

Deployment of a DWDM System with CLA Optical Amplifiers in the CESNET2 Network

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1 Abstract

This paper describes design, deployment and experiences with DWDM systems based on the CLA (CzechLight Amplifiers) optical amplifiers within the CESNET2 optical infrastructure. The key motivation for CLA-based static DWDM systems is optical line deployment with the cost effective solution to get a few independent optical channels (typically 4–8) with capacity 1–10 Gbps for various data connections on one dark fibre pair. Also important is the NIL (Nothing-in-line) approach, i.e., optical line design without the inline components such as amplifiers and chromatic dispersion compensators).

2 Introduction

CLA (CzechLight Amplifiers) were initially designed for the cost effective deployment of gigabit optical lines without the inline amplification (Nothing-in-line approach) by the CESNET optical research group. In the last year we started experiments with the DWDM Mux/Demux to deploy static DWDM systems for gigabit and 10gigabit optical channels.

The first prototypes was successfully verified in CzechLight testbed and then within CESNET2 NREN network on the line Prague-Hradec Kralove (without the DWDM Mux/Demux) at the 1 Gbps capacity and using OSA (One Side Amplification) approach. The first optical line based on CLA PB01 with the 4-channel DWDM Mux/demux, we deployed in early 2006 on the CBF (Cross Border Fibre) line Brno–Bratislava (about 200 km, 45 dB attenuation. G.652 fibre) with the 10 Gbps capacity. In mid 2006 year another CBF line followed, namely Brno–Vienna (224 km, 50 dB, G.652) where a new prototype CLA PB02 with the more powerful amplifiers modules was tested. The DWDM system with the CLA PB01 amplifier types was designed and implemented in the second half

of 2006 on the optical line Prague–Usti nad Labem with the second local DWDM span to Masaryk’s hospital within the medical research activities.

3 CLA technology description and features

The lack of optical equipment suitable for NREN needs in the past years led CESNET to develop own optical building kit composed from commercially available elements and modules. The result is a low-profile and reliable rack mountable device having a plenty of management interfaces. Reliability is increased by power supply redundancy, important parameters monitoring, amplification and management part independence and usage of non-moving parts (hard disc). The device is controlled by software based on Linux that allows easy remote management and future development. In a single 1U box, the device can accommodate up to 4 optical amplifiers

CLA design is now covered by utility model called ”Modular building kit of optical amplification device” registered by Industrial property office on 23 October 2006 under Nr. 16952. The basic functional diagram is shown in Figure 1.

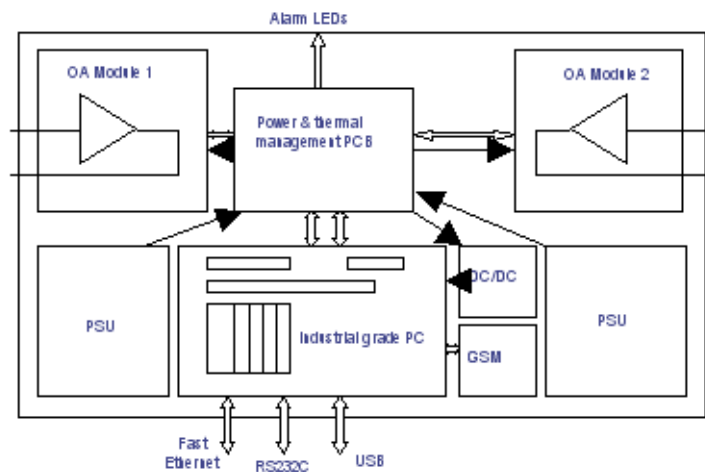


Figure 1: Fundamental schematics of CLA

4 Optical CBF line Brno–Bratislava

The optical line from Brno to Bratislava which is approximately 200 km long has been equipped with CLA PB01 optical amplifiers. Chromatic dispersion of G.652

optical fibre has been compensated by relatively uncommon compensating elements – Fibre Bragg Gratings (FBG). This line has been designed for capacity up to 4x10 Gbps/s and fixed DWDM (Dense Wavelength Division Multiplexing) multiplexers and demultiplexers are used. Detailed optical line design is show in Figure 2.

