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Towards transport networks based on 40 Gbit/s transmission: results from the IST ATLAS project

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Abstract:

We report the main results from the IST ATLAS project on the transmission techniques for new network infrastructures. We report results on the transmission performance on 4x40 Gb/s systems over a link 500 km long, including the wavelength conversion. We show that the wavelength conversion based on the PPLN device and the systems based nx40 Gb/s are now fundamental elements for future transport networks.

1. Introduction.

Future telecommunication networks operating on wide areas will have to support a total traffic of the order of some Tbit/s. Such a huge capacity will be transmitted by means of t Multiplexing (WDM) technique, or better with Dense WDM (DWDM) [5-6] and processed at the nodes by means of devices as Optical Cross Connects (OXC) [1] and Optical Add Drop Multiplexers (OADM) [1]. Due to the traffic increasing and to the fact that transmission at 40 Gbit/s seems to we believe that future telecommunication transport networks, especially if operati areas, will be based on the Nx40 Gbit/s transmission systems [6], even though the network design in this environment requires many ingenious contrivances [7-8]. Furthermore it is well known that the All Optical Wavelength Conversion (AOWC) is a fundamental requirement for future networks [1] and in the current literature many works consider such a process as already commercially available; this scenario is particularly evident in papers dealing with novel switching techniques as the optical packet switching and the optical burst switching. However, also for networks that do not consider a too much deep innovation, and in particular for network still based on a circuit switching operation, the wavelength conversion could strongly improve the network performance. Two are the main advantages of the wavelength conversion: the dynamic allocation of the resources and the restoration. As far as the first advantage is concerning we can simply say that the wavelength conversion permits to carry the information using suitable regions of the fibre bandwidth according to the evolution of the traffic requirements along the time. Wavelength conversion can be considered as a fundamental recipe for networks based on the bandwidth-on-demand.

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In this paper we report the experience of the IST ATLAS project in the field of the advanced infrastructure of transport networks. In particular we show the high performance of the nx40 Gbit/s transmission also in links encompassing G.652 fibres and in the presence of AOWC based on Periodical Poled Litium Niobate (PPLN) devices. We also show how to implement future transport networks based on the nx40 Gbit/s transmission.

2. An overview of the IST ATLAS project

The aim of the ATLAS (All-optical Terabit per second LAmbda Switched transmission) project was to investigate transmission techniques at very high capacity over long distances (500-1000 km), taking into account the behaviour of some fundamental devices that will be used in future Terabit/s networks, such as the optical wavelength converters that should perform routing operations in the network nodes.

In the ATLAS project fibre-optic WDM transmission over 500 –1000 km with an aggregate capacity of 1 Tbit/s was pursued by adopting return-to-zero signal format and the dispersion management technique. 40 Gbit/s and 80 Gbit/s in-line optical wavelength converters were experimented to investigate the role of the wavelength converters in optical transport networks.

The main experiment of the ATLAS project was the field demonstration of the transmission of four channels at 40 Gbit/s in a link 500 km long with an amplifier spacing of 100 km by adopting both G.652 and G.655 fibres. One of the channel was also converted in frequency along the line, simulating in this way the signal behaviour in a future transport network. Theoretical studies showed how extend such performance to a Tbit/s transmission over distances of the order of some thousands of kilometres.

In table 1 we report the list of the ATLAS participants. More details can be found in www.fub.it/atlas/:

Fondazione Ugo Bordoni	ITALY
Pirelli LABS	ITALY
United Monolithic Semiconductors	FRANCE
Opto Speed SA	SWITZERLAND
Thales	FRANCE
University of Ljubljana	SLOVENIA

Instituto de Telecomunicações	PORTUGAL
University of Paderborn	GERMANY
Consorzio Padova Ricerche	ITALY
University College of London	UNITED KINGDOM
Istituto Superiore delle Comunicazioni	ITALY
Optospeed Italia	ITALY

Table 1: ATLAS participants

3. Transmission experimental results

In this Section we report some results on the 4x40 Gbit/s transmission performed in the PIRELLI LABS laboratories. Results on the field trial performed in Rome during summer 2002 can be found in the paper reported at the OFC2003 conference [11].

In fig. 1 we report the scheme of our 40 Gbit/s transmitter based on the electrical 4x10 to 1x 40 Gbit/s multiplexing.

