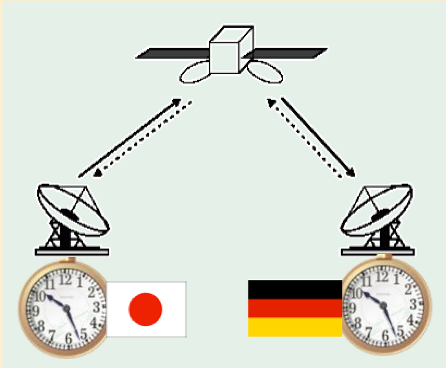
Menu at NICT

Drift-free clock
➡ Ultraminiaturization of CPT MW atomic clock
CLIFS Chip Level Integrated Frequency Standard

Time synchronization technology
➡ Wireless two-way interferometry
Wi-Wi

Cluster Clock System

Wi-Wi



Conventional

Two-way satellite time and frequency transfer (TWSTFT)

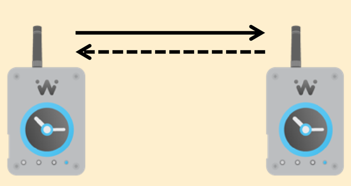
$\Delta T_G = (T_J - T_G) + P$: measurement at Germany site
$\Delta T_J = (T_G - T_J) + P$: measurement at Japan site
$P = (\Delta T_G + \Delta T_J)/2$ (P = Sum of both meas.)
$T_J - T_G = (\Delta T_G - \Delta T_J)/2$ ($T_J - T_G$ = Difference)

measurement of time difference and transmission time via satellite communication.

Our proposal

S. Yasuda et.al. Radio Sci., 54(7), 2019.

Wireless two-Way interferometry (Wi-Wi)

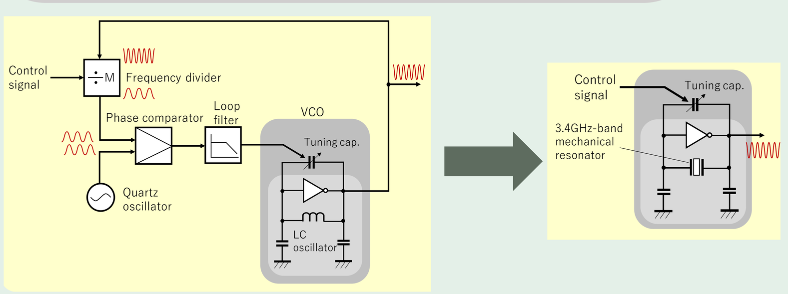


measurement of time and distance via wireless communication

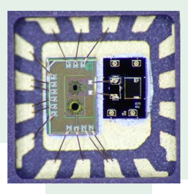
Ultraminiaturized atomic clock (CLIFS): A CONCEPT

Advantages of MEMS technologies
+ Tunability
+ Cost reduction / Downsizing
+ Thin film deposition and Patterning
  - Low-k film
  - Piezoelectric film

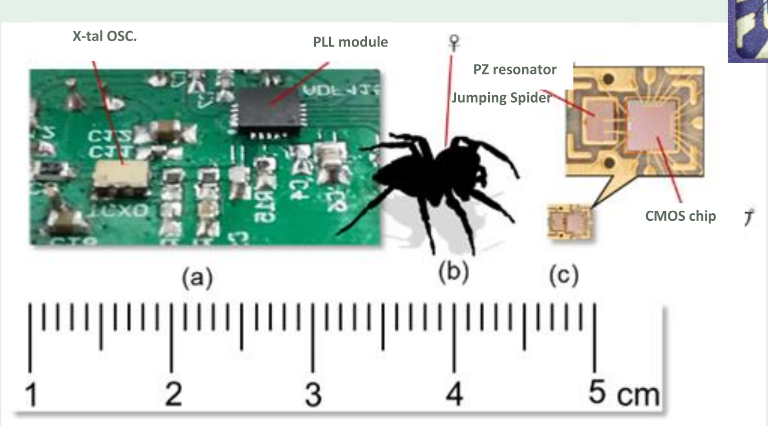
Tunability + Thin film (PZ)

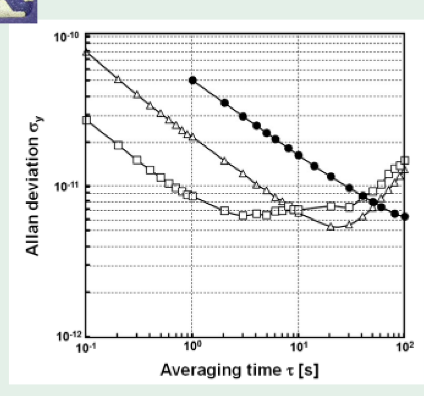


<Under development> Cavity packaging to integrate the physics PKG.



