10817: A universal photonic chip?

Promotor(s): Wim Bogaerts, Roel Baets

Supervisor(s): Alfonso Ruocco

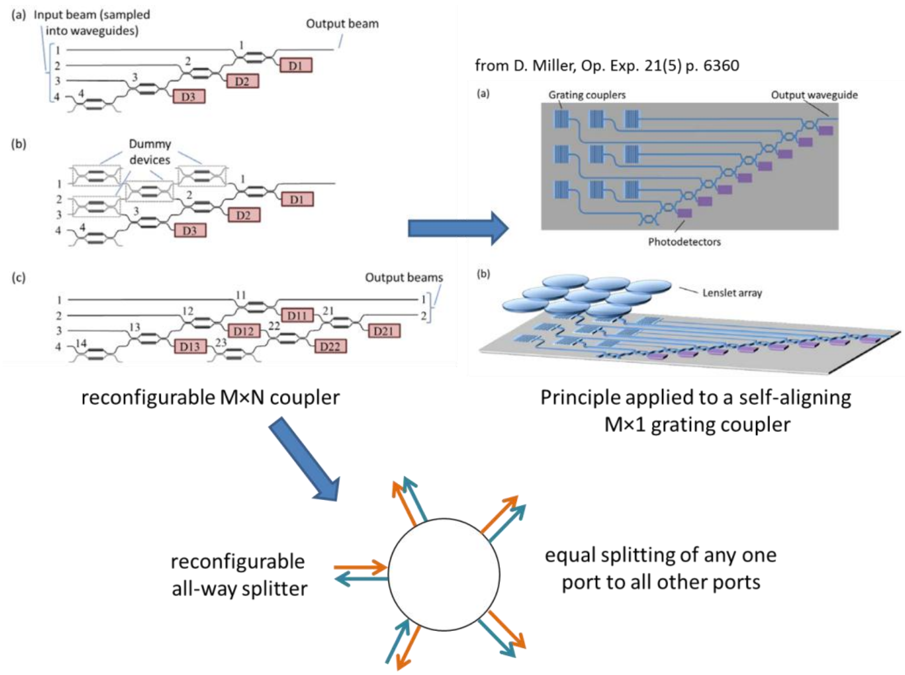
Contactperson: Wim Bogaerts

Background:

Photonic integrated circuits are being increasingly used for telecom and datacom links, but also for sensors, spectroscopy and life-science applications. While the photonic IC technologies (e.g. silicon photonics) already offer a lot of functionality (wavelength filtering, ultra-fast modulation and detection, ...), this functions are usually statically defined. Photonic ICs today resemble the very specialized ASICs, rather than general-purpose CPUs or highly flexible field-programmable gate arrays (FPGA). In this work we want to explore some concepts that can lead to a universal (dynamically) reconfigurable photonic chip. Very much like an FPGA, but for light. Such a chip could be used for a variety of purposes and such a concept could dramatically shorten the deployment of new photonic integrated circuits.

Most functions in a photonic chip can be described as a coupling problem. This can be coupling between two or more components on the chip, or coupling between an external fiber and a chip. We

Especially in the latter case, the alignment of a fiber or an input beam is critical to the coupling efficiency. If such a coupling structure could be made reconfigurable, a dynamic optimization procedure could actively optimize the coupling. Such a concept has been proposed by David Miller (Stanford) in [1], but not yet executed in a real technology. It consists of a cascade of directional couplers and optical phase shifters, and by tuning every individual phase shifter a complete control of phase and amplitude in each section can be obtained. The feedback required for the control could be global (by monitoring the outputs) or local, using integrated photodetectors in each stage of the cascade.
Another coupling problem, which might look very different (but could be solved with the same technology) is that of a universal N-way splitter: This is a device with N waveguide ports. The input light from any of these ports is distributed over all other ports. And this would work for all ports at the same time. While it has been theoretically shown that this device cannot be perfectly implemented for N=3 and N=4, it is possible for higher port counts. Such a device could be constructed using the same type of cascaded network of phase shifters. The challenge is in the precise control of the phase shifters to obtain the correct balance between all ports. The symmetric N-way splitter can actually be reconfigured to couple any port to any set of other ports, as long as the laws of physics (reciprocity, linearity) are obeyed. It would be interesting to explore novel uses of such a universal NxN coupling system.



[1] D. Miller, "Self-aligning universal beam coupler," Opt. Express 21, 6360-6370 (2013).

Aim:

In this thesis project, we intend to bring the universal photonic chip one step closer, by looking at the most challenging aspect of it: reconfigurable coupling. We will demonstrate one or both the the above concepts on a real reconfigurable photonic chip. The photonic chip will be based on the world-class silicon photonics technology of IMEC. The IMEC technology comes in two flavors. One consists of pure passive optical waveguides, where additional active phase shifters can be added by processing resistive heaters in the Ghent University clean rooms in Zwijnaarde. A second flavour supports not only passive waveguides, but can also incorporate electro-optic and thermo-optic phase shifters, photodetectors, and the metal wiring to control this. In the prepaation for this thesis, we are preparing some chip designs for both technologies.

While in many cases photonic chips with complex functionality are difficult to design, the general-purpose configuration we described above make the design fairly straightforward. The challenge will be largely in the characterisation and feedback mechanisms. Therefore, we are already preparing chip designs that can be used by the time the thesis starts. The work in the thesis would then focus on the following aspects:

- A thorough understanding of the theorectical concepts to be used. This involves precalculating estimates for the phases and coupling constants
- Processing thermo-optic phase shifters in the clean room in Zwijnaarde.
- Developing measurement routines for controlling the phase shifters while measuring optical transmission. This might involve some electronics work.
- Demonstrating the self-optimizing grating coupler using the electronically controlled measurement setup
- Demonstrating the universal N-way splitter

This thesis topic has as much to do with optics/photonics as with developing control algorithms. Therefore, a decent background in programming is advisable (the language used in the lab is Python, for design, simulation and controlling the measurement equipment).

Location:

Technicum, Zwijnaarde

11544: Active Waveguide based on Metal-Semiconductor-Metal Configuration

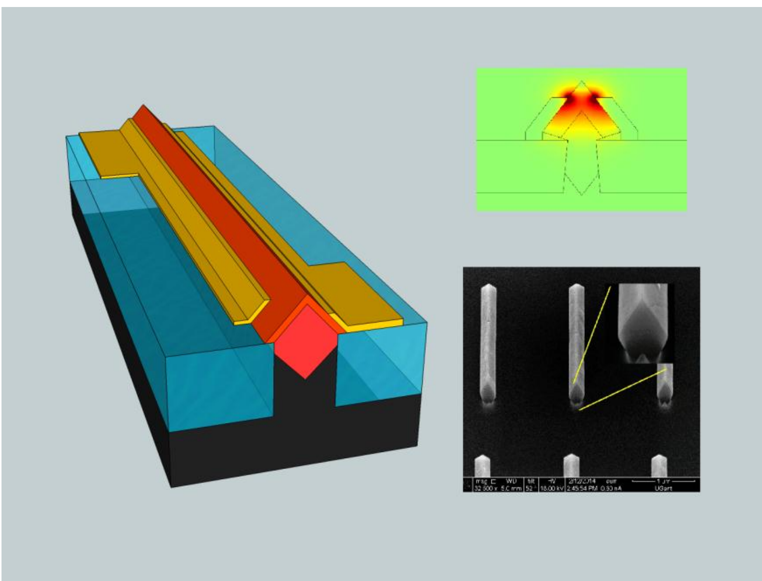
Promotor(s): Dries Van Thourhout, Zhechao Wang

Supervisor(s): Bin Tian

Contactperson: Bin Tian

Background:

In the last decade, the study of the interaction between electromagnetic waves and electron plasmas on metal surfaces - plasmonics, has attracted enormous attention. Potential applications range from novel sub-wavelength nanophotonic circuits to photothermal cancer therapy and many others. Although great benefits have been predicted, the substantial attenuation of the electromagnetic wave due to absorption (ohmic loss) in the metal becomes the main obstacle, preventing use of plasmonics in practical applications. To address the aforementioned problem, solutions based on loss compensation by using gain materials have been proposed. Either polymers or quantum dots were integrated together with plasmonic waveguides. However, most of these schemes are not compatible with high-density integration and mass-production.



Aim:

In this master thesis project, the most advanced III-V on silicon epitaxial growth technology [1], currently being developed at imec for next generation electronic ICs, will be adopted to form a novel metal-semiconductor-metal (MSM) hybrid waveguide configuration, a sketch or which is shown in the figure above. A Si / GaAs / InGaAs waveguide is grown in a narrow silicon-oxide on silicon trench. The inset shows a SEM picture of a fabricated device. In the project metal will be deposited on the two sides of the III-V waveguide, to form the MSM configuration. Due to the plasmonic effect, most of the electrical field is then confined in the active region of the structure (see insert of the figure). If this active region is pumped, the optical mode will experience optical gain and the metal loss can be overcome. In the first phase of the thesis work, the student will gain a solid understanding of plasmonics and master the tools for numerical simulation, and systematic analysis of the MSM waveguide will be performed to obtain an optimal design. In the next step, the student will work together with the supervisor in the clean room to realize the designed device, and characterization of the fabricated devices will be carried out on a novel micro photoluminescence setup. This work links strongly to the ERC project ULPPIC funded by EU commission.

[1] Z. Wang, B. Tian, Mohanchand Paladugu, Marianna Pantouvaki, N. Le Thomas, Clement Merckling, Weiming Guo, Johan Dekoster, J. Van Campenhout, Philippe Absil, D. Van Thourhout, Polytypic InP Nano-laser Monolithically Integrated on (001) Silicon, Nano Letters, 13(11), p.5063-5069 (2013)

Location:
Technicum
Website:
More info: photonics.intec.ugent.be

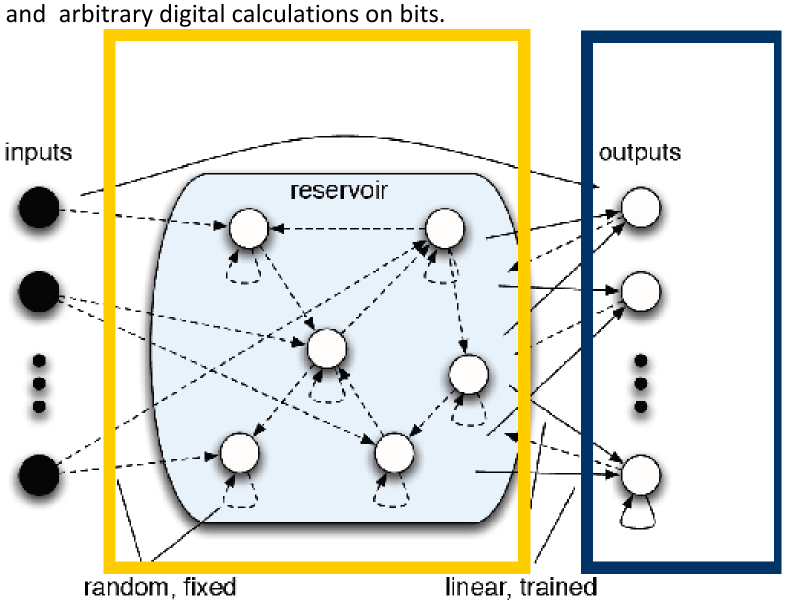
11262: An LDPC Decoder based on photonic reservoir computing

Promotor(s): Peter Bienstman, Joni Dambre

Supervisor(s): Andrew Katumba

Contactperson: Andrew Katumba

Background:
All modern telecommunications systems strive to operate as close as possible to channel capacity. This requires special attention to be paid to the issue of channel coding on order to achieve the best possible (optimal) decoding for transmitted data. Many modern decoders use low-density-parity-check (LDPC) codes for error correction, notable examples are in Digital Video Broadcasting and Long-Haul Optical Communication Systems. LDPC codes are particularly attractive due to their excellent error correction abilities coupled with a decoding complexity that only increases linearly with code length.
However, classical LDPC decoding algorithms are iterative in nature with high accuracy of error correction requiring a large number of iterations. This makes LDPC codes less than ideal for real time communications and not particularly power efficient.
The reservoir computing machine learning technique presents a potential alternative to iterative decoder used in conventional LDPC decoding. Reservoir computing utilizes dynamical systems with 'fading memory', i.e., systems for which the state dependence on past inputs decays exponentially with time, together with a linear readout to process temporal problems. In our group, various applications using integrated photonics hardware for reservoir computing have been demonstrated. These include speech recognition, signal generation, header recognition and arbitrary digital calculations on bits.