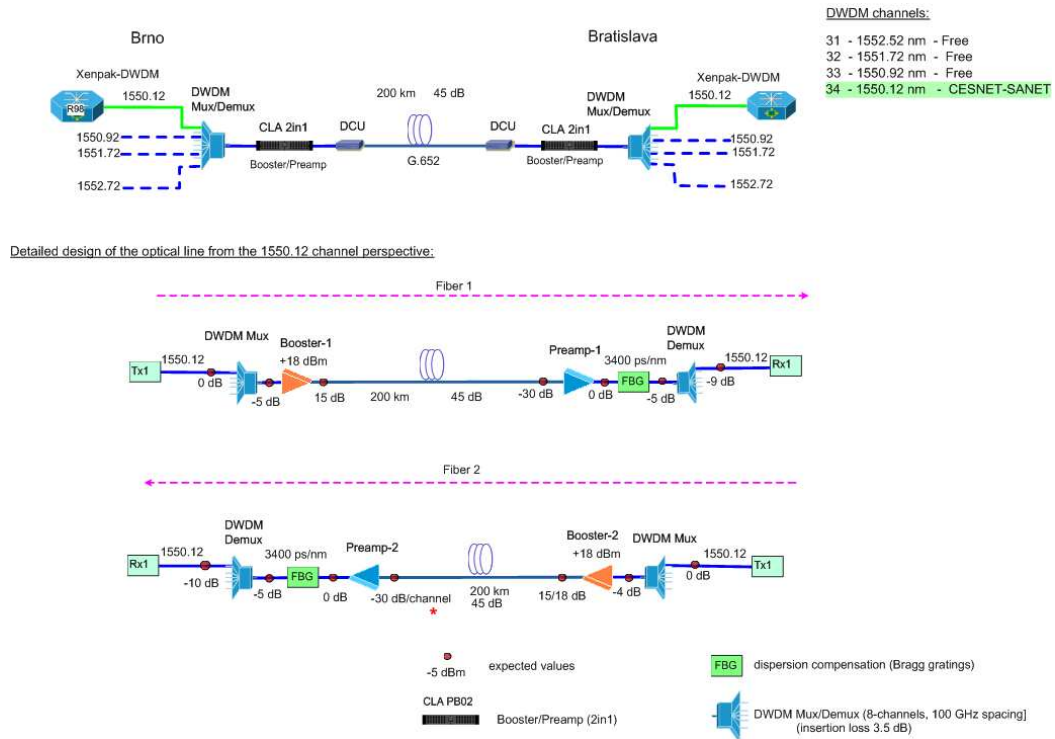


Figure 2: Deployment details for the optical line Brno–Bratislava (4-channel static DWDM)

The wavelength of 1550.12 nm is connected to the peering routers Cisco OSR7609 and Cisco 6500 which are equipped with the DWDM Xenpaks.

5 Optical CBF line Brno–Vienna

The static DWDM technology deployment on the CBF line Brno–Vienna is a joint project of CESNET and AConet (Austria) NRENs. The optical line from Brno to Vienna, which is approximately 224 km long, has been equipped with CLA PB02 optical amplifiers. It is a new type of CLA optical amplifiers with better optical parameters, which has been developed as prototype and tested in real environment. Chromatic dispersion of G.652 optical fibre has been compensated by relatively new compensating elements – Fibre Bragg Gratings (FBG). FBGs

were successfully deployed and tested for the first time on the CESNET2 line Brno–Bratislava in February 2006. This line has been designed for capacity up to 8x10 Gbps/s and fixed DWDM (Dense Wavelength Division Multiplexing) multiplexers and demultiplexers are used. Detailed optical line design is shown in Figure 3.

These two lines (Brno-Bratislava, Brno-Vienna) are parts of A-CZ-SK CBF triangle. In comparison with point to point Cross Border Fibre connection, in the case of fibre failure, triangle connection allows redirection of traffic in times less than 60 ms, so overall reliability of end to end connections is improved significantly. This is achieved by Layer-2 protocols (802.1q and 802.1w), avoiding a slower and more complicated solution on the IP level. 10 GE VLANs are implemented on this background, giving the impression that distances between countries have disappeared.

