Very high throughput intra data centre communication networks based on orbital angular momentum modes in optical fibre

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Roma – Consortium GARR

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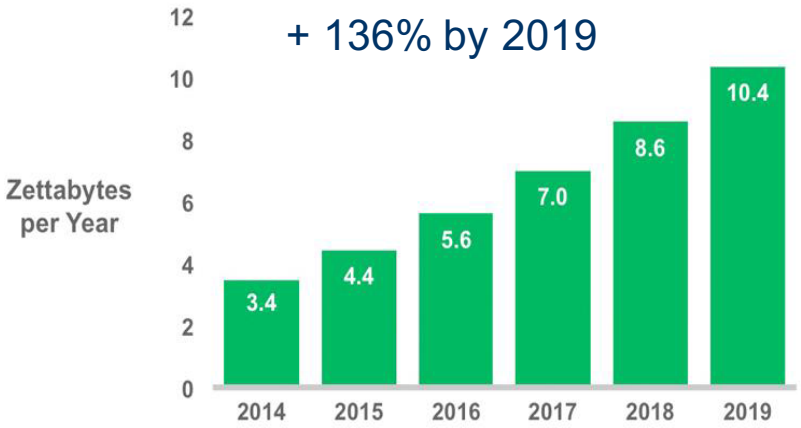
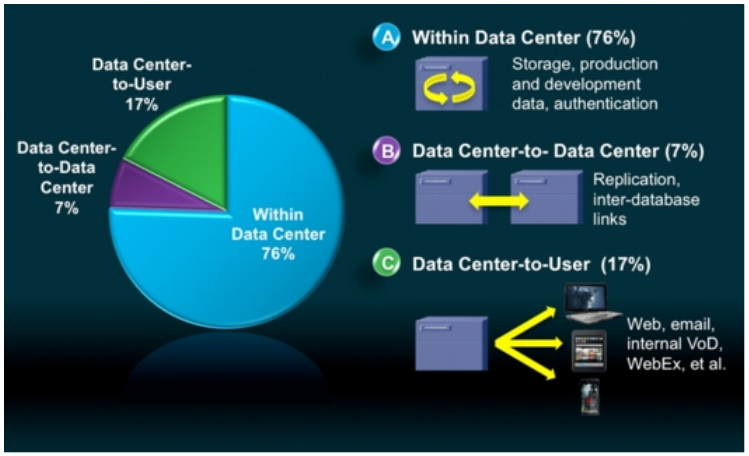
Traffic Growth & Power consumption

Global Data Center IP Traffic Growth[1]





Data centers consumed 1.1 to 1.5 % of global electricity in 2010 [2]

76% of data centre traffic : within data centre

[1]CISCO global cloud index: forecast and methodology, 2012-2017," CISCO,
[2]Koomey, Jonathan. 2008. "Worldwide electricity used in data centers." Environmental Research Letters. vol. 3, no. 034008. September 23
[3]*Vision and Roadmap: Routing Telecom and Data Centers Toward Efficient Energy Use.* Vision and Roadmap Workshop on Routing Telecom and Data Centers (2009).