While attempts have been made to perform LDPC decoding using Artificial Neural Networks, the decoding process based on a silicon photonic reservoir computing platform would allow for high speed, low power decoding of the transmitted code words, with the accuracy only determined by the quality of the training phase of the reservoir.

Typically, a decoder employing reservoir computing techniques would be limited to short codes to allow for realistic reservoir sizes and training duration, however numerous techniques have been demonstrated that could be leveraged to yield a faster training and decoding procedure.

Aim:
In this thesis, you will investigate the implementation of an LDPC decoder to take advantage of the best from both the photonic reservoir hardware platform and LDPC coding.
The first part of your work will use the in-house simulation models and tools for reservoir computing to investigate the best reservoir architecture for this task. Here, you will also investigate techniques to improve the speed of the decoding process.
In a second part, you will perform measurements on the current generation of passive silicon photonic reservoirs to validate the results obtained from the simulation phase.
Location:
Website:
More info: photonics.intec.ugent.be/research/topics.asp?ID=112

11641: Development of a laser ablation process for etching silicon photonic chips

Promotor(s): Geert Van Steenberge, Nicolas Le Thomas

Supervisor(s): Saurav Kumar

Contactperson: Saurav Kumar

Background:
In the integrated photonics research area, fabrication of freestanding silicon membrane based nanostructures is intensively investigated in view of several applications, for example, for probing of biomolecules with photonic crystal cavities, or for fabricating microelectromechanical systems (MEMS) based photonic devices. In all cases, the silicon substrate hinders an optimal use of the photonic nanostructures of interest by limiting its accessibility.
Standard silicon wet etching is currently challenging as there is no suitable hard mask capable to protect for a sufficiently long time the top silicon surface. Laser ablation is an alternative solution to this problem as no hard mask is required. By controlling laser parameters such as spot size, incident power, pulse repetition rate, exposure of laser pulse at one place on silicon substrate can be optimized.

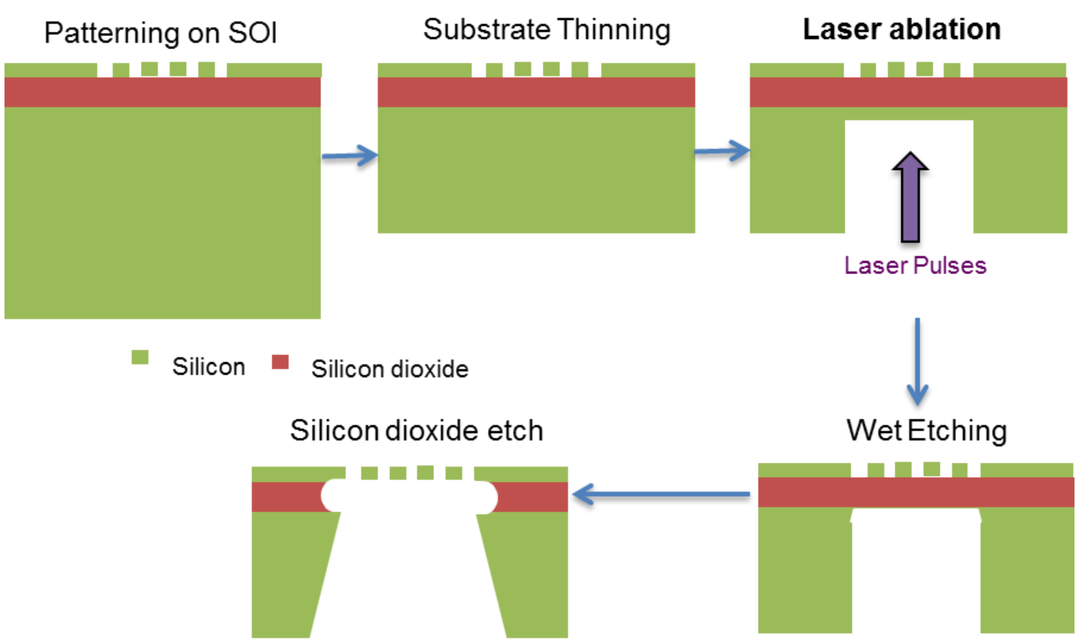


Figure 1. Silicon substrate removal using laser ablation

Aim:

The aim of this Master's thesis is to develop a laser ablation process dedicated to silicon etching on photonic chips. A proper design of experiment will be elaborated to reach the best possible accuracy without impacting any layer of interest. More specifically, during the project, the process will be optimized to stop the ablation when only thin (≈ 10µm) or no silicon substrate stays on a buried oxide layer as shown in figure 1. Figure 2 shows picture of combined picosecond / femtosecond laser set-up available, in the UGent cleanrooms. The project will also lead towards better understanding of the physics involved during the ablation process. This Master's thesis will be carried out jointly with the Center for MicroSystems Technology (CMST) and the Photonics Research Group (PRG).

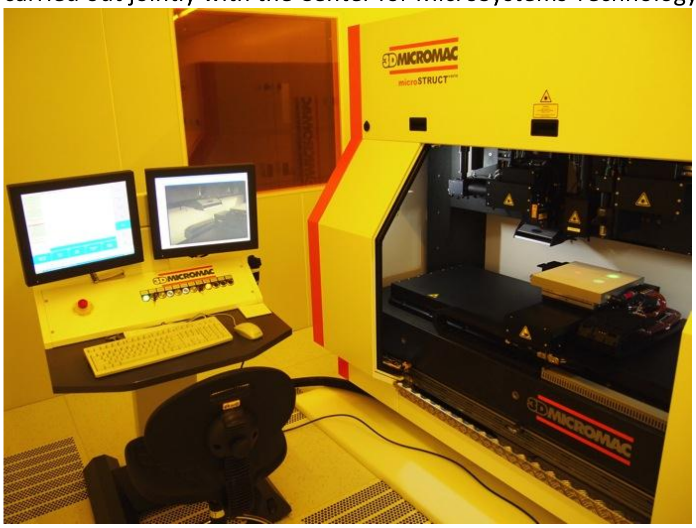


Figure 2. Combined picosecond / femtosecond laser set-up available in the UGent cleanrooms

Website:

More info: photonics.intec.ugent.be

11258: Double layer silicon photonic integrated circuits based on transfer printing

Promotor(s): Günther Roelkens, Dries Van Thourhout

Contactperson: Günther Roelkens

Background:

Silicon photonic integration is an enabling technology for the realization of miniaturized and cheap optical systems. While silicon photonics – compared to competing technologies - allows the densest integration of optical functions on a chip, the complexity of the circuits has in some cases become so large that double layer waveguide circuits are of interest. Typically this double layer circuit is only required in a particular part of the circuit, thereby making a cost-effective approach to implement this non-trivial.

Aim:

One way of implementing such a double layer waveguide circuit is to make two single layer waveguide circuits separately (i.e. on a separate wafer) and then transfer the circuit on one layer piece by piece to the other wafer, in the places where the material is needed. This provides a cost-effective way to locally obtain double layer silicon circuitry. The optical coupling between both layers should be realized using an "optical via", much like the electrical vias used in printed circuit board and electronic IC technology. This Master thesis comprises both the design of such an optical via in terms of efficiency and optical bandwidth as well as the proof of principle demonstration of the realization of such a double layer waveguide circuit.

Location:

Technicum, Ardoyen

11264: Dual Polarisation Biosensing

Promotor(s): Peter Bienstman

Supervisor(s): Jan-Willem Hoste

Contactperson: Jan-Willem Hoste

Background:

The pharmaceutical industry is having a hard time developing new medical drugs. The development cycle is too long because validation of new medicines can only occur in a final stadium. This is why modern drug research is extremely costly and risky and a healthy financial return of investments is difficult to obtain. It looks like the golden days are over in pharmacy. To stop this negative evolution, research must be done in a more efficient way. One way to increase the efficiency is to look at a more physical level of what is happening when drug candidates bind to target proteins. This usually induces a change of the shape of the protein-drug complex, for good or for bad. This conformational change plays a big role in determining whether the drug works or not. It is even so that all key processes in the human body resolve around subtle conformational changes of the constituents! However, screening of drugs based on this phenomenon is non-existant. Here at the photonics department of intec we use photonics to design biosensors by using microrings based on the silicium platform. Binding of certain molecules on the surface of the ring causes the resonance wavelength to shift, which can be measured accurately. This shift is a function of both the thickness and the refractive index of the bound protein layer. In order to get access to the conformation of the bound protein layer we excite the rings in two modes simultaneously, allowing us to disentangle this thickness (and hence the conformation) and the refractive index of a bound layer.

Aim:

The goal of this thesis is to use this new breed of microring biosensors to study the behavior of relevant drugs, proteins or polymers. The device can be researched in an applied way, trying to pinpoint its performance in relation to these biomolecules. In this way, the student will be involved in analyzing its behavior and improving the performance, both by suggesting improvements in the optical design and in the device from a system standpoint of view. As such combining optics and engineering skills. The other branch of this thesis will be about performing experiments with these biomolecules and interpreting the results to draw conclusions on the behavior of these biomolecules. This thesis is a fine example of the type of research that is possible when combining different fields of science, and as such requires an open-minded student with a broad interest, eager to learn about science which might not have been covered in its master program. However the student will get a good taste for the design of a photonics device in a very applied context, which inevitably requires this cross-contamination.

Location:

Technicum, Zwijnaarde

Website:

More info: photonics.intec.ugent.be

11771: Experimental characterization of the pulse compression occurring in the early stage of supercontinuum generation in silicon nanowire

Promotor(s): Bart Kuyken, dhr. Simon-Pierre Gorza [université libre de bruxelles]

Contactperson: Bart Kuyken

Background:

Extreme spectral broadening that occurs when narrowband input pulses propagate in nonlinear optical media is known as supercontinuum (SC) generation [1]. The integration of such sources still remains an important topic in photonic research owing to their possible applications. Recently, we have demonstrated the generation of supercontinuum in CMOS compatible silicon waveguides at telecommunication wavelengths [2]. Numerical simulations of the pulse propagation show that the SC is the result of an initial pulse compression followed by a temporal splitting into several fundamental solitons. It is expected the pulse to be compressed by a factor of 5 from 150 femtosecond pulses, but this as not yet been experimentally confirmed or even observed.

