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# Alternative method of implementation of frequency encoded N bit comparator exploiting four wave mixing in semiconductor optical amplifiers

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ABSTRACT

A frequency encoded all optical N bit comparator is proposed. The implementation is ultrafast one and the frequency encoding makes it intensity loss dependent problem free. The use of polarization insensitive four wave mixing makes the design polarization independent and the hardware simple. The frequency conversion by the RSOA makes the design faster compared to other SOA based design. The required gates, i.e. X-OR and AND gates for the implementation of the comparator in frequency encoded format are also discussed.



## 1. Introduction

Future high speed transmission system and network will require the implementation of different all optical signal processing units because all optical logic gates and functional devices are the key units in future all optical network and systems. One of the widely used devices for this purpose is semiconductor optical amplifier (SOA) because it can exhibit a strong refractive index variation and allow photonic integration characteristics [1–6]. Various logic gates are implemented using SOA [2–6]. Many other SOA based devices such as ultra high speed half adder based on FWM [7], all optical half adder using XGM [8,9], 2.5 Gb/s all optical half adder and half subtractor using two parallel SOAs and PPLN [10,11], 10 Gb/s recirculating shift register with SOA assisted Sagnac switch and SOA feed back [12], 10 Gb/s all optical half adder based on interferometric SOA gates [13], 10 Gb/s all optical full adder using XGM [14], all optical logic gates using Mach Zhender configuration [15] are demonstrated.

But for controlling interconnection network, several complex functions are required. If a number of packets are directed towards the same node output port, the priority field of the contending packet is compared, i.e. the packet with highest priority is directed towards the designated output port first and the other packets are delayed according to their priorities. So a comparator which can compare two Boolean numbers is essential [16].

Still now some papers reports on the implementation of all optical circuit which can determine whether two numbers are equal or not (i.e. pattern matching) using optical loop mirror [17], using a single SOA MZI [18] and a single bit comparator using SOA is demonstrated [19]. An all optical N bit comparator using a single SOA based on XGM and cross polarization rotation is demonstrated in [20], but this scheme is complex in hardware and intensity encoding is used. So intensity loss dependent problem is there. In the design three AND gates, one NOT gate and an X-OR gate are used with an extra serial to parallel converted. So complexity increases and speed is less. The scheme in [20] is modified to generate frequency encoded all optical N bit comparator with less number of AND gates (two only) and an X-OR gate only. No serial to parallel converter or NOT gates are required. Recently frequency encoded N bit comparators are also proposed using SOA [21,22], but have the disadvantages of using N single bit comparator in series. This makes the system complex in hardware and most importantly of lower speed because it operates sequentially. Also the use of polarization rotation makes them not so efficient with respect to frequency encoding also and the use of four wave mixing in co propagation scheme increases the complexity of hardware. In this paper the authors wish to present the design of an all optical frequency encoded N bit comparator using polarization insensitive four wave mixing in semiconductor optical amplifier, the method of comparison is very much different from the proposals in [21,22]. In some earlier paper frequency encoded logic gates [23–25] half adder, half subtractor and full adder [26], encryption decryption system [27], read only memory [28] have been proposed by the authors. The frequency encoding makes the design independent of intensity loss dependent problems and polarization insensitiveness makes the design free from the use of polarization controller so that we do not have to bother about the change of state of the polarization of the propagating optical signals. In the next two sections the working

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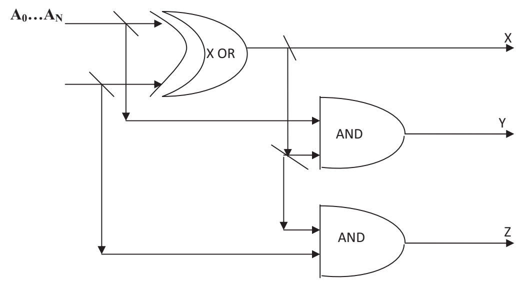


**Fig. 1.** N bit comparator.

principle of the logic gates required and the operation of the N bit comparator will be presented. To best of our knowledge this type of a frequency encoded all optical N bit comparator is proposed first time in this paper.

## 2. Working principle

The block diagram of the comparator is shown in Fig. 1. In this comparator two N bit numbers will be compared bit wise starting from most significant bit [MSB] of both the numbers. If MSBs are equal i.e. $A_N = B_N$, the output X will be '0' and the corresponding outputs Y and Z are also '0'. If the MSBs are un equal (i.e. $A_N \neq B_N$) then the output X is '1' and one of the outputs Y or Z will be '1' and the other will be '0'. If $A_N = 1$ and $B_N = 0$ then Y = '1' and Z = '0'. If $A_N = 0$ and $B_N = 1$ then Y = '0' and Z = '1'. So if there is a mismatch between the same bit position in the two numbers the output X will be '1' and any one of the Y or Z will be '1'. After MSB the next bit of the two numbers are entered and they will generate outputs X, Y and Z in a similar manner. For all the N bits we will get N bit data streams on the three outputs X, Y and Z.