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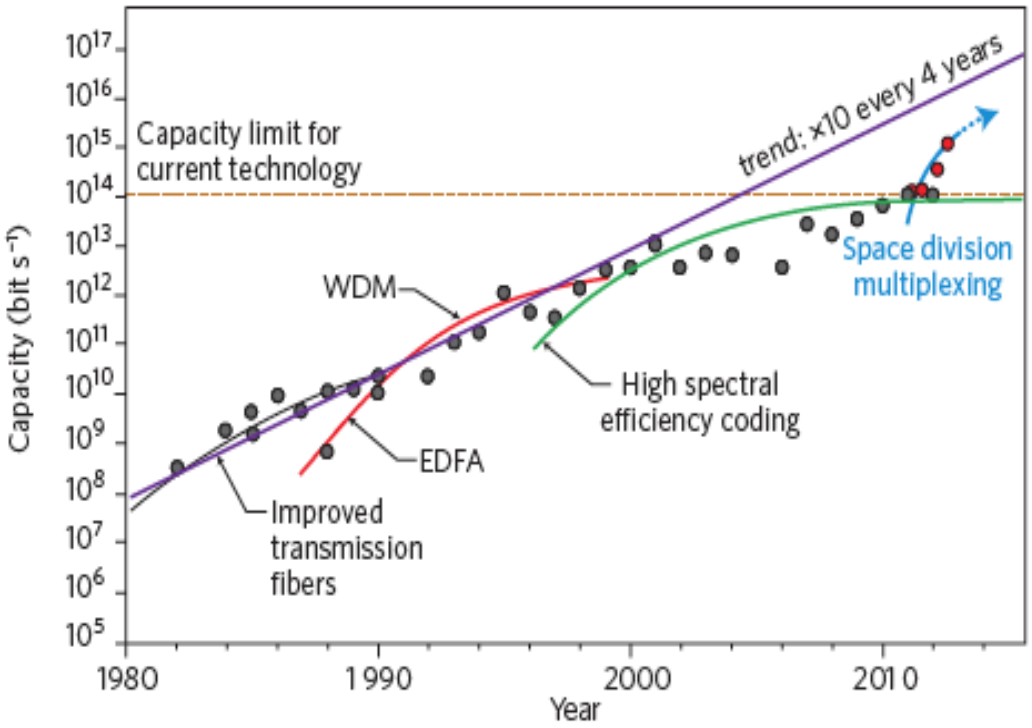
Capacity increase

Last decades exploitation:
- ❑WDM
- ❑PDM
- ❑Complex modulation (QAM /PSK) formats with coherent systems

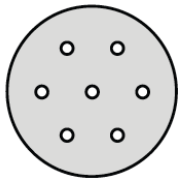
Actual technologies are approaching theoretical limit



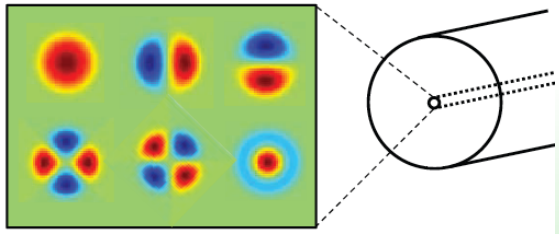
Feasible way to increase capacity : **Space-division Multiplexing (SDM)**

