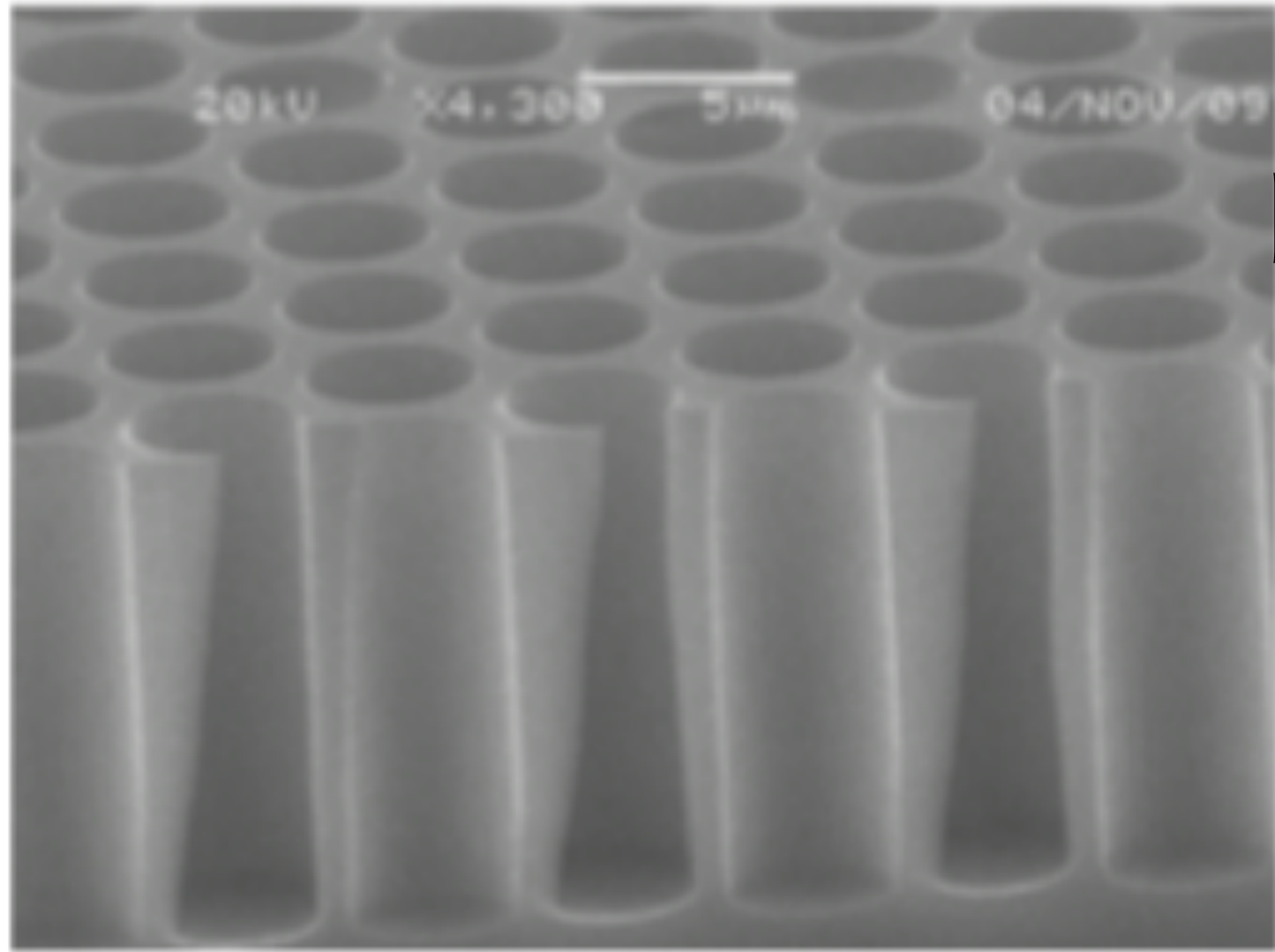


## Background

Using sub-wavelength structure (SWS) enables us to control of the refractive index.

SWS(Si) for IR with radiation wavelength around  $30\mu\text{m}$ .