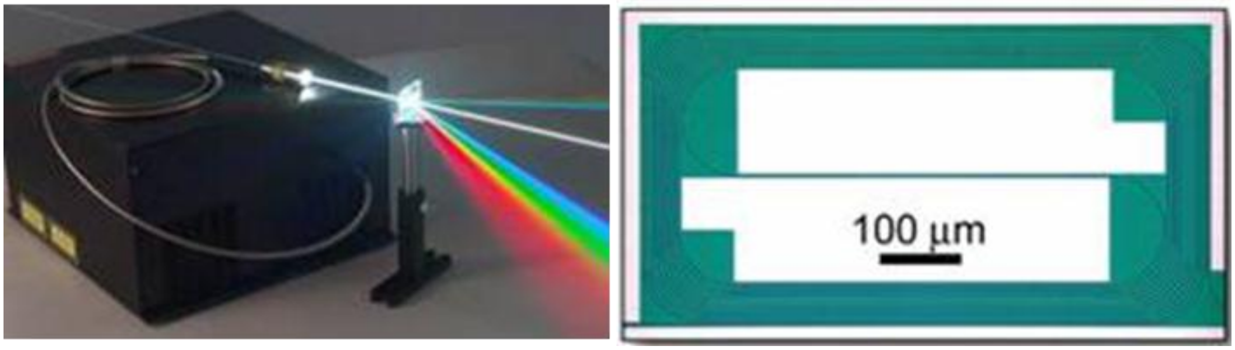


Figure 1: The white light generated coming from a supercontinuum source is shown on the left. The right picture shows a tiny silicon waveguide wrapped in a tiny coil on a chip .

Aim:

The purpose of the master thesis is to experimentally demonstrate and characterize the pulse compression that occurs in the first milimeters of propagation in silicon nanowire waveguides. The first part of the master thesis will be to identify the most promising structure (waveguide geometry and propagation length) based on numerical simulations of the pulse propagation. Because of the weakness of the signal, conventional ultrashort pulse characterization techniques such as FROG or SPIDER cannot be directly applied. The student will thus have the challenging task of designing and building a more sensitive characterization technique such as XFROG [3].

REFERENCES

[1] J. M. Dudley, G. Genty, and S. Coen, Rev. Mod. Phys. 78, 1135 (2006).
[2] F. Leo, S-P Gorza, J. Safioui, P. Kockaert, S. Coen, U. Dave, B. Kuyken, and G. Roelkens, arXiv link here
[3] S. Linden, H. Giessen, and J. Kuhl, “XFROG: A New Method for Amplitude and Phase Characterization of Weak Ultrashort Pulses”, phys. stat. sol. (b) 206, 119 (1998)

11799: Highly sensitive graphene/quantum dot photodetectors for integrated photonics

Promotor(s): Günther Roelkens, Zeger Hens

Supervisor(s): Enrico Da Como, Chen Hu

Background:

Integrated silicon photonics whereby densely packed photonic integrated circuits are fabricated starting from silicon-on-insulator (SOI), is rapidly evolving from a technology platform for tele- and datacommunication at wavelengths around 1.3 and 1.55 µm to a generic platform for signal processing, sensing and chemical analysis over a broad spectral range in the infrared. This requires small footprint, highly sensitive photodetectors – ideally with single-photon sensitivity – that can be easily combined with silicon-based photonic circuits. Currently, the most efficient near-IR detectors (efficiency of 95%) are based on superconducting nanowires, a sophisticated and reliable technology. These detectors are however not useful for large volume, low cost photonic chips due to their low operation temperature (<4 Kelvin), high production cost and complicated interfacing with integrated monolithic photonic circuits. As breakthrough solution we propose here hybrid photodetectors based on the combination of graphene and colloidal quantum dots. Those could offer a highly competitive alternative with less stringent operation temperatures and competitive performance. Efficient light absorption in the IR by the quantum dots and the unique transport properties of graphene, combined with atomic-thick heterostructures, can boost the detector responsivity, i.e., the number of electrons flowing through an external circuit per absorbed photon. Moreover, the two-dimensional nature of this hybrid material promises a remarkably suitable interfacing with planar structures, such as planarized SOI waveguides, making it an ideal starting point for high sensitivity, low cost integrated photodetectors.

Aim:
The aim of the research is to demonstrate the on chip detection of IR light using an integrated hybrid graphene/quantum dot photodetector. In doing so, you will learn to work with two of the most attractive new nanomaterials for opto-electronic applications, i.e., quantum dots and graphene. The project will start with the selection of the appropriate quantum dots to achieve photon absorption in the infrared and charge transfer to graphene. Next, you will work on the practical development of the photodetector, which involves the on-chip deposition of graphene and quantum dots and the simulation-supported design of integrated photodetectors. Finally, you will characterise the response characteristics of the photodetector with optical experiments on integrated waveguides and use the results to further optimize the photodetector responsivity.
Location:
Technicum, De Sterre, Ardoyen

11811: Improvement of waveguide coupling efficiency to a microscopy system using an ultracompact grating coupler

Promotor(s): Dries Van Thourhout, Edouard Brainis

Supervisor(s): Yunpeng Zhu, Suzanne Bisschop

Background:
Integrated photonics has a wide range of applications in telecommunication, information processing and lab-on-chip analysis. These applications all need a compact light source integrated with the waveguide platform. A promising solution consists in a hybrid technology, in which the photonics integration platform is combined with optical nanomaterials such as colloidal quantum dots (QDs). Colloidal QDs are currently the subject of intense research because of their controllable properties, such as a size- and shape-tunable energy levels and luminescence lifetimes, high quantum yields, and chemical processability. In addition, their integration with photonic devices based on classical fabrication processes and their potential to be ideal single photon sources present a real asset and offers many perspectives. However, the integration of these nanoscale functional elements, into micrometer- and submicrometer-scale devices is still one of the main challenges of present day science and engineering.
A fundamental research topic, in combining QDs and photonic integrated devices, is to investigate the coupling between QDs and waveguides. This calls for a technique to excite the QDs and measure the light output from waveguides. To do this, we have a microscopy system at our disposal that can excite and measure photoluminescence of (single) QDs (see figure 2). However, we need a more compact grating coupler, which fits this microscopy system while allowing very low coupling losses between the waveguide and microscopy system.

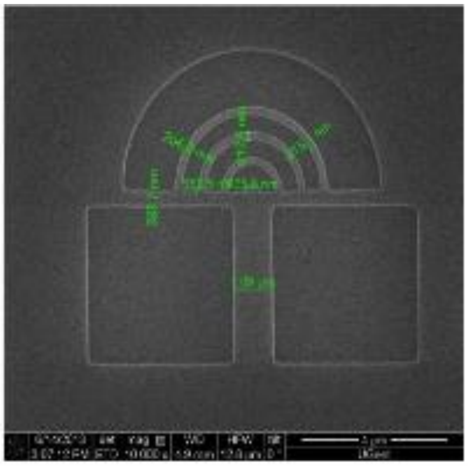


Figure 1. Proposed compact grating coupler structure

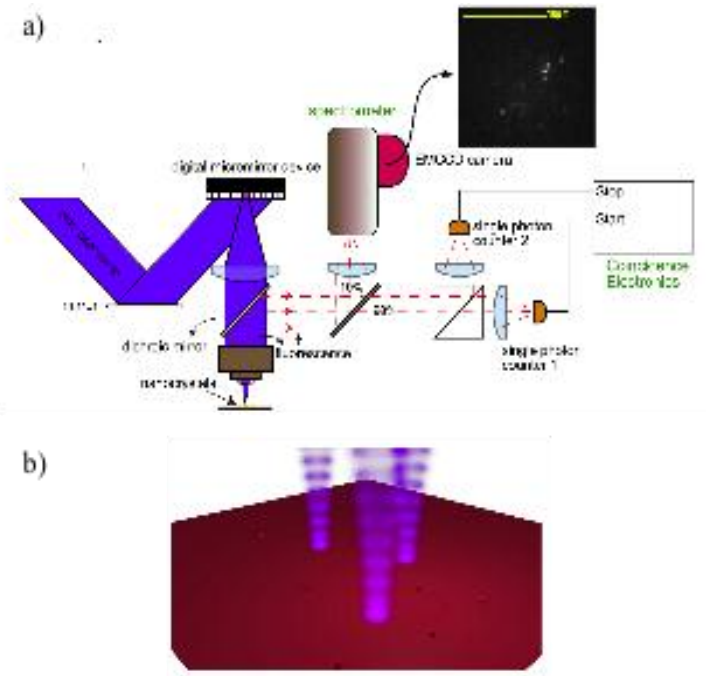
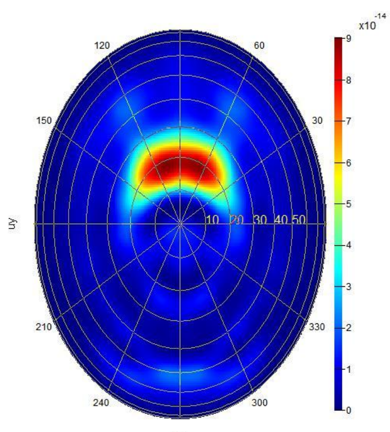


Figure 2. a) Experimental setup for generating multiple micro-beams and simultaneously exciting an arbitrary number of selected nanocrystals. b) Illustration of multiple micro- beams reaching the nanocrystal plane.

Aim:



During this master thesis project, you will tackle this problem by studying the principles of grating couplers and designing a novel grating coupler. We have already proposed one grating coupler structure that potentially can be used for the microscopy system, as shown in Figure 1. There is still much improvement possible, e.g. by adding a mirror underneath the grating, to enhance the power that is going up. You will learn to optimize the grating coupler by changing its parameters, and design the DBR based or metal based reflector. After getting a proper simulated reflector structure, you will fabricate the grating coupler structure using the available cleanroom facilities . Finally you will use the available microscopy system with single photon sensitivity to characterize the fabricated structure.

Location:
technicum / de sterre

11772: Integrated-photonic chips for evanescent-field Raman excitation to enable label-free analysis of cell membranes.

Promotor(s): Roel Baets, Andre Skirtach

Supervisor(s): Pieter Wuytens

Contactperson: Pieter Wuytens

Background:

Nowadays, most studies on cellular processes and interactions rely on fluorescence microscopy. Despite their strong intrinsic signals, the use of labels comes with significant drawbacks, like biased measurements and difficult multiplexing. Raman spectroscopy, in which the vibrational states of a molecule are directly probed, offers a promising label free alternative for bio sensing. Confocal Raman microspectroscopy allows acquiring Raman maps

with diffraction-limited lateral resolution. However, the axial resolution is insufficient (>1um) to use Raman spectroscopy for monitoring thin layers in a complex environment, like cell membranes. This problem will be solved by using the evanescent field of a waveguide for the excitation of Raman scattering, while collecting the scattered photons through a confocal Raman microscope. This allows to selectively probe thin layers (<100nm) on top of the waveguide. This technique is envisaged to enable the label-free characterization of cell membranes and cell adhesion.
The recently developed silicon-nitride (SiN) technology platform at the Photonics Research Group enables to fabricate these integrated photonic chips for visible frequencies, allowing efficient Raman excitation in the low-bio damage window at 785 nm.

Aim:
The goal of this project is to develop an integrated SiN chip for Raman excitation and use this in combination with a state-of-the-art confocal Raman microscope for probing cell membranes and adhesion. In the philosophy of the center for Nano- and Biophotonics, this thesis is highly interdisciplinary. It is collaboration between the Photonics Research Group and the Department of Molecular Biotechnology. You will actively perform research and experiments at both departments. On the one hand, you will use and adapt optical setups for light coupling and characterization of existing integrated SiN chips. The optical properties will be verified using simulations (FDTD/FEM). On the other hand, you will culture mammalian cells on a SiN substrate, and investigate the possibilities of Raman micro spectroscopy for the label-free imaging of fixed and living cells using evanescent-field excitation. You will use hyperspectral data analysis methods to evaluate acquired spectra. Furthermore the availability of advanced fluorescence microscopes on the same location enables to perform option cross-correlated fluorescence and Raman measurements.

Location:
Technicum, Faculty of Bio-Engineering (Coupure Links)

11751: Light-sound interaction on the nanoscale: what's next?