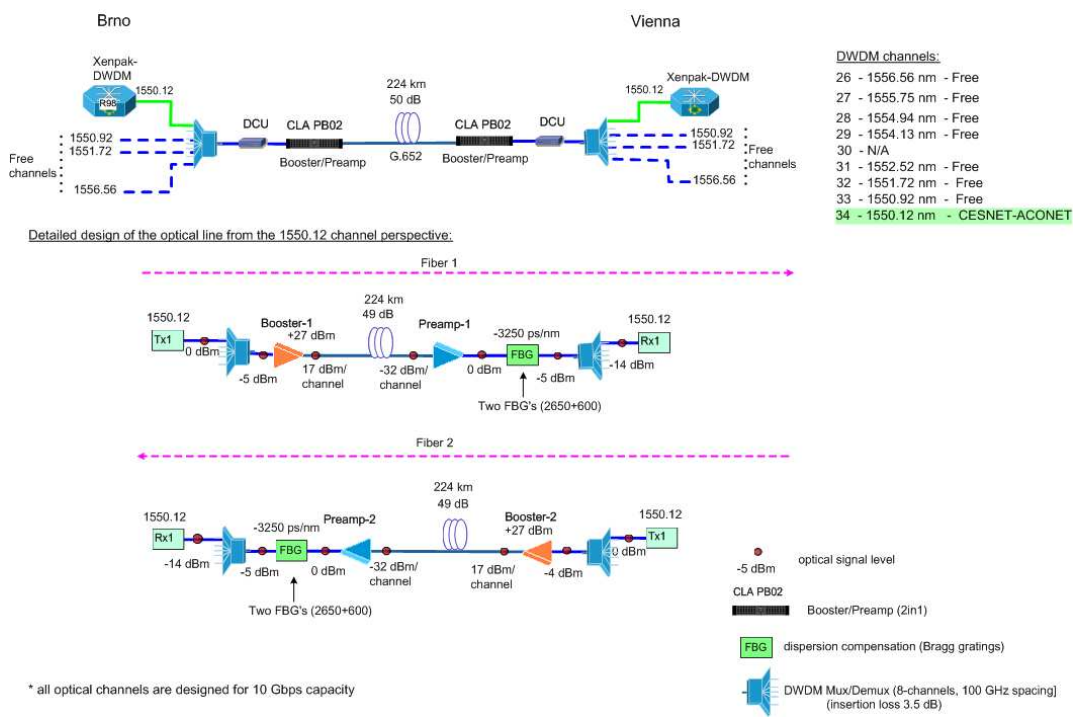


Figure 3: Deployment details for the optical line Brno–Vienna (8-channel static DWDM)

The wavelength of 1550.12 nm is connected to the peering routers Cisco OSR7609 and Cisco 6500 which are equipped with the DWDM Xenpaks. The deployed HW supports DOM (Digital Optical Monitoring) functionality so that it is possible to monitor optical levels and other parameters (laser bias). The SNMP monitoring of DOM by G3 measurement system is under development.

The final cost of this solution (with better optical amplifiers 2in1 modules) is about 36 thousand EUR for 8 channels up to 10Gbps speed, including 2 pcs CLA PB02 amplifiers, 2 pcs of Braggs Grating, 2pcs of 8-channel DWDM multiplexers and 2 pcs of 8-channel DWDM demultiplexers for the optical line deployment. Each optical wavelength must to be terminated in a network device (router, switch, etc.) with pluggable optics support (Xenpaks, XFP). Various types of converters may be used as a workaround solution to convert DWDM signal to "grey" optics or UTP. The cost of pluggable optics is not included in the estimated price.

6 CBF triangle Brno–Bratislava–Vienna and redundancy solution

The newly created CBF triangle A-CZ-SK created the interconnections of neighbouring NRENs – CESNET2, SANET and AConet – at the optical level (Layer-1) enabling wavelength services for research projects and activities (with the exception of Bratislava–Vienna line where "grey" 10GE LAN optics is used). The triangle allows the peering routers interconnections at 10 Gbps speeds. To provide the connections between Poland (NREN PIONIER) and this triangle we use EoMPLS (Ethernet over MPLS) L2 tunnels through the CESNET2 backbone. The IP peering routers (Cisco 7600 router on CESNET2 and Catalyst 6000 series on AConet and SANET sides) run in a hybrid Layer-2/Layer-3 mode. 802.1Q trunks are configured for the PtP connections which also allows for mapping the EoMPLS tunnels into VLANs, thus supporting end-to-end Layer-2 services. The detailed A-CZ-SK triangle solution and PIONIER interconnection is shown in Figure 4.

