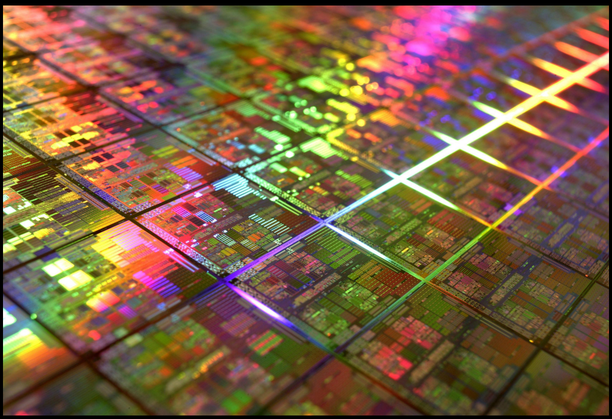
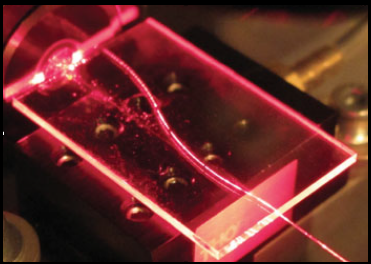
Astro-photonics: Moulding the flow of starlight



SUMMARY:
State of the art photonic technologies can control, route, and manipulate light at microscopic scales with unprecedented precision. This new technology has been used to great effect to revolutionise broadband telecommunication networks, develop non-invasive bio-medical sensing, and even used to create quantum-computing chips. Now this powerful tool is becoming an integral part of astronomical instrumentation, providing functionality not previously possible with traditional optics. From simple fiber-optics to advanced on-chip light circuits, this course will provide theory and hands-on experience with the future of astronomical instrumentation.

OBJECTIVES

- Students taking the Astrophotonics METEOR will become competent in a wide range of photonic technologies that are currently used in astronomy. These include standard photonic devices such as optical fibres, optical waveguides, lasers, laser frequency combs, and photonic crystals, as well as more complicated devices designed for astronomical use such as photonic lanterns, pupil remappers, and on-chip interferometers. They will also become familiar with the unique ways these devices are integrated into astronomical instrumentation.



Photonic technologies bend and manipulate light on fundemental scales.

- In addition to learning about the theory of photonic devices and astronomical instrumentation, students will gain hands-on experience in the KERNEL-laboratory working with advanced interferometric photonic chips. They will gain real-world experience working with lasers, deformable mirrors, optical fibres, spectrographs, integrated waveguide circuitry, and on-chip thermo-optic modulation.

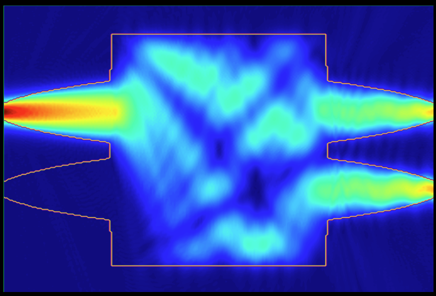
PREREQUISITES

General Astrophysics, Fourier optics

THEORY

by Nick Cvetojevic & Frantz Martinache

When light is focused and confined in a small area, and begins to interact with materials on microscopic scales, a different language of electro-magnetism needs to be used to better understand what is happening. The framework of light rays used to explain traditional optics (lenses/mirrors), gives way to discussing 'mode-structure' and 'photonic band-gaps' at these scales. For modern state-of-the-art astronomical instrumentation, understanding this theoretical background is becoming critical.



At microscopic scales the modal nature of light propagation becomes important.

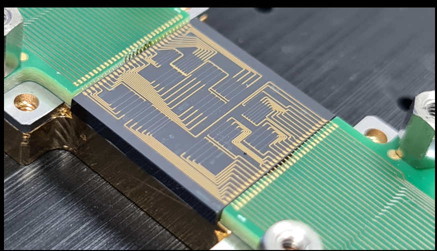
As part of this course, students will get an introduction to the underlying theoretical framework that underpins the microscopic guiding of light, including waveguiding theory, mode theory, and photonic structures. In addition, we will cover the creation and manipulation of coherent sources, including laser fundamentals and non-linear optics, from an astronomical instrumentation perspective.

Building on this, students will get an overview of how these technologies are used in the context of state-of-the-art astronomical instrumentation. These include Multi-Object Wide-Field Spectrographs, Laser guide stars & Adaptive Optics, Laser frequency combs & high-resolution spectroscopy, High-angular resolution & long baseline interferometers.

While not exhaustive, this course will provide a high-level overview to the theory behind the operation of a wide array of photonic technologies used in astronomy.

APPLICATIONS

by Nick Cvetojevic



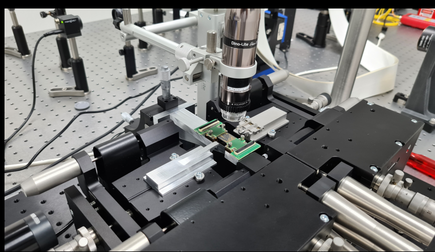
The Kernel Nulling photonic chip the students will characterize.

During the second-half of this course, students will take part in the characterization of a new astrophotonic device in the KERNEL laboratory.

This photonic-chip is a novel kind of interferometer, called a 'Kernel-Nuller', which enables high-contrast and high-resolution imaging of exoplanets. The chip contains photonic waveguides, beam-combiners, and thermo-optic phase controllers, whose properties must be measured before deployment on a telescope.

Students will use the photonic characterization bench to probe and measure the chip. They will learn how to operate lasers safely, the fundamentals of wavefront control, how to efficiently couple light into waveguides and fibers, and how to measure key properties of an astronomical interferometer. In addition, they will gain real-world experience operating high-precision multi axial alignment stages, a skill which is integral to working with photonic devices. Students will keep a comprehensive lab book to track their experiments and progress, and will learn how to analyse and present experimental data.

The laboratory characterization will culminate in an oral presentation by the students explaining the measured results.



The photonic characterisation setup.

MAIN PROGRESSION STEPS

For instance :

- First half of the period : theoretical courses
- First half of the period : Written exam
- Second half of the period : laboratory project
- Last week : preparation of the final oral presentation.

EVALUATION

- Written exam based on the lecture content(40%)
- Lab-book notes (20%)
- Oral presentation of the lab project(40%)

BIBLIOGRAPHY & RESSOURCES

KERNEL Project News
Astrophotonics Review Paper

CONTACT

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