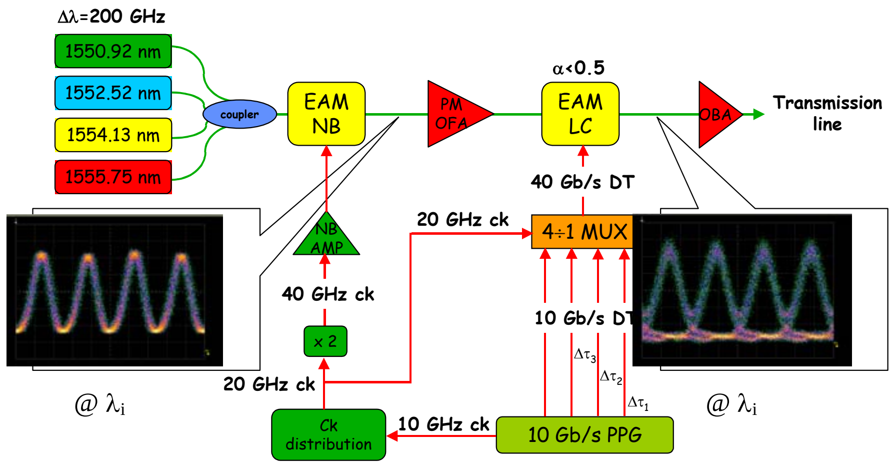
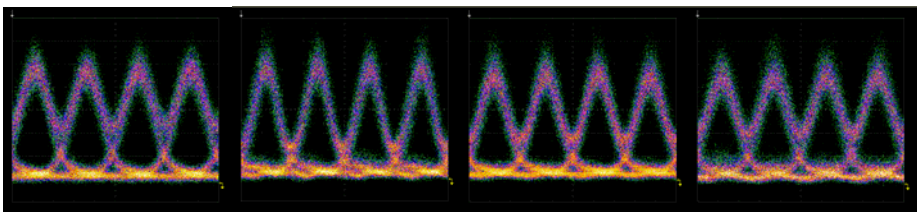


Fig. 1: scheme of the 40 Gbit/s transmitter. By means of the 4 CW laser four 40 Gbit/s channels are obtained.

In fig. 2 we report the eye diagrams of the four channels after the transmission in a link 500 km long encompassing G.652 fibres with an amplifier spacing of 100 km. The transmission was obtained by compensating the chromatic dispersion at each fibre span by means of Dispersion Compensating Fibres (DCF).



Ch 1 (1550.92 nm) **Ch 2** (1552.52 nm) **Ch 3** (1554.13 nm) **Ch 4** (1555.73

Fig. 2: eye diagram of the four channel after the transmission in a G.652 link.

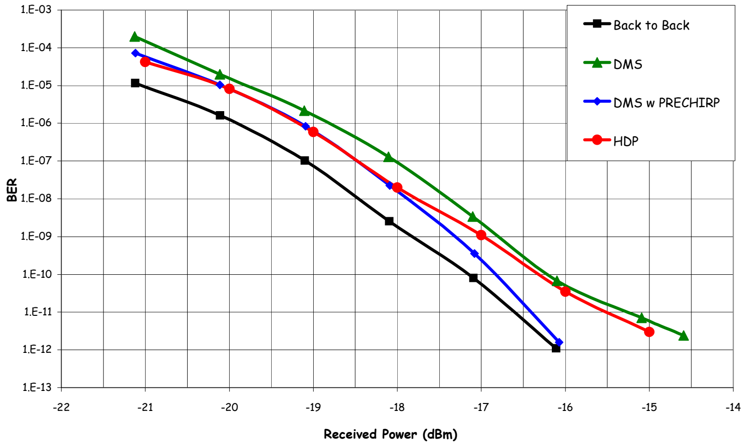


Figure 3: 4 channels 40 Gb/s transmission performance over 5 x 100 km G.652. Channel 2 BER curves with different compensating map: DM and DM with –78 ps/nm pre-chirp (14 dBm/span, 4 dBm/DCU), and HDP (12 dBm/span, 10 dBm/DCU). OSNR is 17 dB for all cases.

In fig. 3 we report the BER measurements on channel 2 considering different dispersion schemes: DMS means periodically compensation of the chromatic dispersion at each amplifier position, DMSPRECHIP is as DMS but with a prechirp at the link input [7] and HDP high dispersive pulse means a scheme in which all the compensation is performed at the end.