We investigated the options for fast converging backups of all connections in the triangle as a measure against fibre or HW failure. We considered the alternatives of Level-2 protocols providing subsecond failover, which can be quite different in comparison with the eBGP timeout in case of Level-3 backups. Within the triangle we have trivial topology based on the same routing/switching technology (there are no compatibility problems). As the final solution we implemented and tested Rapid-PVST (Rapid-Per-VLAN-Spanning Tree) which achieves rapid convergence based on the IEEE 802.1w standard. Primary and secondary root bridges are defined per VLAN on the routers (see Figure 4). Due to HW limitations of the OSR 7609 router (mapping EoMPLS tunnels into VLANs is not supported), we used a workaround solution with external physical loopback between the Layer-2 and Layer-3 configured 10GE ports.

The failover tests we were able to show that the redirection of traffic happens within 60 ms, so overall reliability of this setup was increased.

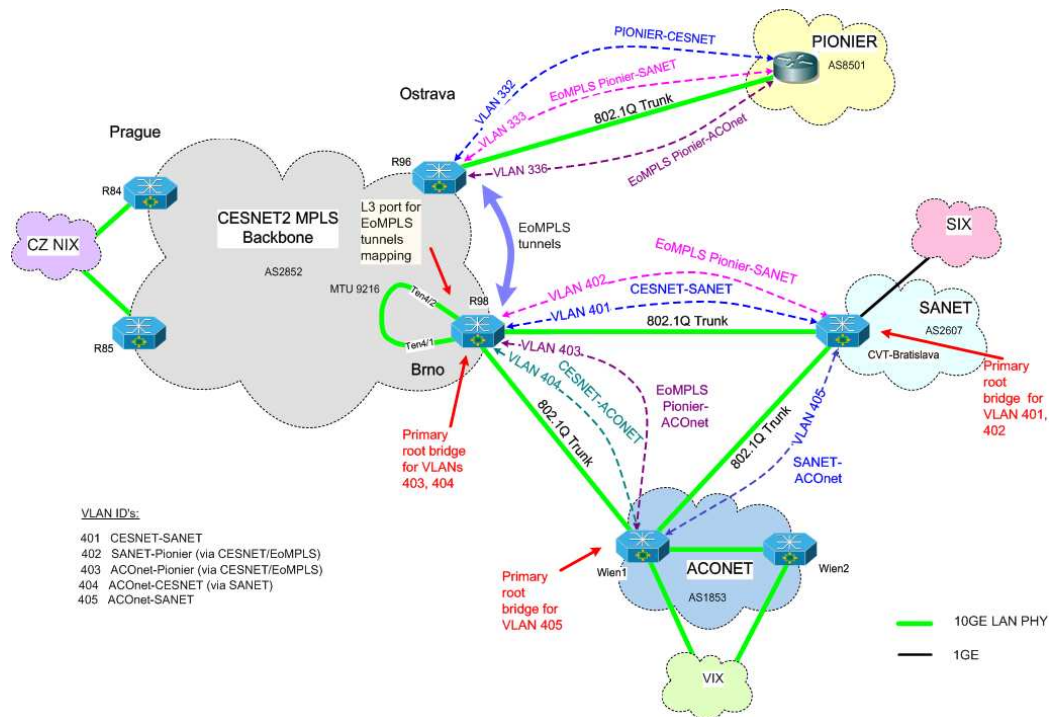


Figure 4: The triangle A-CZ-SK topology at Layer-2/Layer-3 and PIONIER inter-connection.

The A-CZ-SK connection and setup works without any problems with the static DWDM CLA systems and Layer-2 redundancy implementation. The current load statistics are shown in Figure 5 (line Brno-Bratislava) and Figure 6 (Line Brno-Vienna). We experience no Ethernet errors or outages.

7 Optical line Prague-Usti nad Labem

The optical line Prague-Usti nad Labem deployment originated by the requirement of pilot project for interconnection data centers of Masaryk Hospital in Usti nad Labem, Central Military Hospital and Thomayer Teaching Hospital in Prague. The interconnection of data centers requires high capacity data circuits with low latency. For security and other reasons, the data circuits must be designed as private and separated from normal network traffic. The static DWDM systems based on CLA amplifiers can be a reasonable and cost-effective solution to this problem.

