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Light and Matter: Interaction in Nanostructures

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The interaction of light and matter in nanostructured materials is not only governed by material properties but also by the geometry of the nanostructures. This can be utilized to fabricate e.g. lenses with thicknesses of few hundred nanometers using regular arrangements of nanostructures on surfaces, so-called optical metasurfaces. In this lecture we focus on current topics in light-matter interaction in nanostructures and cover aspects such as fabrication processes, characterization, optical properties of photonic crystals, plasmonic structures and metamaterials.

- **1: Introduction**

- **2: Basics**
  Depending on students' background in solid state physics and quantum mechanics, we (re-)introduce the following concepts of solid state physics and quantum mechanics that are necessary for the understanding of the subsequent chapters of the lecture:
    - *Quantisation of states in quantum wells, wires and dots*
    - *Density of states*
    - *Band structure*
    - *Bloch wavefunctions*
    - *Drude model*

  Supporting material for independent study:
  Quantum mechanics
  https://link.springer.com/book/10.1007/978-1-4939-1151-6
  https://link.springer.com/chapter/10.1007/978-3-319-75708-7_4
  Solid state physics
  https://link.springer.com/referencework/10.1007/978-3-319-69150-3
  https://link.springer.com/book/10.1007/978-3-319-75708-7

- **3: Fabrication Processes: Top-Down- and Bottom-Up-Structuring**
  How can nanostructures be fabricated? We discuss the most important fabrication processes.

  Supporting material for independent study:
  Top-down-structuring:
  https://link.springer.com/chapter/10.1007/978-3-319-19758-6_13
  Bottom-up-structuring:
  https://link.springer.com/book/10.1007/978-3-540-77899-8

- **4: Experimental Characterization Methods**
  How can the properties of nanostructures be characterized? Here, we focus on methods where light-matter-interaction already plays a role such as optical near-field microscopy and optical tweezers.

  Supporting material for independent study:
  https://link.springer.com/book/10.1007/978-1-4615-4835-5
  https://link.springer.com/book/10.1007/978-3-030-32573-2

- **5: Semiconductors and Dimensionality**
  Nanostructuring semiconductors can have a large influence on the interaction between light and matter, one example of this is the quantum cascade laser. This chapter focuses on the role of dimensionality for absorption and emission processes.

  Supporting material for independent study:
  https://link.springer.com/book/10.1007/978-3-540-38347-5

- **6: Photonic Crystals**
  Structuring dielectric materials on length scales that are approximately equal to the wavelength of incident light can be used to fabricate photonic materials whose properties are in many ways analogous to those of crystalline materials: Photonic crystals can have a band gap for incident light, for example. We discuss the physics and possible applications in optical devices.

  Supporting material for independent study:
  https://link.springer.com/book/10.1007/978-3-540-38347-5

- **7: Metamaterials**
  Permittivity and permeability can be tailored in metamaterials. This can be used to fabricate cloaking devices and perfect lenses.

  Supporting material for independent study:
  https://link.springer.com/book/10.1007/978-1-4419-0573-4
  https://link.springer.com/book/10.1007/978-3-319-66044-8

- **8: Plasmonics and optical metasurfaces**
  Metallic or dielectric nanostructures support collective oscillations of the electron gas that can be excited by incident light. Those nanostructures can act as antennas for light in the visible or infrared spectrum. We discuss the physics and possible applications of these structures.

  Supporting material for independent study:
  https://link.springer.com/book/10.1007/0-387-37825-1