Fabrication is easy



Only etching

wada et al.(2010)<sup>[1]</sup>

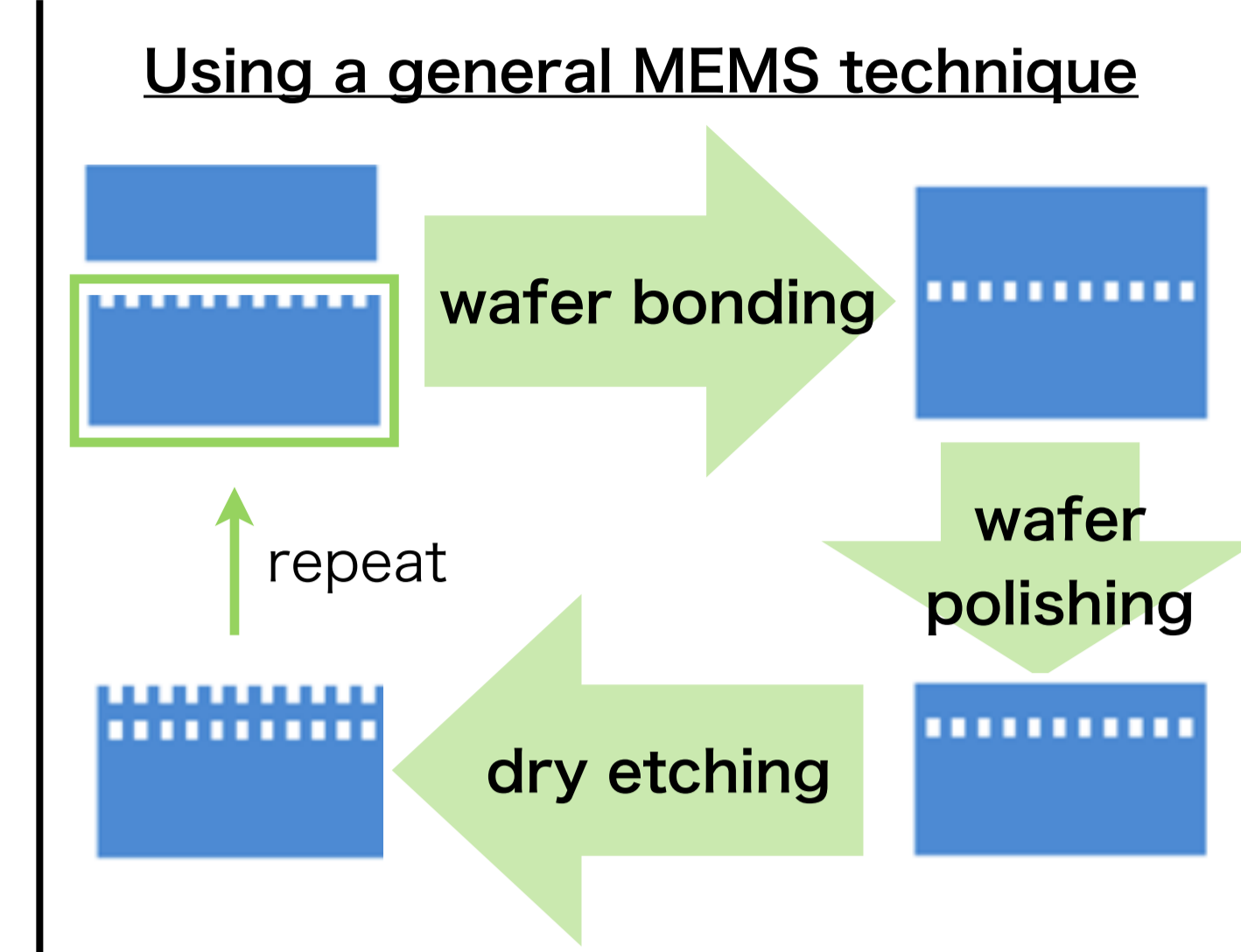
Effective index of SWS is determined by the porosity.