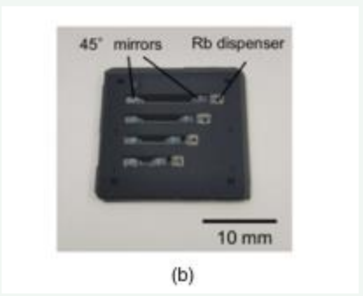
M. Hara et.al. Rev. Sci. Instrum., 89(10), 2018.

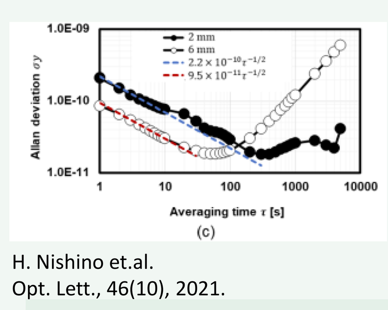




Thin film (Low-k) + Nano pattern

Dielectric mirror (Prior works) (Bulky)

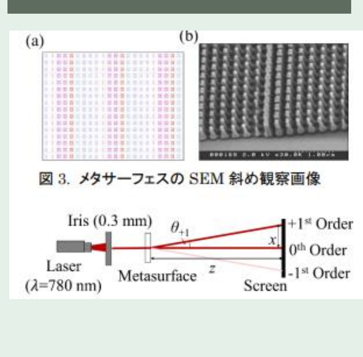




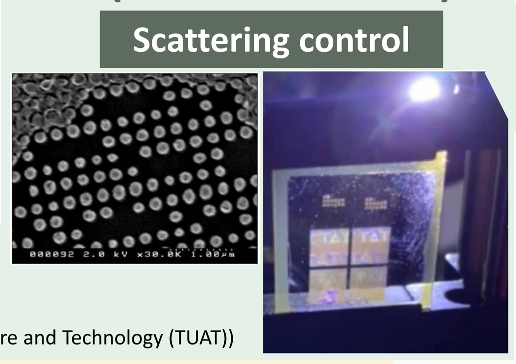
H. Nishino et.al. Opt. Lett., 46(10), 2021.

Nano pattern (New work) (Surface control)

