Electronic and Photonic Materials and Devices Specialization in Bachelor Program

Core Recommendations:

The **"Electronic and Photonic Materials and Devices"** specialization lays a solid foundation for a fundamental understanding of the physics and operation principles of components and devices. Students in this specialization will typically work at the forefront of research and invent and develop the next generation of devices or sensor concepts. The "Electronic and Photonic Materials and Devices" specialization typically prepares students for contributing latest devices and components to applications related to quite a variety of fields such as "Communications", "Renewable Energies & Power Systems", the "Medical Field" area and last but not least to the field of "Integrated Circuits". The difference between e.g. studying the specialization of "Communications" and communications within "Electronic and Photonic Materials and Devices" is that the first has the focus on protocols and algorithms whereas the latter deals with the hardware, specifically its physical operation. Likewise when the specialization on "Energy and Power Systems" has a focus on power plants and their control the focus in "Electronic and Photonic Materials and Devices" will be on developing the latest solar cell or newest battery.
The core lectures of this specializations are as follows

- **"High-Speed Signal Propagation"** lays the foundations for understanding how fast signals behave in the time and frequency domains, including in particular "transmission line behavior" which in this context means signal traces on circuit boards and USB cables at Gigabit/sec data rates. For signal risetimes < 200 ps, the significant frequency content of digital signals extends up to at least 10 GHz which corresponds to a free space wavelength of 3 centimeters. Keeping in mind that transmission line effects (distributed circuit behavior such as signal reflections, delays) become apparent when circuit dimensions reach 10% of the wavelength it is clear that anyone working with high data rates must be aware of such effects. Advances in high performance microprocessors, Gigabit networks, and the need for broadband Internet access, necessitate the development of high performance packaging /interconnect structures for reliable high-speed data transmission inside every electronic system. Key concepts include Conductor Characterization, Losses, Intersymbol Interference (ISI), S-parameters, Coupled Lines, Crosstalk and Signal Integrity, Eye Diagrams. The same basic skill set is also required for students interested in RF circuit design.
- **"Solid-State Electronics"** introduces the microscopic origins of electrical, thermal, mechanical, and optical properties of materials. By studying crystal structure and the electronic configuration of elements and compounds, students will learn why materials behave as they do and how their properties can be systematically tuned. The class emphasizes the practical application of these fundamental concepts such as charge and thermal transport with examples from batteries, thermoelectrics, photodetectors, solar cells, and LEDs. This class is critical for students looking to eventually design next generation semiconductor-based devices.
- **"Optics and Photonics"** conveys the fundamentals of optics and introduces the most important photonic components. The wider scope of the lecture is the generation, processing, transmission and detection of photons. In particular, this includes discussion of the operation principle of the laser or the guiding of light in a waveguide or a fiber and many other topics. The field of Photonics is increasingly becoming important as it plays an important role in various fields such as communications, energy harvesting (solar cells), sensing (such as medical sensing, environmental detection,…). To give just a few examples: For instance, when until recently photonics was only used to transmit signals

in backbones, photonics is now even used to communicate between or when until recently only silicon solar cells were considered to be viable solutions we now are discussing devices based on nano-engineered photonic compounds.

- **“Advanced Electromagnetic Waves“** provides a systematic overview on the propagation mechanism of electromagnetic waves in homogeneous media as well as in various wave guiding structures including surface waves, stratified media, rectangular wave guides and optical fibers. The key issue of this lecture is not only giving a clear understanding of selected possible solutions of Maxwell’s equations but also creating a generic feeling for the limits, i.e., of what is impossible with electromagnetic waves. The respective discussions include almost arbitrary material parameters such as negative permittivity/permeability or near zero material parameters.

The four courses are organized to cover the basics in high-speed electronics, photonics and solid state physics.

Recommendations for Complementary Courses:

Given that the specialization in “Electronic and Photonic Materials and Devices” relates to a wide field of applications there is also a wide selection of subjects that complement well.

Students interested in innovating the field of integrated circuits with novel devices might preferentially select more courses from within the following subjects:

- VLSI Design 1
- Communication Electronics
- Analog Integrated Circuits

Students with an interest in the wider field of mobile and wireless communications should consider these subjects

- Zeitdiskrete und Statistische Signalverarbeitung
- Kommunikationssysteme

Students that would like to innovate the field of renewable energies and power conversion should consider the following subjects

- Regelsysteme
- Leistungselektronik

Computer engineering courses, biomedical instrumentation, bio-electronic also serve well as complementary courses for students interested in Electronic and Photonic Materials and Devices as core subjects.