FSO for inter-rack communication in data center

Describe today's solutions (if any):

Today's solution is optical fibers, kilometer of them. However, most of the data centers are still using multimodes fibers that cannot accommodate WDM, or PSK due to dispersion.

To increase the bandwidth, the current fibers need to be replaced by SMF. This is a huge capital investment that is not guarantied to be future proof. Moving directly to FSO would ensure that the next generation of optical coding will be compatible with the infrastructure.

Considering the data center is a controlled environment, FSO can easily be implemented without running into the difficulties presented in open areas such a line of sight, atmospheric constrain (cloud, rain, dust), eye safety.

Define the fundamental research problems that must be addressed:

The difficulty for the implementation of FSO into the data center is mostly engineering and cost. The most important metric for the client is $/bit, including the capex and opex. In the operational expenditure, the power consumption is a huge factor and every watt spared in the electronic count twice considering it is not thermally dissipated and does not require cooling.

Identify benefits if the problem gets solved:

FSO can become an attractive alternative to fiber if it can be implemented along optical switching which is by far more power lean than electronic switching. Fiber injection after switching is a lossy process with as best 3dB loss, this energy can be saved by using FSO.

Every time there is a transformation to or from electronic (storage and computation) to optics (communication), there is a substantial lost of energy. FSO should be part of an ongoing effort to bring optics closer to the chip for a more efficient data center (and super computing) architecture.

FSO implementation of inter rack communication make the infrastructure future proof to coming optical codings and wavelength bands. The leading datacom band is the c-band at 1550nm because of the transparency and dispersion in optical fiber.   However, there are advantages going to shorter wavelength such as visible from a pure data transfer point of view.

FSO for chip-to-chip interconnect inside computers

Describe today's solutions (if any):

Chip-to-chip communication inside computer is ensured by copper lines on the PCB board, and have not changed since the invention of the printed circuit in the mid 20th century.

Event though the transistor and logic gate have been subjected to dramatic reduction in size and energy consumption (Moore's law), the same is not true for the inter chip communication. In today's computer, most of the energy dissipated by the CPU is used to communicate.

This is particularly true for supercomputers where the computation is scattered over several CPUs, and the results need to be shared for the task to complete. Entire classes of problems are defined as communication intensive rather than computational intensive due to the large amount of information that needs to be exchanged/shared between the processors.

Without a substantial increase in inter-chip communication bandwidth density, and a similar reduction in the energy per bit exchanged, our society cannot continue on its exponential trend of use of information.

Define the fundamental research problems that must be addressed:

There are several areas of research that need to be covered for chip to chip FSO interconnect to become viable:

- High efficiency laser diodes and detectors: sub-femtojoule per bit.

- Diffraction limited micro and nano optical elements: free form micro lenses, pattern generation holograms.

- Integrated photonics compatible with silicon process: amplifier, modulators, wavelength multiplexer demultiplexer, high frequency phase shifters.

- Low loss coupling: grating coupler, interconnect, optoelectronic packaging.

Identify benefits if the problem gets solved:

The physic of FSO for in chip to chip communication addresses both the limitation in bandwidth and energy consumption, and have the potential for orders of magnitude improvement over the current solution.

It can easily be demonstrated by using the diffraction limited size of optical beams, the surface of the chip, and the chip clock rate, that a 20 Tb/mm^2 bandwidth density can be obtained.

By improving the chip to chip communication, large problems can be solve much faster on distributed architecture, first by increasing the number of CPUs involved in the processing task, and second by reducing the downtime imposed by the communication delay.

The advantage of reduced energy consumption of FSO for inter-chip communication can also be beneficial for personal computing and portable devices which will have improved battery life. One can also imaging the an external port can easily be created using the same technology for inter devices short range communication (laptop, smart-phone, cameras, hard drive) with extremely high bandwidth for data transfer.