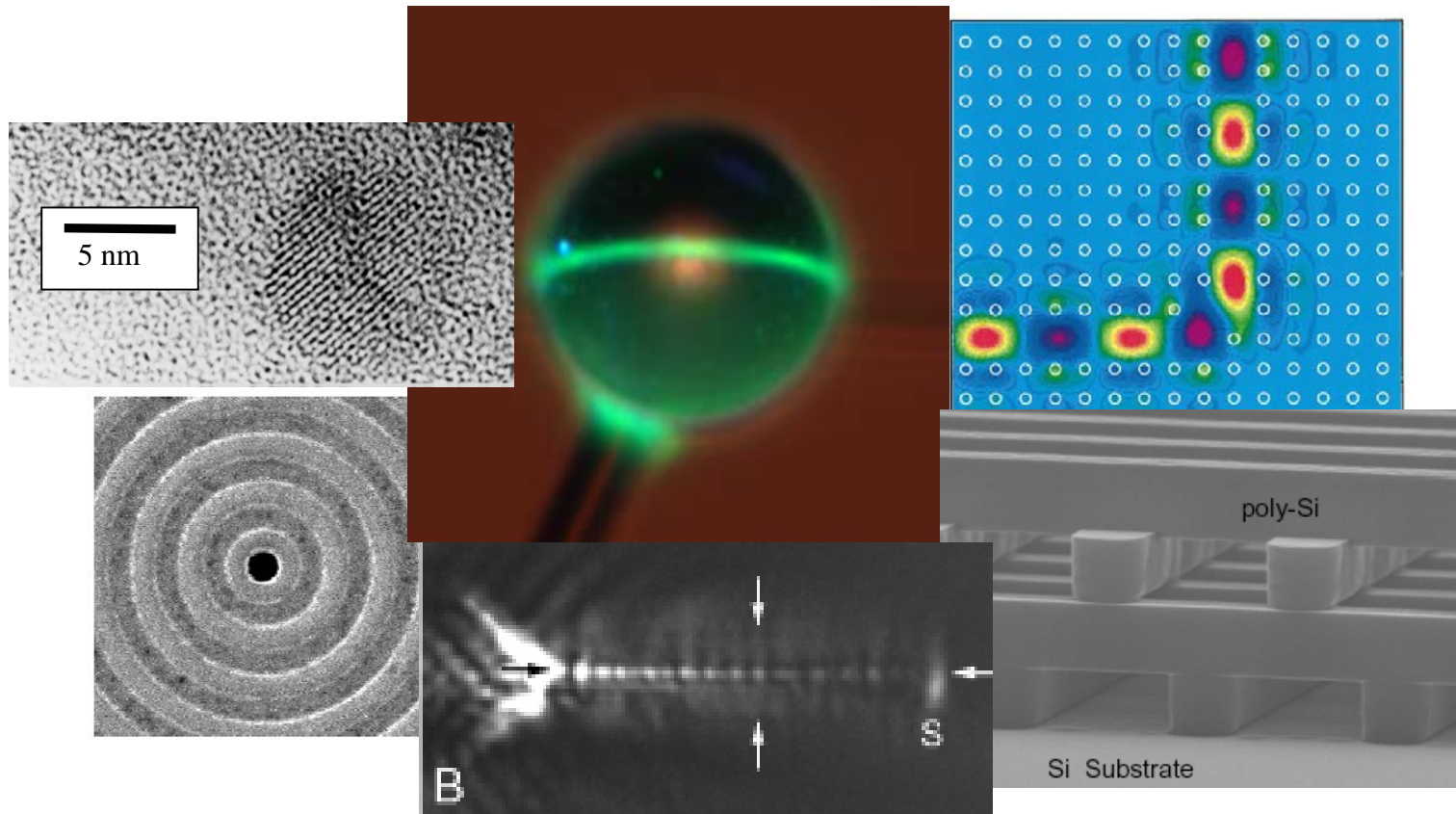


Nanophotonics and Metamaterials*

Professor Vladimir M. Shalaev
ECE695S



*) This course was prepared with M. Brongersma and S. Fan from Stanford. Their help is highly appreciated.

Nanophotonics and Metamaterials

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Course Web page

<http://cobweb.ecn.purdue.edu/~shalaev/teaching.html> - to download lectures

Recommended Textbook:

1. *Photonic Crystals: Molding the flow of light.*

By Joannopoulos, Meade and Winn, (Princeton University Press, Princeton, 1995).