Space- division Multiplexing

Bundles of fibers



Multicore fiber

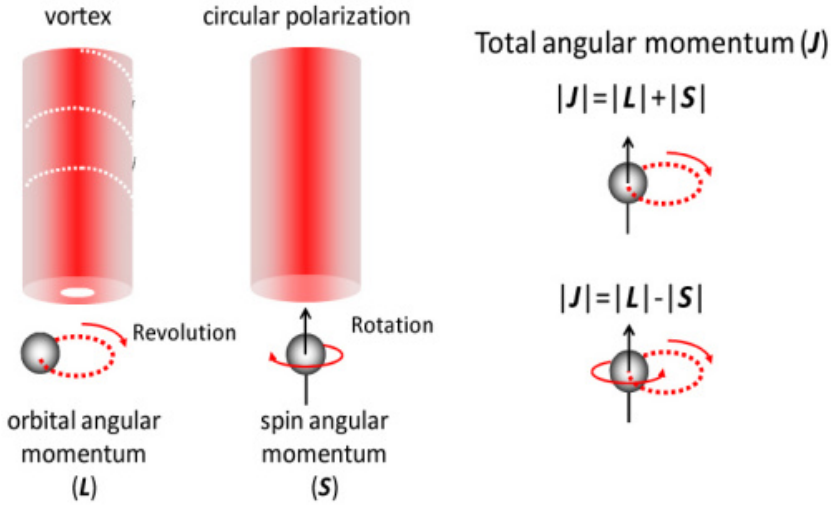


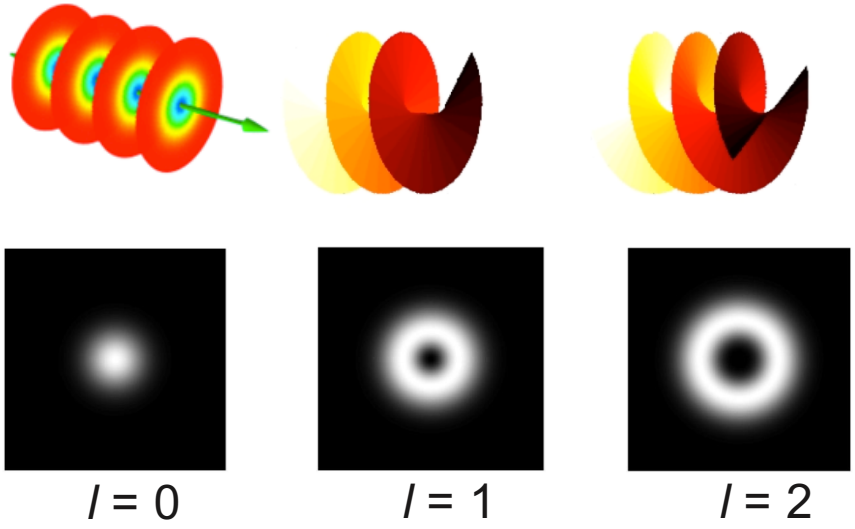
Mode division multiplexing (MDM)

Mode Division Multiplexing

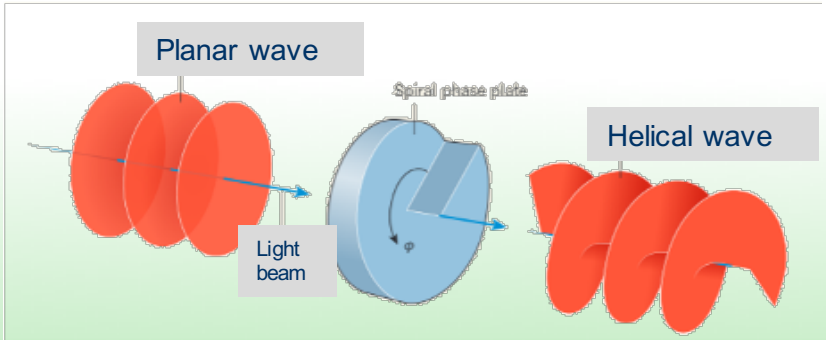
Modes can be labelled with **Orbital Angular Momentum** (OAM).

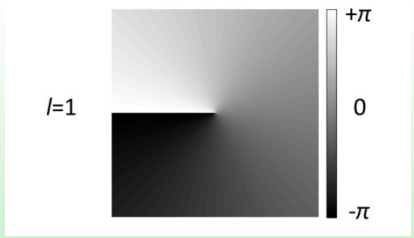
optical vortices

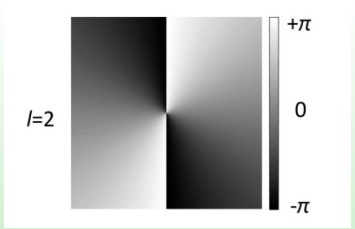




Generated from Gaussian beam by a **Spiral Phase Plate** (SPP)

