Speciality fibre in high speed transmission application

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ABSTRACT

The multi core fibre can be successfully applied not only the long-haul ultra-high capacity transmission but also in data interconnects and integrated distribution networks. In this paper, the proposed application areas are reviewed.

Keywords: optical communication, space division multiplexing, multicore fibre, data interconnect, 5G

1. INTRODUCTION

Data traffic is increasing driven by the growth of the user base and growth of applications requiring high speed connections. Ever growing data traffic must be carried by the transmission systems and networks ranging from a few meter distances (data interconnects) to transcontinental distances. Therefore, new technologies are needed to serve the ever growing traffic transmission in the most economical way. That is particularly important for the transmission infrastructure operators, which revenues and profits are not growing in line with the traffic growth. For a last few years we observe growing interest in speciality fibres like the nonlinear fibres, the multi-core fibres (MCF) or a few mode fibres (FMF). MCFs are known for over 35 years, e.g. [1], the recent activities are caused by necessity to combat the fibre capacity crunch [2]. MCF and FMF offer enormous transmission capacity and remarkable transmission records have been established, e.g. 10.6 Peta bit/s transmission over 13 km MCF/FMF [3] or 172 Tbit/s transmission over 2040 km of FMF [4], including 255 Tbit/s transmission over 1 km fibre link [5] recognized also by the Guinness World Records [6]. However, despite significant research effort the MCF based solutions are not available to be deployed in the field. Further many question arise, e.g. handling and operability including splicing, cost advantage over legacy technology, failure resistance and consequences etc. Nevertheless, the are other applications areas, where MCF can be successfully applied omitting some of the mentioned issues. Two most promising application areas are the data interconnects as well as the integrated next generation distribution networks.

2. DATA INTERCONNECTS

The data interconnects are transmission systems covering distances up to a few hundred meters and data rates of a few dozen Gbit/s. The development of data interconnects is driven by the boom of their application area namely hardware infrastructure for data storage and processing centres. Data interconnect provide connectivity ranging from sub-meter distances, e.g. intra-rack communication to a few hundred meters as the internal data centre connections. The dominating data interconnect technology is based on the vertical cavity emitting lasers (VCSELs) [7] operating in the 850 nm window and the multi-mode fibre (MMF). The decisive advantages of that solutions are high speed operation, low energy consumption, small foot print and low capital and operational cost [8]. One of the current key challenges in the data interconnect field is limited bandwidth of VCSELs and photoreceivers, which is currently limited to about 25-30 GHz. Further increase of the data rate, e.g. 100 Gbit/s and more requires application of the advanced modulation formats, e.g. [9] with the resulting undesirable increased systems complexity, energy consumption and higher latency, since they require significant signal processing [10]. The solution here could be application of the multiplexing of parallel channels in the wavelength or the space domain. In such a way, high capacity transmission can be formed by the sum of separate data streams transmitted at lower data rates. The wavelength multiplexing has disadvantage of introducing additional losses and therefore limiting the available power budget as well as put new requirements to the fibre and VCSEL performance since the four channel band covers about 100 nm. A viable option here is the space multiplexing, through the separate fibre lanes, e.g. ribbon fibre, with disadvantage of handling and space. The most promising solution here is based on multi-core fibre, which except MCF requires VCSEL and photoreceiver arrays [11], [12], [13].

Fig. 1 shows pictures of the developed 6-core fibres [14]. The difference between two presented fibres are the wholes that due to the pattern structure allow easier fibre adjustment and limit the inter-core crosstalk. The core diameter was 5.16 um, the core-to-core distance 39.5 um, the outer diameter 175 um, the numerical aperture 0.13 and the cut-off wavelength of 780 nm. Such fibre can be used for transmitting the optical signals at 850 nm.

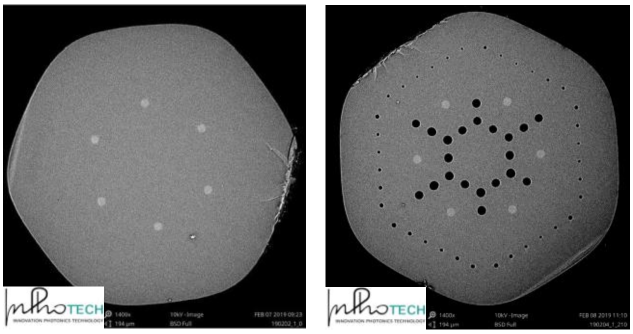

Figure 1. 6-core fibre for data interconnect application.

