NOVEMBER 2025

HOMTECH NEWSLETTER

Optical Fiber Higher Order mode Technologies: HOMTech

Project Objective

Optical fibres supporting propagation of light in so-called higher order modes (HOMs) have gained major research interest in the last years. However, there are still quite a few obstacles to overcome before HOM fibres can be used for major commercial applications.

In the HOMTech doctoral network, seven leading European universities, within the field of HOM fibres and their applications, join forces with one research institution, as well as three European industrial partners and a world leading industrial research lab in Japan with the aim to significantly progress the field of HOM fibres and their applications. Five European countries are represented. Ten doctoral candidates (DC) are working within the network.

HOMTech aims to bring European industry and academia to the forefront of HOM fibres and their applications.

Project Info

Call: HORIZON-MSCA-2021-DN-01

Type of Action: HORIZON-TMA-MSCA-DN

Start Date: 01 Oct 2022

Requested EU Contribution: €2,807,107.20

Project Coordinator: DTU

Duration: 48 months

This project has received funding from the European Union’s Horizon Europe Research and innovation Programme under the Marie Sklodowska-Curie Grant Agreement No. 101072409.

Meet the Consortium

5 Training Schools completed

TS1: OPTICAL FIBER SENSORS, UNIPD

TS2: SPATIAL DIVISION MULTIPLEXED OPTICAL COMUNICATION, TUE

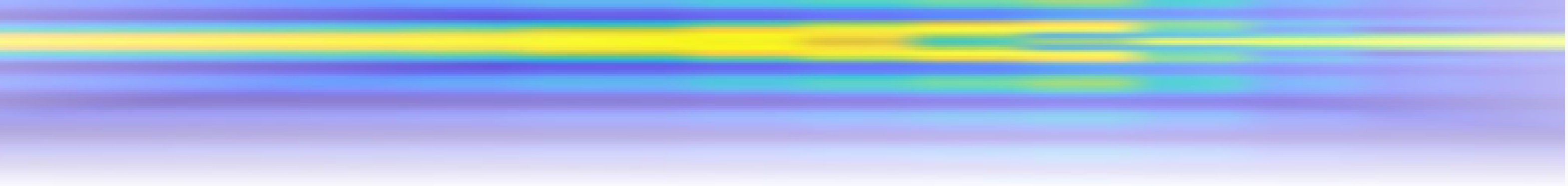
TS3: NONLINEAR OPTICS IN HOM FIBRES, CHALMERS

TS4: QUANTUM PHOTONICS, DTU

TS5: ENTREPRENEURSHIP AND INNOVATION, FAU

Meet the Doctoral Candidates

On the following pages, meet the 10 HOMTech Doctoral Candidates and hear about their exciting PhD projects and achievements thus far.



Rodrigo Silva

DC 1 - DTU
MODE CONVERSION OF QUANTUM STATE

The goal of my PhD project is to demonstrate single-photon generation in various nonlinear platforms, such as silicon waveguides and optical fibers, and to explore methods for manipulating the spatial mode of these photons. We have already achieved efficient single-photon generation in an amorphous silicon waveguide and successfully demonstrated spatial mode conversion of single photons propagating through an optical fiber. Direct applications of this work can be found in the fields of quantum communication, quantum computation, and quantum sensing.

Inaki Beraza

DC 2 - DTU
LP MODES FOR QUANTUM COMMUNICATION

My research focuses on exploring new ways to use light for secure communication. In particular, I have been working with special types of light patterns, called linearly polarized (LP) modes, to implement quantum key distribution (QKD), a technique that enables completely secure data exchange. We were the first to demonstrate that these LP modes can be successfully used for QKD. In addition, I am also investigating photon-pair generation sources that can produce entangled photons, which are essential for more advanced quantum technologies.

Manish Raj

DC 3 - CHALMERS
MEASUREMENTS AND ANALYSIS OF INTERMODAL NONLINEARITIES

Every time we stream a movie, make a video call, or send a photo, invisible pulses of light race through hair-thin strands of glass beneath our feet. These optical fibers form the backbone of the internet, carrying vast amounts of data across continents in the blink of an eye. But as global data demand soars, the capacity of existing single-mode fibers is reaching its limit. One way to boost data throughput is to pack more light-carrying cores within the same cladding known as space division multiplexing (SDM). One of the promising candidates for SDM is randomly coupled core fiber (CCFs), which has high spatial efficiency, low differential group delay and high tolerance to non-linearity. The coupling between the cores can be manipulated to achieve better transmission properties, nonlinear coupling and parametric interactions. The efficient power transfer between cores happens only when the cores are phase matched. High power induces nonlinear phase shifts that disrupt phase matching condition. As a result, most optical power remains in the same core which leads to power suppression in the adjacent cores. However, interplay between random coupling and nonlinearity can modify the power transfer trends further. These nonlinear properties of randomly coupled core fiber can have applications in all optical switching, optical signal processing and wavelength conversion.

Divya Ann Shaji

DC 4 - UNIVAQ
MODELLING OF HOM TECHNOLOGIES FOR TRANSMISSION AND SENSING

Divya Shaji is a PhD student at the University of L'Aquila, Italy. Her research focuses on enhancing optical network capacity through ultra-wideband and space-division multiplexed (SDM) transmission systems. Ultra-wideband systems expand the transmission window beyond C-band, thereby maximizing the capacity and lifetime of already deployed fibers. Similarly, SDM fibers can also significantly improve data rates, supporting transmission over multiple spatial channels within a single fiber. Together, these approaches aim to support the ever-growing capacity demands on optical fiber networks. Her work includes experimental investigation of C+L+U and E+S+C+L bands transmission over unrepeatered and repeatered links, as well as the characterization of deployed SDM fibers in L'Aquila, Italy.

Brhanu Areaya

DC 5 - FAU
DISTRIBUTED SENSING

The combined few mode FBG and MI sensor is a hybrid sensing approach that combines the well-known FBG sensing with few mode fiber based sensing. This approach can help in dual parameter sensing, exploiting the transmission/reflection characteristics of FBG and modal interference to achieve a temperature and strain discrimination.

Temperature and strain sensitivity of an MI sensor was experimentally demonstrated with a promising sensitivity coefficient, -11 pm/°C and 0.19 nm/μ. Then FBG is inscribed to our FMF, two mode step index fiber from Lightera, in our FBG inscription laboratory. Because the phase matching conditions reflection peaks obtained are three being the fundamental mode (LP01) self-coupling, higher order mode (LP11) self-coupling and LP01 and LP11 cross coupling. Temperature sensitivity of both LP01 and LP11 self-coupling peaks was performed yielding 12.3 pm/°C and 12.26 pm/°C, which agreed with previous research results. Theoretical modeling of the coupling from the LP01 to the higher order modes is also being investigated using numerical tools like MATLAB and COMSOL multiphysics.

The next step is to experimentally investigate a combined FBG and MI temperature and strain sensing, and go for array of sensors for multipoint sensing.

Loreto Romero

DC 6 - UNIPD
DISTRIBUTED CHARACTERIZATION AND SENSING USING HOM FIBRES

Increasing demand of optical channels capacity has promoted the development of spatial division multiplexing (SDM) fibers, where multicore fiber (MCF) is a variety known for putting several cores that behave as independent parallel channels inside one single fiber. Due to small inhomogeneities in the fiber proper from fabrication, there exists a fundamental limit in signal quality and length of every link that is the phenomena of polarization mode dispersion (PMD). Up until now, efforts in mitigating PMD had shown success for standard fibers by applying specialized spinning techniques during the manufacturing process. Then, motivated for exploring SDM technologies, during my PhD research I have been studying PMD reduction in MCFs by performing experimental characterization of its polarization behavior. In particular, my studies have focused on exploring the property of birefringence, a quantity that reveals information about polarization variations induced by mechanical stress in the fiber. Analyzing in detail the core's birefringence, we were able to compare MCF samples with a different number of cores and spinning parameters, where we have verified that there is a strong inter-core relation of their polarimetric properties, revealing how all cores of an MCF are affected by the same intrinsic birefringence. Furthermore, our study has shown that it is possible to obtain better PMD mitigation when spinning parameters are properly optimized. In the future, it will be interesting to continue understanding inter-core polarization dynamics for MCFs.

