Plasmonic color filter for multispectral imaging from visible to near-infrared

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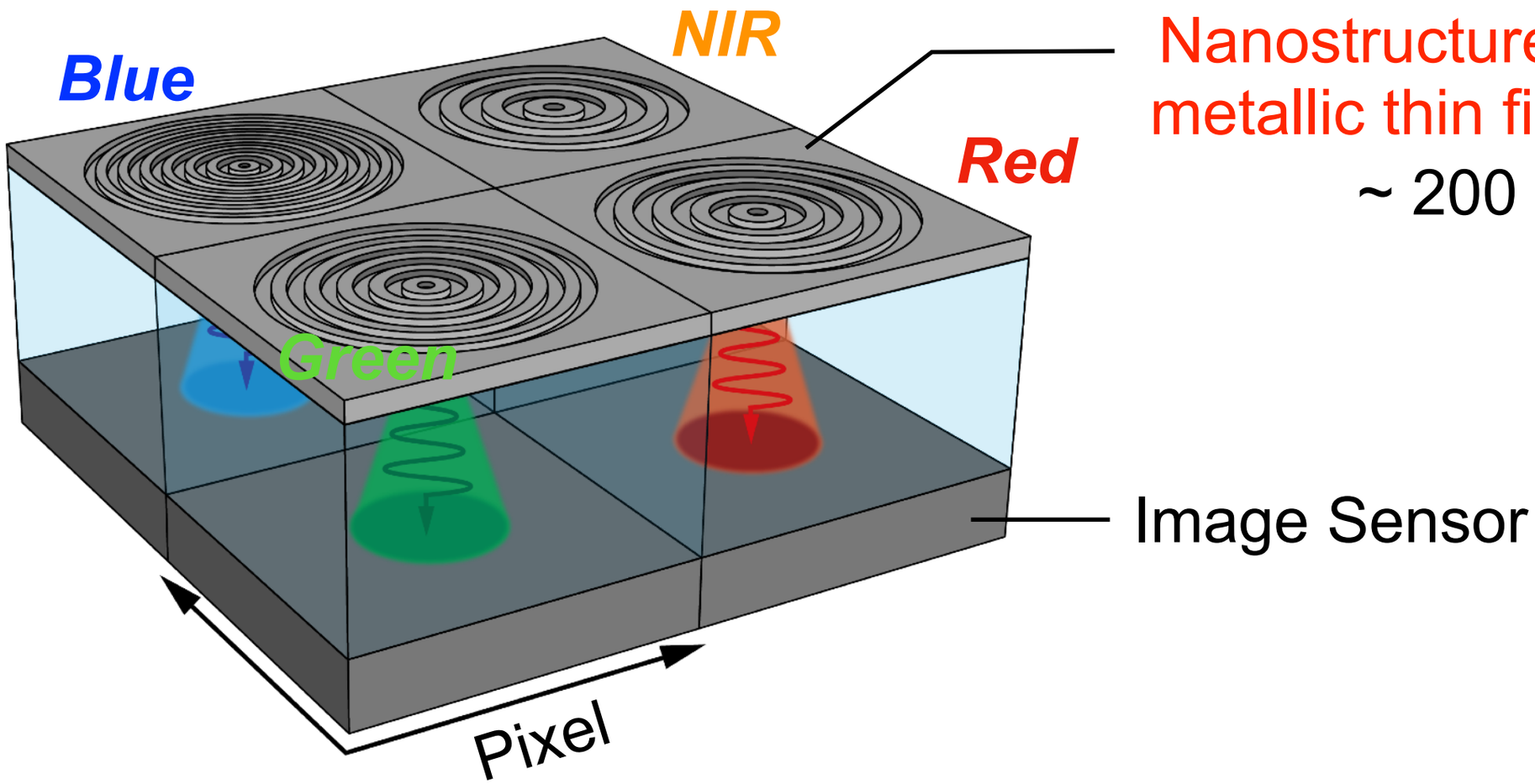
National University Corporation Shizuoka University

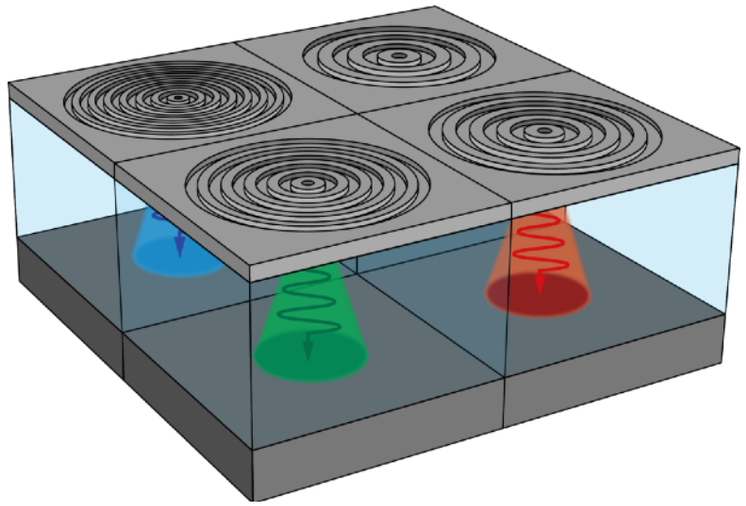
Purpose ***Development of multispectral imaging sensor from visible to near-infrared range.***

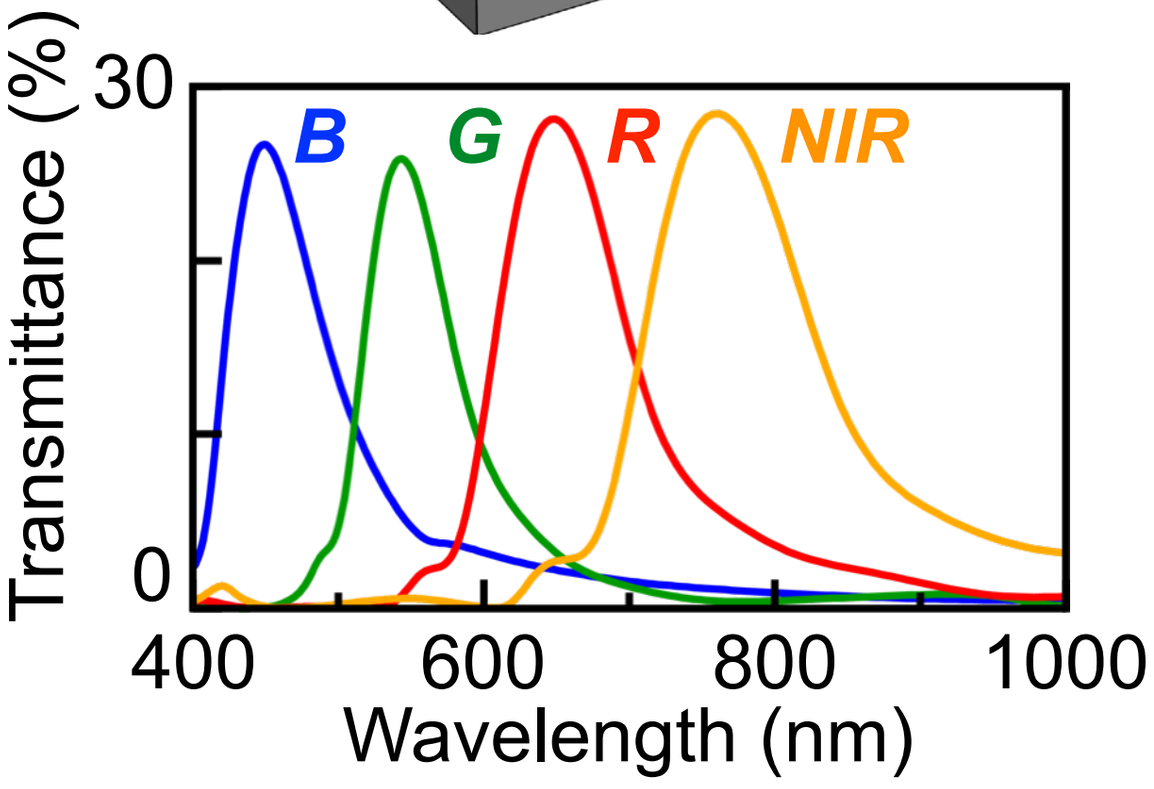
Image sensor integrated with
RGB-NIR plasmonic filters



Plasmonic filters realize the multispectral imaging of visible and NIR light by integrating onto a single image sensor.

