

Abstract

Optics plays a crucial role in information and data processing due to its inherent parallelism and numerous other advantages. Compared to electronics, optics offers significant benefits in terms of speed and efficiency for super-fast computation and data processing. Over the past few decades, several all-optical data processors have been proposed based on Boolean logic. Optical systems and logic devices using optical switches have proven to be more efficient than their electronic counterparts in terms of speed, accuracy, and other aspects. Various types of all-optical methods have been suggested for implementing optical logic and arithmetic processors and devices. To realize these optical systems, certain optical switches such as those based on non-linear materials, electro-optic materials, optical bi-stable materials, optical filters, optical converters, beam splitters, and Semiconductor Optical Amplifier (SOA) based optical switches are required. Several encoding principles can be used to implement all-optical logic and arithmetic devices, including intensity, polarization, spatial, phase, and frequency encoding. Among these, frequency encoding is the most reliable and accurate. In optical computing and data processing, high speed is paramount. The frequency encoding/decoding technique uses different frequencies to represent different states of information, which remain consistent during reflection, refraction, and absorption. In this encoding technique, the '0' logic state is represented by ν_1 frequency and the '1' logic state is represented by ν_2 frequency. This thesis employs reflected semiconductor optical amplifier (RSOA) and add/drop multiplexer (ADM) optical switches to develop all-optical logic gates and circuits using frequency encoding. The dibit representation technique, which represents digital '0' logic state as $[0][1]$ and digital '1' logic state as $[1][0]$, is highly accurate and promising for data processing, reducing bit error problems by increasing the signal-to-noise ratio and supporting high parallelism. The presence of frequencies side by side $[\nu_1][\nu_2]$ indicates digital logic state '0', while $[\nu_2][\nu_1]$ indicates digital logic state '1'. Using ADM and

RSOA optical switches, we have developed all-optical, frequency-encoded, dibit-based integrated AND/NAND and OR/NOR logic gates with control input, XOR and XNOR logic gates, multiplexer and de-multiplexer circuits and controlled full subtractor circuit. These dibit-based systems using frequency encoding are expected to be significantly more advantageous than conventional logic gate-based optical systems. All proposed schemes have been verified through proper simulation experiments, with results aligning perfectly with the expected characteristics.

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