## Application②

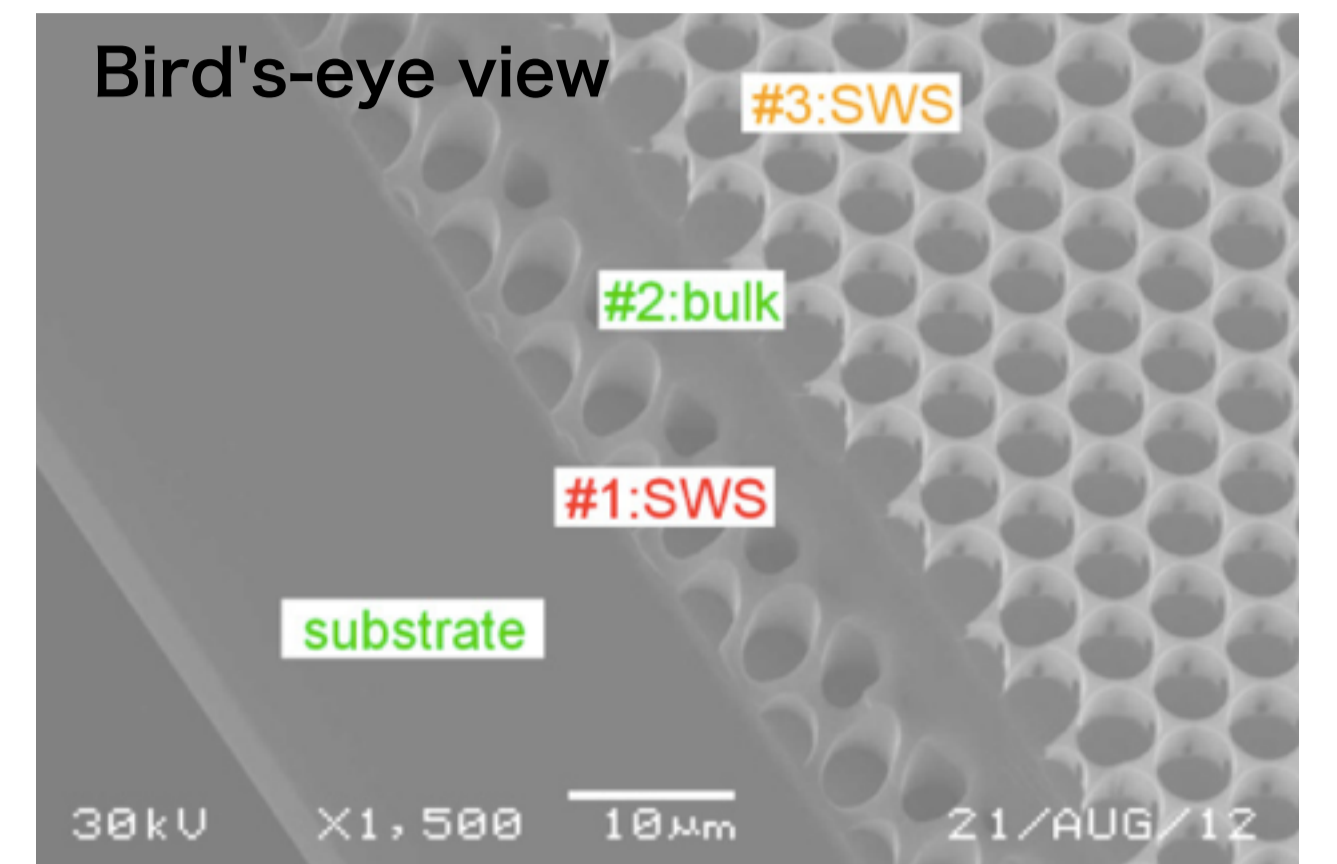
Applying to the Mono-material optical interference filter