As shown in figure 3, where BER curves versus received power are reported for the same channel with the different schemes, DMSPRECHIRP (the prechirp was –78 ps/nm) is confirmed as the best choice: no power penalty is noticeable with respect to back to back at 10^{-12} BER, with 14 dBm/span and 4 dBm at DCF. With the same power levels and OSNR (17 dB) but without pre-chirp, the penalty increases and a slope decline is evident too. With HDP scheme we had to slightly decrease the power level per span (12 dBm), increasing the power levels on the DCF modules (10 dBm) instead: the performance is quite similar to straight periodic post-compensation.

The results shown in fig. 3 illustrate that the multichannel transmission at 40 Gbit/s can be obtained with negligible degradation (especially by using suitable dispersion management) also in long links with strong impairments as high chromatic dispersion and long amplifier spacing.

4. All Optical Wavelength Conversion

One of the objective of IST ATLAS project was the development of all-optical wavelength converters based on three different methods: (I) quasi phasematched (QPM-) cascaded $\chi(2)$:$\chi(2)$-difference frequency generation (cDFG) in Ti-diffused, periodically poled $LiNbO_3$ (Ti:PPLN) waveguides, (II) four-wave mixing in semiconductor optical amplifiers, and (III) non-linear switching in semiconductor quantum well structures. These techniques have different advantages, disadvantages and degrees of technological maturity. It was therefore decided to develop the three techniques and then select the most suitable one for use in the ATLAS field experiments. After several experiments we have verified that the PPLN device, with polarisation independent scheme, is the one that can be assumed as almost ideal device.

In fig. 4 we report the PPNL AOWC [9].

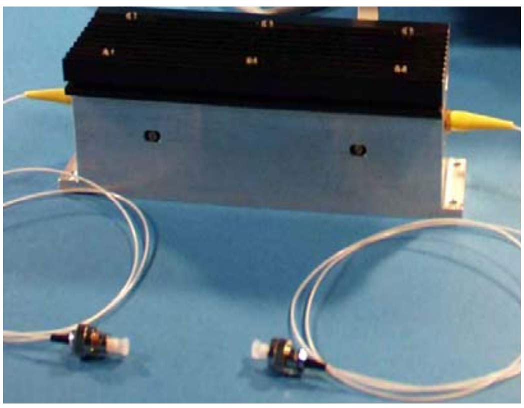


Fig. 4: The PPLN AOWC.

In fig. 5 we report the eye diagram after the conversion with PPLN (on the left) and after the transmission in a G.655 link 500 km long. Also the 10 Gbit/s demultiplexed signal is reported.

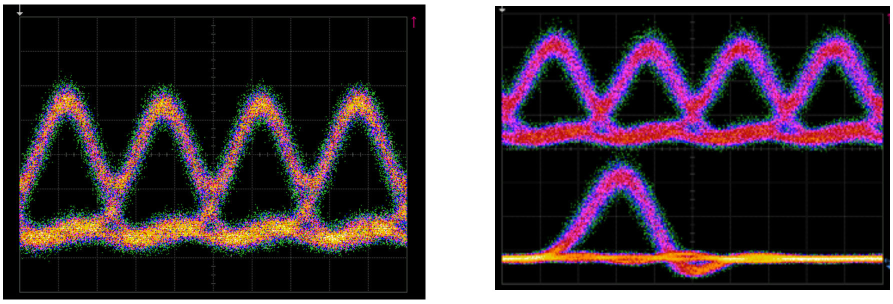


Fig. 5: eye diagram after the conversion with PPLN (on the left) and after the transmission in a G.655 link 500 km long.

As shown by figure 5, and also by BER measurements [9], no relevant penalty was observed after conversion and transmission.

6. CONCLUSIONS

The ATLAS project has demonstrated that future reconfigurable transport telecommunication networks, also in very wide terrestrial applications, can be based on the RZ transmission a DWDM technique in combination with all-optical wavelength conversion to enable the nodes. The experience made in the fabrication of electronics devices shows that receivers will be integrated in small devices with a predicted cost that will be co components for 10 Gbit/s WDM networks.

The results which we achieved, together with the recent market research repo traffic, show that the 40 Gbit/s WDM techniques are a correct promising solution they can reduce the number of optical components needed in the core switches. In size of switching matrices and the number of filters is reduced since only a quarter o

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