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All optical Reflective Semiconductor Optical Amplifier based half adder

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All optical Reflective Semiconductor Optical Amplifier (RSOA) based half adder using Gaussian pulse is described and analyzed. In RSOA cross gain modulation is used for optical switching. This switching is utilized to design optical half adder. The practical feasibility is confirmed by calculating output ER, CR and Q value of the RSOA based half adder which shows distinguishes between the high levels to low level.

Keywords: Half adder, RSOA, cross gain modulation, Q value.

Introduction

All optical signal processing can overcome the problem of speed limitations encountered in electronic systems[1]. Semiconductor optical amplifier (SOA) is an important device showing different optical nonlinearities suitable for all optical switching and due to its ease of integration[2]. Another device in this category of switching with enhanced performance is double pass SOA or reflective SOA (RSOA)[3]. The main advantage of RSOA over conventional SOA is that it offers larger gain for the same length and biasing current[3–5]. In this communication, a half adder is designed and simulated using RSOA as an optical switch for the first time as far as our knowledge goes.

Half adder is an important unit for arithmetic operation in digital computation, and can be extended to design full adder with extra elements. In the following sections, working of RSOA based switch, working of RSOA based half adder and results of operations of the device are described.

RSOA based switch

The RSOA based switch as shown in Fig. 1.

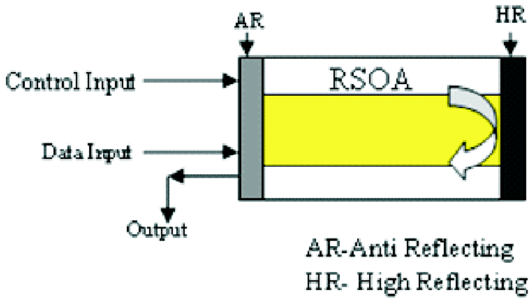


Fig. 1. RSOA based switch.

When a control signals enter in the RSOA, it saturates and the gain reduces[6]

$$G(t) = \{e^{[h(t)]}\}^2 \quad (1)$$

where h(t) expressed as the equations[6]

$$\frac{dh(t)}{dt} = \frac{g_0L - h(t)}{\tau_e} - \frac{P_{in}(t)}{E_s}[\exp(h(t)) - 1] \quad (2)$$

where $P_{in}(t)$ is a input power and E_s is a saturation energy of the RSOA and g_0 is the gain coefficient. Now the unsaturated gain is[6]

$$G_s = \exp\{L(g_0 - \alpha_d)\} \quad (3)$$

where α_d is the internal loss of the Reflective SOA.

We used a Gaussian pulse as a pump and probe signal of the form[6]

$$P_{cp}(t) = \frac{E_c}{\sigma\sqrt{\pi}} e^{-\frac{t^2}{\sigma^2}} \quad (4)$$

where E_c is the control pulse energy, t is the time and σ =

$T_{fwhm}/1.665$, T_{fwhm} is the full width half maximum. Now when the both pump and probe signal passes through the Reflective SOA its becomes amplified and Reflective SOA output is[4]

$$OP_{rsoa} = RG(t)P_{in} \tag{5}$$

when the only probe signal passes through the Reflective SOA, the Reflective SOA output is[4]

$$OP_{rsoa} = RG_sG_sP_{in} \tag{6}$$

RSOA based half adder

Half adder has two inputs and two outputs, one output is called 'SUM' and another is called 'CARRY'. RSOA based half adder as shown in Fig. 2. It is consists of 4 RSOA based switch. Operational principle of RSOA based half adder as given below:

Case 1: When both the inputs A_1 and A_2 are '0', in Fig. 2, no probe signal existing in RSOA 1 and RSOA 2, the output SUM contains '0' state i.e. 'LOW'. In Fig. 2 there is no pump signal present in RSOA 3, so RSOA 3 output contains high but there is no probe signal existing in RSOA 4, so the output of the RSOA 4 becomes zero i.e. output of CARRY bit is zero.

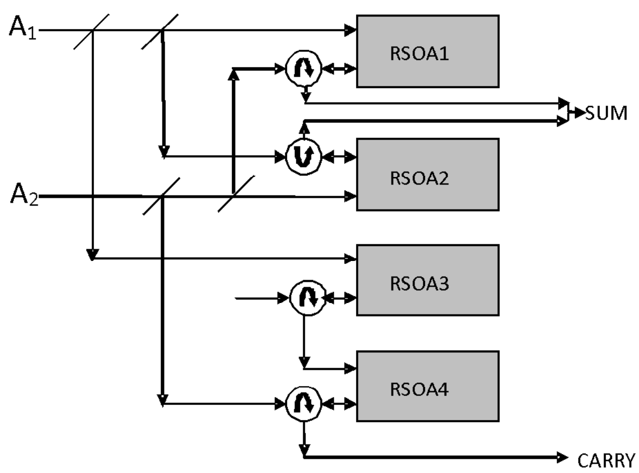


Fig. 2. RSOA based half adder (/ BS - Beam splitter).