Makitsubo, Yamamoto et al.(2017)<sup>[2]</sup>

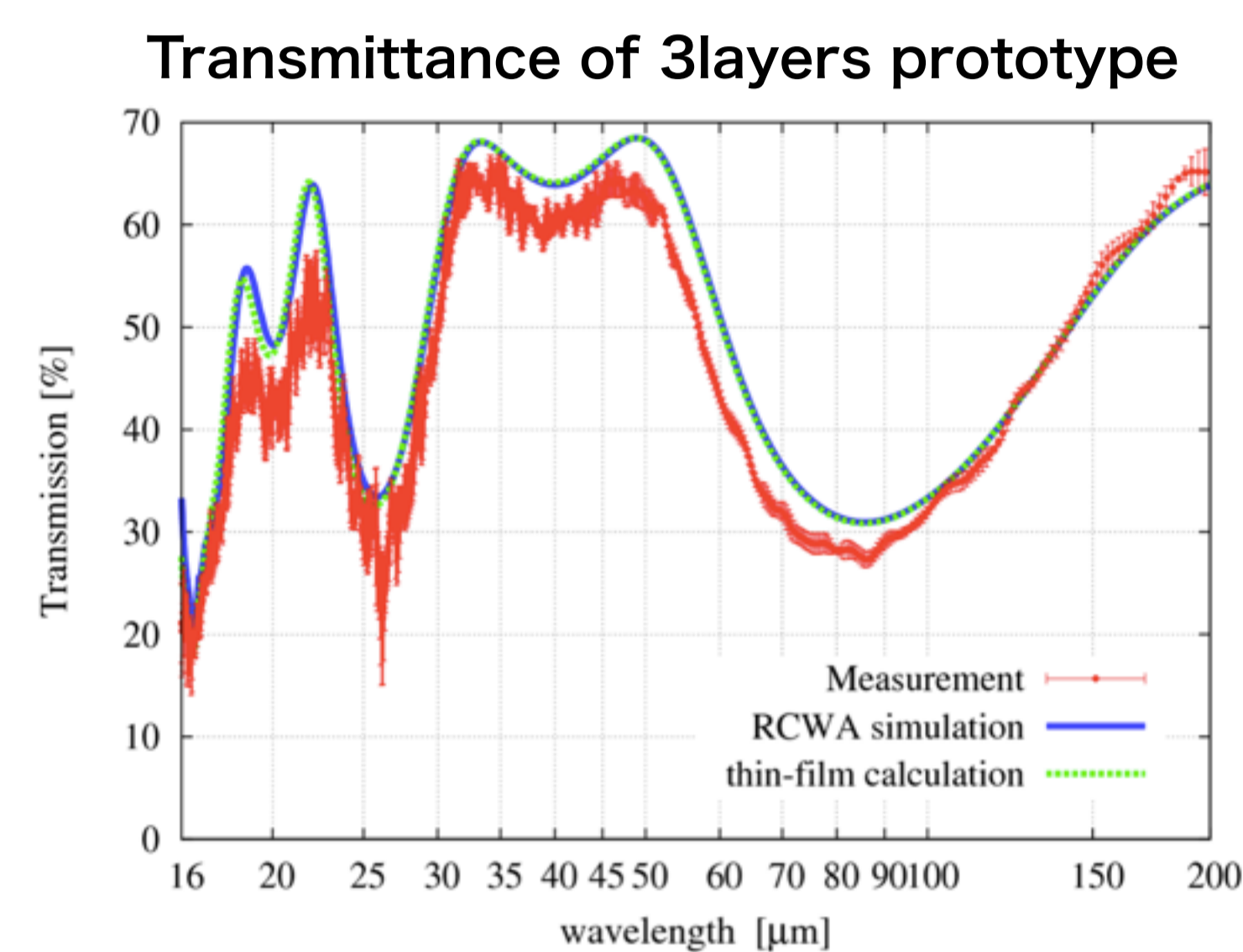
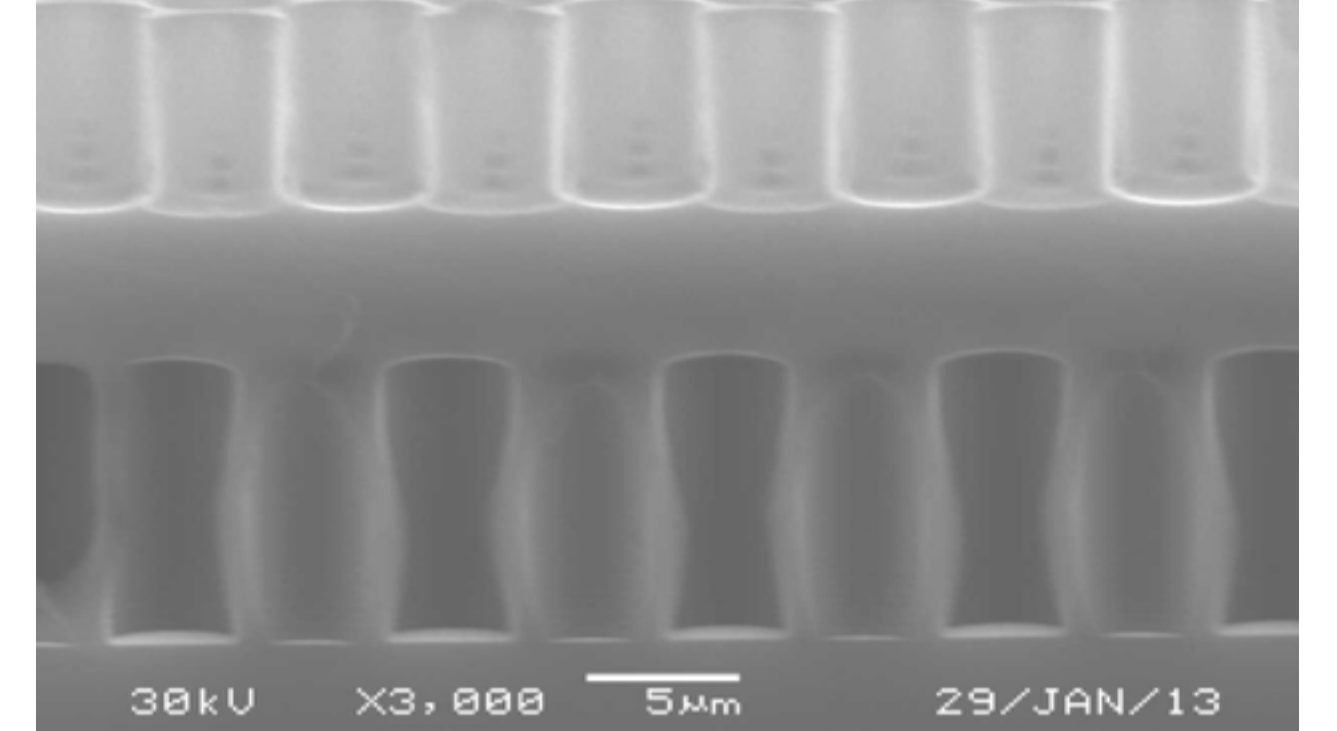
Conception diagram of the manufacture method