Promotor(s): Roel Baets, Dries Van Thourhout

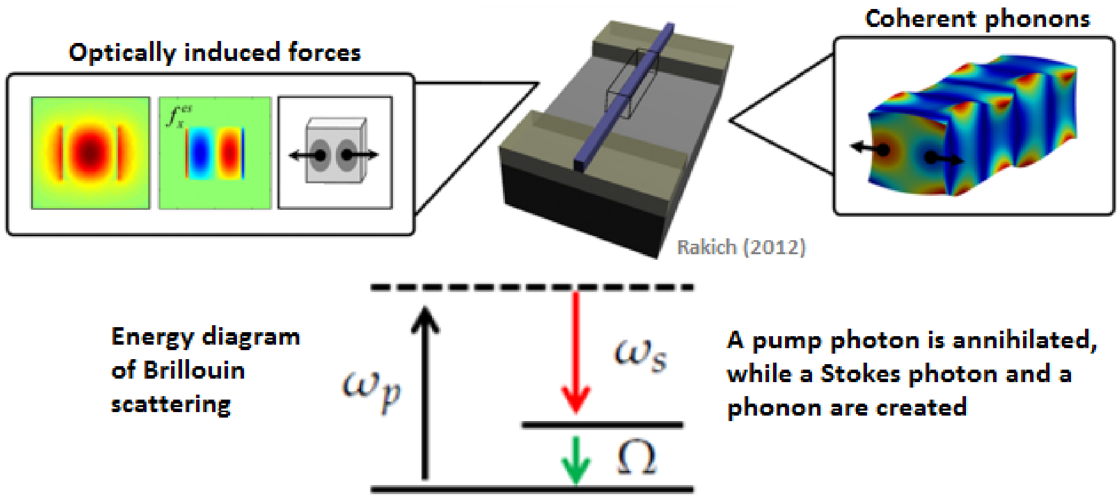
Supervisor(s): Raphaël Van Laer, Bart Kuyken

Contactperson: Raphaël Van Laer

Background:

In the 16th century, Johannes Kepler suggested that a comet's tail points away from the sun because of radiation pressure. Today, optical forces are widely used to trap and manipulate small particles, such as living cells, DNA and bacteria. The forces used in these 'optical tweezers' result from the strongly varying electromagnetic field in the focus of a high-power laser beam. In these two examples the photon-phonon coupling is one-way: light traps the particles, but the effect of the particles on the light is negligible. In recent years, there has been a massive effort towards the study of two-way photon-phonon coupling – in particular on the micro- and nanoscale. In one famous example, a team of researchers used light to cool the motion of a*macroscopic* object close to its quantum ground state, showing that even relatively large objects obey the laws of quantum mechanics. Since the object cools down, the light has to 'heat up'. Thus there is an interaction between light and the object, which ultimately affects both of them.

In 2012, a highly-publicized theoretical paper claimed that light-sound interaction is radically enhanced in tiny optical waveguides, see figure below. The team looked at a situation in which two optical waves are coupled by a sound wave, while all of them propagate along the waveguide. They predicted that energy could easily be transferred from one to the other optical wave, as depicted in the energy-diagram below. This nonlinear mechanism is called *Brillouin scattering*. Such a device may be useful in a wide variety of applications, but this has yet to be shown.



Aim:
Recently, we observed strong interaction between light and sound in such a waveguide. The goal of this project is to take the next step: what can we do with this? For instance, could we delay optical pulses by converting them to mechanical pulses? Or could we make a laser for sound (a saser)?

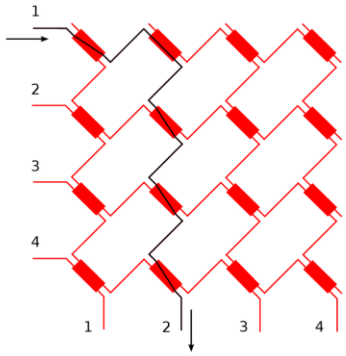
The project consists of a small literature study to find all the applications light-sound interaction has been linked to. After a while, the student zooms in on one of the applications. Finally, we will design experiments and carry them out. Interested students are invited to mail *raphael.vanlaer@intec.ugent.be* or pass our offices for more information.

Location:
Technicum, Zwijnaarde
Website:
More info: journals.aps.org/prx/abstract/10.1103/PhysRevX.2.011008

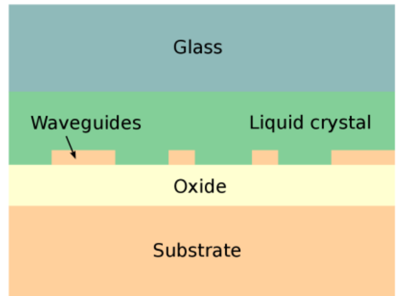
11790: Low power optical switch fabric by liquid crystal integration

Promotor(s): Dries Van Thourhout, Jeroen Beeckman
Supervisor(s): Herbert D`Heer

Background:
Today in central offices there are a huge number of optical fiber connections. One of the attempts to automate these connections are MEMS based switching devices. The size of these devices, however, is large and they are prone to mechanical vibrations. On top of that the power consumption is not negligible (in the order of tens of Watts for a 300x300 switch). Instead, realizing optical switches in silicon photonics technology has many advantages, such as a substantial reduction in device size and stability to mechanical vibrations. In silicon photonics tuning of components is typically done by the thermo-optic effect. For a large number of switch elements, which each would require a heating element, the power consumption still remains too high. Integrating the chips with liquid crystals eliminates this problem and because of the large anisotropy of the liquid crystal the performance of the switch can be improved. The integration of both technologies is demonstrated by the Photonics Research Group and the Liquid Crystals and Photonics Group, but up to now only for individual components such as ring resonators. Combining the advantages of both material platforms to make a switch circuit has never been done before. Because these switches will potentially be used in telecom applications broad wavelength operation needs to be taken into account during the design. This work fits in the context of the European project SWIFT.



Example layout of 4x4 switch



Liquid crystal on silicon waveguide

Aim:
In this thesis you will develop a low power integrated switch fabric by combining liquid crystals and silicon photonics. You will validate the concept by realizing a 4x4 switch, which operates over a broad wavelength range. The switch will be designed using various software tools. The circuit layout of the designed switches will be send to imec, which will provide the silicon chip. Integration of the LC and the silicon chip will be partially done in the cleanroom facilities in Zwijnaarde. After fabrication you will characterize the performance of the designed switch.

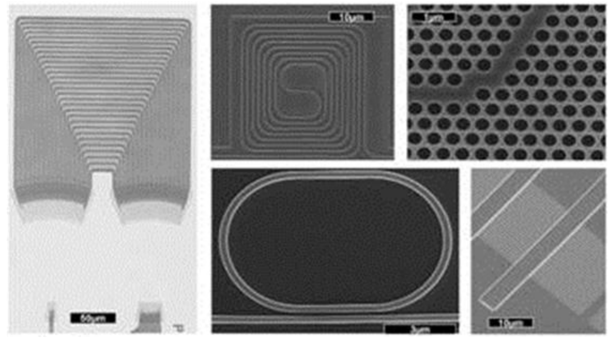
Group websites:
http://photonics.intec.ugent.be
http://lcp.elis.ugent.be
Location:
Technicum, Ardoyen

11762: On chip source of frequency bin entangled photons

Promotor(s): Bart Kuyken, prof. Serge Massar [Université Libre de Bruxelles]

Contactperson: Bart Kuyken

Background:
Quantum optics is the ultra low intensity limit of optics in which photons are manipulated and detected one by one. In this regime novel feature emerge such as the impossibility of cloning, or entanglement (the quantum correlations between pairs of photons), and novel applications are possible such as quantum cryptography and quantum computers.
The teams at UGhent and ULB have shown in a recent collaboration how pairs of photons can be generated using waveguides on silicon chips (similar to the chips used in the computer industry). The CMOS compatible fabrication process could potentially lower the footprint and cost of traditional sources of entangled photons considerably. In parallel the ULB team has introduced the concept of “frequency bin entanglement”, and thereby demonstrated how the entanglement of photon pairs can be manipulated directly in the frequency domain.
The aim of the present project is to create a bright, compact, on chip, source of frequency bin entangled photon.



Aim:
The work will consist of three main parts:
First it will be necessary to design the chips that will be used as photon pair source. In order to have a very bright source compatible with the frequency entanglement experiment setup at ULB, ring resonators will be used. The challenge will be to design the ring resonators such that the photon pairs are efficiently generated (technically, such that the group velocity dispersion is zero and that the propagation loss is very low). Both these properties can be fine tuned by the appropriate post-processing which will be done in the cleanroom of Ghent University.
Secondly, after fabrication, these chips will be characterized both in the classical regime and in the quantum regime where photon pairs are produced.
Third this novel source of frequency bin entangled photons will be evaluated using the experimental setup at ULB. The quality of the source will be measured by the violation of a Bell inequality.
Location:
Technicum, ULB (Universite libre de Bruxelles)
Opmerkingen:
This project will be jointly supervised by promoters at UGhent and ULB, and the work will be carried out in the laboratories of both institutions.

11773: On-chip CARS sensing based on supercontinuum generation

Promotor(s): Roel Baets, Günther Roelkens

Supervisor(s): Haolan Zhao, Bart Kuyken

Contactperson: Haolan Zhao

Background:
Spectroscopic techniques are a valuable technique in determine the presence and concentration of contaminants in substances. The use of free space optical components make traditional spectroscopic techniques very complex, hard to maintain and as such very expensive. Although these techniques could be used in a various set of applications the use of free space expensive optical components limits their use to a lab environment. Recent development of microphotonics facilitates the miniaturization of spectroscopic equipment, however reducing the price and increasing sensitivity and then enabling the realization of portable, super-sensitive sensor. Especially sensors fabricated with silicon nitride technology on a silicon in a CMOS fab allows for cheap sensors with high performance.

Coherent Anti-Stokes Raman spectroscopy (CARS), as a spectroscopic sensing technique, attracts increased attention. CARS is fundamentally a nonlinear process with two source beating at the frequency of vibrational modes. By sweeping the wavelength of one source one can obtain the full information of vibrational modes. It is currently adopted for gas sensing, bio-imaging and explosive detection. Its requirement of a tunable laser is prohibitive for further miniaturization and cost reduction. To replace a tunable laser, one can generate a coherent white-light coined supercontinuum (SC).