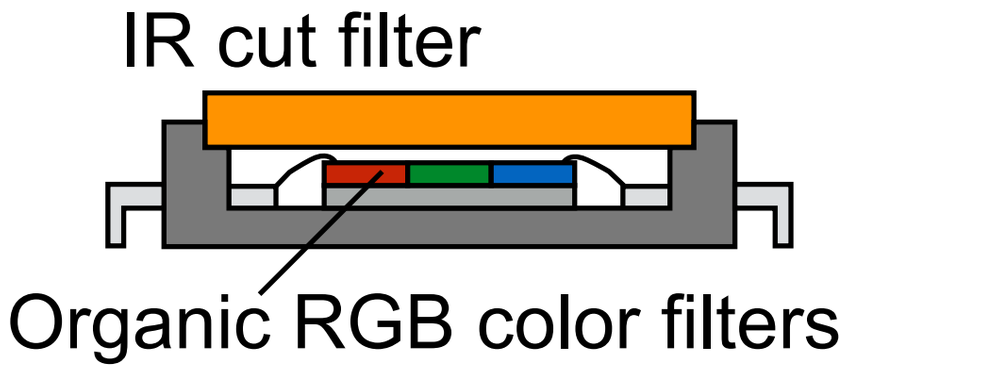
Our proposed plasmonic filter

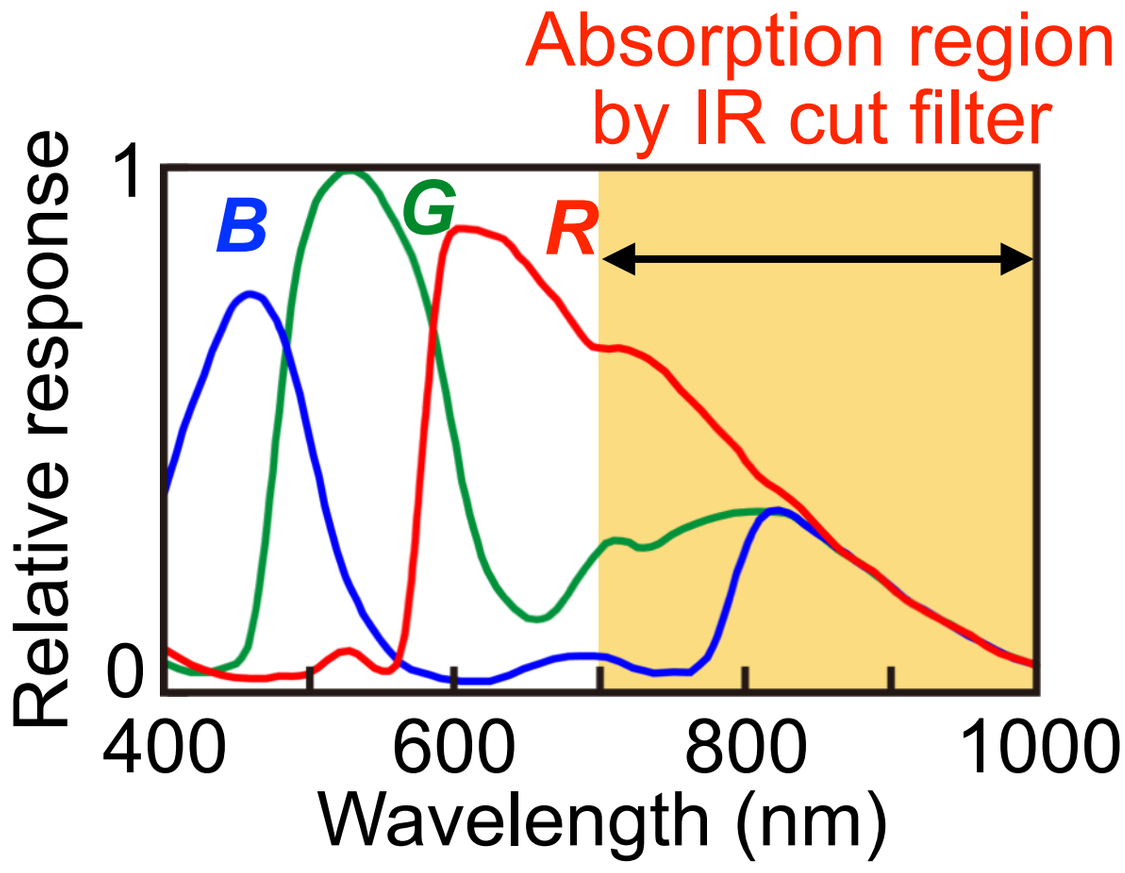




Visible and NIR lights are filtered by our proposed plasmonic filters.

Conventional color filter





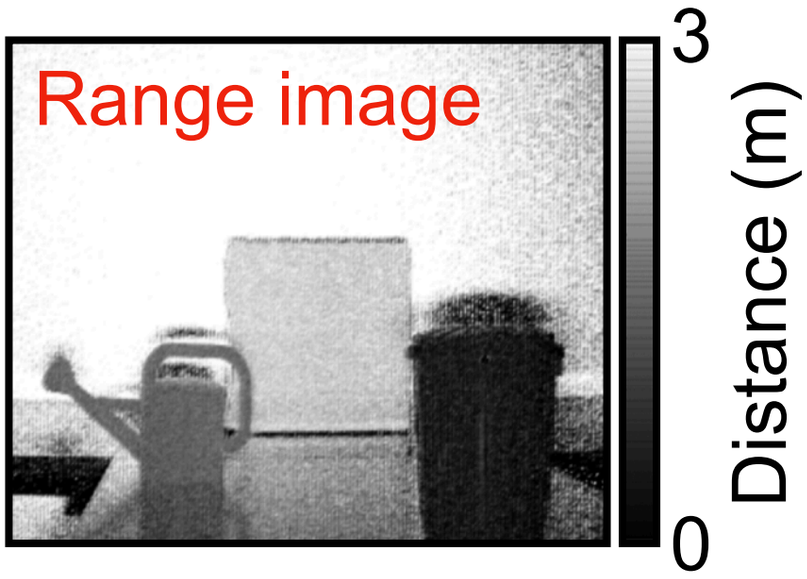
Filtering of visible and NIR lights is difficult due to external IR cut filter.

Imaging application : NIR information + RGB information

Range measurement imaging using NIR LED as light source.

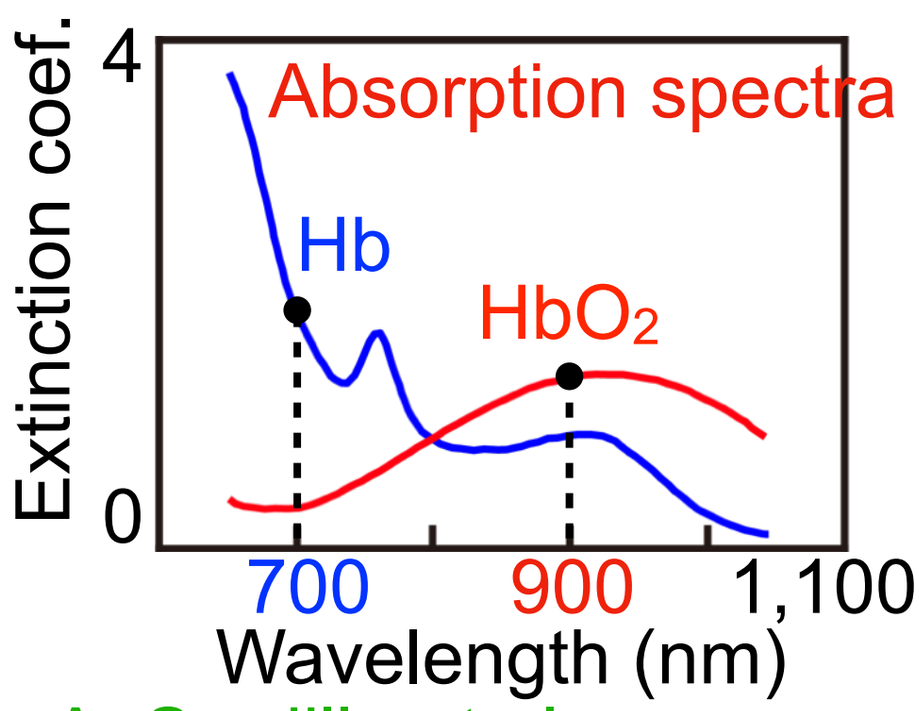
Biological imaging for hemoglobin (HbO_2) concentration.

Range image + Color image



cf. S. Kawahito et al.,
IEEE Sens. J. **7**, 1578 (2007).

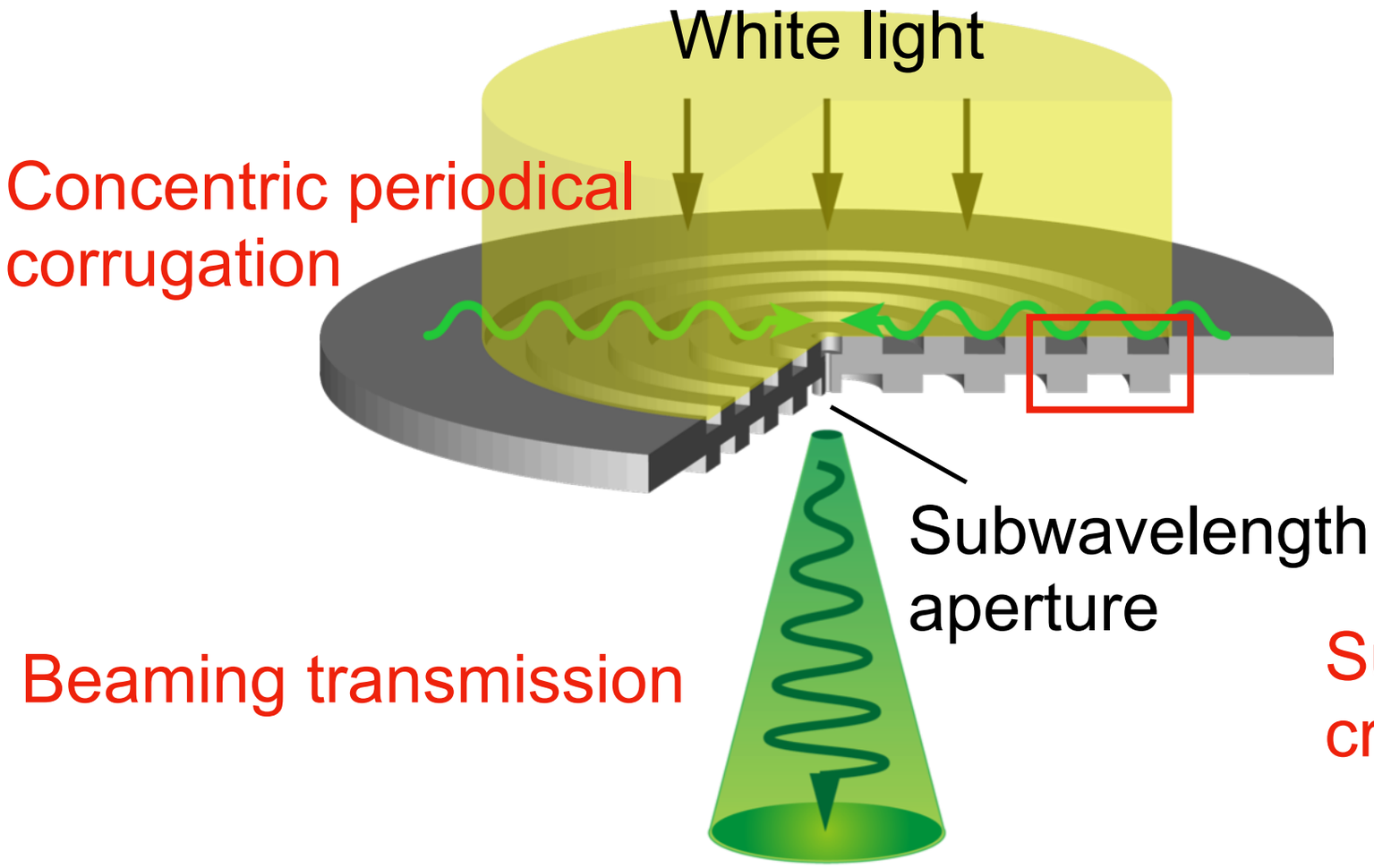
Color image + Tissue image



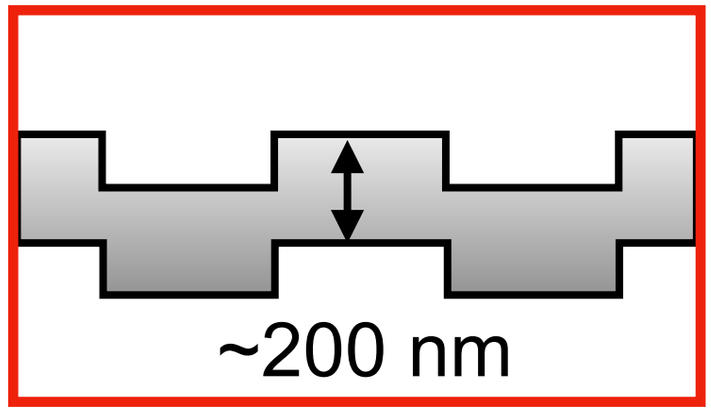
cf. L. A. Sordillo et al.,
J. Biomed. Opt. **19**, 056004 (2014)

Simultaneous imaging provides reduction of conventional system size and improvement of image recognition.