SEM image of 3layers prototype(Si)



Cross section

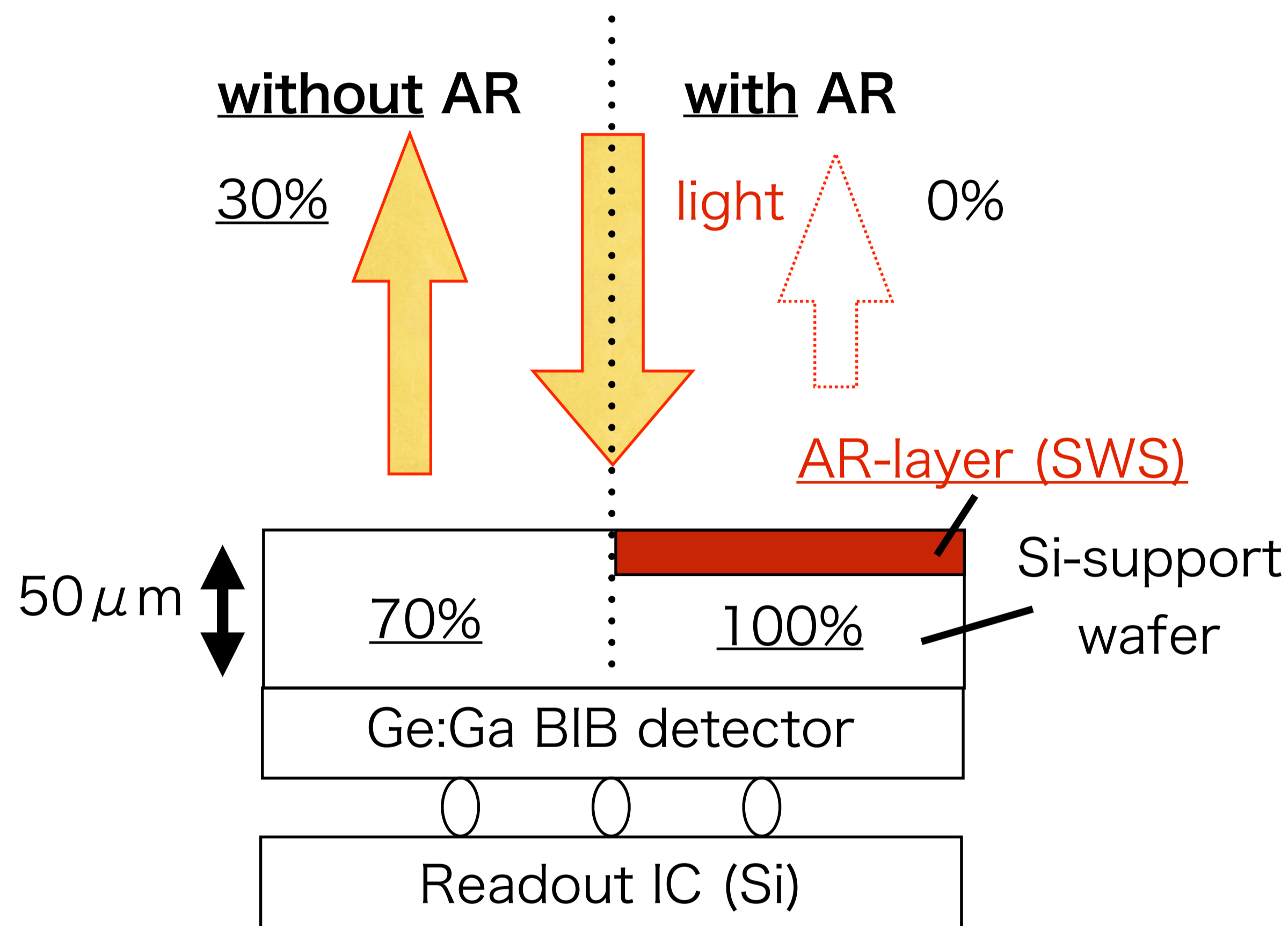


SWS enables us to avoid the limitation of selecting optical materials and CTE mismatch.