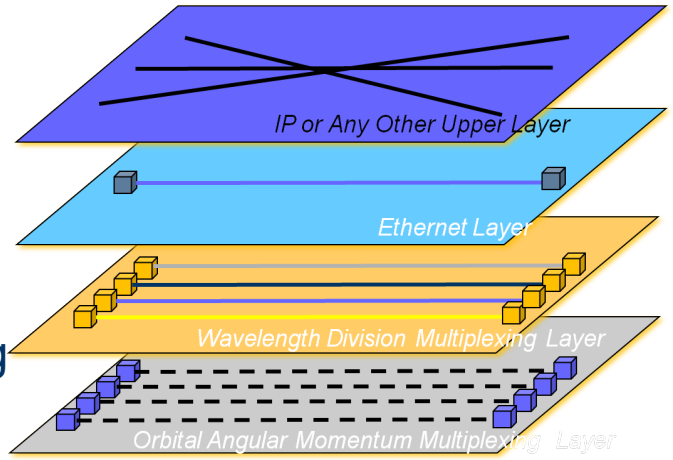






Development of the OAM layer

- OAM modes as transmission modes :
  - limited intermodal crosstalk in short optical links
  - enable increase of throughput
- **all-optical OAM-mode MUX/DEMUX** and switching
  - high speed
  - energy saving

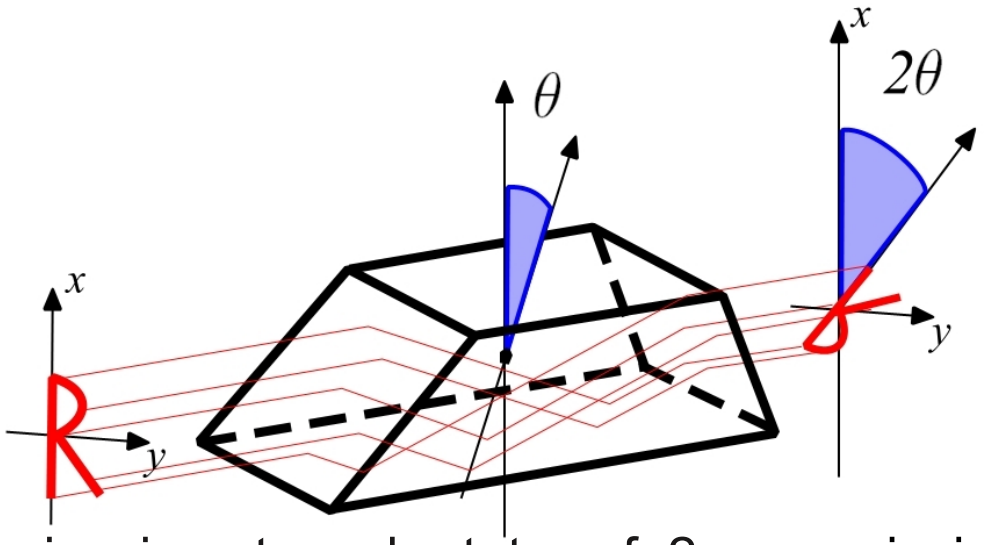


OAM layer in short-distance links inside data centers: avoid MIMO processing, ACDs, ultra-fast DSP

All-optical node architectures : up to 75% energy savings in the data centres[1]

[1] *Vision and Roadmap: Routing Telecom and Data Centers Toward Efficient Energy Use.* Vision and Roadmap Workshop on Routing Telecom and Data Centers (2009).

