Research Centre for Integrated Nanophotonics

Research objectives

Modern society depends on sustained increases in internet bandwidth, connectivity and computational power for business, entertainment, comfort, safety and communications. But the hardware at the heart of the internet consumes an unsustainable amount of energy and projections are showing a relentless increase. The energy consumption limits design and constrains connected bandwidth at every level of the network: inside computer systems, inside fiber-optic routers and at the final wireless connections to the user.

A radical new technology paradigm is required: we envisage a pervasive end-to-end optical connection between users and computing resources and a radical enhancement in electronic-to-optical conversion efficiencies. This requires the intimate integration of electronics and photonics at both the system level and at the physical layer and a re-engineering of photonics close to the quantum limit. It raises formidable scientific and technological challenges. We focus on the key hardware challenges on all scale levels.

Theme 1 Pervasive optical systems

We aim to create new integrated photonic circuits, which connect users optically to the network, which keep information in optical form as it passes through data routers in the internet backbone, and which handle unprecedented information densities as data streams converge at the servers at the heart of the internet.
The systems must help solve the capacity bottleneck at every network level from the long-haul transmission systems through data-center networks and including down to access networks and in-home networks, where billions of users need fast connections with the local and global internet.

The Gravitation research targets different parts of the communication infrastructure:

- Long haul transmission of data, where photonic integration techniques will be exploited to open new dimensions and increase the amount of data that can be transported over a single fibre.

- Signal routing and processing, where applications of adding versatile photonic circuits to CMOS circuitry are being investigated as well as the introduction of optical switches for energy-efficient and transparent switching and routing of data.

- Closer to the user, the research is aimed at photonic chips as a means to create dynamically reconfigurable indoor access points, a low-cost indoor optical network, and beam-steering techniques for short-range wide-band low-power radio- and optical-wireless connections.

**Theme 2 Nanophotonic integrated circuits**

We aim to integrate intimately photonic circuits with electronic CMOS circuits using nanophotonic technology to push integration density and power efficiency several orders beyond today’s state-of-the-art.

The research line has two parts:

- Creation of a nanophotonic membrane based integration platform that supports integration of compact and energy efficient basic building blocks used in photonic circuits for a variety of applications. These membrane-based photonic circuits are created on top of silicon or CMOS integrated circuits, which contain the electronics for driving and controlling the optical circuits and for processing the electronic data that they generate.

- Creation of compact and ultra-low power components for future integration in the platform. Emphasis is on nanolasers and photonic switches.

**Theme 3 Ultimate control of light and matter**

We aim at ultimate control of light-matter interaction on an atomic scale, to ensure the ultimate in energy efficiency and information density, and to explore ways of manufacturing. The emphasis is on tools to create and analyze optical nanomaterials for efficient nanophotonic devices and to develop and study novel devices for efficient generation and detection of light at the femtojoule (fJ) energy level. We also study the exchange of information between photons and magnetic spin as a route to fast and ultra-dense optically addressable memory.

We are investigating techniques for creating and manipulating structures on the nanoscale, which display properties which are not found in natural materials. One example is the growth of hexagonal
Si and SiGe nanowires, which could feature a direct bandgap and thereby efficient emission from silicon, or the monolithic integration of materials with different crystal structure or lattice constant (e.g. III-V on Si or vice versa). This work is made possible by the use of atomic-scale characterization techniques which identify these structures atom-by-atom. Another research line investigates processes where light directly interacts with magnetic properties of matter, which opens ways for optical memories. These are still a major target in the design of optical circuits. Major challenges are encountered and addressed in both the scientific analysis and the manufacturing methods.

The focus on new technology hardware offers a unique opportunity to proceed beyond the “proof-of-principle” and tackle both fundamental challenges and opportunities for large-scale applications.