## Application①

Applying to the anti-reflection coating(AR-coating) at the surface of Ge:Ga BIB detector

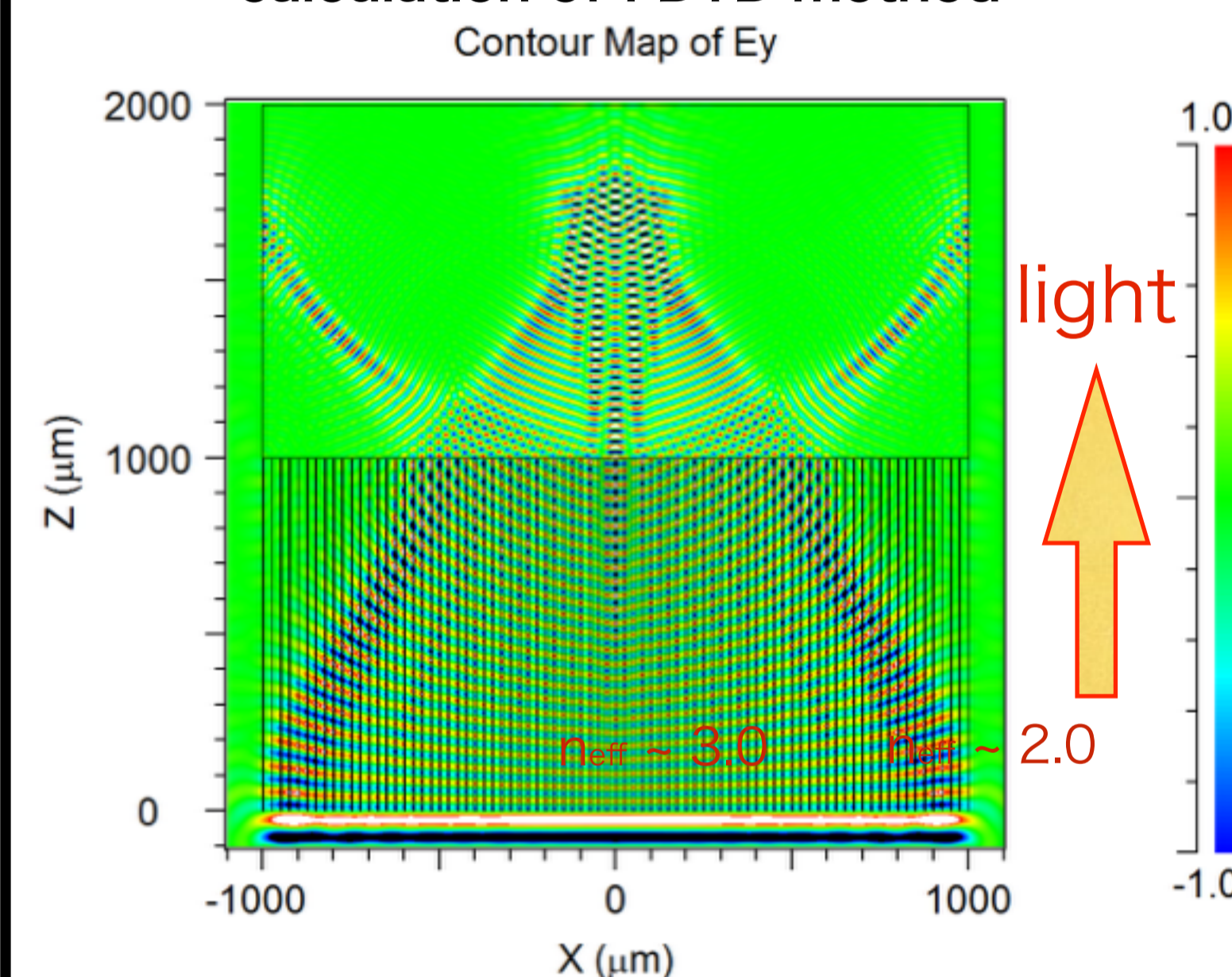
cf, Ishimaru, SOPIX 2017 poster, P-02



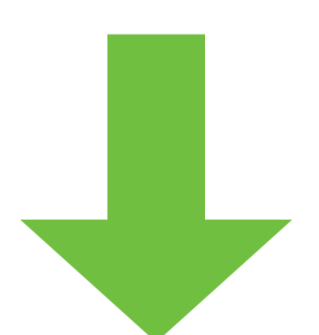
## Application③

We have been trying to apply to the microlens arrays.

calculation of FDTD method



The light rays bend toward the region which has higher refractive index.



