First Design of Dynamically Reconfigurable Broadband Photonic Access Networks (BB Photonics)

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The BB Photonics develops reconfigurable access networks for providing the user with congestion-free access to virtually unlimited bandwidth. First design of reconfigurable access network architecture is presented in this paper together with preliminary specifications for components and modules. The simulation results of a reference network with wavelength agnostic optical network units based on a reflective semiconductor optical amplifier (RSOA) and a wavelength router based on ring resonators filtering characteristics give an encouraging perspective for further research. Consideration is given to a possible migration scenario.

Introduction

It is expected that by 2009 the number of TDM-PON users will pass 10M worldwide [1]. Taking into account the increasing bandwidth demands of future applications one need to investigate improved network solutions introducing migration from TDM to WDM and solving the problem of network dynamic reconfiguration [2-4].

By enabling the network operator to easily and remotely reconfigure his access network, the capacity distribution across the users can timely be adapted to his varying service demands. Optical fiber carrying multiple wavelength channels is chosen for the broadband flexible network infrastructure. Within BB Photonics project reconfigurable access network architectures and access network modules are being investigated.

We present the first design of dynamically reconfigurable access network called reference network together with preliminary specifications for the network elements.

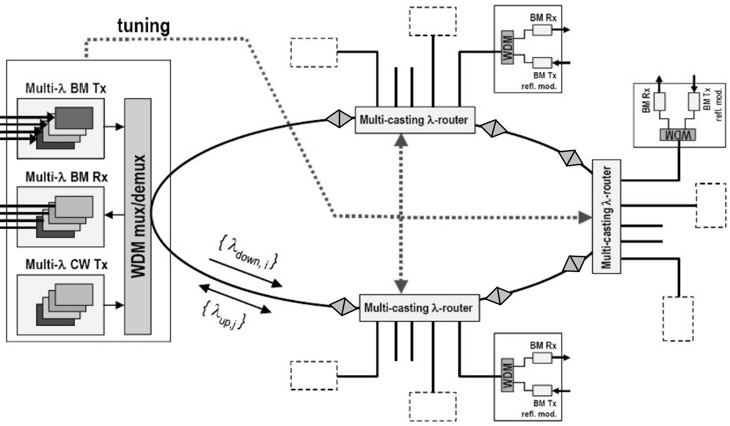
Reference network architecture and preliminary specifications

Access network architectures need to have several key characteristics in order to make them suitable for large-scale economic deployments. One of the main new requirements is the need to have a large level of flexibility in order to deliver a wide range of services to many users via various upgradeability scenarios. Thus, reference network architecture, which is shown in Fig. 1, has been chosen as a starting point [5].

A ring-shaped optical distribution network is chosen in order to provide network redundancy which leaves the choice to run the bidirectional traffic along the upper part of the single fiber ring or along the lower part. Therefore, the break of ring fiber does not cause loss of the connection.

The inter-node distance is limited to 20km maximum, since one or more nodes may be at significant distance from the central office. The maximum node-to-user distance is set at 5km. Single mode fiber ITU G.652 (SMF) is applied.

Three remote nodes are inserted into the fiber ring. Each node contains a wavelength router and a bidirectional amplifier construction for both the input and output of the remote node. A bidirectional amplifier construction consists of 2 unidirectional optical amplifiers and 2 circulators. A remote node connects up to 16 users.



channels

DOWN 1	1539,77 nm
UP 1	1541,35 nm
DOWN 2	1542,94 nm
UP 2	1544,53 nm
DOWN 3	1546,12 nm
UP 3	1547,72 nm
DOWN 4	1549,32 nm
UP 4	1550,92 nm

Figure 1: Reference network architecture.

The wavelength architecture is designed around pairs of wavelengths. In each pair one wavelength is used for downstream traffic and the second wavelength is used to send continuous wave (unmodulated) optical power towards the ONUs to permit modulation within the ONU. The maximum wavelength range chosen for this network architecture enables commercially available C-band EDFAs to be applied. The target bit rate for this network is 1.25Gbit/s per channel (upstream and downstream symmetrical), however a bit rate of 10Gbit/s is planned at the final stage of the project.

The central office contains a set of 4 burst-mode transmitters generating the signals for the downstream traffic, 4 transmitters for the CW downstream signals and 4 burst-mode receivers for the upstream traffic. Two AWG elements are used as downstream WDM multiplexer and upstream WDM demultiplexer. A circulator is used in order to separate upstream and downstream traffic. 8 wavelengths on ITU 200GHz grid are generated by central office in total.