Aim:
During this thesis, the student is supposed to understand the physical process of CARS and SC generation and build a setup for a CARS experiment. The work is split into three stages. In the first stage, the student will familiarize himself with home-made simulation software and determine the scheme for SC generation and CARS.
Next the student will be guided to build a setup for a CARS experiment and perform benchmark experiments on bulk materials with known Raman peaks. Based on the simulation result, the student should be able to generate two sources, one SC as a probe and one narrow band source as a pump.In the final stage the student will perform CARS on integrated silicon nitride waveguides designed.
Location:
Technicum

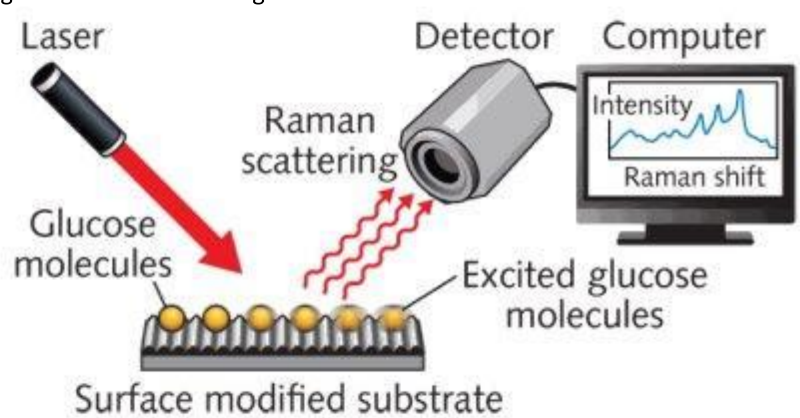
11794: On-chip Raman spectrometer for glucose sensing using silicon nitride photonic integrated circuits

Promotor(s): Roel Baets, Ananth Subramanian

Supervisor(s): Ashim Dhakal

Contactperson: Ashim Dhakal

Background:
Raman spectroscopy is a technique to identify and analyze the presence and composition of a material by probing the mechanical vibration of molecules using laser beam and detecting the inelastic scattering of light (shift in the optical frequency) induced by the vibrating molecules. The resulting vibration spectrum forms a fingerprint that allows identifying the molecules. Therefore, Raman spectroscopy is a very important technique in the context of biology, healthcare and chemistry. Raman spectroscopy is usually done with bulky and expensive equipment but there has been a surge of interest in the miniaturization of Raman spectroscopy using lab-on-a-chip approach. The mature CMOS fabrication technologies has allowed integration of different functionalities on a single photonic chip . Our group [1] has recently demonstrated glucose monitoring based on absorption spectroscopy at infrared wavelengths on a Silicon-On-Insulator (SOI) platform. However, the very weak absorption of glucose in the presence of water renders glucose sensing and monitoring an extremely challenging task in Such systems. One way to counter this challenge is to use the specificity of the Raman sensing rather than absorption for the accurate glucose level monitoring.



Aim:
In this project, the student will work towards a glucose sensor on a silicon nitride waveguide chip using Raman spectroscopy in the visible-near infrared spectral region (pump at 785 nm). Towards this end, we have already

demonstrated [2] Raman spectroscopy on low-loss silicon nitride technology [3] using Rhodamine dye. The student will first evaluate and explore Raman emission from glucose and determining the characteristic Raman lines of glucose with respect to the background emission from the host liquid. In this study, first a commercial Raman microscope will be used and the knowledge gained will then be applied to the waveguide-based sensing as done in [2]. The sensing principle is to measure the strength of Raman emission when probed by a pump laser (eg, 785 nm), at the characteristic Raman wavelengths that are specifically emitted by glucose. The power of Raman emission is proportional to the concentration of the glucose molecules, thus directly giving information about the glucose concentration. The project will focus on enhancing the useful collected Raman signals through different photonics structures such as slot waveguides and ring resonators. The Raman experiments with spiral waveguides would allow determining the most suitable Raman peaks for monitoring glucose and identifying the required design parameters for the ring resonator-based sensor. This project Involves optical measurements, design work and simulations using in-house and commercial tools.

References

[1] R. Baets et al. "Spectroscopy-on-chip applications of silicon photonics," Photonics West (invited), United States, (2013).

[2] A. Subramanian et al. IEEE Photonics Journal, 5(6), p.2202809 (2013)

[3] A. Dhakal et al. "Raman spectroscopy with excitation and collection by silicon nitride photonic wire waveguides," submitted for publication in CLEO US, United States, (submitted).

Location:

Technicum

Website:

More info: http://photonics.intec.ugent.be/research/topics.asp?areaID=26

11806: On-Chip Ultrafast all-optical switching using hot carrier intraband absorption in lead-chalcogenide nanocrystals

Promotor(s): Zeger Hens, Dries Van Thourhout

Supervisor(s): Geert Morthier, Pieter Geiregat

Background:

Colloidal nanocrystals are nanometer sized crystals of classic semiconductor materials (CdS,PbS, ZnS, …) obtained through a solution based hot-injection synthesis1. As zero-dimensional materials ('quantum dot' sopposed to e.g. quantum wells (2D) or quantum wires (1D)), they are at the extremes of what nanotechnology has to offer: novel physical properties intimitately related to their size, shape and internal structure which are not found in their bulk counterparts.

In the Physics and Chemistry of Nanostructures (PCN, www.nano.ugent.be) group (Faculty of Science, Prof. Hens & Prof. Brainis), we synthesize such nanocrystals not only to study the fundamental (photo-) physics of these extreme materials but even more for a variety of opto-electronic applications (such as integrated photonics (wavelength conversion, photodetection, integrated light sources and modulators), LEDs, solar cells, etc. … The latter is achieved through collaboration with the Photonics Research Group (www.photonics.intec.ugent.be, Prof. Van Thourhout) where we combine the quantum dots with the SOI (silicon-on-insulator) platform to realize more power-efficient and functional chips for integrated photonics with applications in light detection, generation and modulation2–4. Recently, a new ultrafast optical setup was acquired, allowing us to study and finally use the ultrafast dynamics present in (and mostly unique to) these quantum dots.

One of these properties is 'intra-band absorption'5. Opposed to inter-band absorption, where an electron is promoted from the valence to the conduction band by photon absorption, intra-band absorption relies on the absorption of light by conduction band electrons to higher energy levels. As such, intraband absorption requires the nanocrystals to be excited before the intraband event can take place. Since the presence of an electron in higher energy states is not favourable due to a large amount of excess energy, it will cool very fast to the lowest possible energy states. This fast cooling (typicall 1 to 2 picoseconds) allows us to modulate light based on this intraband absorption as the interaction of light with electrons in different energy levels (higher up in the conduction band or at the edge of the band gap) is distinctly different. As such, we could envisage a device where using only light beams, information is transferred from one pump beam creating the ‘hot’ electrons to a target beam which is modulated by the intraband absorption caused by the ‘hot’ electrons. We have shown this effect in solution on colloidal PbS nanocrystals, where high exctinction ratios (up to 10 dB) and ultrafast dynamics (1-2 ps) were demonstrated, a combination not easily achieved using other approaches (graphene, epitaxial materials, four-wave mixing, Kerr effect, …) which typically suffer from higher energy thresholds or the need for long interaction lengths (limiting power-efficienycy and dense on-chip integration respectively).

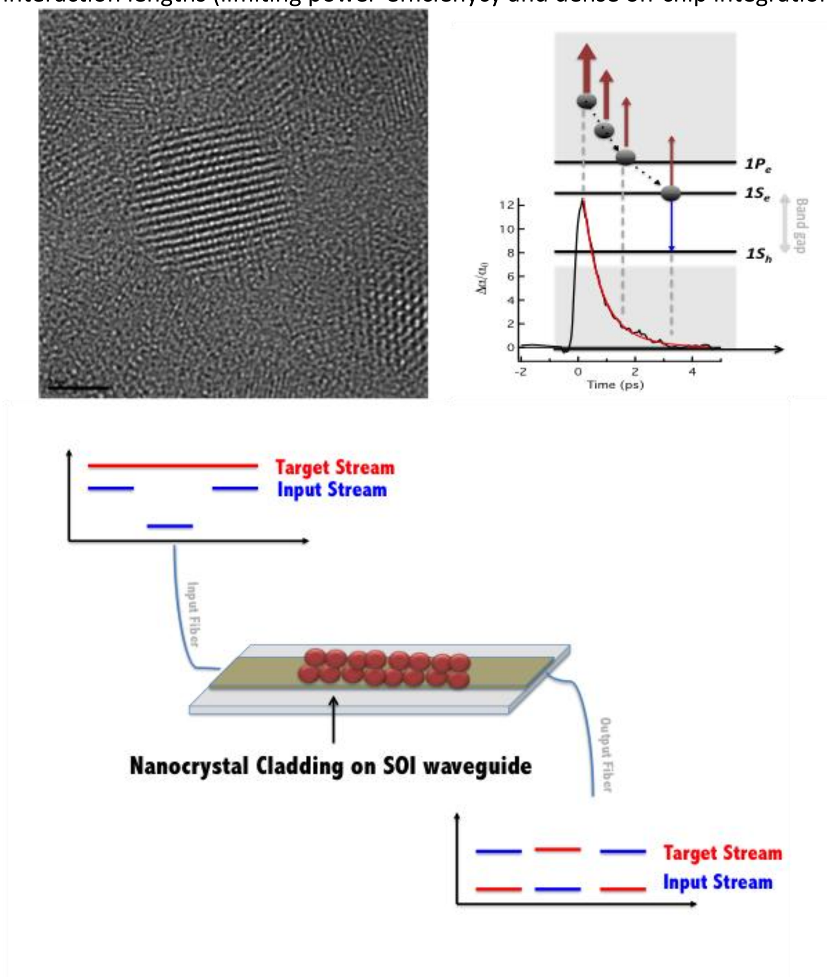


Fig. 1: (top,left) Transmission Electron Microscope image of a 5 nm CdSe/ZnS nanocrystal. Note that you can see the individual atoms making up the crystal ! (top,right) Schematic of intraband absorption of hot electrons cooling to the conduction band edge on a picosecond timescale. (Bottom) Cartoon of all-optical wavelength converter based on nanocrystal clad SOI waveguide with input/output fibers and two streams (Target and Input)

Aim:

The goal of this thesis is to further study the physics of this intraband absorption using the ultrafast optical setup now available in Ghent. Next, we will combine the nanocrystals with silicon photonics attempting to make an integrated all-optical wavelength converter active in the near-infrared part of the spectrum.

As such, this thesis will take you from the fundamental ultrafast photophysics of zero-dimensional colloidal nanocrystals to a real-life integrated photonic device with the potential of usage in future all-optical networks required for more power efficient and functional datacommunication ! You will work with synthesize colloidal nanocrystals (PCN), work with ultrafast optical setups (femtosecond pulses), fabricate devices in the INTEC cleanrooms and characterize them using state-of-the-art signal generation/evaluation tools (INTEC-Photonics labs).

References:
1. Yin, Y. & Alivisatos, P. Colloidal nanocrystal synthesis and the organic-inorganic interface. *Nature* 437, 664–70 (2005).
2. Moreels, I., De Geyter, B., Van Thourhout, D. & Hens, Z. Transmission of a quantum-dot-silicon-on-insulator hybrid notch filter. *J. Opt. Soc. Am. B* 26, 1243 (2009).
3. De Geyter, B. *et al.* From fabrication to mode mapping in silicon nitride microdisks with embedded colloidal quantum dots. *Appl. Phys. Lett.* 101, 161101 (2012).
4. Omari, A., Geiregat, P., Van Thourhout, D. & Hens, Z. Light absorption in hybrid silicon-on-insulator/quantum dot waveguides. *Opt. Express* 21, 23272 (2013).
5. De Geyter, B. *et al.* Broadband and picosecond intraband absorption in lead-based colloidal quantum dots. *ACS Nano* 6, 6067–74 (2012).

Location:

11097: Optical Reservoir Computing for Cell Sorting Applications

Promotor(s): Peter Bienstman, Joni Dambre

Supervisor(s): Bendix Schneider

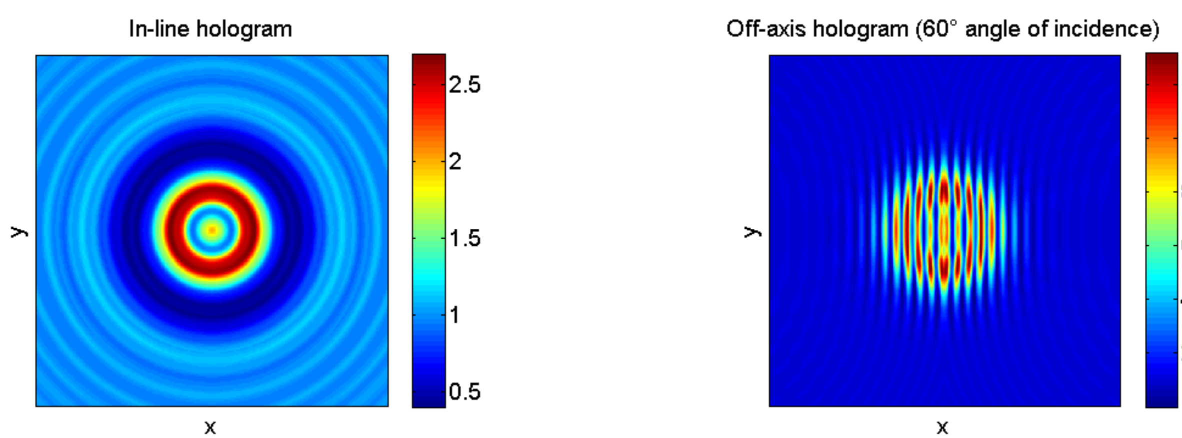
Background:

Reservoir computing is an efficient machine learning technique that can be seen as the spiritual successor to neural networks. Although these techniques started out in software, in the photonics group we have been working for a few years now on an optical implementation of this technique, because it offers the prospect of higher speed and lower power consumption.

