Plasmonic Metamaterials

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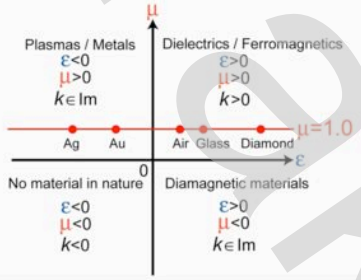
No. 8

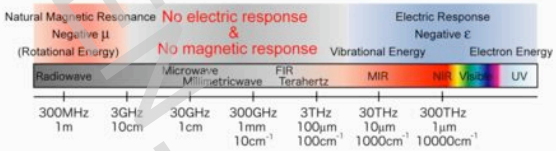
Nanophotonics

Plasmonic metamaterial

No material in nature has magnetic responses in the optical frequency region.

Magnetic permeability is always unity.



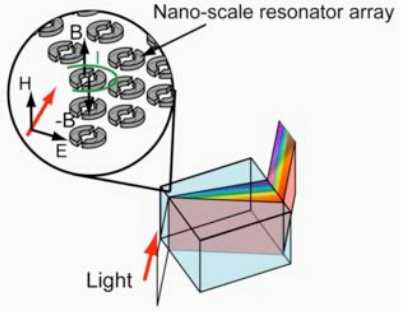


Why is there no magnetic materials in optical frequency region?

Spin of electrons and atoms can not follow the high frequency oscillation.

Control both ε and μ by plasmonic oscillation of free electrons inside metal nano structures

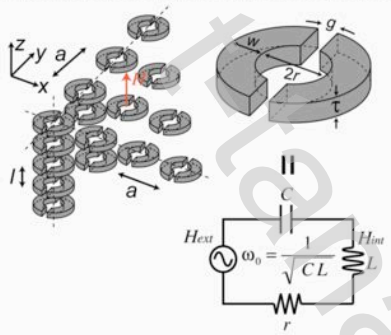
Element size & spacing << λ to avoid diffraction

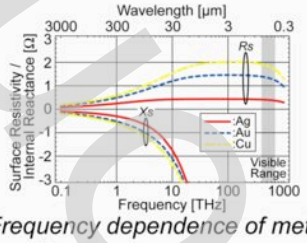


Magnetic response of plasmonic metamaterials

A. Ishikawa, T. Tanaka, and S. Kawata, Phys. Rev. Lett. 95, 237401 (2005).
A. Ishikawa, T. Tanaka, and S. Kawata, J. Opt. Soc. Am. B (accepted for publication).

Plasmonic Split Ring Resonators (SRRs)





Frequency dependence of metal inpedance

In visible light freq. region.

Rs saturates at the inherent frequency.

→ Rs is Not dominant

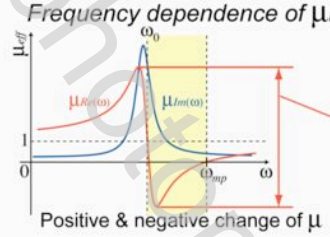
Xs moves away from zero drastically.

→ A large phase-delayed current

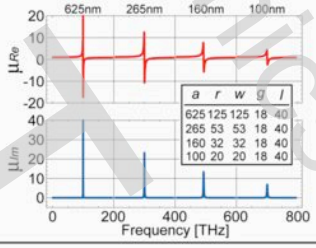
Effective permeability of the SRRs:

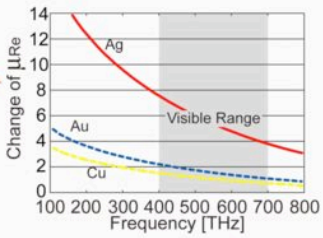
$$\mu_{eff} = \mu_{Re} + i\mu_{Im} = 1 - \frac{F\omega^2}{\omega^2 - \frac{1}{CL} + i\frac{Z(\omega)\omega}{L}}$$