GRadienT INdex (GRIN) lens

To fabricate the microns arrays with SWS at the surface of Ge:Ga BIB detector enable us to reduce the size of pixel and the thermal noises (while keeping the quantum efficiency).

## Design①

Designing AR-layer's structure base on the calculation using RCWA method

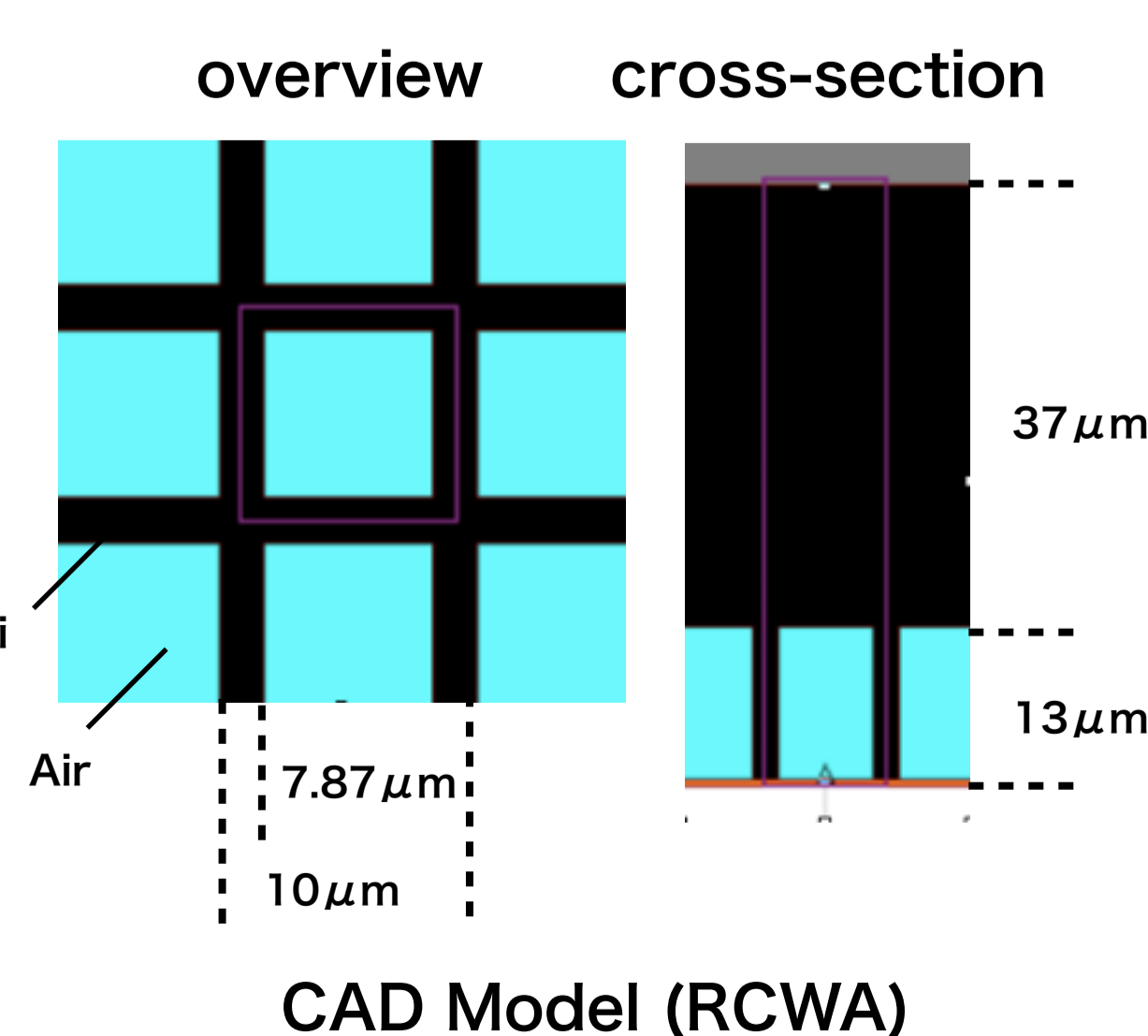
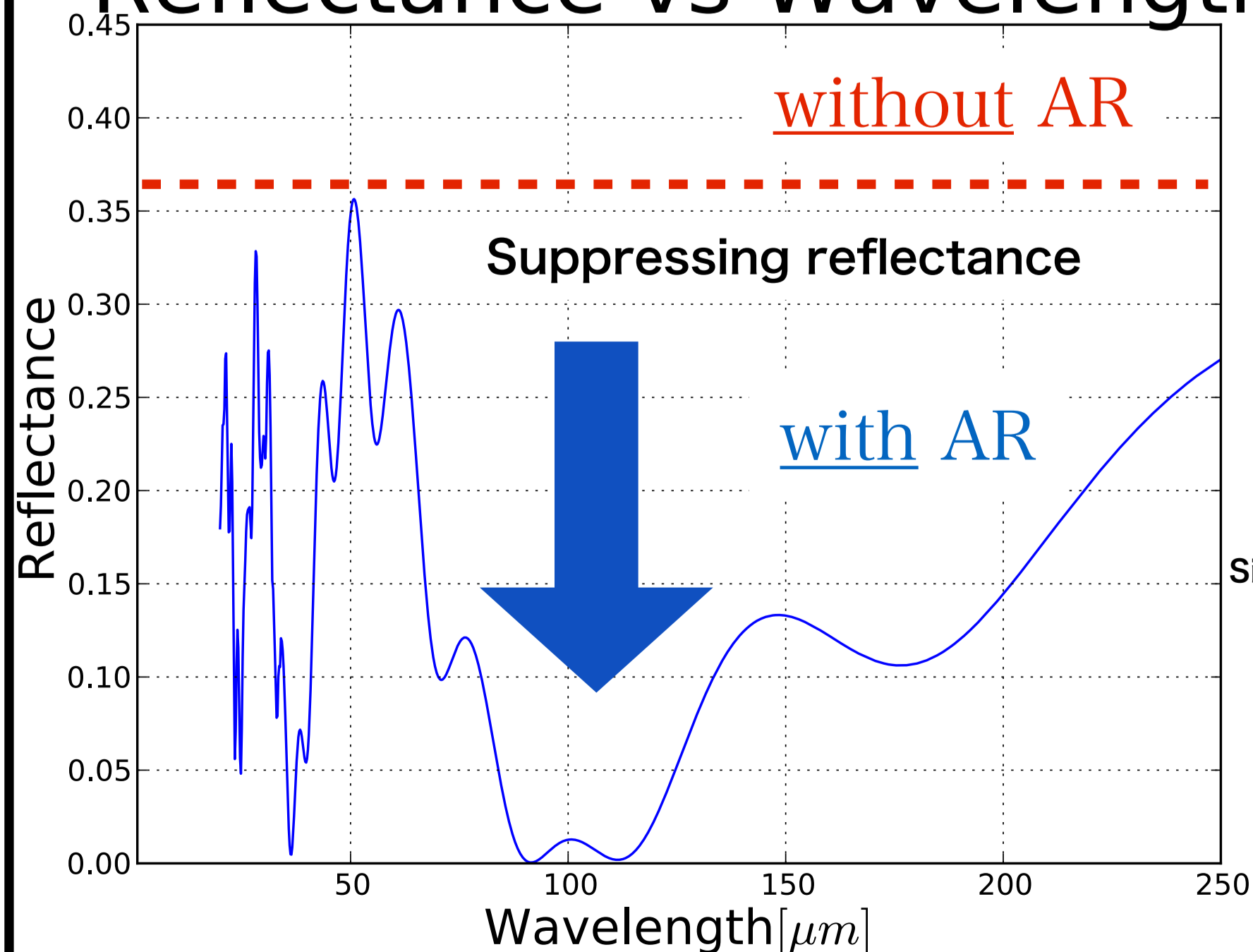
effective index  $\sim 1.85$

The SWS design(AR layer)  $\Rightarrow$  porosity  $\sim 60\%$

thickness  $= \lambda / 4n_{\text{eff}}$

( $\lambda$  is target wavelength,  $n_{\text{eff}}$  is effective index)

Reflectance vs Wavelength



## Summary

- The RCWA calculation shows that the reflectance is reduced to close zero by AR-layer(SWS) nearby the target wavelength.
- Applying SWS to optical interference filter, we had fabricated the 3layer prototype only Silicon.
- The controlling of refractive index with SWS enable us to develop the useful optical devices.

[1] T. Wada, H. Makitsubo, and H. Mita, Appl. Phys. Express 3, 102503 (2010).

[2] Makitsubo, Yamamoto et al, Journal of Infrared, Millimeter, and Terahertz Wave 38, Issue 2, pp 206-214 (2017)

[3] Ide, K., Goto, T., Utsumi, J. & Suzuki, T. 2011, Mitsubishi Heavy Industries Technical Review, 48, 48