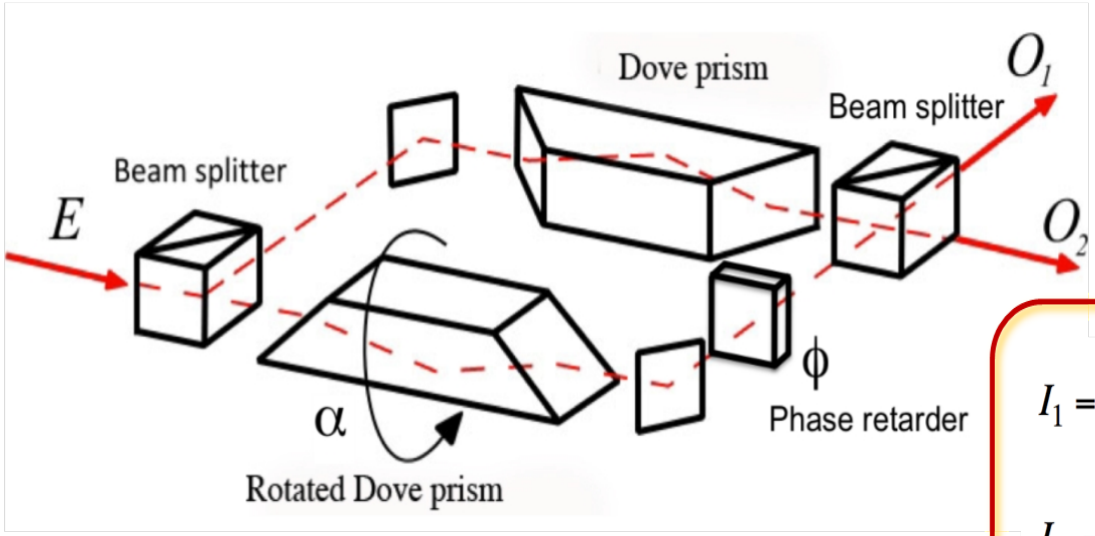
Dove Prism Image rotation



A rotated Dove prism inverts and rotates of 2α any incident image

This image rotation in case of an OAM mode of order l is equivalent to a phase shift of $2\alpha l$. The dependence of this phase shift on both α and l permits to obtain an interferometric OAM mode sorter.

Dove Prism Mach-Zender interferometer



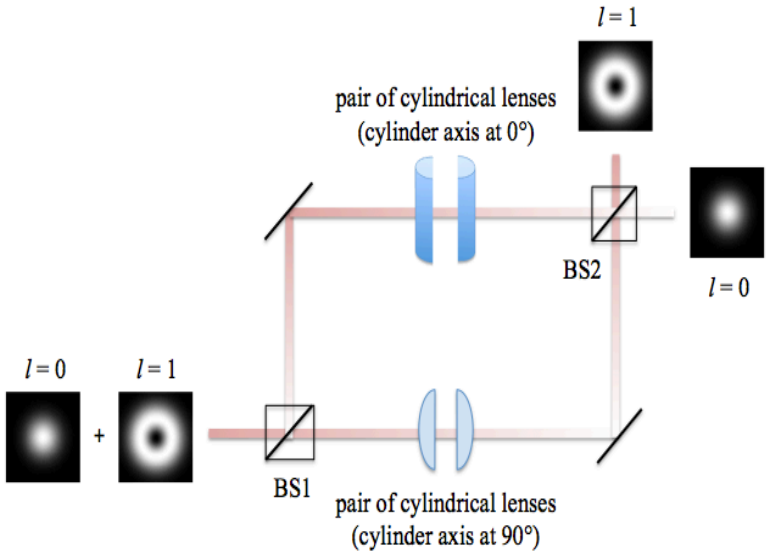
$$I_1 = E_0^2 \sin^2\left(\alpha l - \frac{\phi}{2}\right)$$

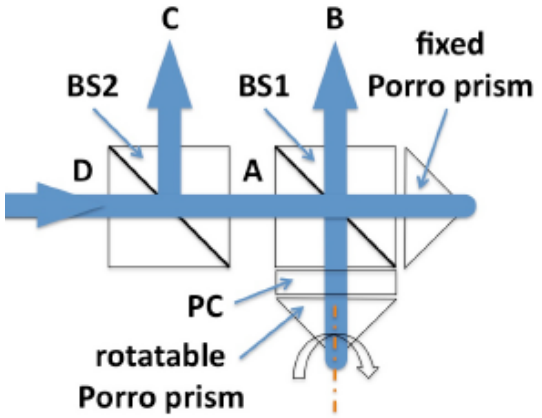
$$I_2 = E_0^2 \cos^2\left(\alpha l - \frac{\phi}{2}\right)$$

[from J. Leach et al., PRL 88, 257901 (2002)]

Our Proposal

We are studying other ways to obtain the same image rotation properties of a Dove Prism, more suitable for micro devices application.