Fig. 2 shows the picture and 3D drawing of the developed 6 VCSEL array [15] as well as exemplary light-current-voltage characteristics (LIV). The chip dimensions are 750 um x 500 um. The VCSELs are uniformly distributed to match the MCF fibre. Each VCSEL has separate ground-signal-ground contacts. As it can be seen with the current of 4 mA, optical power of 3 dBm can be generated. The developed VCSELs are single mode [7] with the side mode suppression ratio of 30 dB. The dynamic operation was verified with the non-return-to-zero modulation and without equalization at the data rate of 50 Gbit/s, see inset Fig.2.

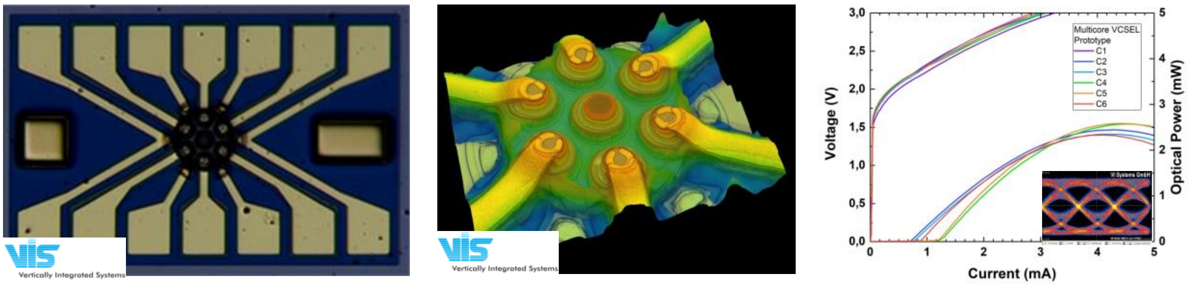

Figure 2. 6-VCSEL array and exemplary LIV characteristics with the 50G NRZ eye diagram inset.

3. NEXT GENRATION OPTICAL DISTRIBUTION NETWORKS

To materialize 5G promises like up to 10 Gbit/s transmission, higher and higher radio frequencies must be used, which implies increased antenna density due to the limited coverage. The antenna sites (remote radio heads - RRH) require high capacity connections to the central office (CO), where the signal and data processing takes place realizing the centralized radio access network (CRAN). The network connecting CO and RRHs is called fronthaul network. Digital-radio-over-fibre (DRoF) or analog-radio-over-fibre (ARoF) can be employed to provide CO-RRHs connectivity. In DRoF the radio signals are transmitted in the digitized form and require digital-to-analogue converters are RRHs [16]. Depending on the digitization scheme, streams of a few dozen Gbit/s can be generated to a single antenna element, resulting in a Tbit/s capacity for the antenna node. In ARoF, the transmitted signal are ready to be radio transmitted just after optical-to-electrical conversion and no additional signal processing is required at the RRH. ARoF and DRoF require high capacity fibre network connecting RRHs and COs, called fronthaul network. Further, such network can be integrated with the access networks, like fibre-to-the-home (FTTH) to achieve cost benefits. The blueSPACE project [17] proposes utilization of MCF or SMF bundles to realize high capacity optical distribution networks based on space division multiplexing (SDM) [18].

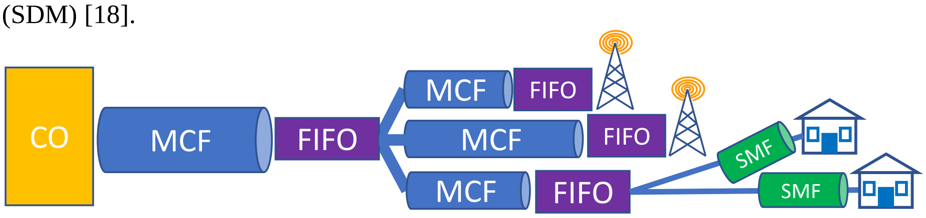

Figure 3. Optical distribution network with MCF.

