Coarse Wavelength Division Multiplexing for the Joint Transmission of 622Mbit/s- and CATV Signals in the Optical Network of a City Carrier

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Abstract *For an existing optical network of a city carrier running at a wavelength of 1.31µm so far investigations were performed to clearify the possibility for extending the transmission capacity. Beside the digital signal channel in use an additional CATV signal in coarse wavelength devision multiplexing (CWDM) technolog was introduced at λ=1.55µm. The experimental results of a field trial are presented in this work.*

Introduction: Since the early `90th the city carrier KomTel (now Versatel) runs an optical network in the urban area of Flensburg, Germany, with standard singlemode fibers and a total length of approximately 150km. Intending to extend the services from purely data, telephone and internet activities to CATV services using the same fibercable infrastructure investigations were undertaken to proof the feasibility of upgrading the network by deploying CWDM technology. In order to get real world results from the experimental investigations the Flensburg University of Applied Sciences got an access to two fiber loops which are part of the KomTel cabling system burried in the city of Flensburg (see Fig.1).

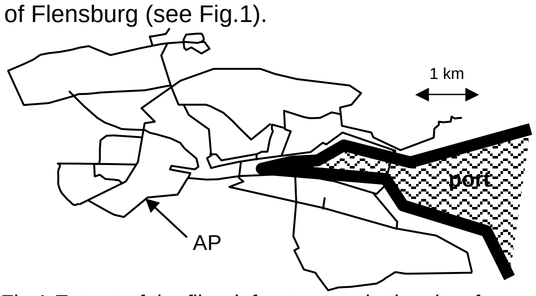

Fig.1 Extract of the fiber infrastructure in the city of Flensburg; AP access point of the university

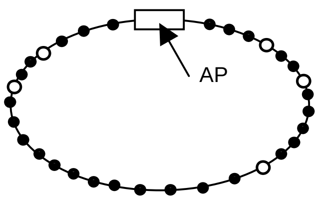

Fig.2 Test loop structure for cable 2; AP access point; open circles: patch fields; closed circles: splices

Total length 13km; distances between patch points and splices [m] clockwise from AP;
200; 493; 534; 332; 478; 438; 604; 679; 288; 261; 65; 450; 142; 703; 358; 380; 505; 340; 261; 359; 426; 323; 334; 546; 703; 260; 35; 382; 567; 511; 534; 493; 200

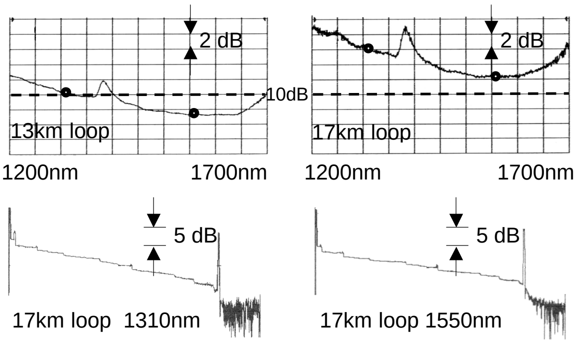

Fig.3 Fiber characteristics including splices and connectors upper part: fiber losses versus λ taken with an OSA and a white light source; dots indicate λ=1310nm and 1550nm; lower part: OTDR response

Fiber loop characteristics: Two fiber loops with 13km and 17km length were used for test purposes. They are composed of different standard singlemode fibers strands connected by splices and optical connectors. An example is given in Fig.2. When combining the two loops a total transmission length of 30 km including 50 splices and connectors is available. The results for the fiber attenuation and the optical time domain reflectometer (OTDR) response are depicted in Fig.3

From the white light source measurements the attenuation for each complete loop amounts to:

0.95dB/km at 1310nm	in loop 1 with 17km
0.73dB/km at 1550nm	
0,79dB/km at 1310nm	in loop 2 with 13km
0.55dB/km at 1550nm	

For single fiber strands from the OTDR measurements the attenuation amounts to:

maximum	0.79dB/km at 1310nm
	0.57dB/km at 1550nm
minimum	0.24dB/km at 1310nm
	0.07dB/km at 1550nm
in avarage	0.38dB/km at 1310nm
	0.23dB/km at 1550nm

A maximum insertion loss for splices and connectors for a complete loop is found to be
1.7dB at 1310nm
1.5dB at 1550nm

and a minimum return loss to be 14.5dB at 1310nm
14.1dB at 1550nm

Hence in average an excess loss for the fiber attenuation related to splices and connectors and return loss is noticed to be 0.49dB/km at 1310nm
0.26dB/km at 1550nm

MUX and DMUX characteristics: For the different experiments one or two MUX/DEMUX pairs were implemented in the transmission system (Fig.4) with

a maximum insertion loss of	0.36dB at 1310nm
	0.72dB at 1550nm
a minimum insertion loss of	0.04dB at 1310nm
	0.17dB at 1550nm
a minimum crosstalk of	24dB
and a maximum crosstalk	33dB

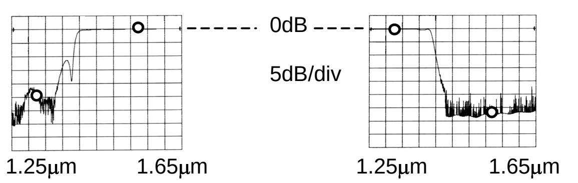

Fig.4 Transmission characteristics of MUX and DMUX circles indicate the wavelenfths of 1.31µm and 1.55µm

Optical amplifier: An erbium doped fiber amplifier (EDFA) was used in one of the experiments (see Fig.6) including an optical filter with a bandwidth of < 1nm for suppression of the amplified spontaneous emission (ASE) and with isolators at the input and output ports resp. The measured total gain was 24 dB, the maximum output power 9dBm, and the noise figure was 5.4dB.