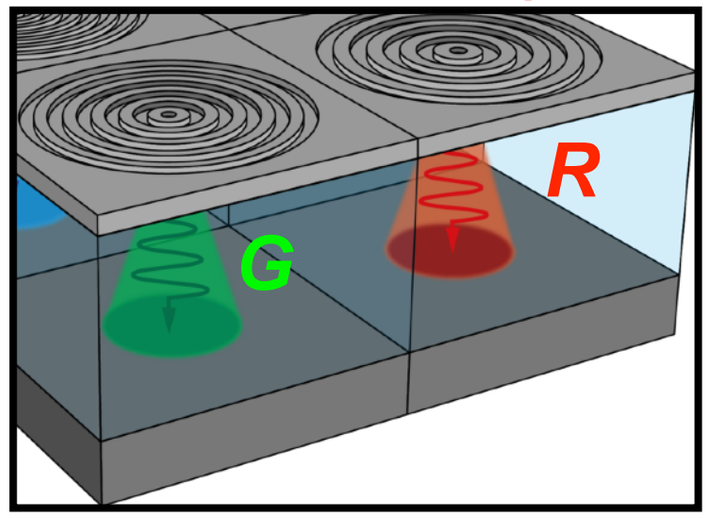
Our proposed plasmonic color filter



Single layer metal film

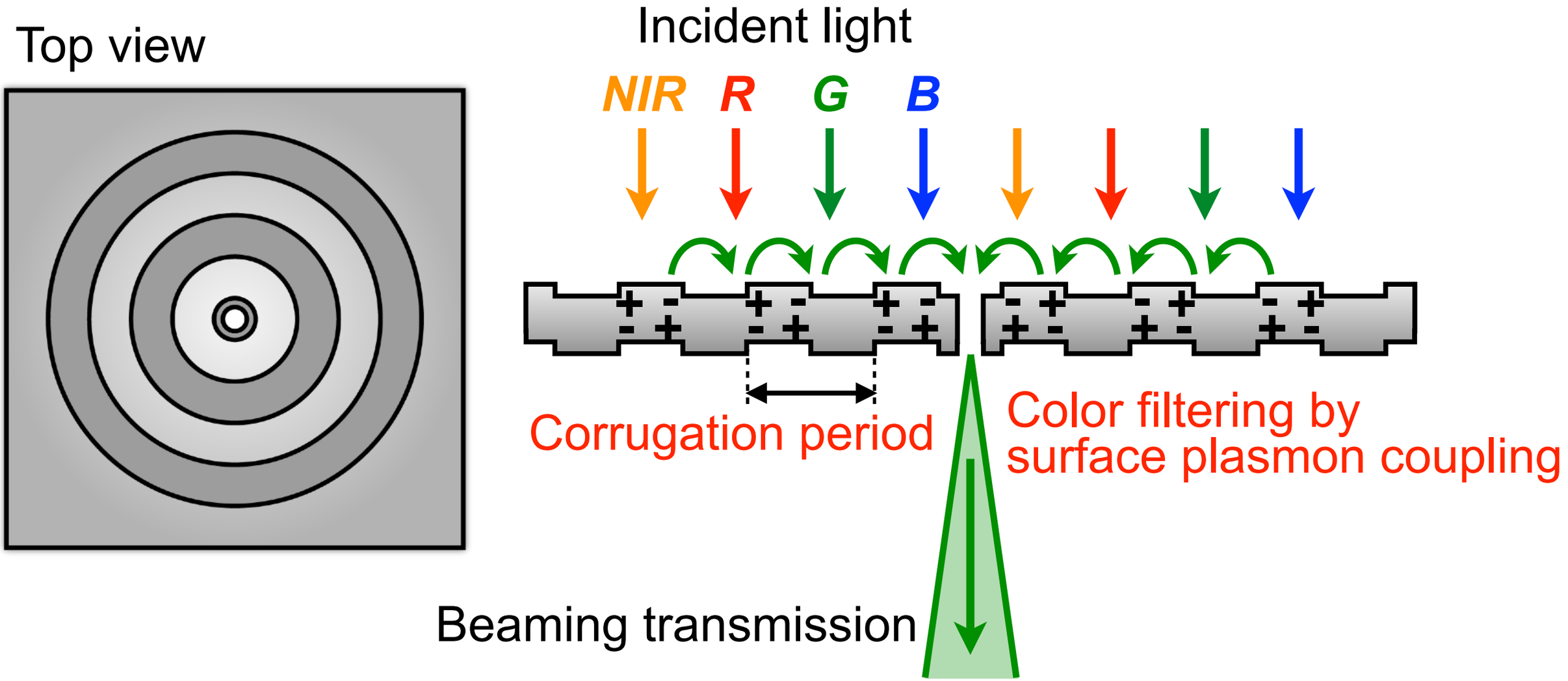


Suppressing spatial color cross-talk between pixels



We demonstrate plasmonic color filtering from visible to near-infrared range.

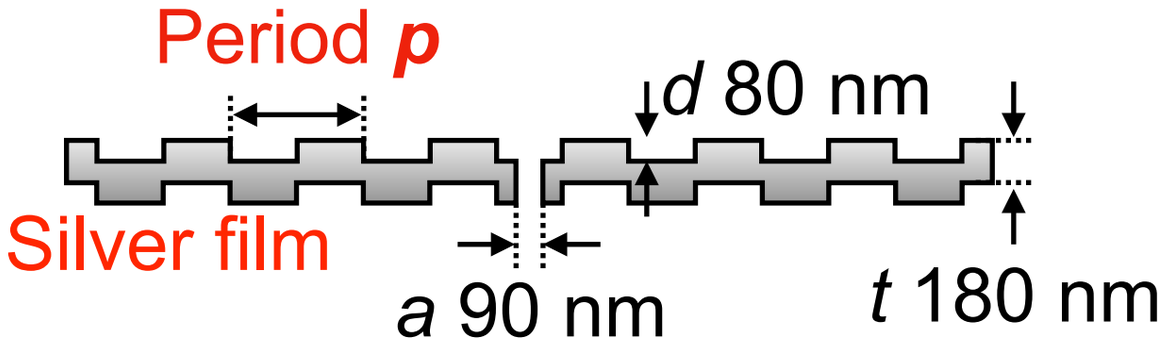
Color filtering principle by surface plasmon resonance

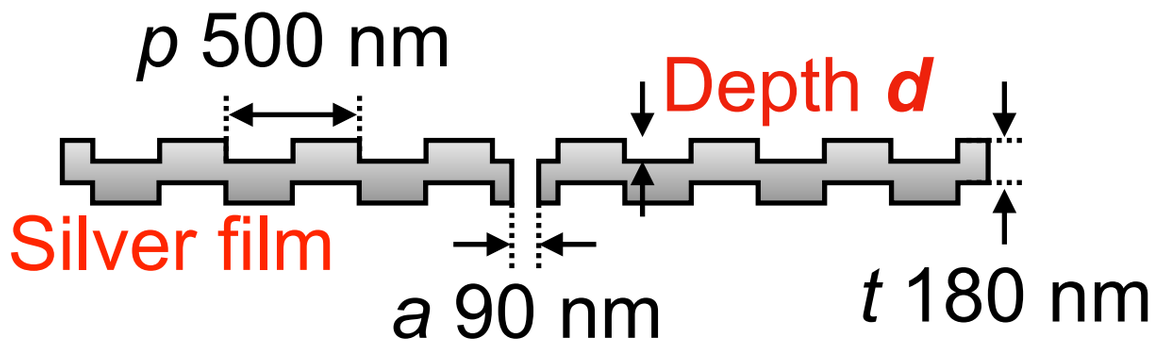


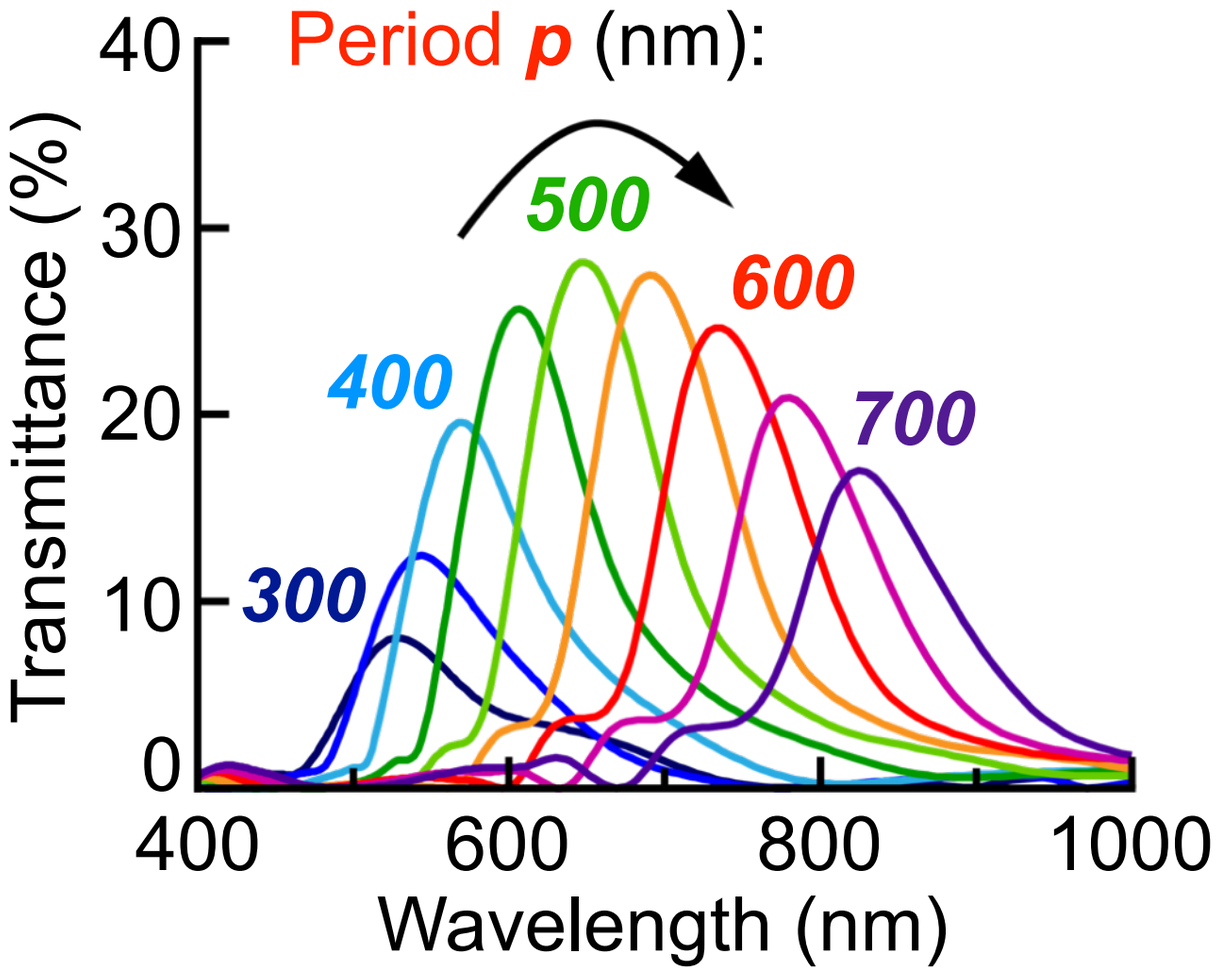
Transmission color selectivity is tuned by changing the corrugation period.

