A 565 Mbit/s FSK coherent system using commercial DFB lasers

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Coherent systems are attracting considerable interest for a diversity of applications such as broad-band distribution networks and long haul links. Such systems require optical sources of high spectral purity. The current work is directed towards developing a coherent system using commercially available distributed feedback (DFB) laser sources.

Wide deviation FSK systems with asynchronous detection can cope with the wide linewidth of commercial DFB lasers. The bandwidth of the detected signal is dependent on the frequency deviation, bit rate, and the linewidth of the lasers. For high bit rates the IF bandwidth required for the receiver front end can be excessively wide. In this case a convenient scheme would be to detect only the low frequency lobe of the spectrum [1].

The system considered here operates at 565 Mbit/s utilising single filter asynchronous detection. The DFB lasers used are Toshiba TOLD385S devices operating at 1550 nm and 0 dBm output power. The lasers are butterfly packaged with an integral isolator and cooler. The measured 3 dB optical linewidths for the devices are approximately 40 to 50 MHz. The experimental arrangement is shown in fig. 1 and features a balanced front end with wideband transimpedance amplifier, a novel demodulator circuit, automatic gain and frequency control loops (AGC and AFC respectively) and frequency compensation of the transmitter laser. The diagram shows additional isolators which were necessary due to the high optical reflections from the receiver front end.

Receiver front-end

The receiver front-end is a balanced design for suppressing local oscillator intensity noise and making effective use of local osillator power. It has a transimpedance first stage and an equalising second stage which counteracts the roll-off caused by the first stage at high frequencies. Series inductive tuning was used to further extend the bandwidth and reduce the noise [2]. The photodiodes [3] have a bandwidth of 25 GHz and a quantum efficiency of greater than 80 % at 1550 nm.

The measured noise performance is shown in Fig. 2. Local oscillator laser RIN cancellation was limited to better than 17 dB across the IF bandwidth.

IF strip

The IF strip uses commercial RF amplifiers, microstrip filters and includes a voltage controlled attenuator. The total bandwidth extends from 1.0 to 3.4 GHz being limited by a high pass filter and the front-end high frequency cut-off. Demodulation is performed by a novel square-law demodulator [4] featuring: very wide RF input bandwidth; good square-law characteristic up to an input power of -15 dBm; dynamic range exceeding 30 dB, including the linear envelope detection region; very low nominal input power of -22 dBm; and low cost implementation. A limiting amplifier reshapes the pulse at the expense of slightly increased jitter.

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AGC and AFC loops
The AGC and AFC loops utilise two matched power detectors. The first monitors the IF power which it controls via the AGC and voltage controlled attenuator in the IF strip. The second monitors the output from a low pass filter, which performs the frequency discrimination. The two outputs together feed the AFC which adjusts the IF frequency via the local oscillator laser bias current. No drift of the IF beat spectrum was observed once the AFC loop was closed. The IF power to the demodulator was controlled to within 0.5 dB for an input power variation of 20 dB.

Frequency Compensation
DFB lasers have very irregular FM frequency responses which give rise to intersymbol interference and consequently high error rates. Responses typically show a pronounced dip between approximately 10 kHz and 1 MHz and a 180 degree phase shift spread over several decades centred in this frequency range [5]. Options available for overcoming this problem include coding, with the objective of concentrating the transmitted data spectrum in the upper frequency region (above 10 MHz) where the FM characteristic is usually more flat, and equalisation by compensating circuitry. This latter approach is only possible over a limited frequency range, the phase being very difficult to match, and can receive limited application since the response to be equalised is device dependent and also changes with bias and temperature.

For this demonstration passive equalisation achieved a FM charateristic which was flat in phase and amplitude between 50 kHz and 500 MHz (see fig. 3). The response was measured by Fabry Perot optical frequency discriminator. The equalisation network was optimised using Touchstone computer simulation.

Results
The local oscillator provided an optical power of 1 mW at the input port of the coupler. The unmodulated IF beat linewidth was 120 MHz. The transmitter laser was modulated at 565Mbit/s with a FM frequency deviation of 2.6 GHz. The low frequency lobe of the beat spectrum was locked at an IF frequency of 2.2 GHz, centred within the 2.4 GHz IF bandpass. The LO polarisation was manually adjusted to match that of the incoming signal. Fig. 4 details the BER measurement for a 2^{15}-1 PRBS and "1010" pattern. A BER of 10^{-9} was measured with an optical power of -40.3 dBm at the connectorised input of the coupler signal arm. Accounting for the excess loss of the coupler this corresponds to an optical power incident on the detector of -41.8 dBm. The penalty for the pseudo-random sequence was 1 dB. No evidence of an error rate floor was observed.