2. *Surface Plasmons – “Plasmonics: Fundamentals and Applications”*, by S. Maier, Springer (2007)

3. *Near-field optics – “Principles of Nano-Optics”* by L. Novotny and B. Hecht, Cambridge (2007)

4. W. Cai and V. Shalaev, *Optical Metamaterials: Fundamentals and Applications*, Springer, 2009

Grading 30% homework, 30% midterm exam, 40% final (presentation and report)

Overview of the Course

Part I: Introduction to light interaction with matter

Derivation Wave Equation in matter from Maxwell's equations

Dielectric properties of insulators, semiconductors and metals (bulk)

Light interaction with nanostructures and microstructures (compared with λ)

Part II: Photonic Crystals

Electromagnetic effects in periodic media

Media with periodicity in 1, 2, and 3-dimensions

Applications: Omni-directional reflection, sharp waveguide bends,

Light localization, Superprism effects, Photonic crystal fibers

Part III: Metal optics (plasmonics) and nanophotonics

Light interaction with 0, 1, and 2 dimensional metallic nanostructures

Guiding and focusing light to nanoscale (below the diffraction limit)

Near-field optical microscopy

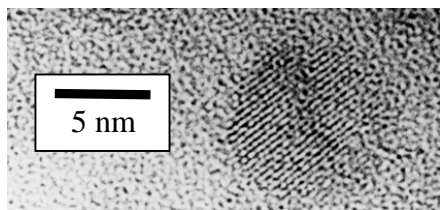
Transmission through subwavelength apertures

Part IV: Metamaterials

Metamaterials, optical magnetism, and negative refractive index

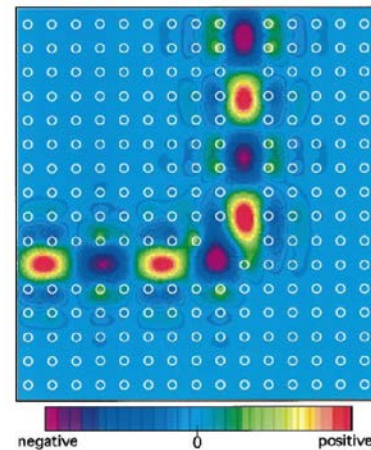
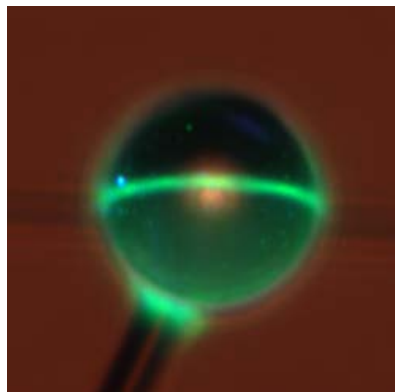
Super-lens and Hyper-lens, Cloaking, Transformation optics

Overview in Images

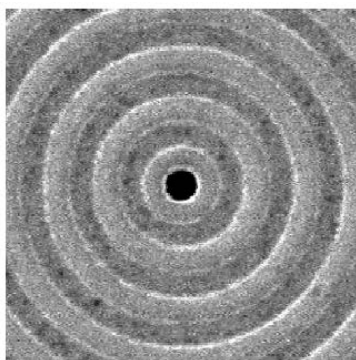


K.S. Min et al. PhD Thesis

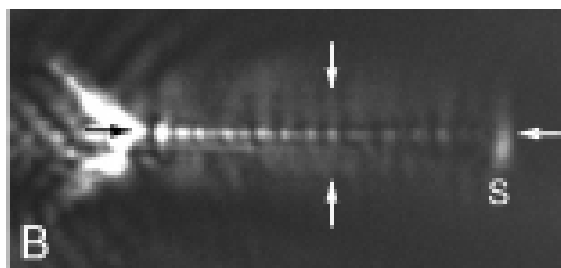
K.V. Vahala et al, *Phys. Rev. Lett*, 85, p.74 (2000)



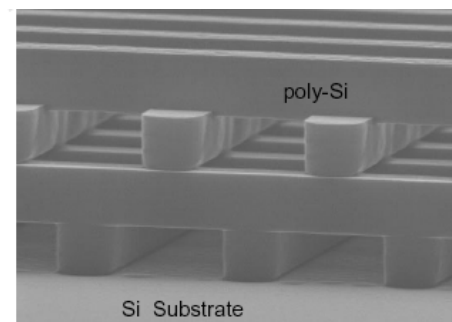
J. D. Joannopoulos, et al, *Nature*, vol.386, p.143-9 (1997)



T.Thio et al., *Optics Letters* **26**, 1972-1974 (2001).



J.R. Krenn et al., *Europhys.Lett.* **60**, 663-669 (2002)




S. Lin et al, *Nature*, vol. 394, p. 251-3, (1998)

Motivation

Major breakthroughs are often materials related

- Stone Age, Iron Age, Si Age,....metamaterials
- People realized the utility of naturally occurring materials
- Scientists are now able to engineer new functional nanostructured materials

Is it possible to engineer new materials with useful optical properties

- Yes ! 
- Wonderful things happen when structural dimensions are $\approx \lambda_{\text{light}}$ and much less
 This course talks about what these “things” are...and why they happen

What are the smallest possible devices with optical functionality ?

- Scientists have gone from big lenses, to optical fibers, to photonic crystals, to...
- Does the diffraction set a fundamental limit ?
- Possible solution: metal optics/plasmonics

Designing New Functional Devices

We need to be able to solve the following problem:

