BORSISTI DAY 2017

GIORNATA DI INCONTRO BORSE DI STUDIO GARR "ORIO CARLINI"
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Consortium GARR

VERY HIGH THROUGHPUT INTRA DATA CENTRE COMMUNICATION NETWORKS BASED ON ORBITAL ANGULAR MOMENTUM MODES IN OPTICAL FIBRE

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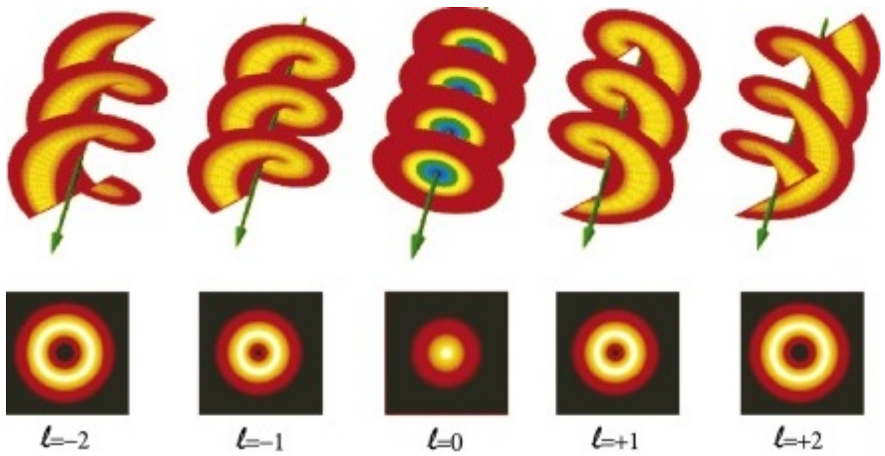
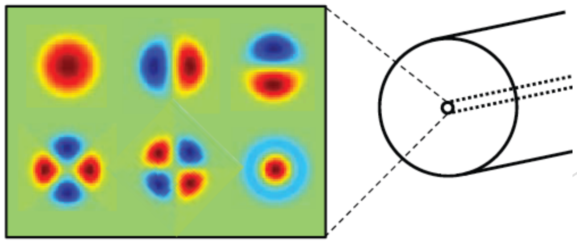
POLITECNICO MILANO 1863

Project overview

Exploiting Orbital Angular Momentum (OAM) modes as independent channels to increase optical fiber capacity.



In multimode fiber (MMF) propagation, *modes spatially overlap* inside the structure giving rise to mode coupling and related impairments.



Mode Division Multiplexing,
as an additive layer to Wavelength Division Multiplexing

MDM challenging points

- ❑ OAM modes as transmission modes :
  - limited intermodal crosstalk in short optical links
  - enable increasing of throughput

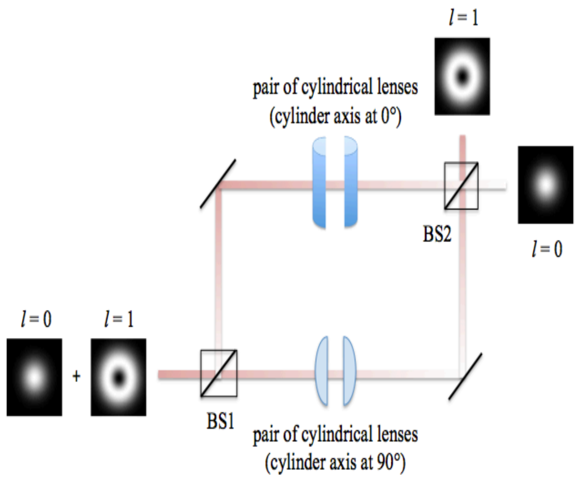
- ❑ all-optical OAM-mode MUX/DEMUX and switching
  - high speed
  - energy saving

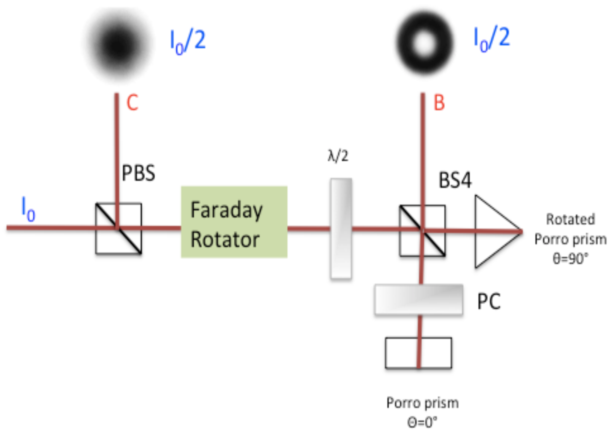
Project objective: developing an all-optical OAM demultiplexer

First year achievements

Free space optical demux:

1. Cylindrical-lenses Mach-Zender interferometer based demux for OAM modes with l=0 and l=1
2. Porro prism Michelson interferometer based demux for OAM modes with l= 0 and l=1
3. Transmission of two OAM modes (of orders 0 and 1) carrying different 10-Gbit/s NRZ-OOK signals and direct detection after OAM mode demux for both configurations
4. Improvement of the Porro-prism configuration by replacing a beam splitter with a polarizing beam splitter + faraday rotator

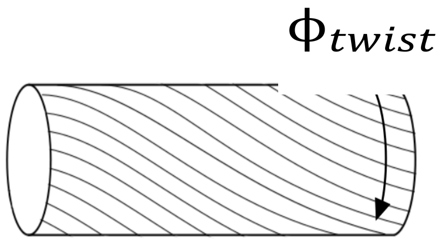




First year achievements

In fibre demultiplexer:

- Study of OAM modes transmission in twisted fibre
- Experimental verification of twist-induced pattern rotation in OAM modes



$$\gamma = e^{-i(\sigma+l)\left(1+\frac{g}{2}\right)\Phi_{twist}}$$

l = OAM
σ =state of polarization

Twist-induced pattern rotation is proportional to TOTAL ANGULAR MOMENTUM

Plan of Second Year: focus on conceiveing an in fibre-demultiplexer

- Verify twisting fibre image rotation for higher modes
- Studying other stressing effect on OAM modes image rotation
- Exploit fibre twisting or stressing image rotation to conceive in-fibre demultiplexer

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Helical winding effect on optical beam propagating in fibre

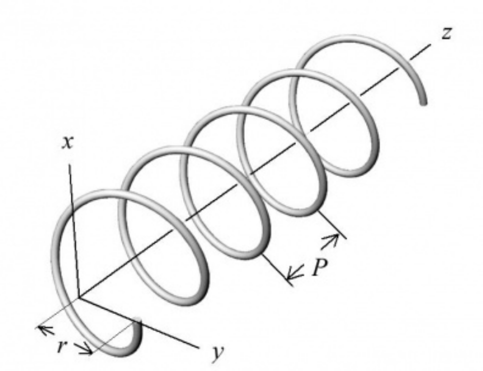
The Pancharatnam-Berry phase:

When the State of Polarization of an optical beam describes a cyclic evolution, the beam acquires an additional geometric phase equal to one half of the solid angle subtended by the cyclic path of the SOP on the Poincaré sphere.

$$\gamma(C) = -\sigma\ \Omega(C)$$

If the beam also carries OAM

$$\gamma(C) = -(\sigma + l)\ \Omega(C)$$

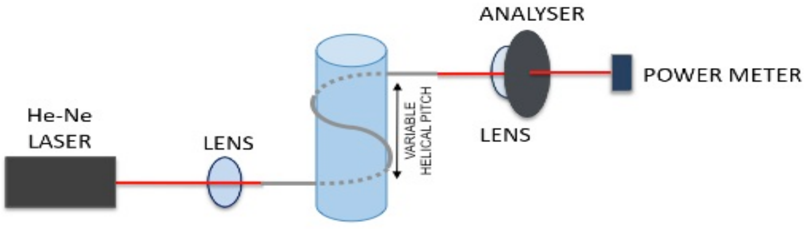


Helical winding

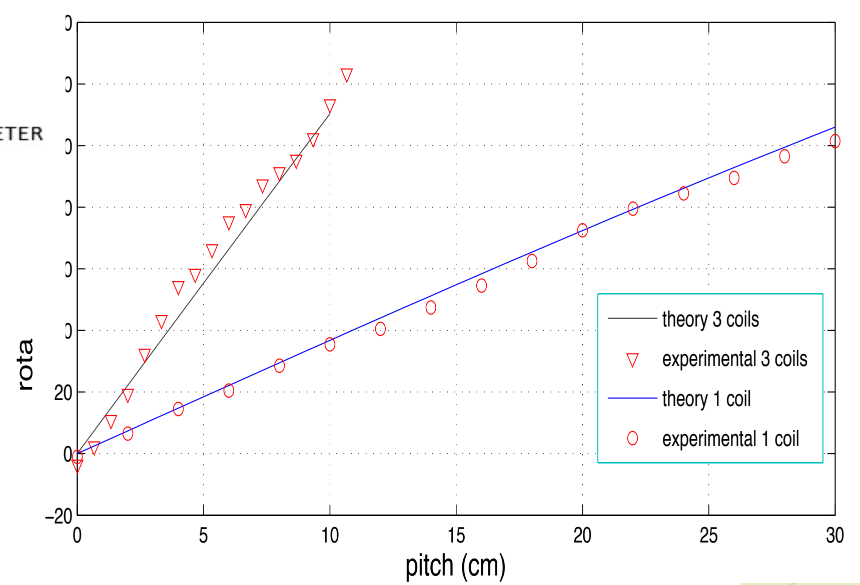
In the case of a uniform helix with circle C, helical pitch p, and arc length s:

$$\Omega(C) = 2\pi N(1 - \frac{p}{s})$$

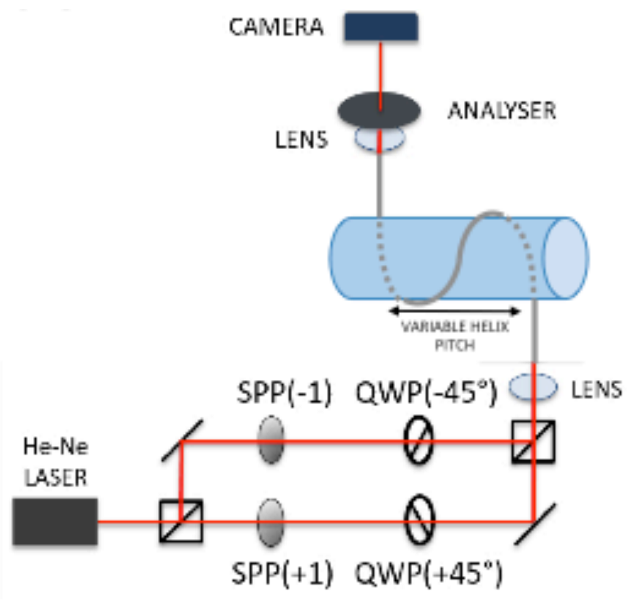
Rotation angle of the plane of polarization due to Berry's phase

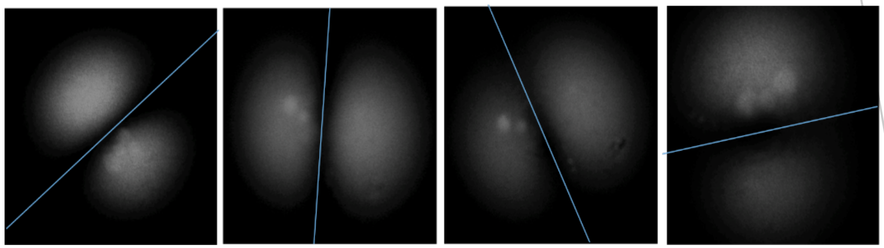


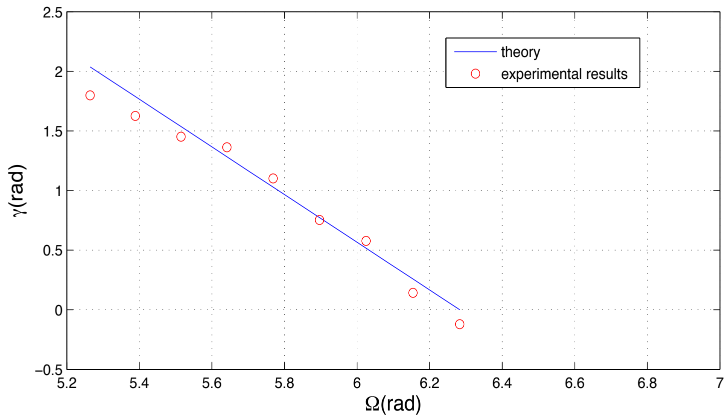
$$\gamma(C) = -\sigma\ \Omega(C)$$



Berry's phase in beams carrying orbital angular momentum l=1

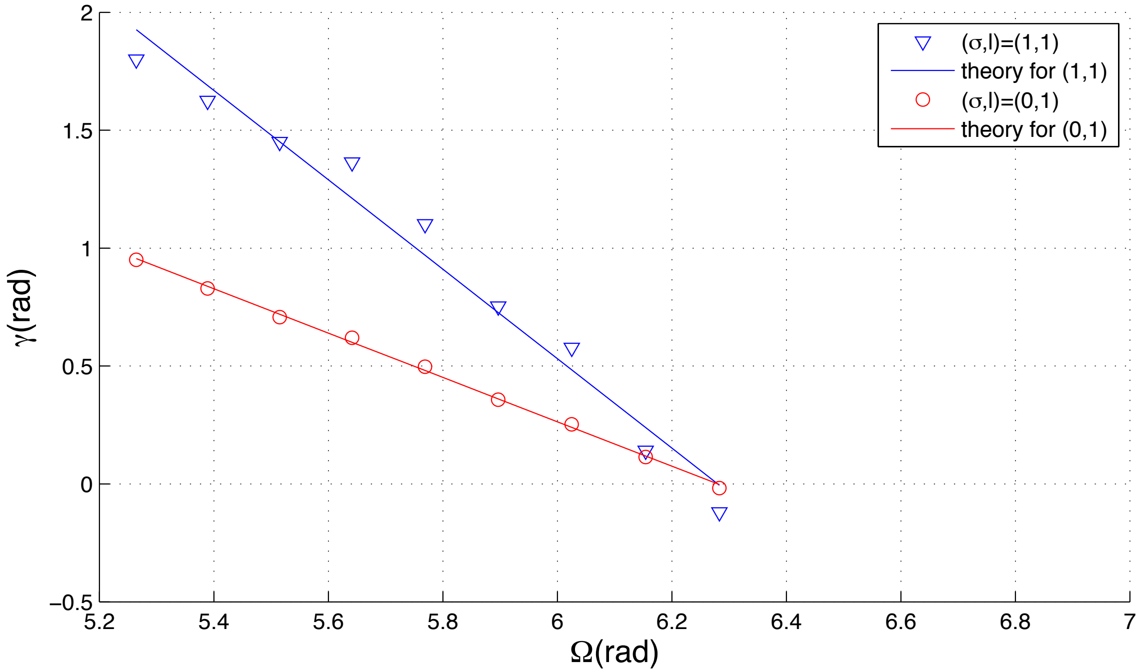






$$\gamma(C) = -(\sigma + l)\ \Omega(C)$$

Berry's phase in beams carrying (σ,l) equal to (1,0) and (1,1)

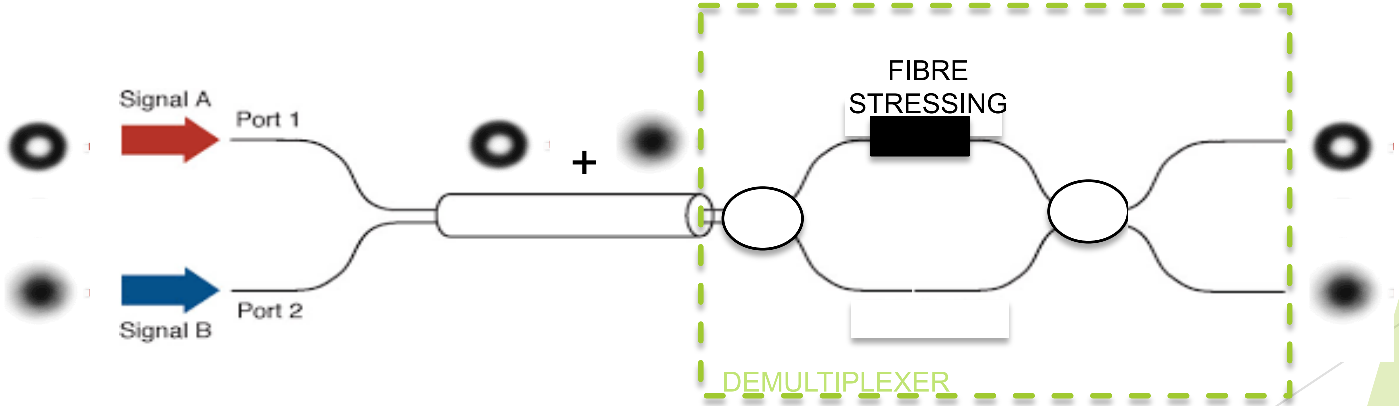


The rotation rate of the beam pattern is doubled when OAM is equal to 1 compared with OAM = 0

Optical activity of a coiled fibre is exploitable to generate a fibre demultiplexer based on OAM modes

Next steps

- Both twisting and winding are eligible for in-fibre demultiplexer
- Verify phase shift for higher modes
- develop a demultiplexer demonstrator based on the more suitable fibre stress.



GRAZIE DELL’ATTENZIONE

DOMANDE

Papers & Posters

- P. Martelli, A. Fasiello, M. Martinelli,

"Berry's Phase and Orbital Angular Momentum", CLEO/Europe-EQEC 2017, 25-29 June 2017, Munich, Germany (2020/EA-P.26)(poster).

- P. Martelli, A. Fasiello, O. Soccali, P. Boffi, M. Martinelli,

"Angular momentum dependence of the twist-induced effect in few-mode fibres",*European Conference on Optical Communication*, Duesseldorf (Germania), 18-22 settembre 2016 W.4.P1.SC1.5 (poster).

- P. Martelli, P. Boffi, A. Fasiello, M. Martinelli,

"Optical mode demultiplexing for data communication networks",*International Conference on Transparent Optical Networks*, Trento, 10-14 luglio 2016, Mo.B3.4 (invited).ISBN: 978-150901467-5. DOI: 10.1109/ICTON.2016.7550268.