Fast channel hopping, zero frequency error source for high spectral efficiency, dynamic wavelength-routed optical networks

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Abstract: Fast (<5 µs, electronics limited) zero frequency error wavelength switching and error-free 10Gbit/s DWDM transmission at 0.56bit/s/Hz spectral efficiency is demonstrated using widely tuneable lasers with optical injection phase lock loop control.

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This paper presents a new rapid channel-hopping DWDM synthesiser system which has channel-frequency exactly determined by supplied optical and microwave reference frequencies [3] and so does not require guard bands. Channel-lasers (SG-DBR or SSG-DBR) are incorporated within optical-injection phase-lock loop (OPLL, Fig. 1b) blocks [4], phase-locked to output lines of an optical-frequency comb-generator (OFCG, Fig. 1a) [5]. We show for the first time that the system can hop rapidly (<5µs) between exactly specified frequencies despite 5K laser sub-mount temperature changes, the widest temperature range for an absolute frequency locking scheme yet reported.

Fig. 1: a) Optical-frequency comb-generator, b) optical-injection phase-lock loop channel block, c) channel-switching measurement system and transmission test system, d) comb spectrum and locked channel block output.

Wavelength monitoring was carried out using a preselecting optical band-pass filter followed by a Fabry-Perot interferometer tuned by a high precision voltage source.

For hopping between 1570nm and 1532nm at a frequency of 100Hz, the new wavelength is acquired to the system measurement accuracy of <500MHz, within <5µs, limited by the speed of the laser current controller, and there was no measurable long-term drift under active-locking (Fig.2). The optical output power stabilises within 15µs.
Fig. 2: Channel-hopping transient 1570-1532 nm (resolution 1 pm). a) wavelength, b) output power. c) long term wavelength drift.

Next, the system was tested in a continuous transmission experiment (no switching): the OIPLL block was used as a WDM source, and outputs were combined and modulated by a NRZ, 10 Gbit/s, 2^11-1 PRBS. After amplification and decorrelation, the channels (~9 dBm/channel) were launched into a metro network typical transmission path (Fig. 1c). A free space diffraction grating demultiplexer [6] was used for channel selection.

BER measurements for channel spacings \( f_m \) from 17 GHz to 21 GHz were performed (Fig. 3). The power penalty to obtain BER=10^-6 increased from 0.2 dB/ GHz of channel spacing reduction for (25 < \( f_m < 21 \)) GHz to 1.7 dB/ GHz for \( f_m < 19 \) GHz. The increasing power penalty with channel spacing reduction is due to linear crosstalk effects and degradation from the fibre nonlinearity [6].

Fig. 3: BER for 10 Gbit/s NRZ transmission as a function of receiver input power with parameter channel spacing.

In summary, all fibre-based OIPLL circuits were used with widely tuneable lasers in a first demonstration of a zero-frequency-error referenced wavelength agile DWDM transmission experiment. Wavelength hopping times of <5 μs were obtained, removing any long term drift. Channel frequency errors remained below the measurement limit of 1 kHz while laser chip temperature was tuned over 5 K range [3]. Data transmission performance of our transmitter was measured with low penalties, demonstrating the versatility of the OIPLL for use in future dynamic DWDM networks. Future work will concentrate on increasing the resolution and speed of the channel hopping test system to determine the ultimate hopping speed of the transmitter (ns region [4]).