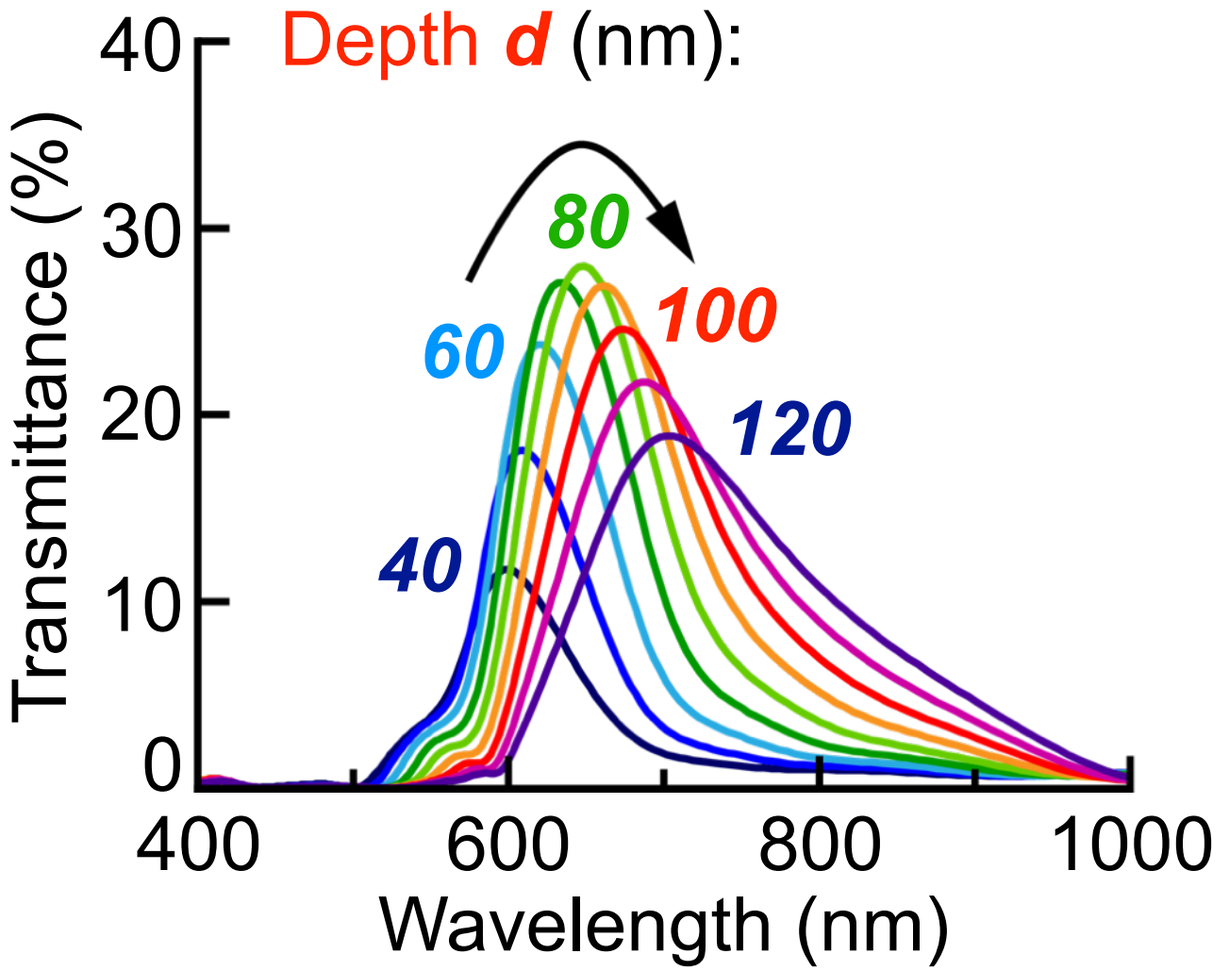
cf. T. W. Ebbesen et. al, *SCIENCE* ***297*** (2002)

Analysis of transmission characteristics by using FDTD algorithm





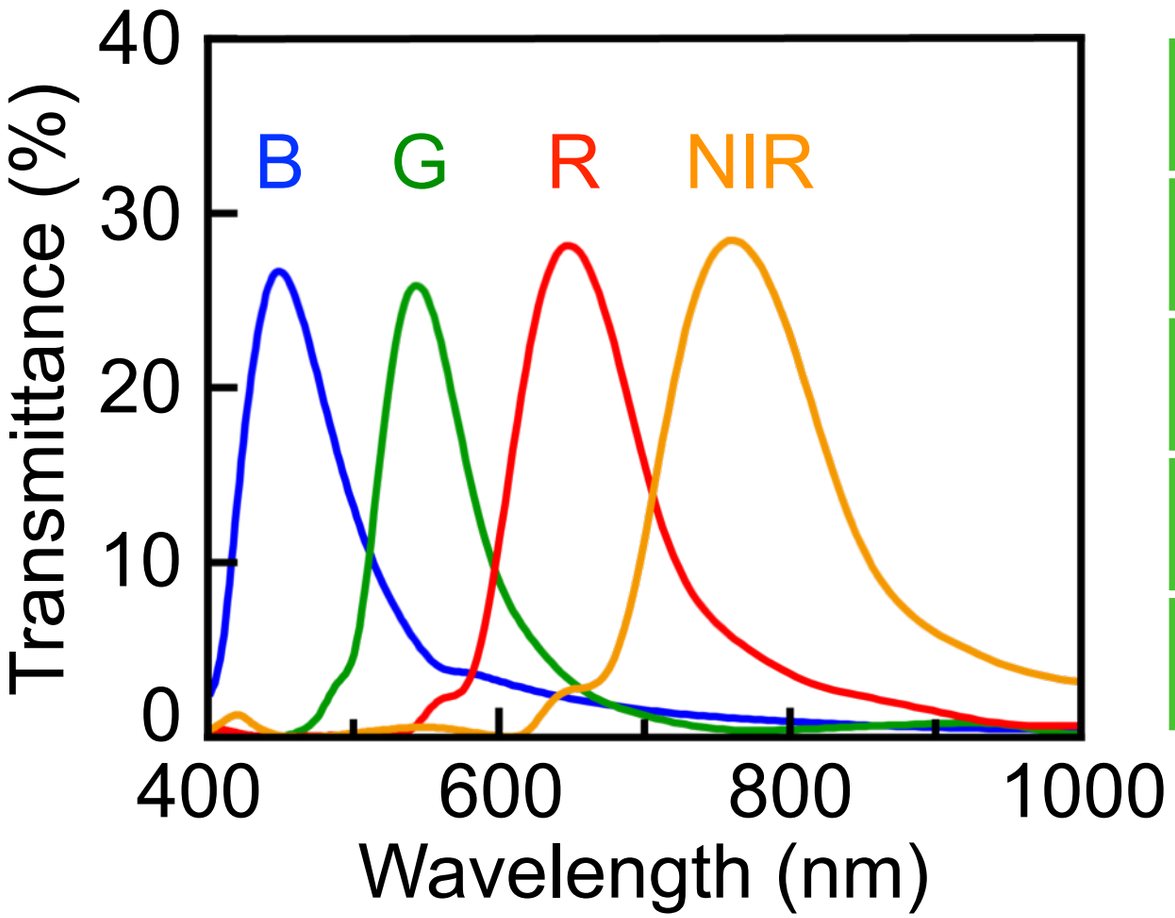


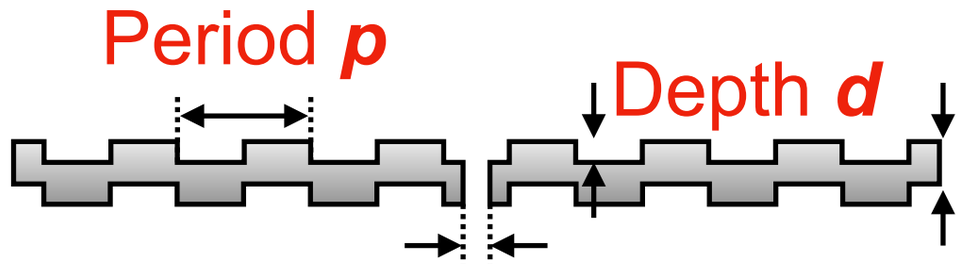


Summary of the simulation results

Filtering property:

- Transmittance of ~28 %
- FWHM of ~100 nm





	p	d	t	a
Blue	200	30	60	60
Green	400	60	140	80
Red	500	80	180	90
NIR	600	100	220	110

(nm)

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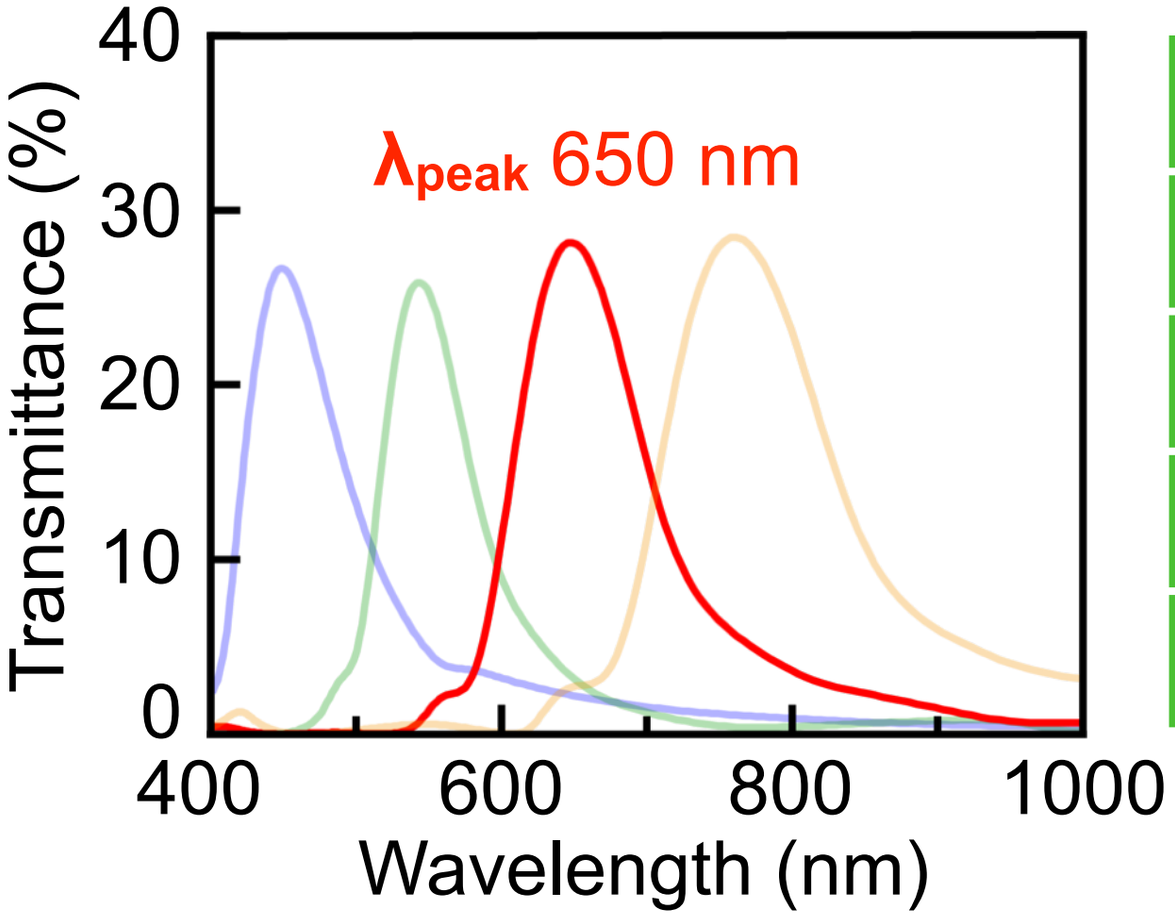