Conclusions
A 565Mbit/s FSK coherent heterodyne optical transmission has been demonstrated using commercially available DFB lasers. A sensitivity of -41.8 dBm was achieved.

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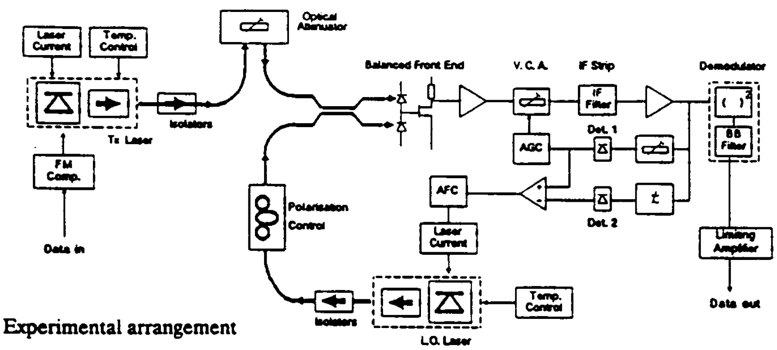

Fig 1. Experimental arrangement

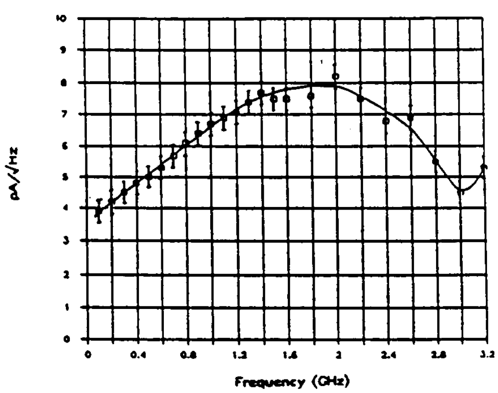

Fig 2. Equivalent input noise current of pre-amplifier

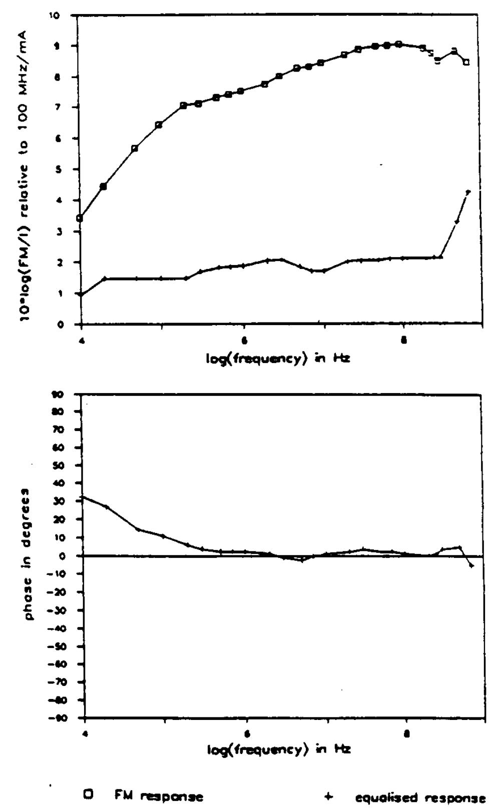

Fig 3. Measured and compensated FM frequency response of the transmitter laser

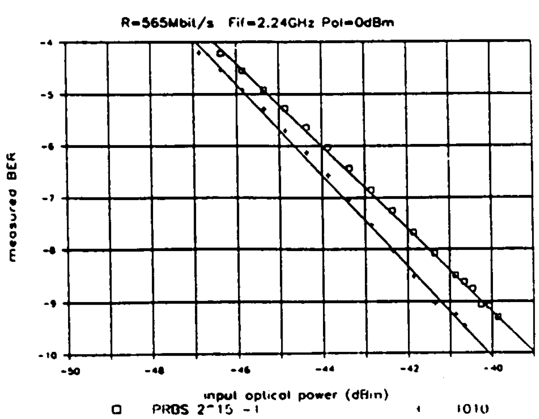

Fig 4. Bit error rate measurement