DMT based multi-Gbit/s communication in indoor optical networks using R-SOA

DMT based Multi-Gbit/s Communication in Indoor Optical Networks using R-SOA

N.Mehta, E. Tangdiongga, and A.M.J. Koonen

COBRA Research Institute, Dept. of Electrical Engineering, Eindhoven University of Technology, Den Dolech 2, PT 11.06, P.O. Box 513, NL 5600MB, Eindhoven, The Netherlands

After 'fiber to the home', fiber has reached in the room. To make such fiber based indoor networks cost and energy efficient, reflective modulators (like R-SOA and R-EAM) are core components which are also wavelength agile. They remove the need of laser sources at antenna access points for upstream signal. The baseband version of OFDM (i.e. DMT) along with bit-and power-loading algorithm can overcome the bandwidth limitation of R-SOA. In this paper, we have shown experimental results of multi-gb/s communication for upstream signal in indoor optical networks. DMT modulation scheme has been used to obtain throughput of 9 Gb/s with a 750MHz R-SOA.

Introduction

Recent years have seen growing demand for multi-media services such as high definition video streaming in hospitals, sharing of large data files in office building etc. To fulfill this ever increasing bandwidth demand from the users, fiber-to-the-home networks is not sufficient [1]; the fiber needs to be extended till the room. The indoor network architecture we propose is outlined in Fig. 1. For downstream path, we use pencil beams to connect mobile devices in a room. For upstream path, 60GHz radio connection is used for high speed wireless connection [2]. Within each room, there are antenna access points (AAP) which consist of 1) pencil–beam radiating antennas (PRAs): to direct pencil beams 2) receiving antenna and mixer: to capture 60 GHz upstream signal and down-convert it 3) reflective modulators: to re-modulate upstream signal on CW light at a room specific wavelength and send back to central communication controller (CCC). The solution for directive beam steering through PRA is ongoing topic of research. The CCC hosts all the intelligence for routing of wavelengths channels in each room.

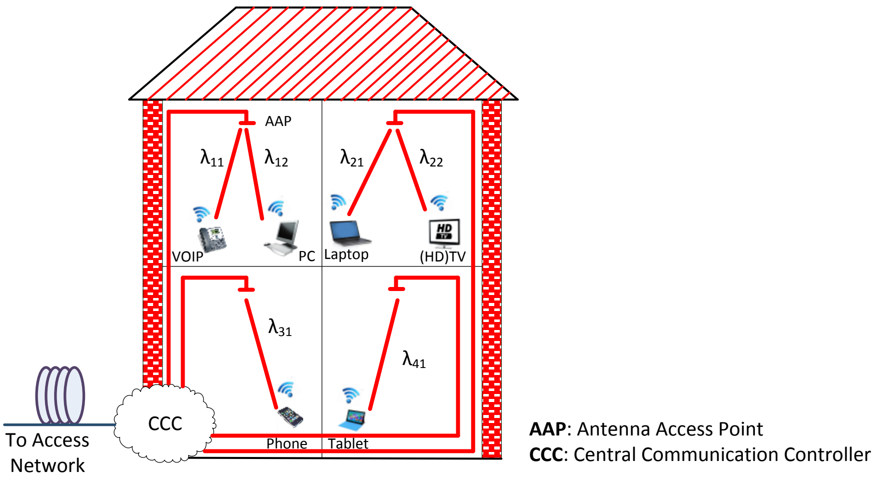

Fig.1. Indoor network infrastructure

The implementation of centrally controlled dynamic wavelength management in CCC allows the reflected upstream signal transmission from the AAP in a wavelength agnostic manner.

Numerous attempts have been made to use colorless reflective modulators at remote end such as reflective-semiconductor optical amplifiers (R-SOA), ASE injected febry-perot laser diodes (FP-LDs) and reflective-electro absorption modulator (R-EAM) etc [3,4,5]. R-SOA seems to be very attractive because of its dual properties of modulation and amplification for broad range of wavelengths (~40 nm). However the bandwidth limitation of R-SOA is not suitable for next generation optical networks. To overcome the bandwidth limitation we use discrete multi-tone (DMT) modulation scheme. DMT is the base band version of orthogonal frequency division multiplexing (OFDM) which is a multi-carrier transmission technique, where a high data rate stream is split into many lower rate sub-streams and allowing low cost implementation.

In this paper, we experimentally demonstrate the use of DMT for remote modulation of upstream signal by using low bandwidth R-SOA at AAP in indoor optical networks.

Experimental Set-up

Fig 2 presents the experimental set-up. For downstream, we use simple NRZ. For upstream path, DMT is being used to fully exploit the narrow bandwidth of R-SOA. In the experiment, we multiplex NRZ signal (directly modulated at λ_1=1550.16 nm) and CW signal (at λ_2=1555.84 nm) and send through 200 m SMF fiber. At AAP, both signals are de-multiplexed. Modulated signal for downstream is sent to PRA for correct directing of a beam to mobile unit and CW light signal is sent to R-SOA (operated at 25°) for re-modulating upstream signal. After re-modulation signal is sent back to CCC through the same fiber. For short distance, Rayleigh scattering is not significant and hence not considered. In this paper, we discuss only upstream performance.