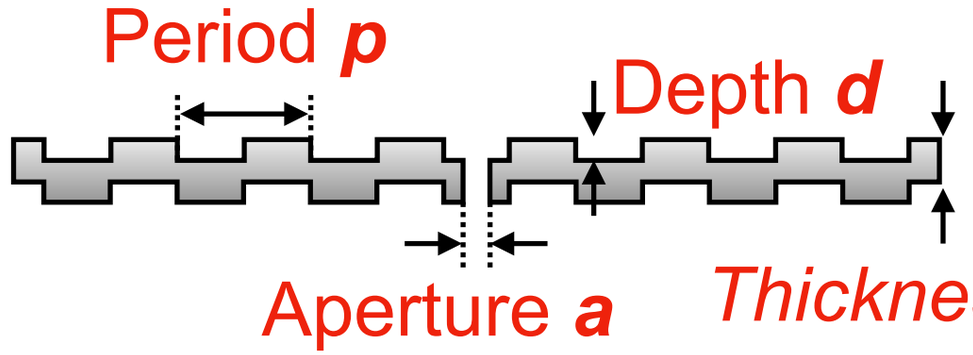

	p	d	t	a
Blue	200	30	60	60
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Red	500	80	180	90
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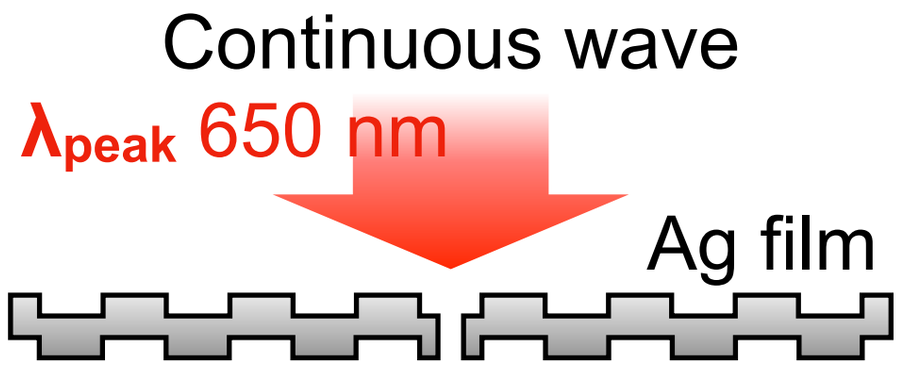
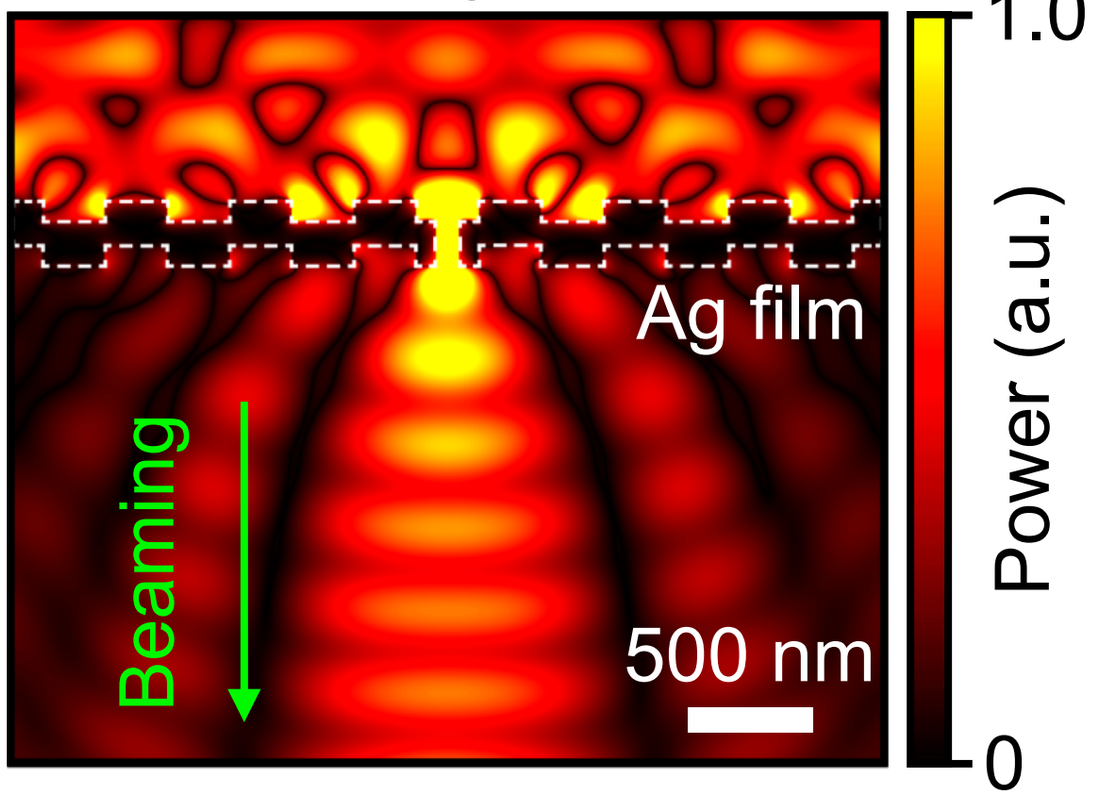
(nm)

Transmitted light distribution at peak wavelength λ_{peak} was calculated.

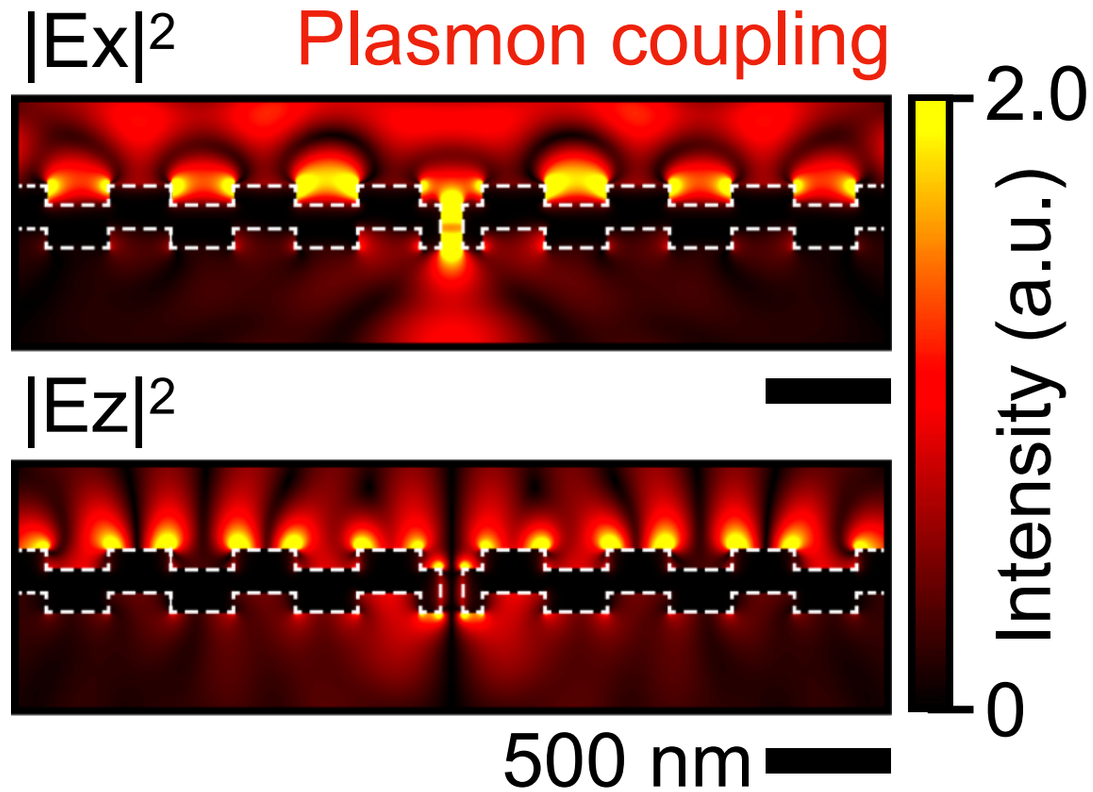
Transmission distribution for peak wavelength



Transmission light distribution

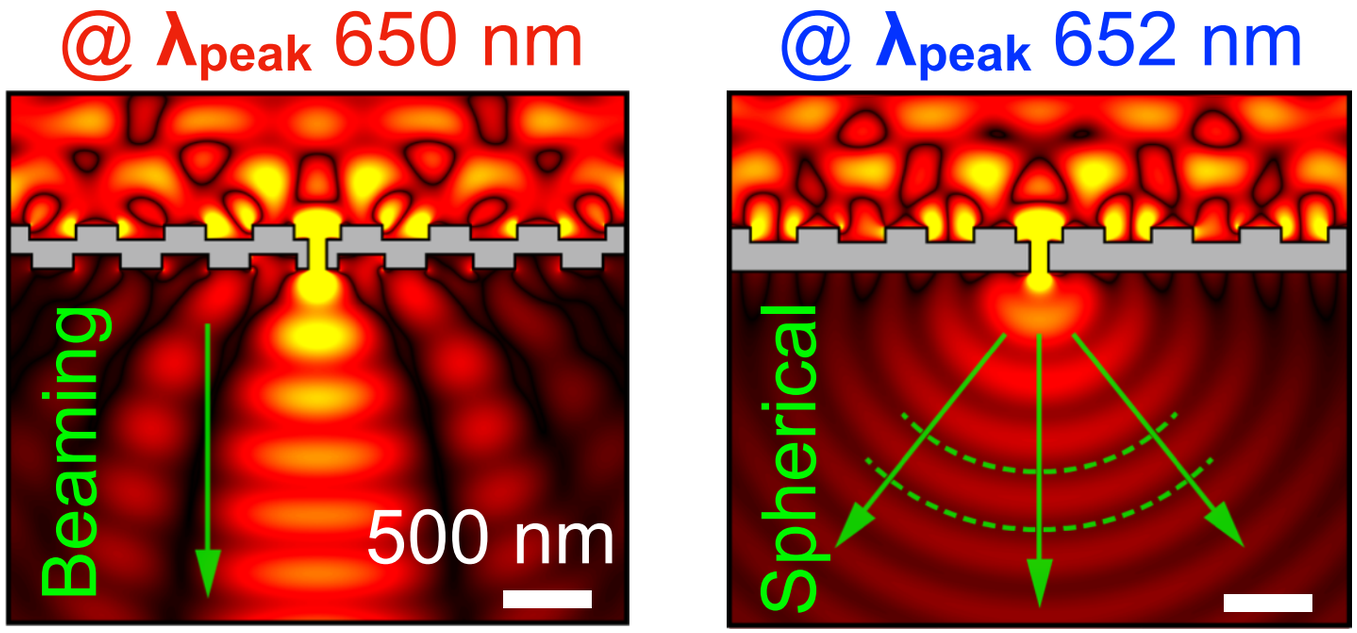


Beaming transmission
at peak wavelength of 650 nm.