The optical network unit showed in Fig. 2a contains a Mach-Zehnder duplexer which sends downstream data to the photodetector from one output and continuous wavelength to the RSOA from the second output. The free spectral range of the duplexer has to cover given wavelength grid.

The continuous wavelength received from the Mach-Zehnder duplexer is amplified and modulated by the RSOA, and is returned containing upstream information. The possibility to provide gain and modulation in the same time rejects the need for additional amplification, while the wide amplification-bandwidth of a SOA implies wavelength independence. In order to obtain high speed modulation, quantum dot material is being investigated as active medium for the RSOA. Another important property of the RSOA that will be investigated is its polarization insensitivity, which is inevitable in the case of commercial implementation.

The wavelength router (Fig. 2b) works on the concept of using thermally tuned micro ring resonators to select channels to be dropped. A single channel can be dropped to multiple users. Fig. 2c illustrates schematically the operation of a micro ring resonator. The ring is coupled into two waveguides with a four port configuration (2 inputs and 2 outputs). For a broadband input at port 1, when the ring is in resonance for λ_{drop}, the wavelength is dropped on port 4. The remaining non-resonant wavelengths are transferred to port 2. Waveguides are situated orthogonally to allow the micro ring resonators to be placed in a matrix array as shown in Fig. 2c.

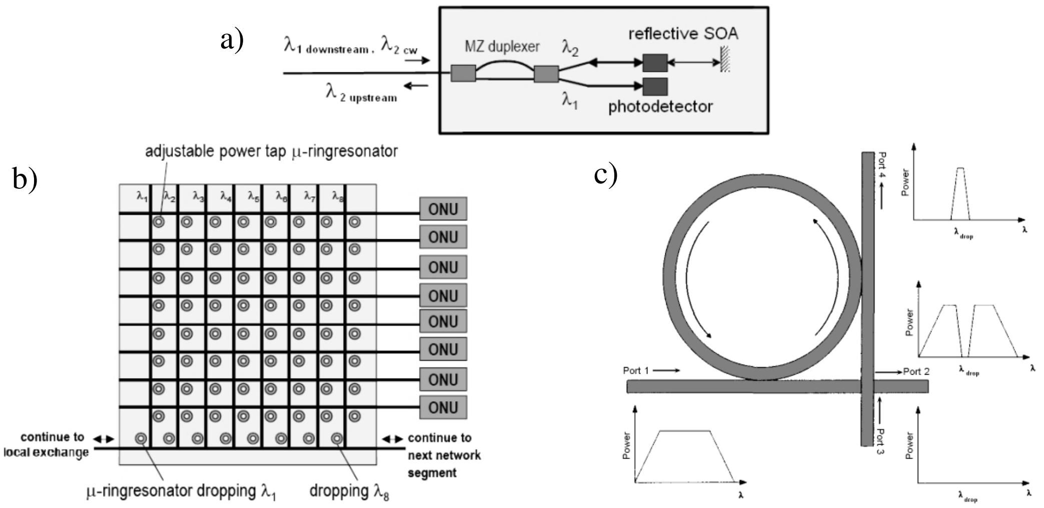
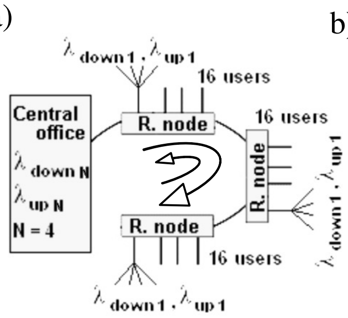


Figure 2: Optical network unit architecture (a), wavelength router schematic (b), micro ring resonator schematic (c).

Power budget of the reference network for the longest light path is given in Fig. 3b. It is assumed that capacity is distributed uniformly which means that each downstream channel feeds 4 users per remote node – 12 users in total. Fig. 3a explains what is meant with the longest light path. Traffic is ruled by TDM.

a)



b)