To establish the private DWDM wavelength connection, it was necessary to deploy a DWDM system on the main fibre optic line Prague-Usti nad Labem and for the local loop as well (see Figure 7).

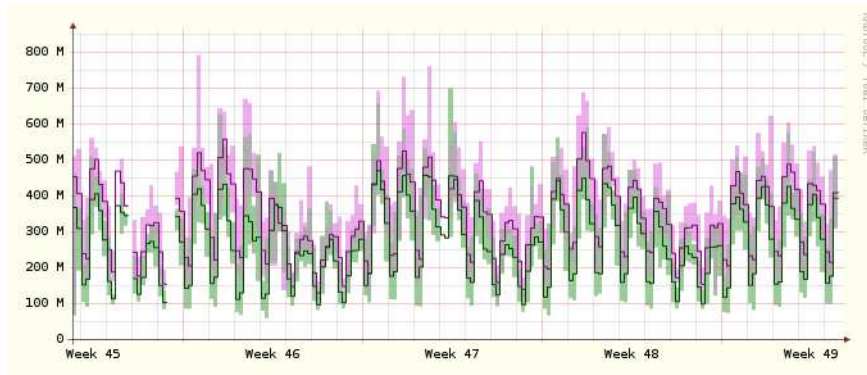


Figure 5: Current traffic load on the CBF line Brno-Bratislava

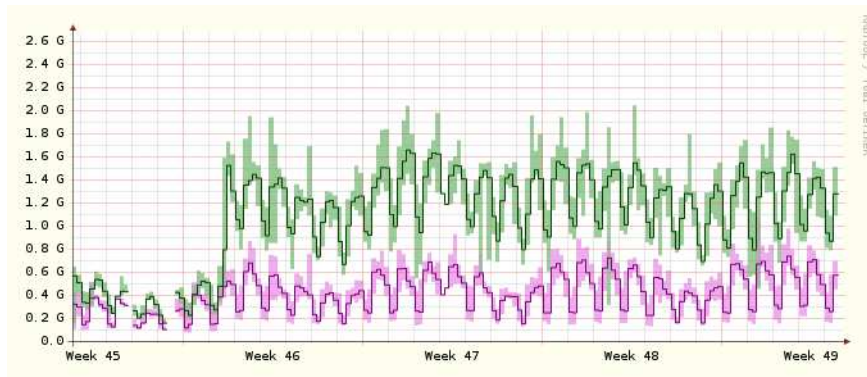


Figure 6: Current traffic load on the CBF line Brno-Vienna

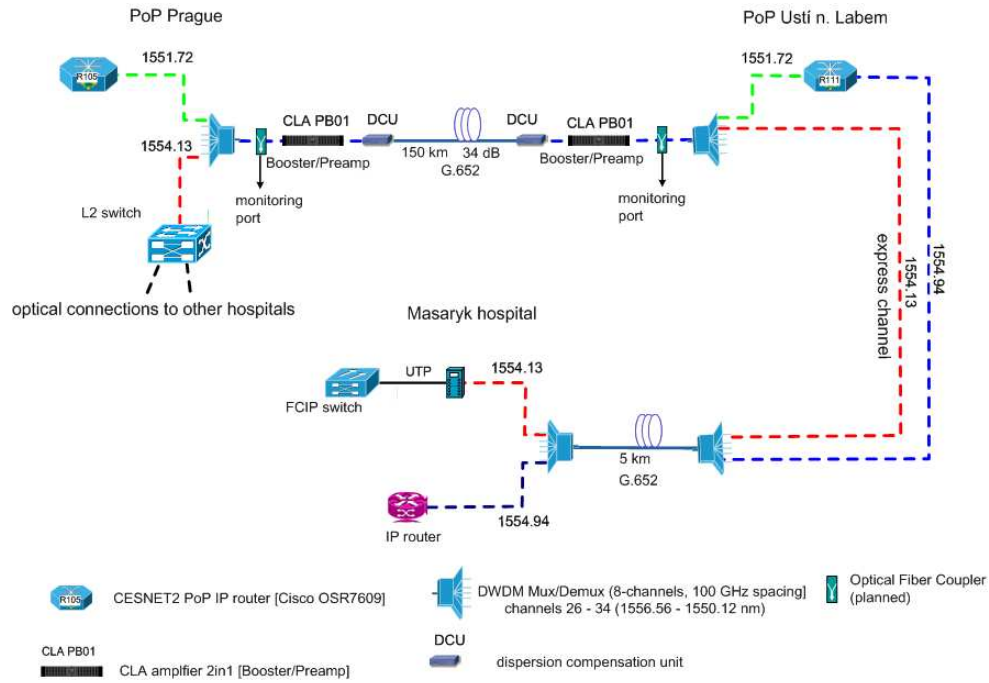


Figure 7: Static DWDM line Prague–Usti nad Labem deployment

The line Prague–Usti nad Labem is about 150 km long and we use the solution with the CLA PB01 amplifiers and 8-channel Mux/Demux with the Braggs grating to compensate the dispersion which is needed to support 10 Gbps speeds. The detailed design and optical signal levels are shown in Figure 8.

Both wavelengths are fully operational without the any problems or errors. The wavelength of 1551.72 nm is terminated on DWDM SFPs installed in the routers, while the 1554.13 nm wavelength has to be converted to "grey" optics or UTP using the SFP-to-SFP convertor because the FCIP switch does not support DWDM optics.

