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Strategies for Ultra-Wide Band Optical Amplifier Development

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Abstract

This talk discusses strategies for the development of ultra-wide band optical amplifiers. The discussion shall start with the transitions of signal bands in WDM market, then explore plausible alternatives for extending transmission band. The amplifier technologies to be discussed shall be Erbium doped fiber amplifiers, Raman amplifiers, and Thulium doped fiber amplifiers. The talk will also refer to the comparison between lumped and distributed amplifiers.

Summary

The Internet explosion has invited a dramatic growth in transmission capacity of wavelength-division-multiplex (WDM) systems. One of the enabling technologies for massive WDM transmissions has been the broadband Erbium doped fiber amplifier (EDFA). Increasing the number of WDM signal channels can simply multiply the transmission capacity. Therefore, extending the bandwidth of WDM transmission is effective to increase the channel counts or the transmission capacity. To transmit many WDM signals over amplifier spans, the wavelength dependence of amplifier gain has to be small in order to maintain an equal optical SNR among the signals. For example, the gain flatness less than 1 dB is a good flatness for 600 km terrestrial transmissions.

Because EDFA gain per se has a large wavelength dependence, a gain-flattening filter (GFF) has to be so prepared as to offset the wavelength dependence. The flattened bandwidth depends on how much the filter curtails the peaky portion of gain shape. Typically, the flattened operating band of a C-band EDFA is approximately from 1530 to 1560 nm, while that of an L-band is approximately from 1575 to 1610 nm [1, 2]. WDM systems have been upgraded from C-band to L-band operations, achieving, for example, more than 80 WDM channels at 10 Gbit/s per channel, or 800 Gbit/s total capacity. It turned out, however, that Internet demands are growing more than such the capacity increase of WDM technologies. Therefore, a new technology to further enhance the transmission capacity began to be sought.

There are two alternatives to further increase the transmission capacity; one is to realize an optical amplifier operating in other bands than EDFA, and the other is to increase the capacity density within the given (EDFA) signal bands. Proposed for the former alternative are Thulium doped fiber amplifier (TDFA) [3] and discrete Raman amplifier [4]. TDFA can operate in 1450 nm band, and gain-shifted technique was found [3] to operate in a preferred signal band from 1490 to 1520 nm band (S-band). The latter alternative can be achieved through many means. One powerful means of amplifier technologies is the use of distributed Raman amplifier along with EDFA [5]. Because Raman amplifiers best fit in a distributed amplification configuration, and the process of Raman amplification is of low noise, a Raman amplifier can be very effective to enhance optical SNR and thereby allow the signal level to be lower reducing nonlinear effects. A technique called 'WDM diode pumping' realizes an extremely flat and wide composite Raman gain [6], which also makes Raman amplifier much reliable and attractive.

In a hybrid Raman-EDFA/TDFA repeater system, the gain of the lumped (EDFA/TDFA) amplifiers may be much lower than a conventional lumped amplifier system. A low average gain for EDFA/TDFA allows the GFF to shave off more gain to extend the flattened band. Therefore, the complementary use of distributed Raman amplifiers is effective in not only reducing noise but also extending the signal band of lumped amplifiers. Likewise, conventional S-, C-, and L-bands can be further extended.

References

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