Employing Mutually Injection-Locked Fabry-Perot Laser Diodes to Setup a Hybrid WDM Transport System

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Abstract: A hybrid WDM transport system based on mutually injection-locked Fabry-Perot laser diodes (FP LDs) for CATV, 256-QAM and OC-48 transmission is proposed and demonstrated. Mutually injection-locked FP LDs as broadband light source could be relatively simple and cost-effective compared with other demonstrated light source schemes.

1. Introduction

Wavelength-division-multiplexing (WDM) transport systems provide many advantages for optical networks, including high transmission capacity, network flexibility and upgradability. WDM transport systems are envisioned to have a multiple number of distributed feedback laser diodes (DFB LDs) which are wavelength-selected for each channel and controlled to operate at a specific wavelength, this process will increase the cost and complexity of the systems. Recently, there has been a proposal of a broadband light source which is based on mutually injection-locked Fabry-Perot (FP) LDs [1]. When FP LD is injection-locked, the multiple longitudinal modes of FP LD can be changed into a similar single longitudinal mode characteristic, and it can be used as cheap light source in hybrid WDM transport systems [2]-[3].

In this paper, we proposed and demonstrated a potentially cost-effective hybrid WDM transport system based on mutually injection-locked FP LDs. By mutual injection between two FP LDs, we realized a broadband light source with flatness and multimode output spectrum. The proposed multimode light source generates fifteen modes, ranging from 1532 to 1544 nm, and with a flatness of <4 dB. This proposed hybrid WDM transport system used two wavelengths (modes) for AM-VSB video signal, one for 256-QAM digital passband and one for OC-48 digital baseband signals. System performances were investigated over a-100 km standard single-mode fiber (SMF) transmission.

2. Experimental setup

Figure 1 shows the experimental setup of our proposed hybrid WDM transport systems based on mutually injection-locked FP LDs. The hybrid WDM transport systems consist of one broadband light source, four optical band-pass filters (BPFs), four external modulators, and 100 km of standard SMF with three cascaded erbium-doped fiber amplifiers (EDFAs). The broadband light source is efficiently split into four optical channels by four optical BPFs with 3-dB bandwidth of 0.4 nm, externally modulated individually, and multiplexed back into the SMF by using two optical couplers. The filtered four wavelengths of \(\lambda_1\), \(\lambda_2\), \(\lambda_3\) and \(\lambda_4\) for externally modulated AM-VSB analog video, 256-QAM digital passband and OC-48 (2.5 Gb/s) digital baseband signals are 1540.4, 1538.8, 1537.2 and 1535.6 nm. Optical output power of E DFA-I and the OC-48 optical channel through a variable optical attenuator (VOA) are coupled together by using an optical coupler.

A multiple carrier generator (Matrix SX-16; NTSC) was used to feed RF sub-carriers into the first and second external modulators. Channels 2-78 (55.25-547.25 MHz) were fed into the first external modulator, and channels 79-112 (553.25-721.25 MHz) were fed into the second one. Four 256-QAM digital passband channels (channels 113-116) were fed into the third external modulator. The transmitted data (40.2 Mb/s) is up-converted from the 44 MHz IF frequency to RF frequencies between 727.25 and 745.25 MHz. The fourth external modulator is externally modulated by a 2.5 Gb/s pseudo-random bit sequence (PRBS). The composite signals are now a combination of the one hundred and eleven AM-VSB video channels, four 256-QAM digital passband channels and one OC-48 digital baseband channel.

We place all VOAs at the start of each optical link so that the optical power launched into the fiber is relatively lower, then there would be a significant reduction in the CSO distortion [4]. For CATV and 256-QAM signals, the detected signals were sent through a tunable RF BPF to select the channel for measurement. All CATV RF parameters were measured using an HP-8591C CATV analyzer at channel 112. The selected 256-QAM channel (channel 116) is down-converted to an IF frequency, demodulated, and then fed into a 256-QAM error detector.
for BER analysis. After receiving, the OC-48 signal is directly fed into an OC-48 error detector for BER analysis.

Fig. 2. The configuration of the broadband light source.

The configuration of the broadband light source is illustrated in figure 2. It consists of two FP LDs, a 50:50 optical coupler, and two optical isolators. As FP LD1 is served as an optical injection source, it injects light into FP LD2 via a 2×2 optical coupler. The output of each FP LD was passed through an optical isolator. We realized an un-polarized broadband light source by polarization multiplexing with two polarization controllers (PCs) and one polarization beam combiner (PBC). The output spectra of FP LDs were measured using an optical spectrum analyzer (OSA).

3. Experimental results and discussions

Flat spectrum due to polarization-multiplexing is present in figure 3. The proposed broadband light source generates a 100 GHz spaced comb with fifteen modes, ranging from 1532 to 1544 nm and with a flatness of <4 dB. This proposed low-cost broadband light source could provide flat spectrum profile to satisfy signal transmission performance in hybrid WDM transport systems.

Fig. 3. Flat spectrum due to polarization-multiplexing.

The measured AM-VSB CNR, CSO and CTB values at AM-VSB channel highest frequency of 721.25 MHz (channel 112) as a function of AM optical modulation index for back-to-back and over a-100 km SMF transmission are shown in figure 4 and 5, respectively. The actual operating point of the CNR/CSO/CTB
parameters is chosen by maximizing the CNR value while maintaining CSO/CTB distortions below acceptable levels. According to figure 4 and 5, CNR >50 dB, CSO <-61 dBc and CTB <-60 dBc can be obtained at the end of the WDM link with an OMI of 3.9%, in which these values meet the fiber optical CATV system demands (CNR >50 dB, CSO <-60 dBc and CTB <-60 dBc).

Figure 6 shows the measured BER of the 256-QAM channel (channel 116) as a function of the QAM OMI for back-to-back and over a-100 km SMF transmission. For an equal BER, the QAM OMI level over a-100 km SMF transmission was found to be higher than that of back-to-back case. For QAM OMI of about 0.37%, the measured BER was <10^{-9} over a-100 km SMF transmission. The BER performance can be improved by operating the 256-QAM channels at a higher QAM OMI level.

Figure 7 shows the performance of the OC-48 digital baseband channel for the 100 km hybrid WDM link. For this 2.5 Gb/s digital channel to be transmitted over 100 km of fiber span without penalty, a received signal level of -33.5 dBm or higher is needed for a BER of 10^{-9}; the received optical power for the digital optical receiver was about -30 dBm, so a BER <10^{-9} over 100 km SMF transmission was readily obtained.

4. Conclusion

We proposed and demonstrated a hybrid WDM transport system based on mutually injection-locked FP LDs. By mutual injection between two FP LDs, we realized a broadband light source with flatness and multimode output spectrum. The proposed hybrid WDM transport systems use two filtered wavelengths for AM-VSB CATV, one for 256-QAM digital passband and one for OC-48 digital baseband signals. Our proposed hybrid WDM transport system can simultaneously transmit one hundred and eleven AM-VSB channels with CNR >50 dB, CSO <-61 dBc and CTB <-60 dBc; four 256-QAM digital passband channels and one OC-48 digital baseband channel with BER <10^{-9}. Since our proposed system does not use multiple expensive DFB LDs, it reveals a prominent one with simpler and more economic advantages than that of traditional hybrid WDM transport systems.

4. References