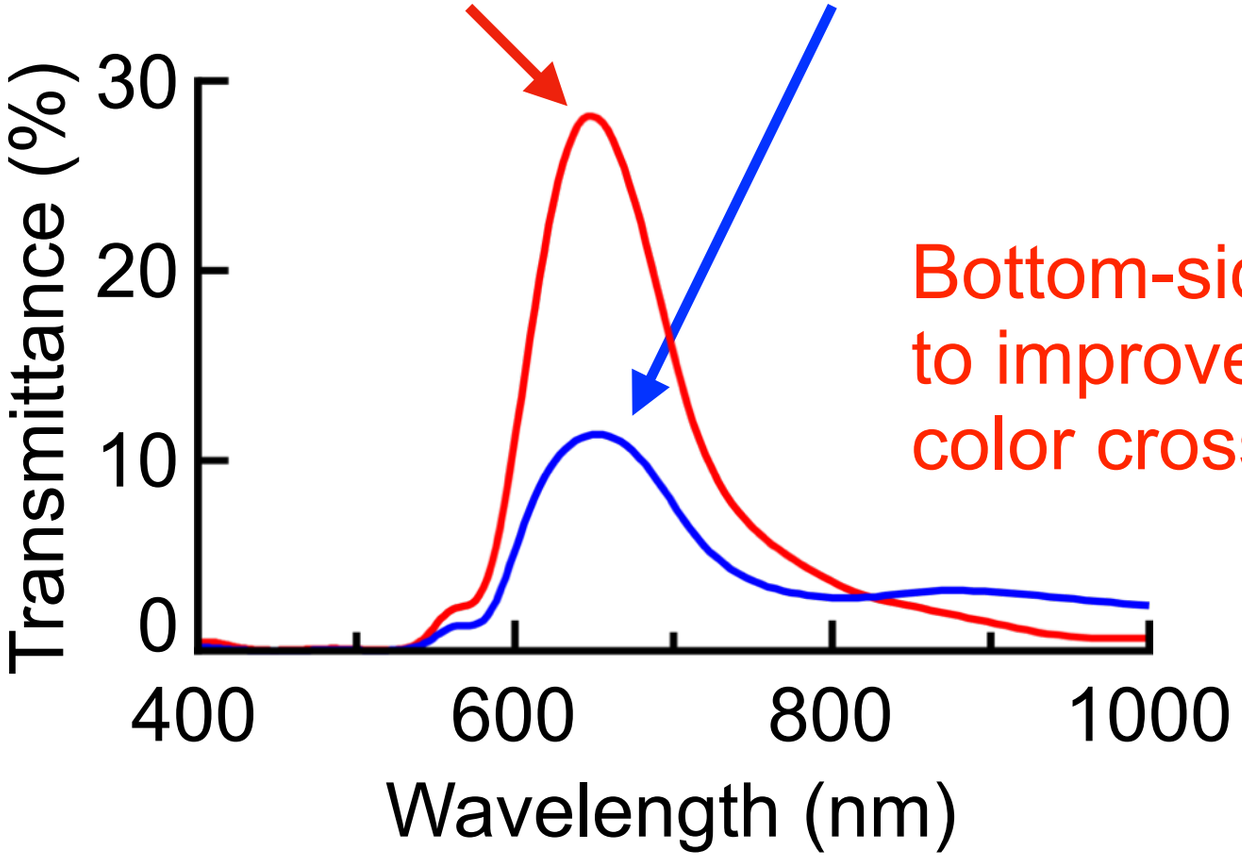


Coupling between incident light
and surface plasmon.

Corrugation vs. Flat bottom surface

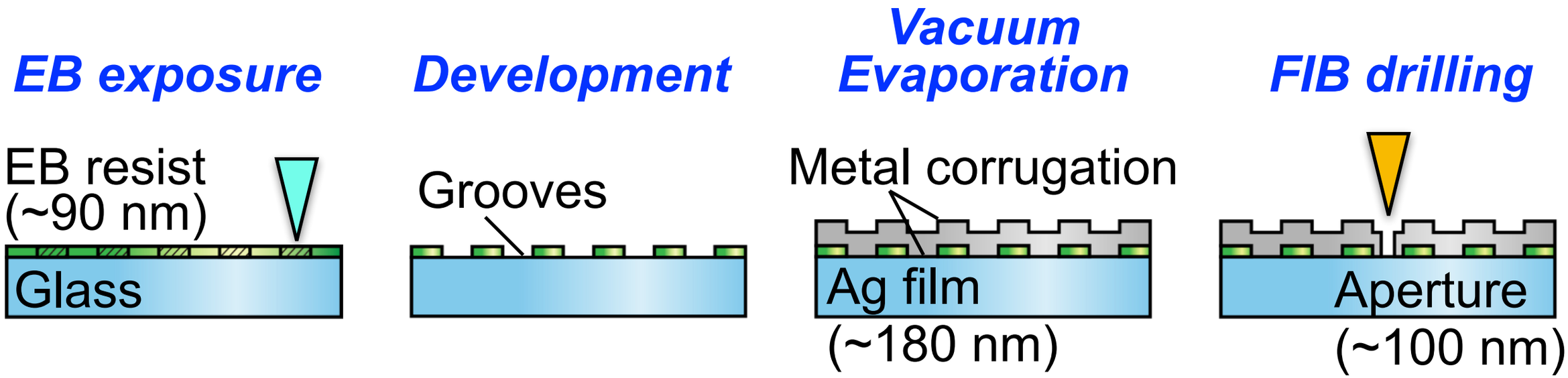


Periodical grooves in bottom-side transmits λ_{peak} as a beaming light.

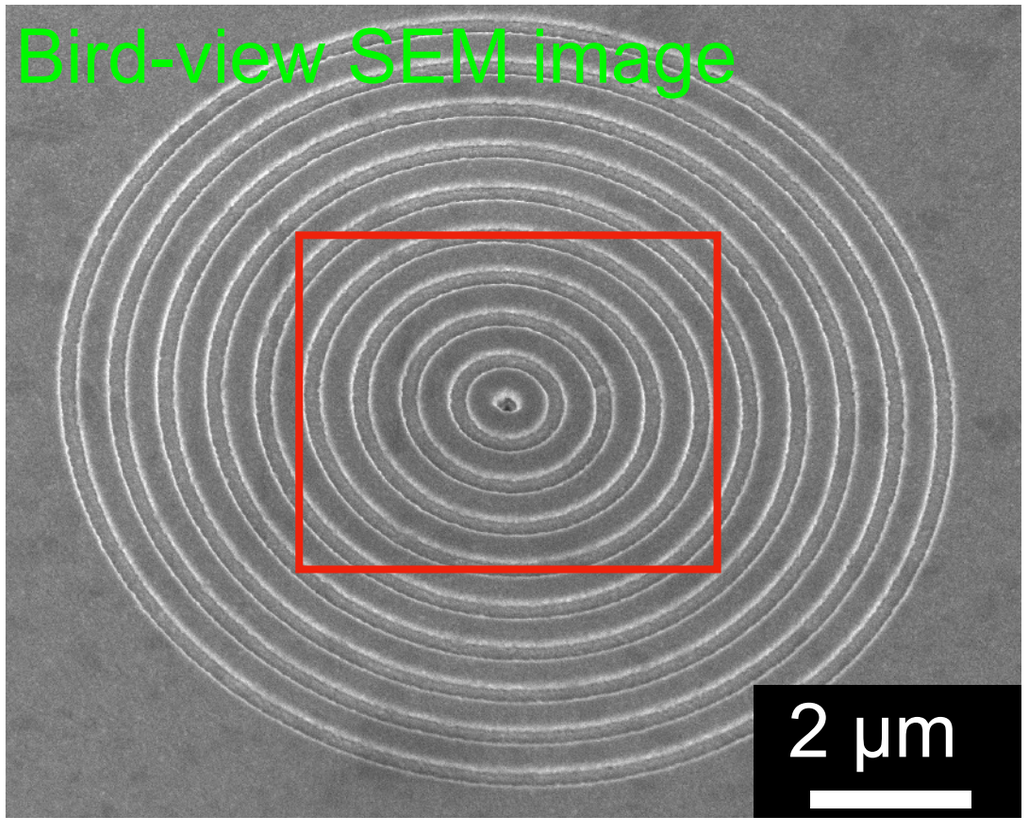


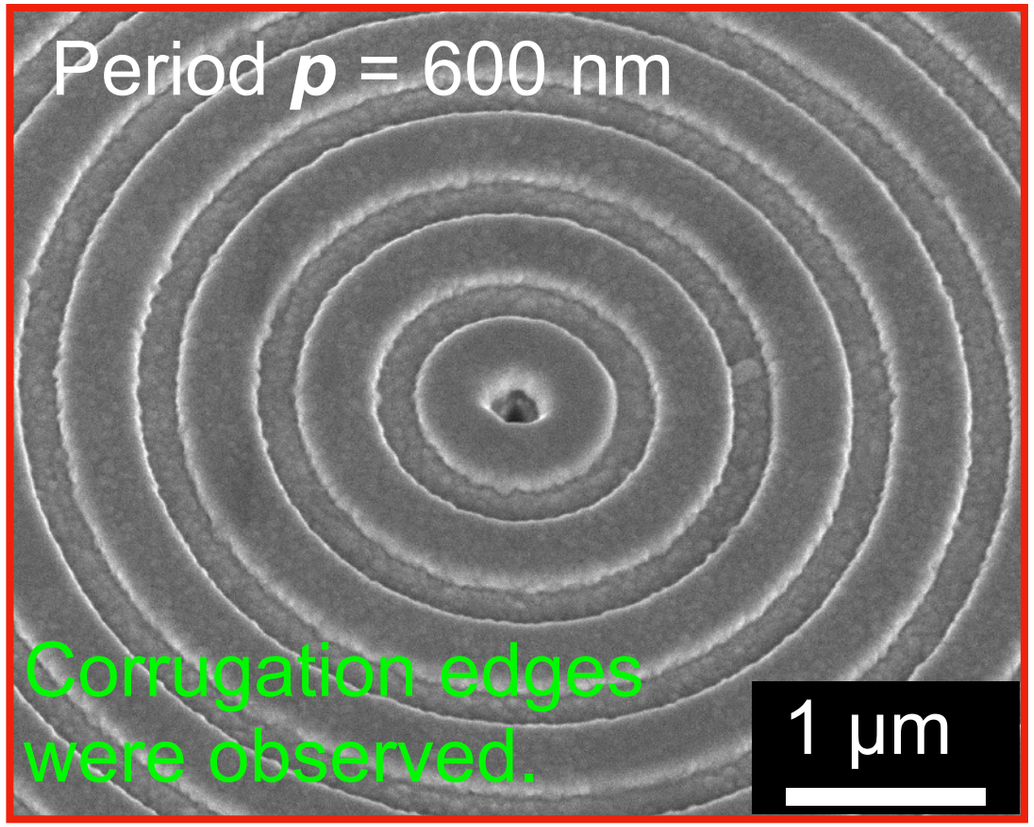
Bottom-side grooves are appropriated to improvement of transmittance and color cross-talk.