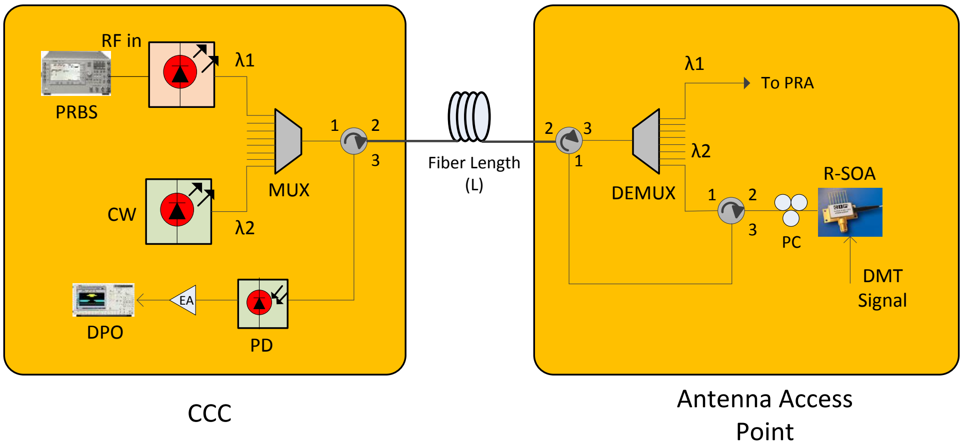

Fig.2. Experimental Set-up

In the experiment, the baseband electrical DMT signal is generated by Tektronix AWG using offline signal processing. Offline signal processing at transmitter side consist of serial to parallel conversion of data, QAM symbol mapping, inverse fast fourier transform, parallel to serial conversion, cyclic prefix (CP) insertion and digital to analog conversion (DAC). For receiving optical signal, we use a photo detector with 7 GHz bandwidth. The received DMT signal is captured with Tektronix 50GHz real time oscilloscope for demodulation. The demodulation process consists of synchronization, de-mapping of QAM signal, FFT, CP removal, and analog to digital conversion. After demodulation, offline signal processing is done in Matlab for obtaining net throughput.

Experimental Results and Discussion

Fig 3 shows static characterization of R-SOA. Fig. 3 (a) shows the frequency response of R-SOA and fig. 3 (b) shows the throughput versus bias current for different input powers. Higher input power increases the relaxation oscillation frequency and hence the modulation speed of R-SOA [6]. The further analysis is done at 30mA bias (highest throughput point).

Fig 4(a) shows bits allocated to different subcarrier indices after bit loading algorithm. For 2 GHz transmitted bandwidth, 64-QAM is used for subcarriers having higher signal to noise ratio (SNR) whereas for 5 GHz, 16-QAM is used. Corresponding constellation diagram @ BER<10^{-3} is shown in fig 4(b).

Fig 5 shows throughput versus transmitted bandwidth for two different subcarrier indices. The highest throughput obtained is ~9 Gbit/s.

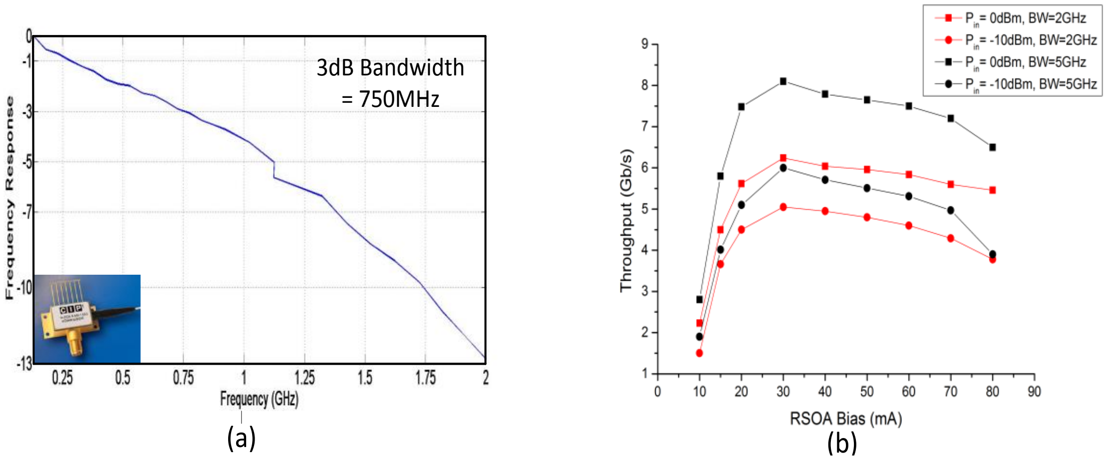

Fig.3. (a) Frequency response of R-SOA; (b) Throughput versus bias current for different input power