Kaifa Xin

DC 7 - MPG
LASERS, MICROSCOPY IMAGING AND PROBING USING HOM FIBRES

As part of HOMTech, my PhD uses higher-order modes that are generated and guided inside optical fibers to read how single molecules are oriented in 3D. With a purpose-built fiber coupler, cylindrical vector beams - light beams with a doughnut shaped intensity profile and spatially varying polarization - are excited and aligned into a home-built microscope setup, avoiding bulky free-space optics. When tightly focused, these fiber-guided modes interact with a single fluorescent molecule like a tiny antenna: the signal depends on the target fluorescent molecule's dipole orientation. So far, we have obtained these modes with both a commercial and a low-cost diode laser, verified high beam quality at the fiber output, and demonstrated a reliable orientation readout by scanning the focused donut. The end goal is a compact, affordable microscope that uses fiber-guided higher-order modes to achieve sub-degree accuracy in single-molecule orientation, opening new ways to map nanoscale processes in materials and biology.

Robert Petersen

DC 8 - DTU

FABRICATION, SIMULATION AND CHARACTERIZATION OF FEW-MODE, RARE-EARTH-DOPED AMPLIFIER FIBRES AND OTHER SPECIALTY FIBRES

My project is about the amplification of light in optical fibres. As light travels along an optical fibre, it becomes weaker and the signal degrades. Long-distance fibre optic communication would not be possible without repeatedly amplifying signals along their path. When a weak light signal travels through an optical amplifier, its intensity can be increased again by transferring energy from a pump laser to the signal inside erbium-doped fibres. I am investigating the effects of higher-order modes on erbium-doped fibre amplifiers and have shown that the higher-order LP11 mode can be used to pump an erbium-doped fibre with a similar performance as when using the fundamental mode in special erbium-doped fibres.

Besma Kalla

DC 9 - TUE

CHARACTERIZATION TECHNIQUES AND METHODS FOR SPACE DIVISION MULTIPLEXING

SDM is one of the most promising technologies to overcome the capacity limits of current optical fibers as global data traffic continues to grow exponentially. Various fiber designs have been proposed to support SDM spatial channels in the form of modes or cores within a single fiber. To fully exploit the potential of SDM systems, it is crucial to understand how these channels interact, as they can couple, experience different losses, and propagate at varying speeds. However, there is no off-the-shelf instrumentation for SDM characterization. To address this, I've been developing and optimizing advanced measurement techniques to make such characterization possible, including for km-scale fiber links. Building on these advances, I have also been working on transmission experiments to demonstrate the suitability of SDM fibers for next-generation high-capacity long-haul communication. Recently, I achieved a world-record capacity-distance product, transmitting 568 Tb/s over 5166 km in standard-diameter 19-core randomly coupled multicore fiber.

Tim Wörmann

DC 10 - KTH
MODE CONVERTERS FOR USE IN FREE SPACE COMMUNICATION

I am working on free space frequency translation of high-modes through the use of sub-micron periodically poled nonlinear crystals. We showed time and spatial phase translation in non-propagting modes (Bessel beams) and investigate propagting modes (LG10, LG20, ..) on a classical and single photon level. Also, use of the crystal as a single photon source has been shown and is being further investigated.
I'm working on a way to change the color (or frequency) of light as it travels through open space, using very small specially designed crystals. These crystals have a repeating pattern on a scale smaller than a micron (a thousandth of a millimeter).
We've already shown that this method can change both the timing and shape of certain special light patterns, called Bessel beams, and we're now studying how it works with other types of light patterns (called LG modes) — both for regular laser light and for individual particles of light, known as single photons.
We've also shown that the same type of crystal can generate single photons, and we're continuing to explore how to make that process more efficient and reliable.

Upcoming Project Event

26 - 28 JANUARY 2026 IN 'AQUILA, ITALY

HOMTECH FINAL CONFERENCE