Fabrication process



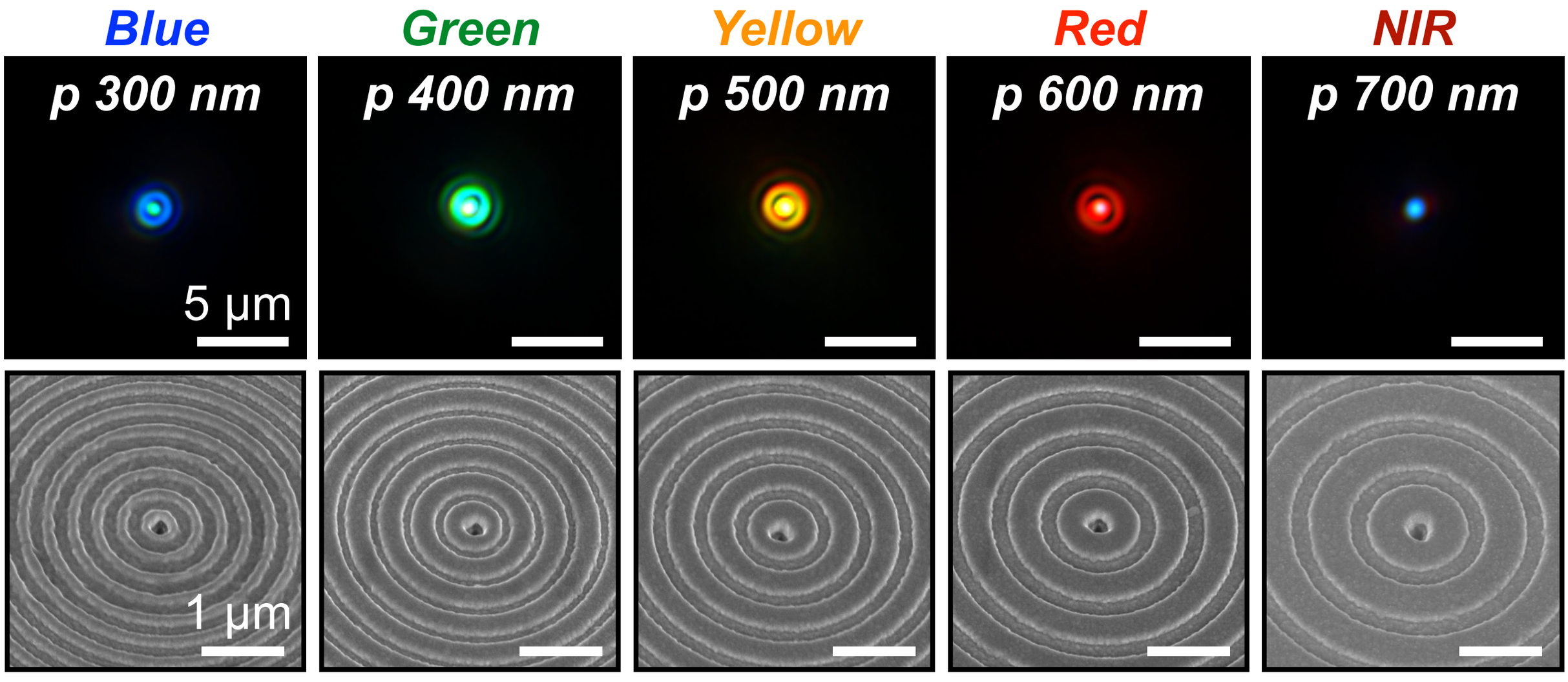
Nanostructured corrugations are easily fabricated on both sides of a single metal film along the resist pattern.





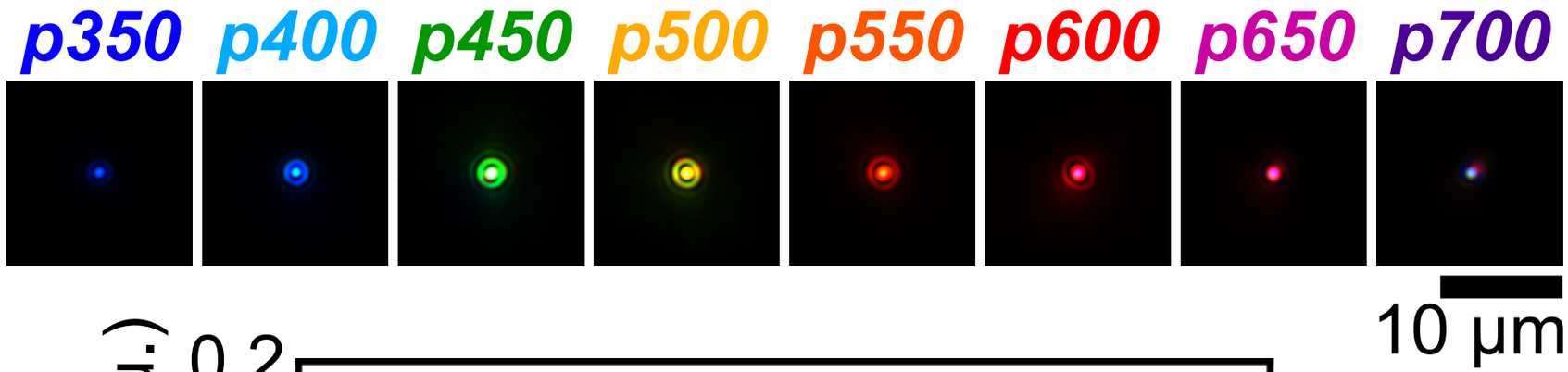
Transmitted light distribution of fabricated plasmonic filter

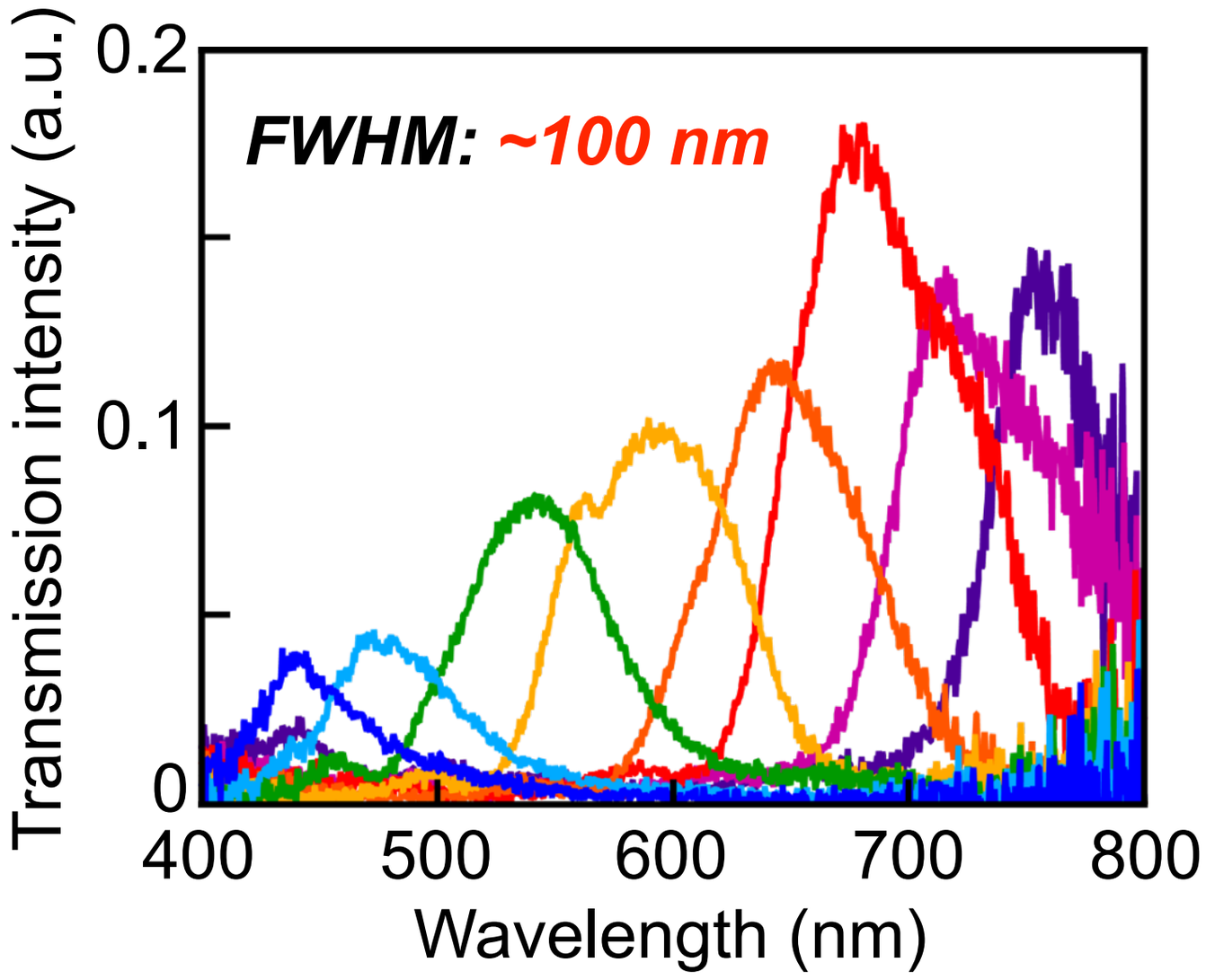
The plasmonic color filters were fabricated with period of 300 nm to 700 nm with 100 nm steps.

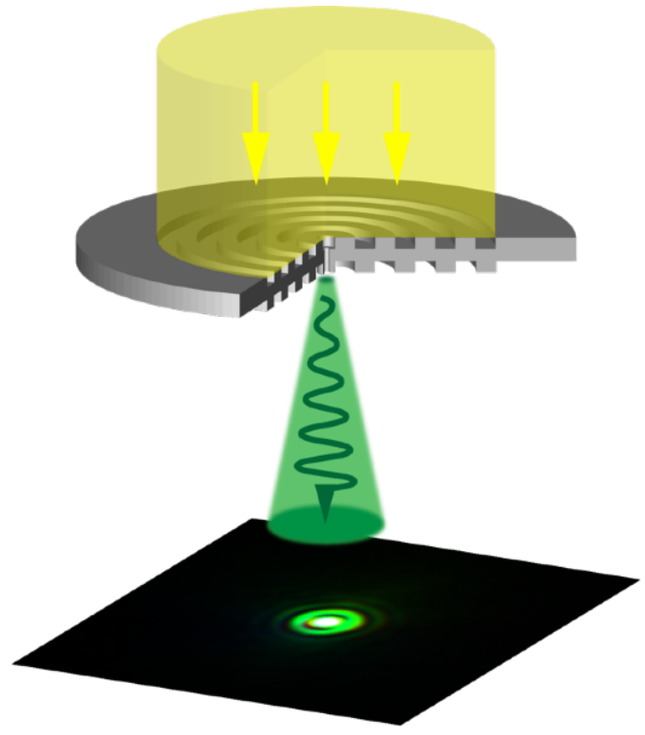


Transmitted light of selected wavelength was observed at the central aperture.