Experimental set up: The experimental set up for the field trial is depicted in Fig.5. All devices were commercially available components with connectorized pigtails. The digital test signal was a 622Mbit/s pseudo random NRZ signal with a word length of $2^{31} - 1$ delivered by a bit error rate transmitter, the light source a 1.3µm direct modulated multimode laser with –1.8dBm launched into the fiber. The CATV signal for the 1.55µm transmission path was taken from the 75Ω CATV network distributed in the campus area with 34 analogue PAL- and 12 digital DVBC TV channels (Digital Video Broadcast for Cable). The electro optical converter E/O was a commercial available standard device with a dual output external modulator, a built in equalizer circuit and an additional phase modulator for the suppression of Brillouin scattering. 6dBm were coupled into the fiber. The light signals were combined by the multiplexer MUX. The optical network ON consisted of different fiber loop configurations as shown in Fig.6. After demultiplexing the digital 1.3µm signal is detected in a receiver with a sensitivity of –31.8dBm for a bit error rate of 10^{-9}. The 1.5µm CATV signal was detcted by a receiver with a pilot tone control and an automatic gain control for the optical signal. The quality of the 1.31µm path was verified by measuring the bit error rate BER of the 622Mbit/s baseband NRZ signal (BERT, BERR) and the 1.55µm path quality by analyzing the analogue channels by means of the CATV analyzer CAN and by measuring the BER in the digital 64QAM channels using the digital CATV analyzer DAN.

Results: The wavelength 1302nm of the 622Mbit/s signal was close to the dispersion minimum of the fiber at 1310nm. Hence the moderate fiber length of 13km, 17km or 30km maximum did only slightly

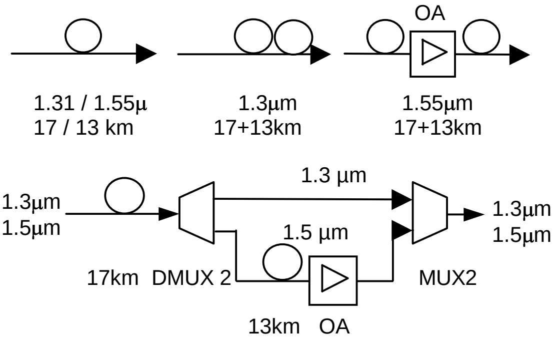

Fig.6 Different network configurations (ON in Fig.5) under investigation; OA: optical amplifier

affect the receiver sensitivity. Back to back measurements and those including the complete optical network (Fig.6.) differed by only ±0.1dB. Error free transmission was always possible for a received optical power >-30dBm regardless of the network configuration. An influence of the 1.5µm channel was not observed. In case of the CATV path at 1.55µm the BER of the raw data synch frame were measured in three different digital TV channels in the middle and the low and high end of the DVBC spectrum at 346MHz, 394MHz and 442MHz. Depending on the network configuration including back to back operation an optical input power into the connector of the receiver between –4.5dBm and 1.5dBm was required for a BER of 10^{-8}. An influence of the MUX and DMUX components and of the 1.3µm channel was not observed

Conclusion: The results indicate that no loss of quality was observed when upgrading a given optical network from digital data transmission for 622Mbit/s to an additional CATV channel by CWDM technology. In the investigated system this can be attributed to the installed moderate fiber lengths of <30km and to the moderate insertion loss of <3dB for the required MUX and DMUX components.

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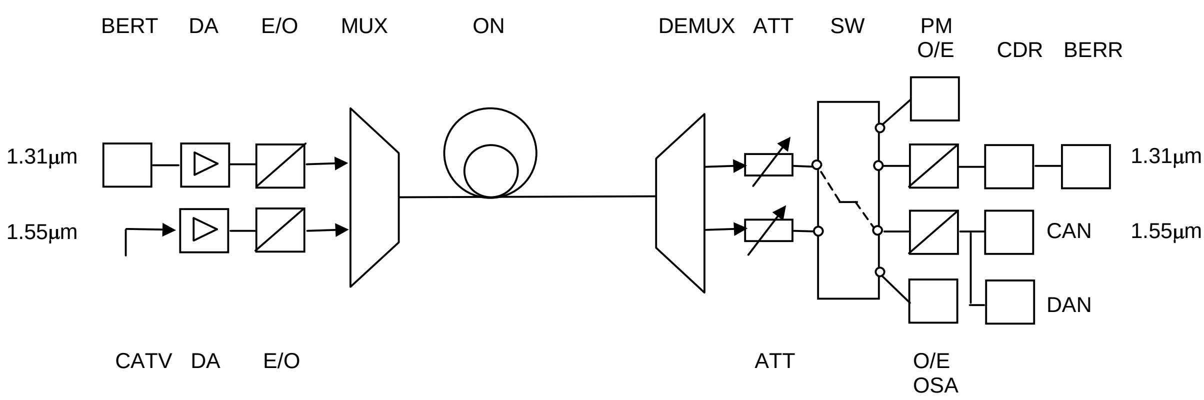

Fig.5 Block diagram for the field trial of a CWDM system for the joint transmission of 622 Mbit/s- and CATV signals
BERT: bit error rate transmitter 622Mbit/s; DA: driver amplifier; E/O: electro/optical converter; MUX: multiplexer; ON: optical network; DEMUX: demultiplexer; ATT: attenuator; SW: switch; PM: power meter; O/E: opto/electrical converter; CDR: clock and data recovery; BERR: bit error rate receiver; CAN: CATV analyzer; DAN: CATV digital analyzer; CATV: cable TV signal input; OSA: optical spectrum analyzer