In this thesis, we want to apply this concept to the task of automated sorting of blood cells and determining e.g. whether they are cancerous or not. This is a task at the interface between photonics, machine learning, and cell biology.

Traditional cell sorting techniques employ adding a fluorescent dye to the cell in order to determine the properties of the cell. Although the existing techniques are high-throughput, they are invasive, and can lead to cell death which prohibits the study of cell proliferation afterwards. However, often it is advantageous to study live cells, which is not possible with this technique.

A recent alternative is the so-called "digital holographic imaging", which records the interference pattern (see fig.) between the light scattered by the cells and a reference beam. Based on this pattern, Maxwell equations are solved in reverse using a complex image reconstruction algorithm. However, this is extremely time-consuming and is not suited to real-time cell sorting.



Recorded holograms (intensity distribution) at the image plane at 20 um distance from the cell center
The cell is modeled as two concentric spheres of different refractive index

In our group we investigate the possibility to extract features, with the help of an optical reservoir, directly from the holographic image which allow for a correct cell classification at high speeds and lower consumption.

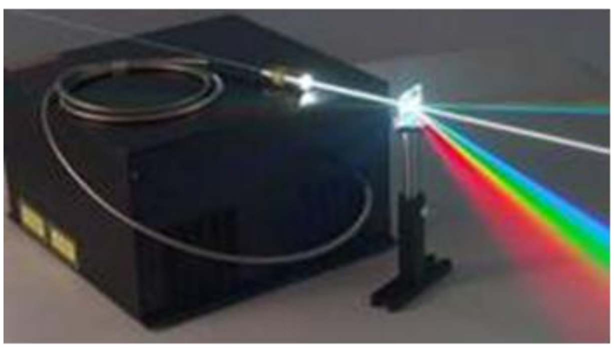
Aim:
Your contribution consists in simulating diffraction patterns of more complex cell structures in order to construct a sound training set. You have to investigate numerically which type of photonic reservoir is best suited to do classification, which are the most important features and how to extract them efficiently in a photonic structure.
You will also help in building a first experimental set-up, where instead of cells, patterns generated by spatial light modulators are used to validate the concept.
Location:

11770: Optimization and control of the properties of supercontinuum generation in topographic silicon nanowire

Promotor(s): Bart Kuyken, dhr. Simon-Pierre Gorza [université libre de bruxelles]

Contactperson: Bart Kuyken

Background:
Extreme spectral broadening that occurs when narrowband input pulses propagate in nonlinear optical media is known as supercontinuum (SC) generation [1]. Recently, we have demonstrated the generation of supercontinuums in silicon nanowires broader that previously reported results [2]. Our results also show an excellent agreement between theory and experiment. Owing to the potential applications of SC generated in integrated devices, the control of some properties of the SC through the optimization of the longitudinal profile of the waveguide is now an important issue. Such a control has recently be successfully applied to the control of the self-frequency shift of soliton in the context of propagation in photonic crystal fibers [3].



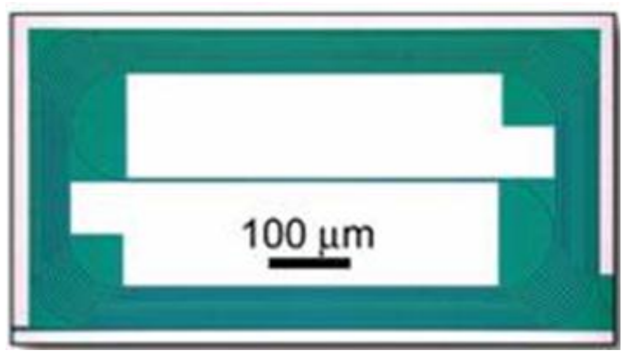


Figure 1: The white light generated coming from a supercontinuum source is shown on the left. The right picture shows a tiny silicon waveguide wrapped in a tiny coil on a chip .

Aim:
The master thesis objective is to identify which properties of the SC can be controlled through the use of an optimized longitudinal profile shape; in which extend as well as how sensitive the optimized SC is to the variability of the parameters encountered in real silicon nano-waveguides. Promising structures will then be realized and an experimental validation of the method will be conducted.

REFERENCES

[1] J. M. Dudley, G. Genty, and S. Coen, Rev. Mod. Phys. 78, 1135 (2006).
[2] A. Bendahmane, O. Vanvincq, A. Mussot, and A. Kudlinski, "Control of the soliton self-frequency shift dynamics using topographic optical fibers", Opt. Lett 38, 3390 (2013)

11278: Photonic biosensing with the Vernier-cascade and on-chip spectral filter

Promotor(s): Peter Bienstman

Supervisor(s): Daan Martens

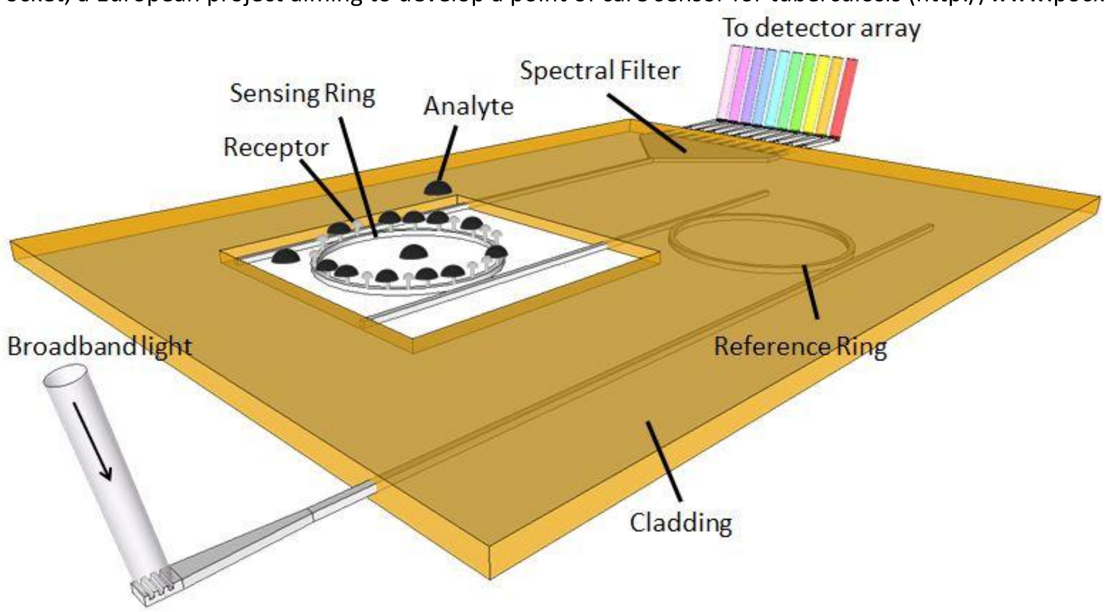
Contactperson: Daan Martens

Background:

On-chip photonic biosensors are very promising due to their sensitivity, versatility and cheap disposable part. The working principle of these sensors is as follows: When a molecule of interest binds to a waveguide, it causes a change in effective index due to interaction with the evanescent field of the waveguide mode. This change in effective index in turn causes a shift in the peak wavelength of a transducer, like the ring resonator. By tracking this wavelength shift in function of time, the presence, quantity or even the configuration of the biomolecules can be detected. The potential application of these sensors has so far been limited by the necessity of a tunable laser, resulting in high instrumentation costs.

Aim:

These high costs can be avoided by instead using a broadband light source in combination with an on-chip spectral filter, like the arrayed waveguide grating (AWG). Two types of transducer can be used in this type of application, the Mach-Zehnder Interferometer (MZI) and the Vernier-cascade sensor. In case of the former, one of the arms is exposed to the analyte, while the other is isolated from it. The latter consists of 2 ring resonators, with the drop port of the first one connected to the input of the second one. Similar to the MZI one ring needs to be exposed to the analyte while the other remains isolated from it. When used with only a broadband light source, the MZI outperforms the Vernier due to its easier spectrum shape and higher power transmission. In this way however, a lot of information present in the Vernier spectrum is discarded. The goal of this master thesis is to verify the effect of including a fixed wavelength laser to assess extra information on the spectrum of the Vernier sensor in order to improve its detection limit. This thesis will include simulation work as well as measurements. This work fits within Pocket, a European project aiming to develop a point of care sensor for tuberculosis (http://www.pocket-proj.eu/).



Location:

Technicum

Opmerkingen:

For more information, contact daan.martens@intec.ugent.be

10823: Plasmonic nano-antennas for on-chip Raman spectroscopy

Promotor(s): Nicolas Le Thomas, Björn Maes

Supervisor(s): Frédéric Peyskens

Contactperson: Frédéric Peyskens

Background:

Identifying and quantifying bio-molecules with light is foreseen to have a major impact on future medical diagnostics methodology and healthcare in general. Among the different possible optical techniques, Raman spectroscopy is one of the most promising in terms of molecular specificity. However, the inherently weak Raman scattered signal makes the analysis of single molecules or single nano-objects extremely difficult and cumbersome, despite the fact that strategies such as surface-enhanced Raman spectroscopy (SERS) have been developed to dramatically enhance the signal to noise ratio. In the Photonic Research Group (PRG) we are exploring a new route for Raman spectroscopy that is based on silicon photonics and that takes advantage of on-chip signal processing.

Aim:

The proposed master thesis project aims at investigating novel designs of metallic nanostructures that are coupled to integrated silicon nitride channel waveguides. The role of the metallic nanostructures, also called nano-antennas, is to enhance the optical field at the position of the molecule. The main target of the design and simulation methodology is to maximize both the optical field at a nano-antenna and the collection of the Raman scattering into the waveguide.

The numerical simulations will be carried out with software such as Lumerical and Comsol, in collaboration with the University of Mons that has a strong expertise in the theoretical study of plasmonic structures. The best designs will be fabricated and then characterized at PRG.