Multi-band color filtering from visible to near-infrared



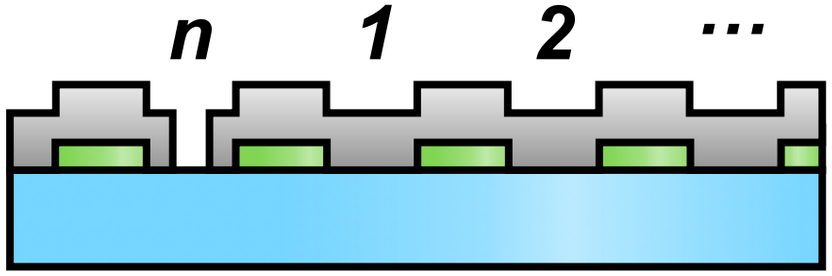


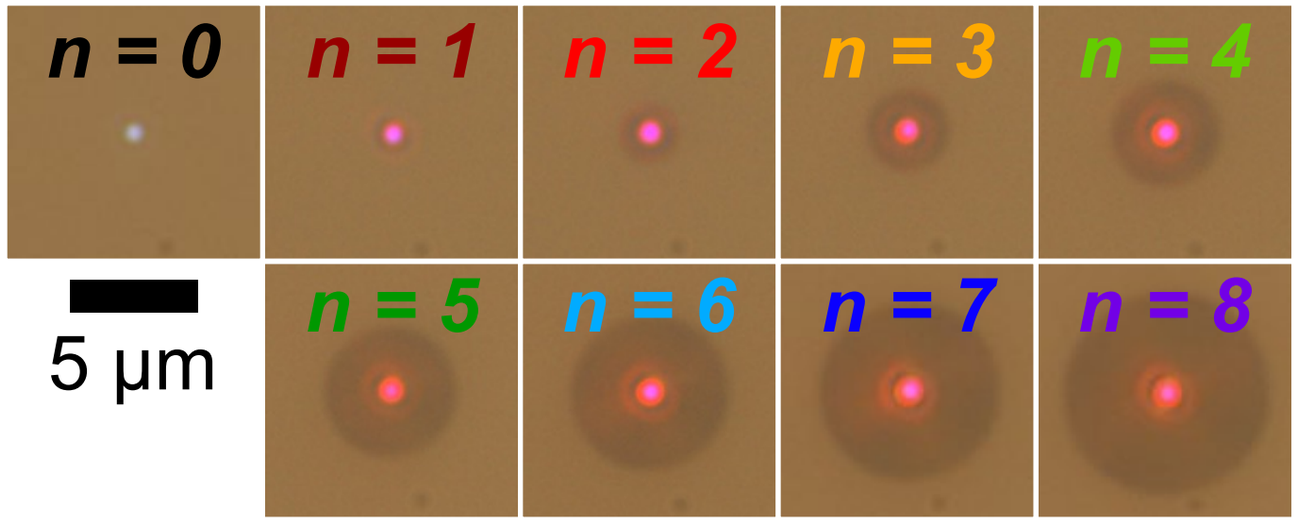


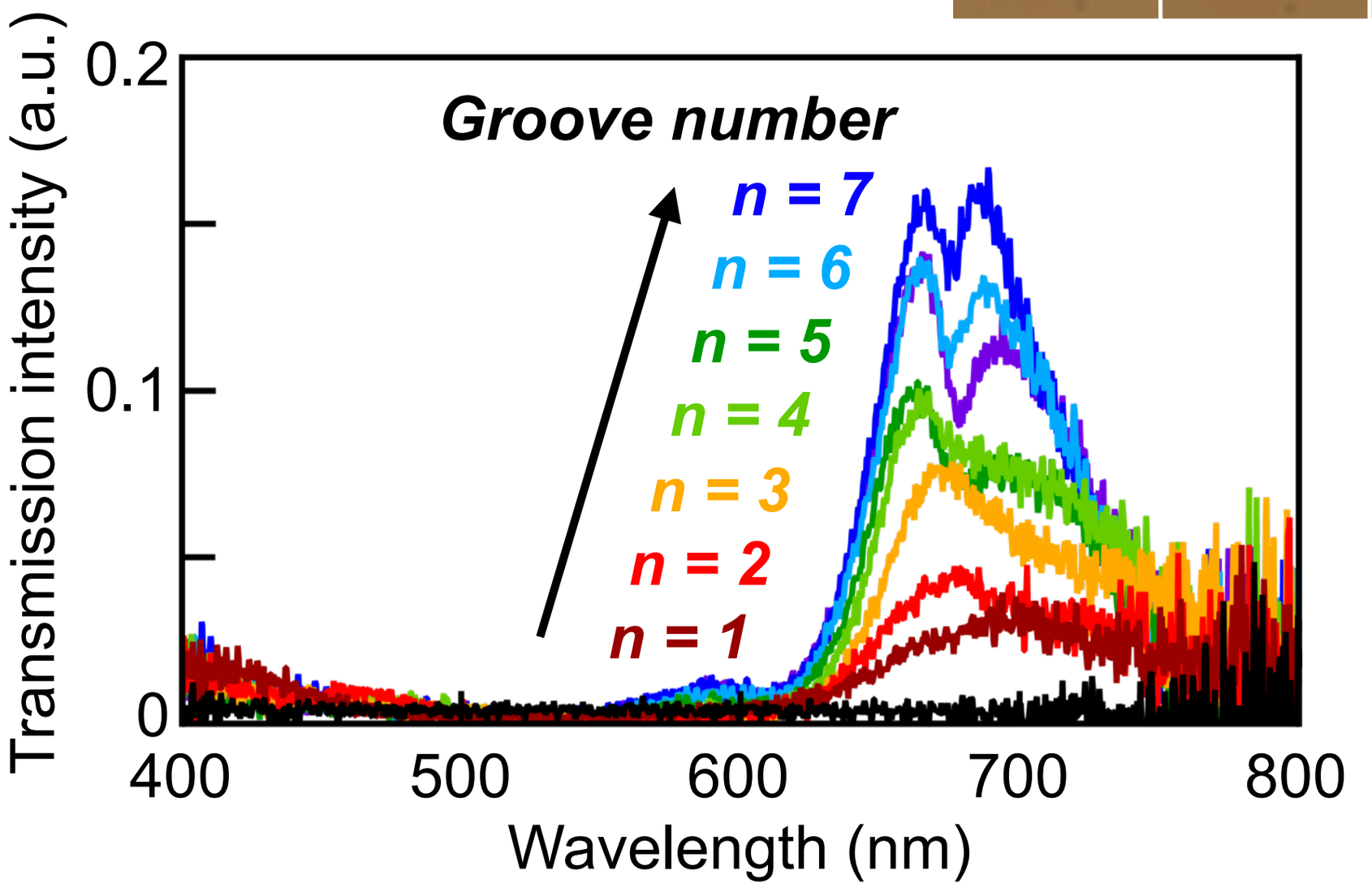
We demonstrated the multispectral transmission from visible to near- infrared range.

Groove number dependence for transmission spectrum

Groove number

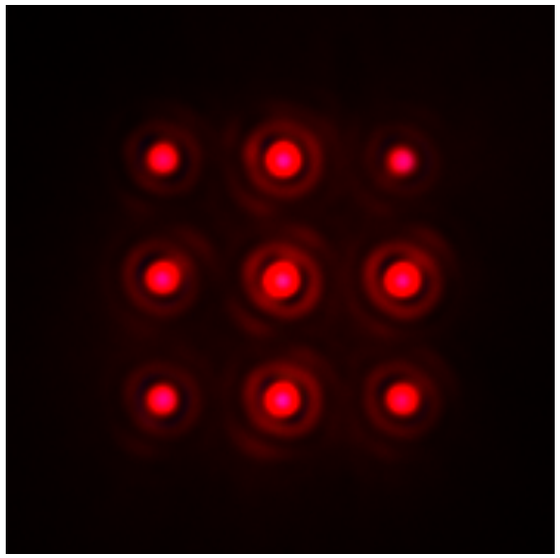




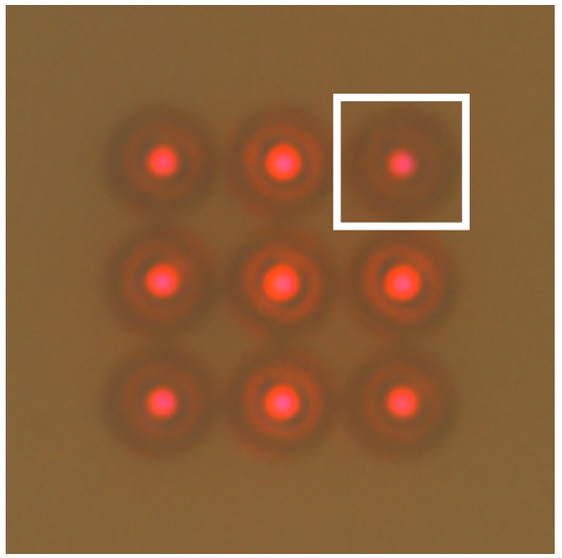


Multi-band color filtering by plasmonic array filters

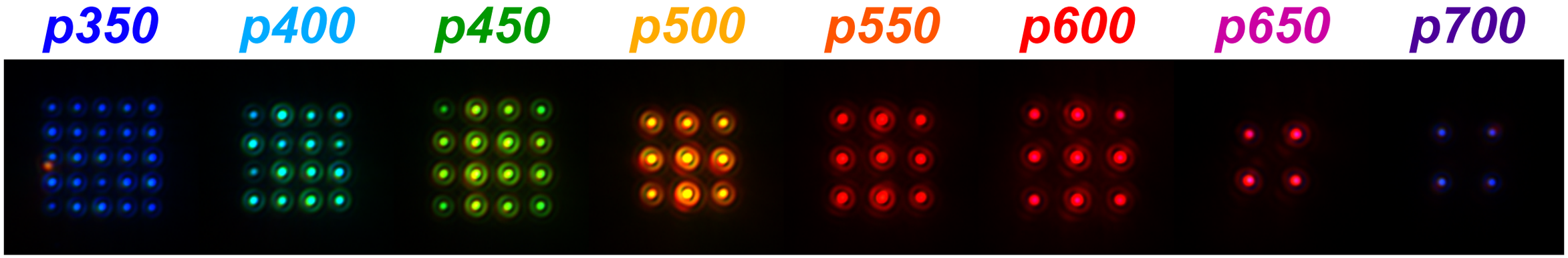
Transmission image



Bright field image



Unit cell: Three grooves



10 μm

Multi-band color transmission was observed in plasmonic array filter by increasing corrugation period.

Conclusions

- We analyzed transmission characteristics of plasmonic color filter with periodic corrugation leading to peak transmission of ~28 % by FDTD simulation.
  - The central wavelength of the filter is tunable by changing corrugation period and groove depth.

- We demonstrated the multi-band color filtering from visible to near-infrared range by our proposed corrugated metallic thin film.
  - Transmission spectral band with FWHM of ~100 nm was obtained in each plasmonic filter with a single aperture.