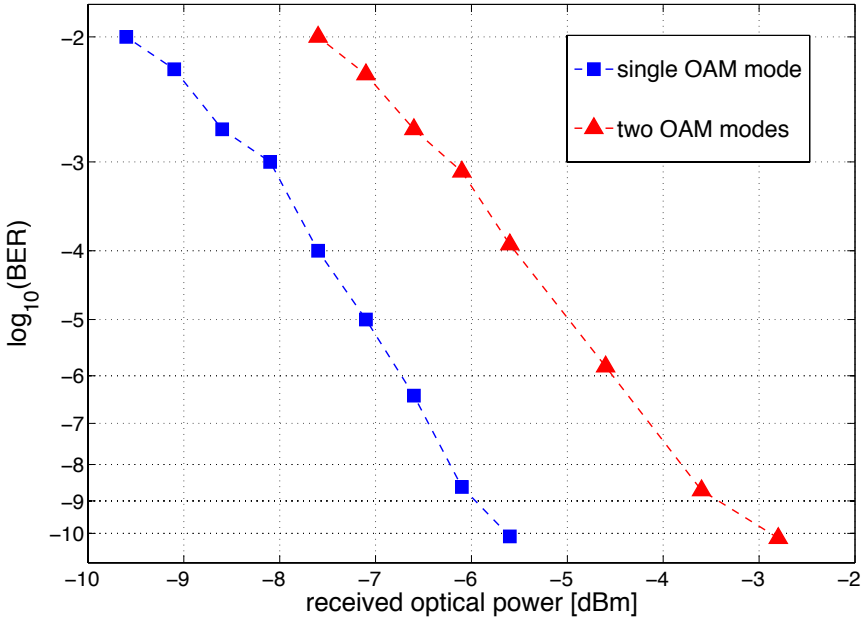


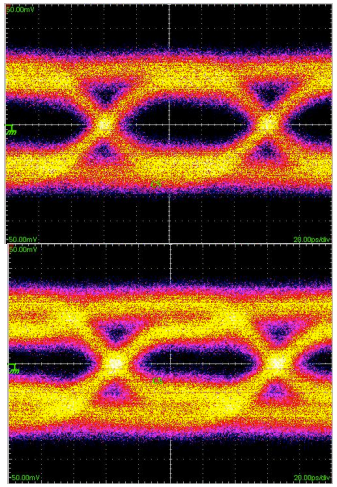


Possibilities to explore:

- Cylindrical lenses
- Porro Prisms
- Other fibre properties

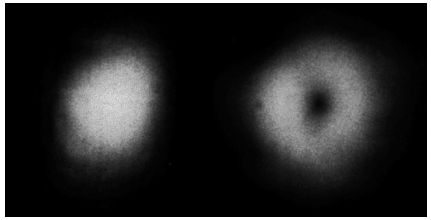
Results for the Cylindrical lenses configuration





without modal crosstalk

with modal crosstalk



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

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Plan of activity

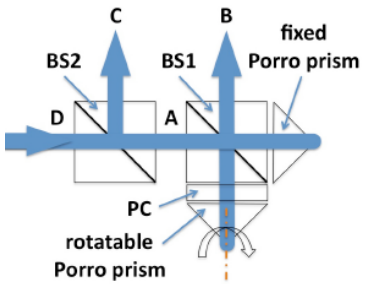
1. Feasibility study of different solutions for OAM mux/demux

- Studying different optical devices to realize modal multiplexing

2. Experimental implementation of OAM mux/demux

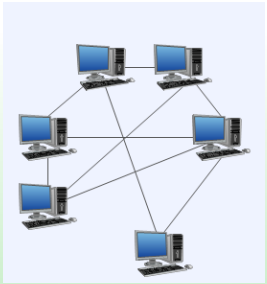
Evaluate transmission quality by meausurement of:

- Crosstalk
- Bit error rate
- Eye diagram



3. MDM impact on LAN and intra data centre networks

- Energy saving
- Cost impact
- Compactness



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GRAZIE PER L'ATTENZIONE