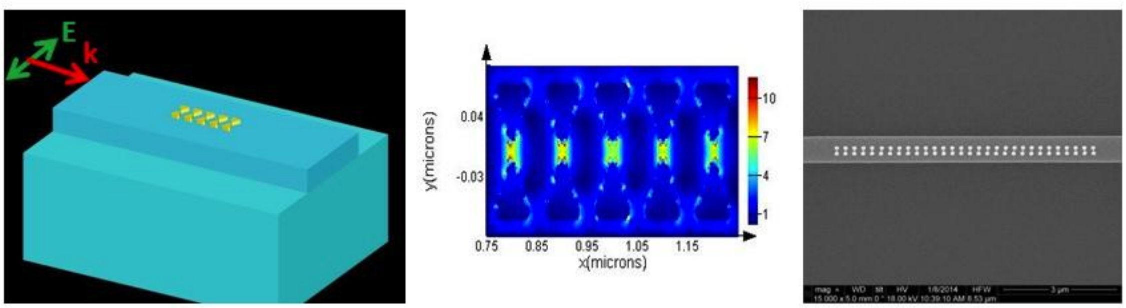


Fig.1: Typical example of several nano-antennas coupled to a channel waveguide

Website:

More info: photonics.intec.ugent.be/default.htm

11823: Simulation and optimization of large scale integrated optics switching fabrics

Promotor(s): Dries Van Thourhout, Wim Bogaerts

Supervisor(s): Martin Fiers

Background:

Large scale switches are becoming ever more important in todays telecom and datacom networks. Today these are fabricated based on MEMS switching devices. The size of these devices, however, is large and they are prone to mechanical vibrations. Therefore there is an increasing interest from network system providers and operators in using integrated optics based switch networks. In the context of a European project (SWIFT) and in collaboration with several European industrial players we are currently developing a novel integrated switch with much lower power consumption than currently existing devices. Our current focus is on the individual building block (a 2 x 2 switch) but ultimately these have to be interconnected into a very large switch fabric, accommodating up to 300 input and 300 output channels – and hence combining 90000 individual switches in a suitable matrix form. Predicting the performance of such large networks before actually fabricating them is essential but not possible using standard methods.

Aim:
The objective of this project is to develop an simulation and optimization framework for large scale switching fabrics. You will thereby make use of a new circuit-level modelling tool (CAPHE), which was developed in the group and extend it such that it can predict the performance of the switching fabric over a wide wavelength range. Important performance metrics for the switch fabric are the crosstalk between the channels, the loss, back reflections … all as function of wavelength. The individual building block can be optimized towards a certain optimized state (e.g. lowest loss when in bar-state) hence a smart design strategy will need to be developed, which optimizes the global switch fabric performance in function of the individual switch characteristics. Finally, automatic layouting algorithms need to be developed, which translate a given circuit level design in a practical device, with optimized floor plan.
Location:
technicum

11807: Solar powered optical sources

Promotor(s): Günther Roelkens, Roel Baets
Supervisor(s): Andreas De Groote, Sulakshna Kumari
Contactperson: Andreas De Groote

Background:
Sunlight is a constant source of energy and nowadays many efforts are being done to capture this efficiently. These efforts range from a green roof to highly advanced solar cells, but all are confronted with the 'harsh' nature of sunlight. It is very broadband, covering the wavelength range of 300nm to 800nm, making it difficult to find materials that have a good efficiency at all portions of the spectrum. Because of the many diffuse reflections it can also propagate in all directions. This spatially incoherence increases the complexity of the system even further. In this Master's thesis we aim to convert the spatially incoherent and broadband sunlight to a more focused light source, making it easier to work with.

Aim:
We propose an optically pumped LED. The device will look as follows: On top of a silicon waveguide we bond a GaAs membrane, containing quantum wells emitting at 1300nm. The GaAs membrane is illuminated from the top (by sunlight), carriers are created in the quantum wells which then relax, emitting a photon at 1300nm. The dominant process will be spontaneous emission. The generated light is then coupled to a silicon waveguide.
This Master's thesis aims to simulate and design an optically pumped LED on GaAs on silicon waveguides. Since the coupling factor of the spontaneous emission to the fundamental waveguide mode is directly related to the output power and thus efficiency, the optimization of this parameter is of key importance. Depending on the expected efficiency, the sources can be fabricated and experimentally characterized.
Location:
Technicum

10793: Study and optimisation of parasitic elements in heterogeneously integrated laser diodes

Promotor(s): Geert Morthier, Günther Roelkens

Supervisor(s): Amin Abbasi

Contactperson: Amin Abbasi

Background:

The Photonics Research Group of the INTEC department has started work on heterogeneously integrated laser diodes (with an InP membrane on top of silicon waveguides) for very high speed (>40Gb/s) modulation. This requires a specific design of the laser cavity (wtih e.g. a short external cavity), but it also requires that the parasitic elements (capacitance, series resistance) are small enough to ensure good current injection up to very high frequencies. The values of these parasitic elements are typically extracted by fitting the measured S-parameter curves, which themselves are obtained using a network analyser.

Several heterogeneously integrated lasers have already been fabricated within the group and more will be fabricated in the future. The parasitic elements of these structures and of commercial laser diode chips will be determined and compared to obtain the best possible design for the laser cross section.

Aim:

The work will involve measurements and fitting of the measurement results to compare the parasitic elements of different laser diode structures. Numerical modelling using commercial software will be employed to design optimised cross sections with minimum parasitics and good current injection up to high frequencies.

If time allows, this work can be extended with the characterisation of the intrinsic modulation response of the laser diodes, through the measurement of the RIN spectrum.

The student is expected to learn more about the high frequency characterisation and modelling tools and about characterisation of active photonic chips (including fiber coupling, probing, ...).

Location:

Technicum

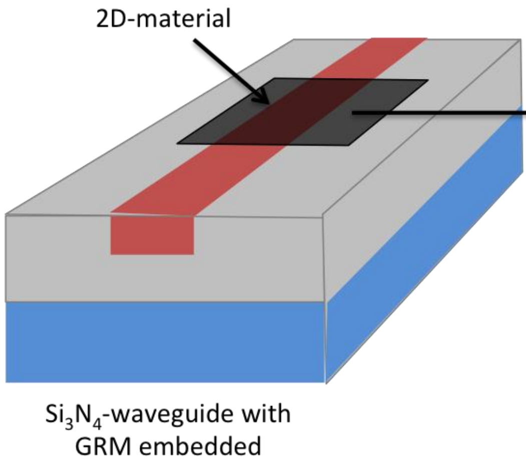
11828: Study of optical properties of novel 2D-materials in a hybrid waveguide configuration

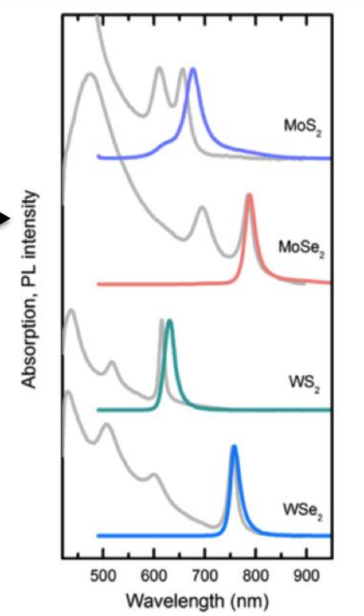
Promotor(s): Dries Van Thourhout, Bart Kuyken

Supervisor(s): Weiqiang Xie

Background:

Recently the successes in graphene research stimulated renewed research in other 2D materials and in particular in those formed from transition metal dichalcogenides (TMDs). As explained by Eda and Maier [1], these materials were already intensively studied in the 1960s but are now revisited with renewed interest, taking inspiration from graphene research. In particular MoS_2, $MoSe_2$, WS_2 and WSe_2 have attracted a lot of interest. As bulk crystals these materials exhibit an indirect bandgap but when the number of layers is reduced the indirect bandgap shifts in energy and the material becomes a direct band gap material with a bandgap in the visible wavelength range (see figure). Monolayers of these materials have shown a clear photoluminescence signal. Also the non-linear optical properties were investigated intensively in the last years. However, these planar materials have so far mostly been characterized by probing them with a beam in free space, such that the interaction between light and material is happening in one atomic layer only. This strongly limits the strength of the interaction and makes it challenging to accurately determine the relevant parameters.





Aim:

To enhance the interaction between the 2D-materials discussed above and the probe beam, we propose to test these materials in a guided wave structure whereby the materials are deposited on top of a nanophotonic waveguide. By injecting a probe beam through the waveguide and measuring its interaction with the 2D-material (absorption, non-linear phase shift, photoluminescence) the properties of the 2D-material can be derived. You will use a silicon-nitride based waveguide platform developed within the photonics research group as a starting point (silicon-nitride is advantageous because of its relatively high index contrast while being transparent from the visible to the mid IR). The 2D-materials will be deposited in collaboration with our partner group at imec (Leuven). You will be involved in developing this deposition process which consists in exfoliating the 2D-materials from a bulk crystal. Next you will characterise the structures, first through measuring its static transmission, next using more advanced pump-probe techniques to define the non-linear properties of the hybrid waveguide structure. By linking the measurements to detailed simulation results the fundamental material properties can then be derived.

[1] G. Eda and S. A. Maier, "Two-Dimensional Crystals: Managing Light for Optoelectronics," *ACS nano,* vol. 7, no. 7, pp. 5660-5665, 2013.

Location:

technicum, imec(Leuven)

11768: Subwavelength Nanopatch Cavities with Colloidal Nanocrystals for Electrically Driven Single Photon Sources

Promotor(s): Dries Van Thourhout, Zeger Hens

Supervisor(s): Pieter Geiregat, Edouard Brainis

Contactperson: Pieter Geiregat

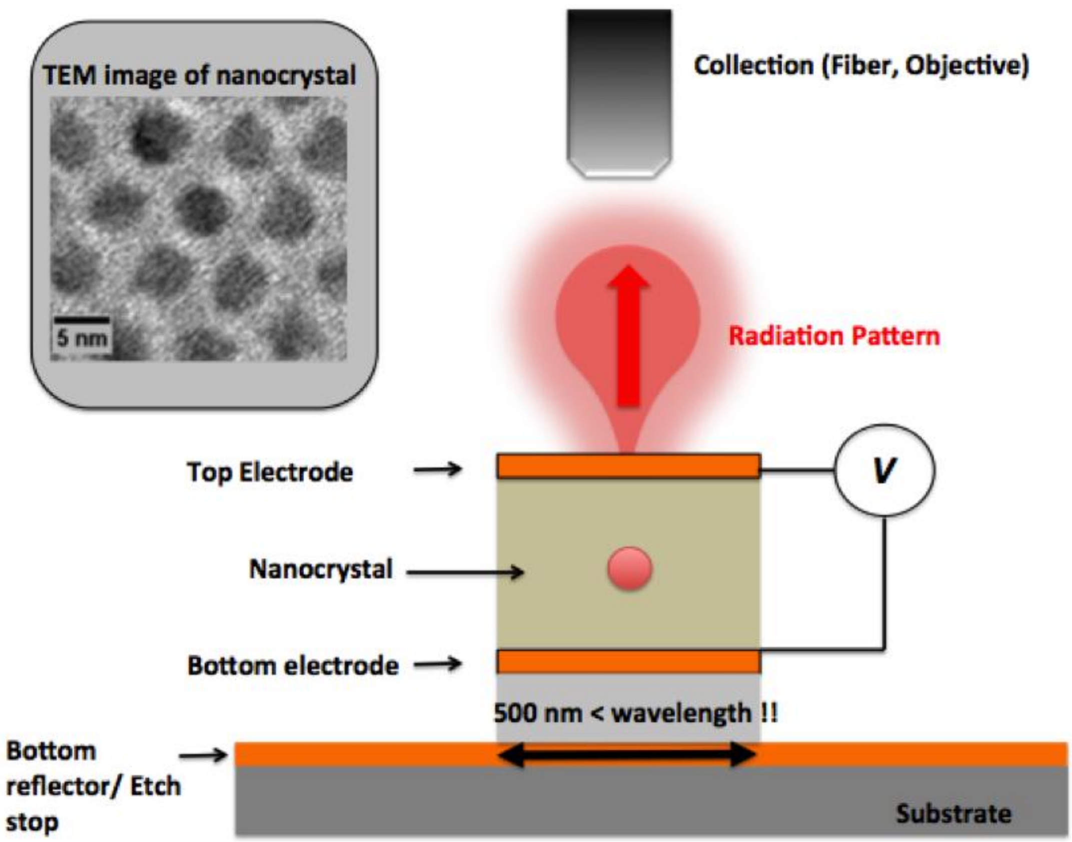
Background:

Single photon sources are a crucial component in next-generation optical communication, quantum computing and metrology. Recently, researchers have shown high detection efficiency for fiber based collection of single near-infrared photons. If a cheap and high-density integrated single photon source, easily interfaceable with an optical fibre, were available at room temperature, the use of quantum optics in modern telecommunication would be only a few steps away.