When the two numbers $A = A_N A_{N-1} \ldots A_0$ and $B = B_N\ B_{N-1} \ldots B_0$ are equal then there are no mismatches in any bit positions of the numbers. This will result all the output bits be '0' in all the three outputs X, Y and Z. When $A \neq B$, then there will be one or more mismatches in the bit positions of the two numbers. Each mismatch will correspond to '1' output at the respective bit of the output X and output bit of any one of the Y or Z will be '1' as mentioned earlier. If '1' comes earlier in Y than Z along with '1' in X output then definitely A > B and if '1' comes in Z first along with X = '1' then A < B. In this way we can compare two N bit numbers by just inspecting the position of the '1' in the outputs. Logically this can be implemented by the following operations with the inputs and outputs. For ith bit of inputs A and B, the ith output bits are:

$$X_i = A_i \oplus B_i$$
$$Y_i = X_i A_i \quad \text{and}$$
$$Z_i = X_i B_i$$

### 2.1. Frequency encoding

In frequency encoding technique the logical state '0' is represented by a frequency $\upsilon_1$ (LOW) and '1' by another frequency $\upsilon_2$ (HIGH). In the inputs or outputs we always get either the signal of frequency $\upsilon_1$ or the signal of frequency $\upsilon_2$ depending on whether the state is LOW or HIGH respectively. The main advantage of this scheme is that, there is no intensity loss dependent problem in this scheme [21–29]. In this communication the input frequencies are selected in the C band suitable for all optical communication, which are $\upsilon_1$ = 1540 nm and $\upsilon_2$ = 1550 nm.

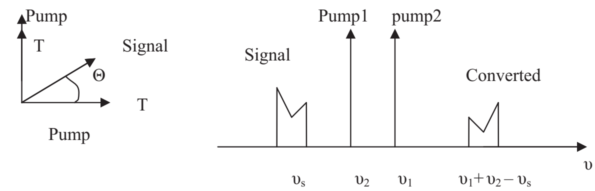


**Fig. 2.** Polarization insensitive FWM.

### 2.2. Four wave mixing

Four wave mixing is a coherent non linear process and can occur in SOA between two signals, a strong pump and a weaker probe signal. For efficient FWM, the polarization state of the pump and the probe signals must be the same. So some polarization control mechanism of either probe or pump will be necessary. But in co-polarized and orthogonal polarized dual pump schemes, the FWM is polarization insensitive. In the implementation of all optical logic gates in this communication orthogonal polarized pumps scheme to generate FWM [30] will be used. In this scheme the orthogonal polarized pumps interact with the input data signal to generate a new conjugate signal, the power of which is also polarization independent. The scheme is shown in Fig. 2.

### 2.3. Reflective semiconductor optical amplifier

It utilizes a high reflecting coating on one facet and ultra low reflecting coating on the other facet to produce a highly versatile reflective gain medium [31]. The basic structure is shown in Fig. 3 as used in this communication. A weak signal of frequency $\upsilon_1$ can be converted to a high power signal of a different frequency $\upsilon_2$ by using a signal of frequency $\upsilon_2$ (probe) from outside. Inside the RSOA multiple reflections occurs and the power of the weak signal (pump) is converted to the high power signal and the output is extracted by using proper filter.

### 2.4. Add/drop multiplexer

The function of ADM is to separate a particular frequency channel without interference from adjacent channels. This is achieved by a frequency demultiplexer by integrated tunable SOA filter as in Fig. 4 [32].

The filter can be tuned by changing injection current. The frequency channel selected is reflected by the filter, amplified second

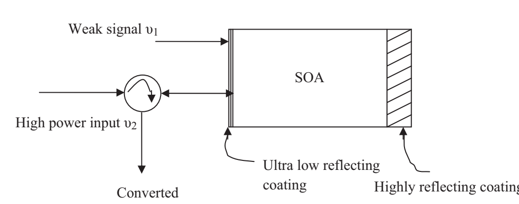


**Fig. 3.** Reflective semiconductor optical amplifier.

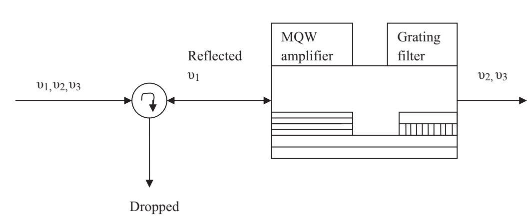


**Fig. 4.** ADM.