Frequency dependence of μ_{Re} & μ_{Im}



Positive & negative change of μ





Two factors toward μ = 1

~ 100THz: due to the increase of Rs

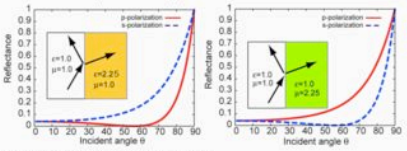
100THz ~: due to the decreae of L

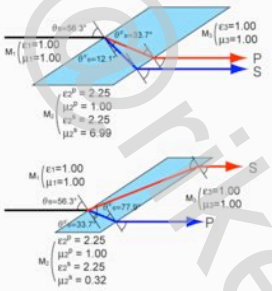
About details see poster No. 11

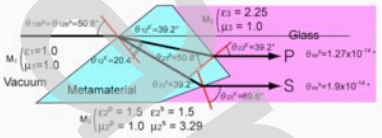
An application of metamaterials to novel photon control device

T. Tanaka, A. Ishikawa, and S. Kawata, Phys. Rev. B **73**, 125423 (2006).

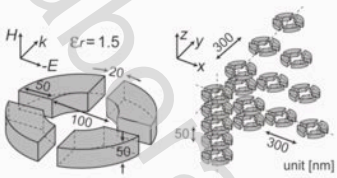
Brewster in p- and s-polarization



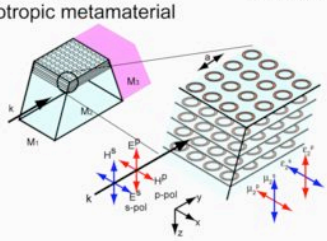


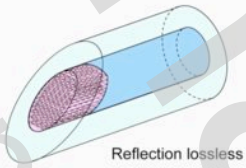


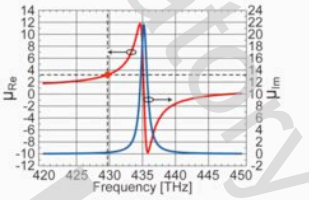
Photons can pass through the boundary between vacuum and glass without any reflection.



Anisotropic metamaterial







Fabrication technique of 3D metal structure

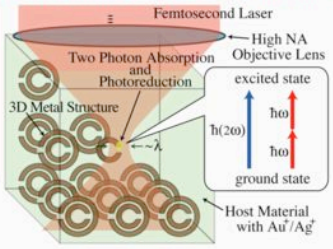
T. Tanaka, A. Ishikawa, and S. Kawata, Appl. Phys. Lett. **88**, 81107 (2006).
A. Ishikawa, T. Tanaka, and S. Kawata, Appl. Phys. Lett. **88**, 81107 (2006).

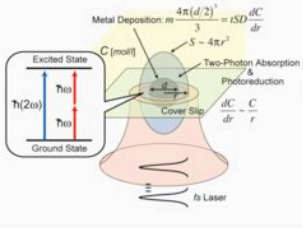
Two-photon micro fabrication

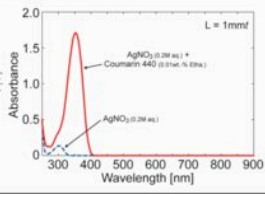
Beam propagation space

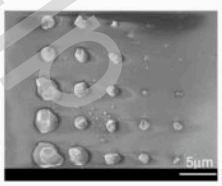
Small spot

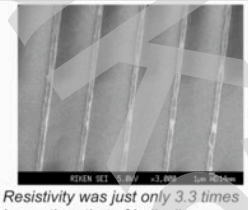
- ~100 nm resolution
- 3D structure
- Wide fabrication area



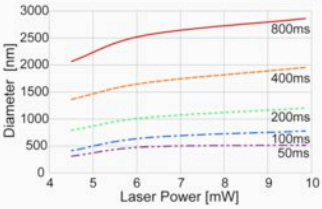




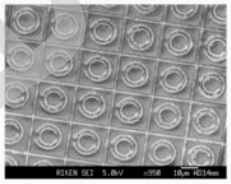




Resistivity was just only 3.3 times larger than that of bulk silver.



Self-standing metal strucure



Resonator array structure

About other methods see poster No. 9 & 10