The on-demand generation of such single quantum states requires both an emitter capable of producing single photons and a means of driving the emitter (e.g. through optical pumping or electrical injection). We propose to use colloidal nanocrystals (or quantum dots), nanometer sized semiconductor crystals obtained through cheap wet chemical synthesis. These zero-dimensional materials are fabricated in the 'Physics and Chemistry of Nanostructures' group at the university of Ghent and have have shown single photon-emission from the visible down to the near-infrared (e.g. telecom) wavelengths. Moreover, their ease of fabrication (through wet chemical synthesis) and deposition (spincoating, dropcasting) makes them very suitable for cheap light sources.

The electrical injection is obtained through embedding the colloidal crystals in a aluminum oxide host, squeezing them between two metallic contacts.

We propose to use the need for electrical injection (through metallic contacts) to our advantage by using the metallic contacts as means to confine light in sub-wavelength dimensions. This concept is shown in figure 1. By using the plasmonic effect introduced by the metals, we can squeeze the light in a box less than half of its wavelength ! In this extreme confinement regime, new properties arise because of strong coupling of the emitter and the cavity.



Aim:

In this challenging thesis subject, you will model the cavity using commercial FDTD (Finite Difference Time Domain) software (Lumerical FDTD Solutions) to understand the physics of such high mode confinement. Next, you will fabricate the sub-wavelength plasmonic cavity yourself with the help of our experienced clean-room staff using e-beam lithography. Patterning the colloidal crystals on sub-wavelength scales and collecting their photoluminescence efficiently, will present a great challenge and possible extensions to current optical setups will be needed.

As such, the thesis provides both experimental (fabrication and characterization) and theoretical challenges with high impact output in a field that combines three of the most appreciated topics in nanoscience today: single photon sources, plasmonics and colloidal nanocrystals. Moreover, the topic is highly interdisciplinary stretching from nanophotonics, physics to even quantum optics and some basic chemistry.

References:

http://www.nature.com/nphoton/journal/v6/n5/full/nphoton.2012.75.html
http://www.nature.com/nphoton/journal/v7/n3/full/nphoton.2013.13.html
http://www.nature.com/nature/journal/v437/n7059/abs/nature04165.html
http://pubs.acs.org/doi/abs/10.1021/nl2013983

Location:

Technicum / De Sterre

Website:

More info: nano.ugent.be

11270: Surface grating couplers for a polymer waveguide platform

Promotor(s): Geert Morthier

Supervisor(s): Rodica Moraresc u

Contactperson: Rodica Morarescu

Background:

The Photonics Research Group of the INTEC department does research on a.o. optical biosensors based on polymer waveguide ring resonators. Coupling light in an out of these chips can either be through butt-coupling or using surface grating couplers. This last solution has a number of advantages, such as easy coupling with high efficiency and is better suited for arrays of biosensors. While such grating couplers have been very well developed for the silicon waveguide platform and first studies have been done for the polymer waveguide platform, further research and development is necessary for the polymer waveguides. Efficient grating couplers have been demontrated just for inverted rib waveguides, but these are not very suitable for optical biosensing. Rib waveguides (i.e. not inverted) are really required for biosensing and it is for such waveguides that the grating couplers must be developed.

Aim:

The master thesis will consist of designing, fabricating and finally measuring and characterising new surface grating couplers for rib waveguides. For the design, modelling using our in-house CAMFR or a commercial FDTD modelling tool will have to be done extensively. If a good grating structure is obtained from the modelling, a mask layout will have to made for the lithographical steps required in the fabrication. Fabrication will be discussed together with the supervisor and the promotor. Most of it will be done using nano-imprint lithography. However, due to the low refractive index of the polymer, it will probably be necessary to cover the gratings with silicon nitride using PECVD. Finally, the efficiency and wavelength dependence of the grating couplers will have to be measured using a vertical coupling set-up, a tunable laser and a power meter.

Location:

Technicum, Cleanroom Zwijnaarde

11800: Thresholdless Optical Gain using Colloidal HgTe Nanocrystals: a Platform for Low Power Integrated Photonics

Promotor(s): Dries Van Thourhout, Zeger Hens

Supervisor(s): Arjan Houtepen, Pieter Geiregat

Background:
Colloidal quantum dots (QDs) are nanometer sized crystals of semiconductor materials (HgTe,CdS, …) obtained through wet chemical synthesis. As zero-dimensional materials ('quantum dot' sopposed to e.g. quantum wells (2D) or quantum wires (1D)), they are at the extremes of what nanotechnology has to offer: novel physical properties intimitately related to their size, shape and internal structure which are not found in their bulk counterparts. However, in spite of these possibilities, the use of these QDs as tunable and solution-processable gain media for optical amplifiers or lasers is still elusive. Even after 15 years of intense research, gain thresholds remain too high and gain lifetimes too short for practical purposes. These properties are intrinsically linked to the QDs being effective 2-level systems, where the emitting transition is countered by absorption. Recently, we have shown that HgTe QDs exhibit size-tunable stimulated emission throughout the infrared telecom window at a threshold 2 orders of magnitude lower than ever reported for QDs. We demonstrate that stimulated emission involves a high oscillator strength transition to a gap state, making HgTe QDs a nearly thresholdless effective 3-level system. The combination of gain coefficient, threshold and lifetime of HgTe QDs meet the requirements for DC electrical pumping !

Aim:
The goal of this thesis is to explore the potential of HgTe as a colloidal gain medium for future integrated photonics. A first step will be to transfer the properties of solution dispersed colloidal HgTe nanocrystals to a solid film, compatible with classic CMOS processing and the silicon-on-insulator platform. A second step will be the realization of optically pumped feedback structures (VCSEL type cavities, DFB structures, ring resonators, …) which will be designed specifically to meet the requirements of a solution-processable gain medium (HgTe quantum dots).

As such, the thesis will focus on simulation, design and fabrication of a variety of optical feedback structures and the characterization of the latter using state-of-the-art ultrafast optical setups and spectroscopy. For the fabrication, some cleanroom work will be required which will take place in the INTEC cleanrooms in Zwijnaarde. The work is a close collaboration between the Physics and Chemistry of Nanostructures group (PCN, www.nano.ugent.be, Prof. Hens & Brainis) where the QDs are synthesized and characterized and the Photonics Research Group (www.photonics.intec.ugent.be, Prof. Van Thourhout) where both simulation and characterization of the photonic structures will take place. It is situated in two European research projects (FP7 Navolchi and ERC-ULPICC).
Location:
Technicum, De Sterre, Ardoyen

11818: Tunable on-chip optomechanical resonator

Promotor(s): Bart Kuyken, Dries Van Thourhout

Supervisor(s): Paul Tiebot, Jesper Håkansson

Background:
The field of cavity optomechanics, covering the interaction between optical and mechanical cavities, has been receiving a lot of attention during the last few years. It has evolved a lot from the pioneering work in the 1970s by Arthur Ashkin where laser trapping of dielectric particles was demonstrated. The work, which serves as the basis for laser cooling in optomechanics was awarded the Nobel Prize in physics 1997.
The Photonic Research Group in Gent has managed to demonstrate the optical gradient force between two coupled waveguides. We are interested in coupling several mechanical resonators in this project. To realize such a scheme, we need to be able to accurately and individually tune these resonators.
Coupling optomechanical cavities or networks would enable both fascinating physics and novel technological applications. An example would be entangled photon generation, usable in quantum cryptography, self-synchronization process with application in high accuracy time measure.

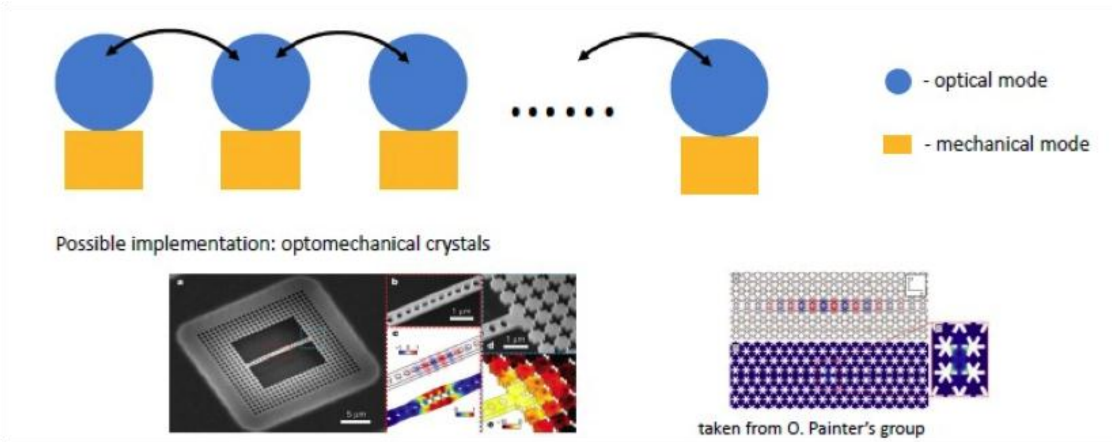
Aim:

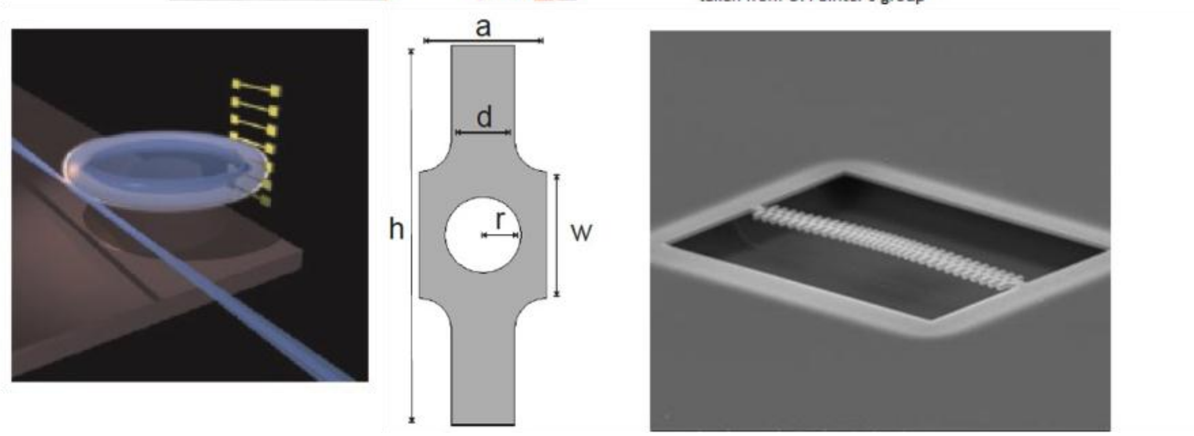
The work will consist of three main parts:

First it will be necessary to compare different approaches, i.e. electrical modification of the effective stiffness or selective laser ablation in order to change the effective mass. These processes will have to be modeled, using Multiphysics modeling software to evaluate the impact on both the mechanical and optical properties of the cavity.

Secondly, you will carry out these processes in our clean room facilities.

Finally you will evaluate this novel tunable optomechanics cavity in a high vacuum chamber in the measurement labs of the photonics research group.





Location:

techicum, technologiepark

Website:

More info: photonics.intec.ugent.be