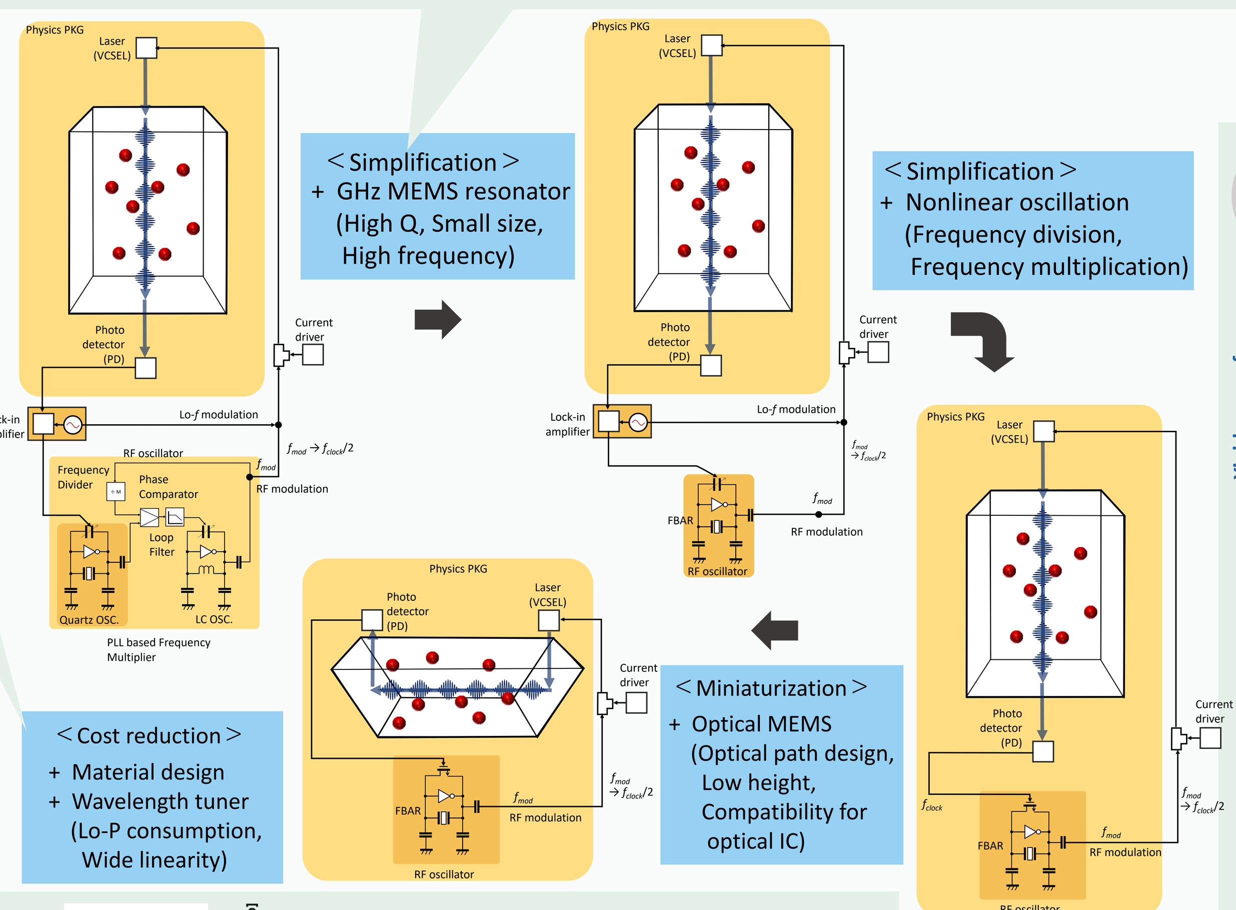
Direction control



Scattering control



Sensor Symposium 2022
(Courtesy of Tokyo University of Aquiculture and Technology (TUAT))



< Simplification >
+ GHz MEMS resonator (High Q, Small size, High frequency)

< Simplification >
+ Nonlinear oscillation (Frequency division, Frequency multiplication)

< Cost reduction >
+ Material design
+ Wavelength tuner (Lo-P consumption, Wide linearity)

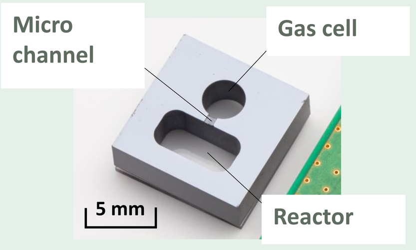
< Miniaturization >
+ Optical MEMS (Optical path design, Low height, Compatibility for optical IC)

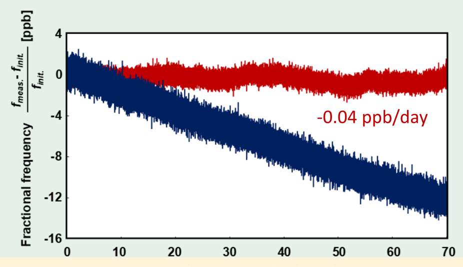
Cost reduction/Downsizing

Residual free Solid Rb source

M. Hara et.al. Transducers2021.

Originally synthesize the azide for mass production.





$2RbN_3 \rightarrow 2Rb + 3N_2$

$18Rb_2CrO_4 + 5Zr_2Al_3 \rightarrow 36Rb + 9Cr_2O_3 + 5Al_2O_3 + 15ZrO_2$

Cluster clock

Y. Yano et.al. EFTF-IFCS 2021.

Modeling

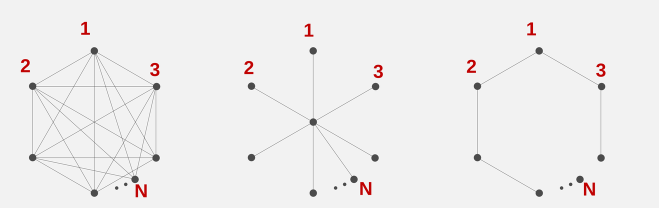
State of clocks ➡ State vector x=(time, frequency, drift, etc) ➡ State space $x = (x_1, x_2, \dots, x_N)^T$

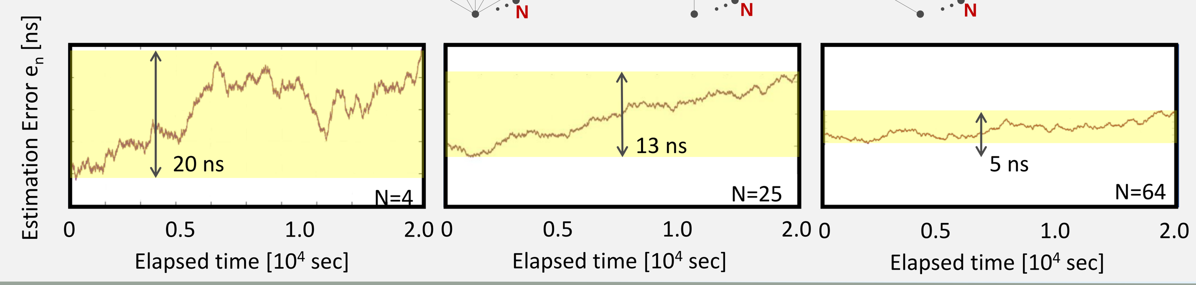
State equation $x_{k+1} = A\, x_k + v_k$

