Optical CDMA for Internet Operation at Terabit Rates

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Fiber based optical communication networks offer an efficient way to meet the drastically increasing demand for multimedia services. The current favorite industrial multiplexing scheme for optical communications is wavelength division multiplexing (WDM), yet code division multiple access (CDMA) can offer several distinct advantages for a computer networking environment. CDMA provides asynchronous access to a network, enhanced privacy against interception, efficient utilization of the time and frequency by each user, and simplified network control.

We describe a design and performance evaluation of an optical network whose function is to allow internet access at aggregate rates of the order of one terabit per second. Utilizing recent advances in optical device and systems technology, communications, and optical networks, we have designed an optical communications system based upon the use of CDMA. The system makes use of an efficient signal design that employs ultrashort optical pulse position modulation, and has been shown to yield performance superior to that of previously designed CDMA-based optical networks that employed ON-OFF keying as the modulation scheme.

The modulation and detection processes rely on novel high resolution temporal modulation and detection techniques for ultrashort laser pulses (ULP) developed at UCSD. Direct electronic domain modulation and detection of such ULP (e.g., 100 fsec) is not possible due to the femtosecond scale phenomena involved. We have developed a novel high resolution temporal encoding technique for ultrashort pulses that enable various data transmission formats to be considered, such as ultrafast packet transmission with pulse position modulation (PPM) or amplitude modulation (AM). The data modulation method is based on 4-wave mixing between the optical waves of spectrally decomposed femtosecond pulses and spatially Fourier transformed quasimonochromatic images. We investigate how to encode several bits of information on each transmitted ULP using PPM. As the number of PPM symbols, M, is increased, the bandwidth efficiency is improved. This scheme requires a detector with very high time resolution, necessary to discriminate the pulse positions. This requirement is mitigated by using an ultrafast imaging system based on 3-wave mixing between the signal and the reference fields. The resultant spatial image, formed by the generated second harmonic field, reveals the information on the temporal signal waveform and can be detected using slower electronic detection devices. The receiver selects the strongest signal of the M possible slots as the transmitted information symbol.

The system on a PPM/ULP method combined with CDMA has been investigated. The results of the analysis show that the performance depends on the following parameters: the ULP duration, τ, the bandwidth of each spectral chip, Ω, used in the CDMA filter, and the ULP repetition time, T_s. We find that employing PPM improves the performance of the system relative to On-Off Keying. The performance can be further improved by increasing the number of PPM symbols, reducing the spectral chip bandwidth, and reducing the ratio τ/T_s. The performance analysis shows that the aggregate throughput of the proposed system could exceed 1 Tbit/s.