8 Conclusion and future development

There is a plan for CLA technology deployment for new lines where only a few DWDM channels are needed (because the commercial DWDM systems are expensive and large) and also new technology improvements and extensions:

- DWDM line Prague–Usti nad Labem extension to Liberec with the OADM deployment and upgrade do 10 Gbps
- new optical lines development (Ceske Budejovice–Brno, Brno–Ostrava)

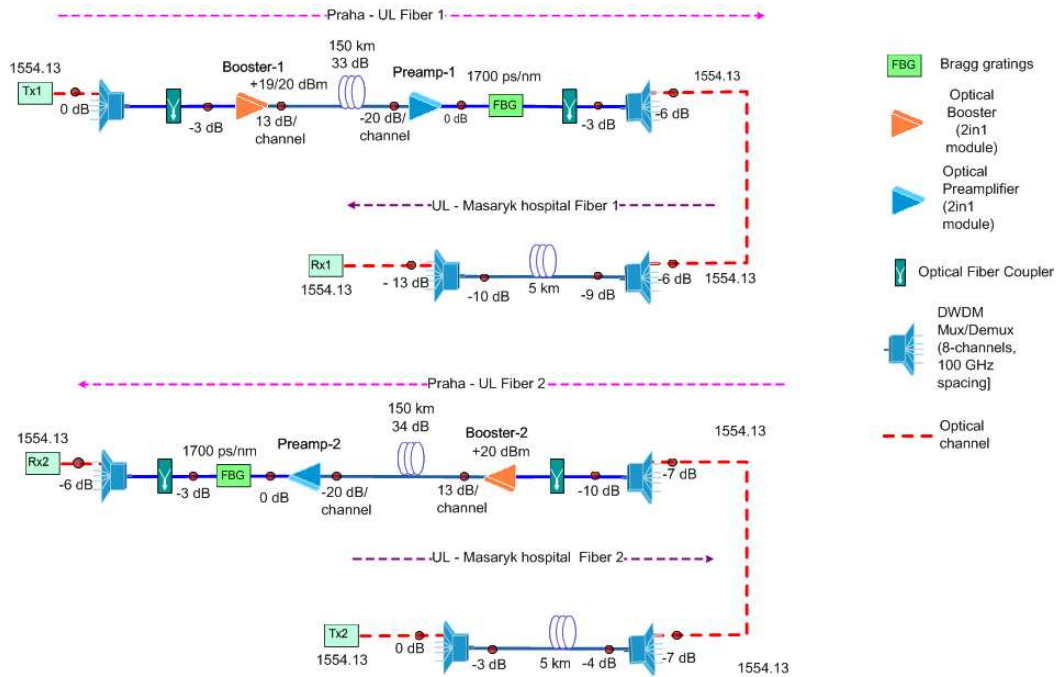


Figure 8: Static DWDM line Prague–Usti nad Labem

- CLA amplifier monitoring via SNMP

With the CESNET2 DWDM optical technology deployment concept we constructed the main DWDM core based on ROADM technology and with the capacity of 32 wavelengths up to 10 Gbps. The static CLA DWDM solution is planned to use on the access optical lines to the optical network core.

References

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