Observation equation $y_k = c\, x_k + w_k = x_{k,n} - x_{k,m} + w_k = \Delta t_{nm} + w_k$

Kalman filtering $\hat{t}_n$: Max. likelihood t **Evaluation** $e_n = \hat{t}_n - t_n$: Estimation error

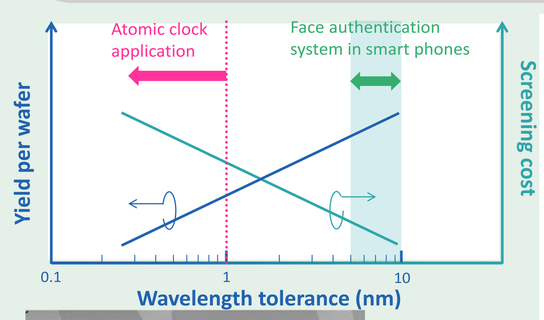
ex) Full-mesh network

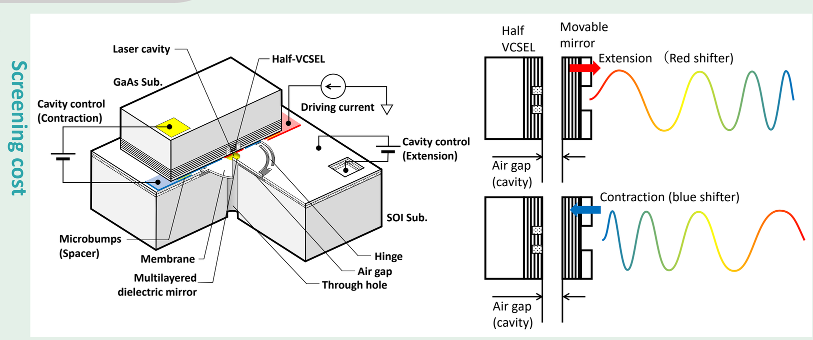


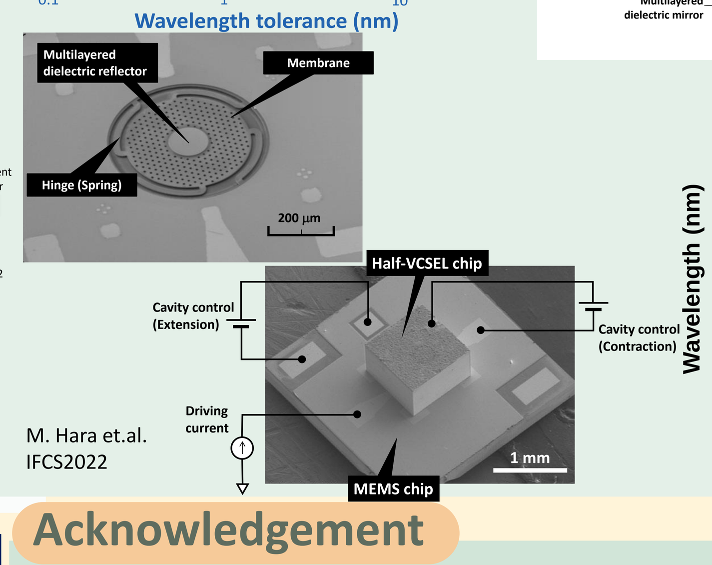


Cost reduction/Downsizing

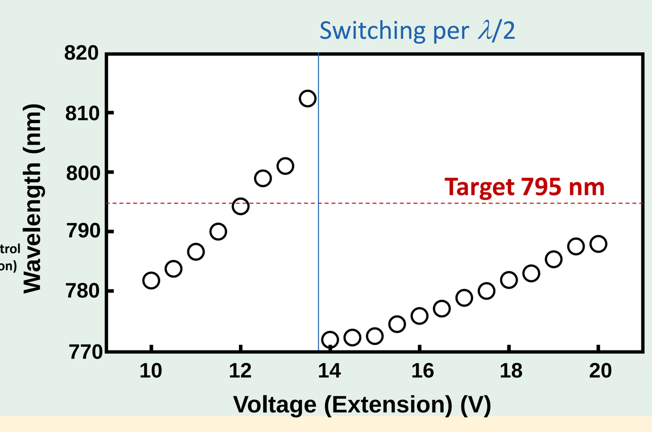
Offset control using electrostatic actuator







M. Hara et.al. IFCS2022



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