2.3.3 Integrated Photonics

Lecturer	Prof. Dr.-Ing. Christian Koos
Course Objectives	The module will introduce the theoretical and technological foundations of photonic integrated circuits. This comprises theoretical basics of wave propagation and of light-matter interaction, fundamental principles of optical waveguides, passive and active optical devices, and optical detectors, as well as state-of-the art photonic integration platforms and applications of PIC in various different fields. Lectures will be complemented by tutorials, laboratory courses and studies of recent scientific literature in the field of photonic integration.
Contents	The following selection of topics will be presented: ▪ Introduction to integrated photonics ▪ Fundamentals of photonics ▪ Optical waveguides ▪ Passive optical devices ▪ Integrated optical sources and amplifiers ▪ Optical detectors ▪ Photonic integration platforms and applications
Learning Targets/ Skills	After course completion, participants should ▪ understand the specific advantages and strengths of photonic integrated circuits, ▪ conceive the principles of light-matter interaction and optical waveguiding, ▪ understand and mathematically describe signal propagation in optical waveguides, ▪ understand the principles of common passive and active optical devices and photodetectors, ▪ have an overview on currently available photonic integration platforms and the associated applications, ▪ be able to start designing and testing photonic integrated circuits, ▪ be able to judge the technical complexity and feasibility of photonic building blocks, and ▪ communicate effectively with designers of PIC and with photonic foundries.
Pre-Requisites	Basic physics and electrodynamics, calculus, complex numbers, interest in photonics and technology
Duration	10 x 2 h
Teaching Method	Formal lectures, tutorial style discussion, lab tour, scientific literature and symposia
Course Material	Lecture slides
Literature	▪ B. E. A. Saleh and M. C. Teich. Fundamentals of Photonics. Wiley, 2007. ▪ K. Iizuka. Elements of Photonics, volumes 2 and 2, John Wiley & Sons, 2002. ▪ Katsunari Okamoto. Fundamentals of Optical Waveguides. Academic Press, 2006. ▪ L. A. Coldren and S. W. Corzine. Diode Lasers and Photonic Integrated Circuits. John Wiley and Sons, New York, 1995. ▪ C. Koos. Optical Sources and Detectors, Lecture notes, available at http://www.ipq.kit.edu/ (2012) ▪ C. Koos. Optical Waveguides and Fibers, Lecture notes, available at http://www.ipq.kit.edu/ (2014)
Contact Lecturer	Prof. Dr.-Ing. Christian Koos, christian.koos@kit.edu

Schedule: Integrated Photonics	
Institute	**Content (selected keywords)**
Day 1	
	Lecture: Introduction to integrated photonics ○ Communication with light ○ Optical interconnects and the need for photonic integration
	Lecture: Fundamentals of Photonics ○ Maxwell's equations in optical media ○ Wave equation and plane waves ○ Material dispersion and Kramers-Kronig relation ○ The Lorentz oscillator model of dieletric media ○ Sellmeier equations
	Lecture: Optical waveguides 1 ○ Reflection from dielectric boundary ○ Slab waveguides ○ Waveguide modes of dieletric waveguides (slab waveguide, fiber, rectangular waveguides) ○ Plasmonic waveguides
	Lecture: Optical waveguides 2 ○ Signal propagation in dispersive waveguides ○ Mode expansion method ○ Signal propagation in nonlinear optical waveguides
Day 2	
	Lecture: Passive optical devices ○ Multi-mode interference devices (MMI) ○ Directional couplers ○ Waveguide gratings and grating couplers ○ Ring resonators ○ Optical filters
	Lecture: Integrated optical sources and amplifiers ○ Semiconductor basics ○ Raditative and nonradiative transisions in direct-bandgap semiconductors ○ Compound seimconductors ○ Semiconductor p-n-junctions fir light generation ○ Light emittion diodes ○ Semiconductor optical amplifiers ○ Semiconductor lasers (incluiding DFB / DBR / VCSEL structures) ○ Dynamic behavior of semincoductor lasers
	Lecture: Optical detectors ○ Basic photodiode concept ○ The p-i-n photodiode ○ Speed limitations and device structures ○ Avalanche photodiodes ○ Optical receivers and noise
	Lecture: Photonic integration platforms and applications ○ Waveguide technologies and fabrication methods
Day 3	
	Lab tour, tutorial, scientific literature Students will deepen their understanding by solving problem sets, visiting integrated optics laboratories at KIT, and by studying scientific literature or attending scientific talks in the field of integrated photonics. In 2014, a scientific symposium “Photonic Integrated Circuits: Technology and Applications” will be part of the module. The symposium will take place on June 13, 2014, and will be jointly hosted by HIRST and by the German Association of Applied Optics (DGaO), see http://www.teratronics.kit.edu/news_events.php/event/25239 for more details.