Fig. 3 presents the architecture of the optical distribution network envisaged in the blueSPACE project. The MCF and SMF are used to connect CO and the end nodes like the antenna sites or FTTH customers. In the given schematic, the MCF with high number of cores, e.g. 19 is connected to the multiple MCF with lower number of cores, e.g. 7. This functionality is achieved with a fan-in-fan-out (FIFO) component, which can be realized as the laser scribed 3D glass waveguides [19]. Such devices show losses <3dB therefore not affecting significantly the available power budget, i.e. being in the range of other devices like arrayed waveguide gratings (AWGs). Such multicore fibre can be connected to the antenna site, where after the next FIFO stage it can feed ARoF or DRoF equipment. Further, the FIFO stage output can be connected to the transmission SMF, e.g. to realize FTTH connections. In this case an integrated mobile fronthaul and FTHH optical distribution network is formed. Further, the distribution network can enhanced with the cable, power and wavelength split as show in Fig. 4. The cable split divides one high fibre count cable into a number of lower fibre count cables, e.g. 144 to 2×72. The core split can be realized with FIFO. The power split with the passive power splitter, e.g. 1×16 and the wavelength split with AWGs.

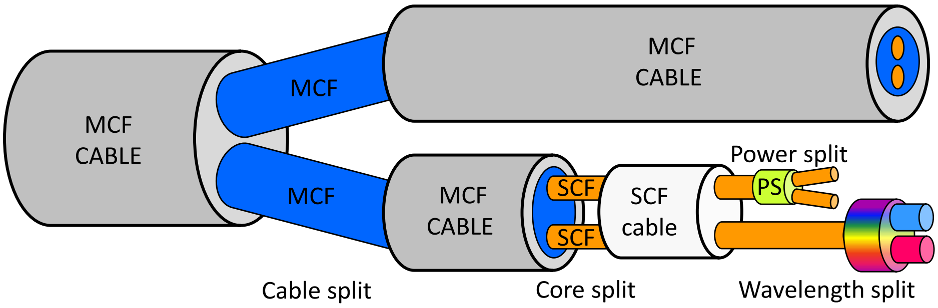

Figure 4. Split stages in distribution networks

Application of the MCF in distribution networks lies not only in the increased capacity, but also that the cores can form dedicated transmission lines from CO to end element and as such allow utilization of cost-effective transmission technologies like the uncoloured (unspecified wavelength) transmission. Due to the relaxed requirement on the lasing element and lack of the wavelength multiplexing and demultiplexing stages, such transmission can be realized at lower cost. Further, that allows cost-effective realization of the coherent optical beam forming [18],[20]. In the given application, the ARoF signals on the same wavelength are transmitted through different cores, then converted to electrical domain and feed the antenna array elements, Fig. 5. The time delay between the ARoF signals results in the directivity of the formed beam. One of the key issues associated with the presented ARoF beam forming technique is necessity to control inter-ARoF signal delay. As has been shown, the inter-core delay varies and changes with temperature [21]. That implies necessity for the active delay compensation or to keep the transmission distance within the signal tolerance limits to the inter-core skew delay.

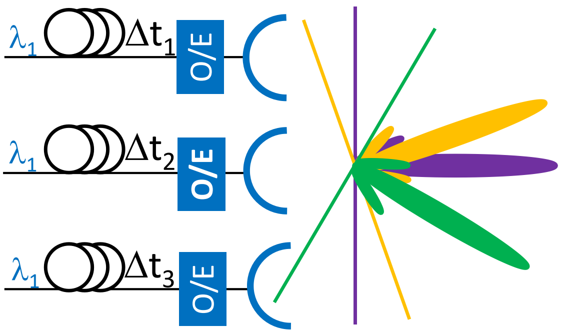

Figure 4. Schematic of the ARoF coherent beam forming

4. CONCLUSIONS

The very promising areas for applications of multicore fibres are data interconnects and distribution networks. In such application areas, the MCF does not ultimate capacity, as in the long haul transmission systems, but other key advantages like separate transmission channels lowering the system cost. As such MCF cane inevitable element of the future mobile fronthaul networks as well as data centre infrastructure.

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