Parameter				Value [dB]
Central office	1 x	Modulation loss (4 dB)[1]	=	- 4
	1 x	AWG insertion loss (0.3 dB)[1,2]	=	- 0.3
	1 x	Circulator insertion loss (1 dB)[1,2]	=	- 1
Optical distribution network	8 x	Fiber connection loss (0.5 dB)[1,2]	=	- 4
	3 x	Internode fiber attenuation – 20 km (0.2 dB/km)[1,2]	=	- 12
	10 x	Circulator insertion loss (1 dB)[1,2]	=	- 10
	5 x	**Optical amplification (10 dB)[1,2]**	**=**	**+ 50**
	3 x	Wavelength router insertion loss (6 dB)[1,2]	=	- 18
	3 x	Wavelength router multicast loss (6 dB)[1,2]	=	- 18
	1 x	Drop fiber attenuation – 5 km (0.2 dB/km)[1,2]	=	- 1
User side	1 x	Mach-Zehnder interfer. Insertion loss (3 dB)[1,2]	=	- 3
		[1]**Total power budget for down- and upstream data**	**=**	**- 21.3**
		[2]**Total CW downstream budget**	**=**	**- 17.3**

Figure 3: The longest light path definition (a) and the longest light path power budget for down- and upstream transmission (b).

Simulation results

Fig 4. presents eye diagrams of a) received downstream and b) received upstream signals for the longest light path, together with peak power. The bit rate is 0.5Mbit/s per channel.

Simulation results include amplified spontaneous emission. Also some device reflections are taken into account, however the value of reflected power is kept on the noise level and does not perform any significant influence on data streams. Because of relatively short distances and low signal power involved no FWM or other nonlinearities were observed. Transmission is error free.

From Fig. 4b it can be deducted that signal rise time (and fall time) will be one of the limitations of the achievable bit rate. Dual rising slopes in this figure are caused by the pattern effect. Changing the active material from bulk to MQW or QD can improve performance of upstream signal quality.

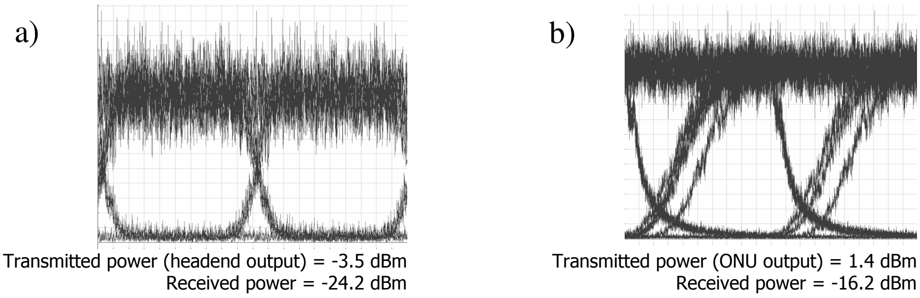


Figure 4: Eye diagrams of received downstream (a) and received upstream signals (b).

Migration scenario

Existing passive optical networks support TDM in tree architecture. Remote nodes in TDM-PONs consist of passive couplers. Therefore one of the major points of the BB Photonics project is to define different migration scenarios leading to WDM-PONs. One of possible migration scenario includes two steps.

Firstly, feeder fibers of TDM-PON are replaced with a single fiber ring that connects the remote nodes, and the passive couplers are replaced with a pair of CWDM band splitters in order to add/drop a group of DWDM wavelengths for up- and downstream. Functionality of the network stays constant - only short downtime for upgrade is needed.

Secondly, wavelength routers are inserted into the fiber ring. If dedicated switches are used for protection and restoration functionality, inserting a new remote node in the network will not disturb the network operation [1, 3, 4].

Conclusions

In this paper we presented first design of access (reference) network architecture, where the key features are: colorless optical network unit based on RSOA and wavelength router based on thermally tuned ring resonators. Calculated power budget shows that there is a possibility to design network architecture with longer inter-node or node-to-user distances. Also the possibility to increase the bit rate needs to be investigated as well as the influence of noise on system performance.

Acknowledgements

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References

[1] D. Gutierrez *et al.*, "FTTH standards, deployments and research issues," *Proc. of JCIS,* July 2005, pp. 1358-1361.

[2] D. J. Shin *et al.*, "Hybrid WDM/TDM PON with wavelength-selection-free transmitters", IEEE/OSA JLT, January 2005, pp. 187-195.

[3] Y.-L. Hsueh *et al.*, "SUCCESS-DWA: a highly scalable and cost-effective optical access network", IEEE Optical Communications, August 2004, pp. 24-30.

[4] F.-T. An *et al.*, "SUCCESS: a next generation hybrid WDM/TDM optical access network architecture", IEEE/OSA Journal of Lightwave Technology, November 2004, pp. 2557-2569.

[5] "D1.1 Service and Network Requirements", BB Photonics project deliverable.

[6] "D1.2 Preliminary Specifications of system components and modules", BB Photonics project deliverable.