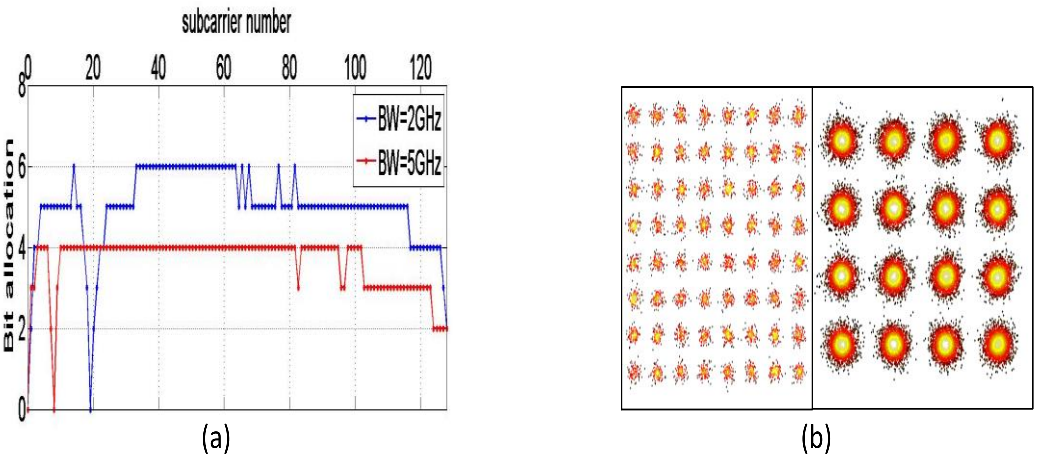

Fig.4. (a) Bit-loading per subcarrier @ BER<10^{-3}; (b) Constellation for BW=2GHz (64-QAM) and BW=5GHz (16-QAM)

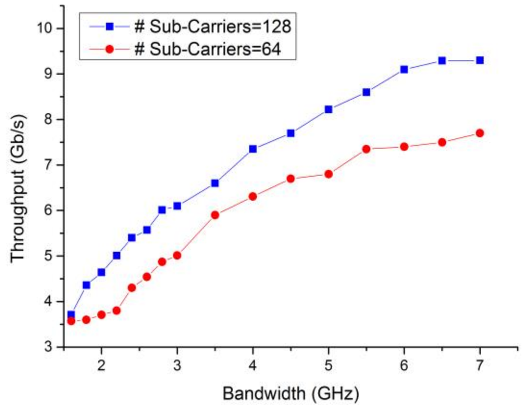

Fig.5. Throughput versus transmitted bandwidth

Conclusion

We have demonstrated the feasibility of operating an R-SOA based indoor optical network architecture by using DMT. Although R-SOA is bandwidth limited by 750MHz, maximum throughput of 9Gbit/s is achieved at BER<10^{-3} by using 7GHz DMT with 128 sub-carriers. The maximum throughput can further be improved by using reflective-electro absorption modulator (R-EAM) as a reflective modulator.

Acknowledgement

This work is part of the Beam-Steered Reconfigurable Optical-Wireless System for Energy-efficient Communication (BROWSE) project, funded by the European Research Council within the FP7 program.

References

[1] M. Popov," The convergence of wired and wireless services delivery in access and home networks," Proc. OFC 2010, San Diego, Mar. 2010, paper OWQ6.

[2] Su-Khiong Yong, Pengfei Xia and Alberto Valdes-Garcia, "60 GHz technology for Gbps WLAN and WPAN: From theory to practice," John Wiley & Sons Ltd, 2011

[3] Hong M-K, Tran N.C., Shi Y., Tangdiongga E., Han S-K, Koonen A. M J, "10Gb/s transmission over 20km single fiber link using 1GHz RSOA by discrete multi-tone with multiple access," Proc. Optical Communication (ECOC),Sep 2011

[4] Nguyen Q.T., Vaudel G., Vaudel O., Bramerie L., Besnard P., Garreau A., Kazmierski C., Shen A., Duan G-H, Chanclou P., Simon J.-C., "Multi-functional R-EAM-SOA for 10-Gb/s WDM access," Proc. OFC 2011

[5] Hanlin Feng, Shilin Xiao, Pei Yang, Zhao Zhou, Jie Shi, "A re-modulation scheme in WDM-PON based on FP-LD and RSOA cascaded structure," *Communications and Photonics Conference (ACP), 2012 Asia* , Nov. 2012

[6] Chien-Hung Yeh, Chi-Wai Chow, Ming-Feng Chiang, Ci-Ling Pan and Fu-Yuan Shih, "Compensation of power drops in reflective semiconductor optical amplifier–based passive optical network with upstream data rate adjustment," *Opt. Eng*. 50, 095004(2011)