Case 2: When the input A_1 = '1' and A_2 = '0', in Fig. 2 there is no probe signal existing in RSOA 1, so RSOA 1 output is zero and in RSOA 2 only data signal present so the output SUM contains '1' state i.e. 'HIGH'. Similarly in the RSOA 3 control signal present but there is no probe signal in RSOA 4. So the output of CARRY bit is zero.

Case 3: When the input A_1 = '0' and A_2 = '1', there is no pump signal existing in RSOA 1, so the output SUM contains '1' state i.e. 'HIGH' and CARRY bit contains '0' state.

Case 4: When the input A_1 = '1' and A_2 = '1' both data and control signals enters into the RSOA 1 and RSOA 2, both the outputs RSOA 1 and RSOA 2 are low so the output SUM contains '0' state i.e. 'LOW'. In RSOA 3 and RSOA 4, both the data and control signals present. So output CARRY contains '0' state.

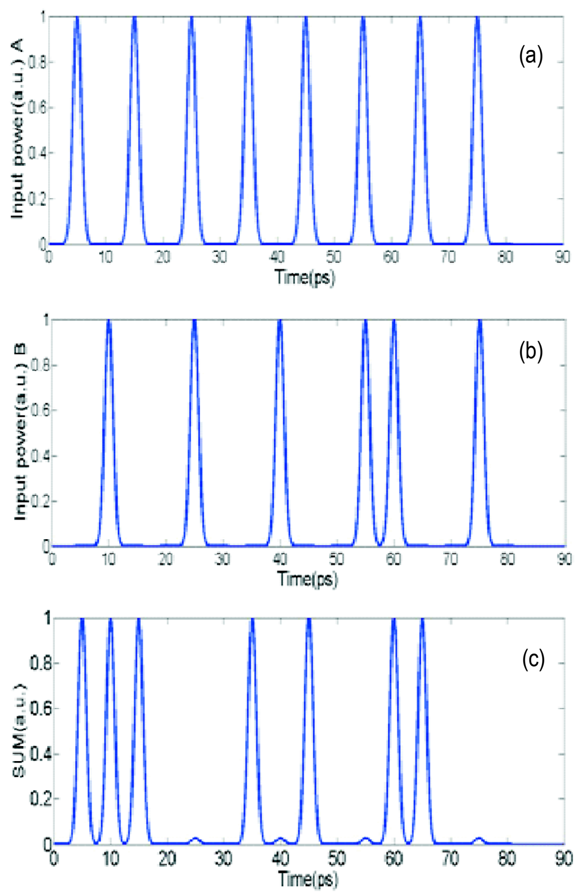
From the above discussions we found that SUM becomes 0110 and CARRY becomes 0001. So the output expressions of SUM and CARRY are

$$SUM = \bar{A}_1A_2 + A_1\bar{A}_2 \tag{7}$$

$$CARRY = A_1A_2 \tag{8}$$

Simulation and results

We consider a input control pulse and probe signal as a Gaussian pulse. So the simulated input and output of the half adder as shown in Figs. 3(a) to 3(d).



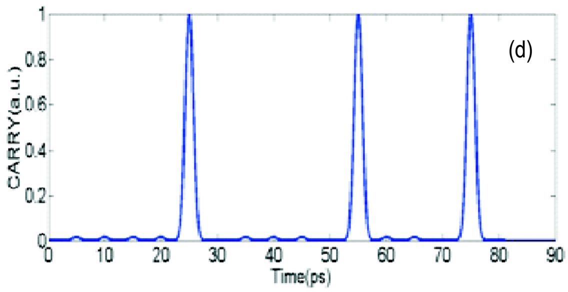


Fig. 3. Inputs: (a) A_1, (b) A_2. Outputs: (c) SUM and (d) CARRY.

The output extinction ratio[7,8] is the ratio of the minimum value of peak power of high level ('1') to the maximum value of peak power low level ('0') which is found to be 15.70 db for SUM and 24.16 dB for CARRY of the half adder.

The contrast ratio[9] is the ratio of the mean value of peak power of high level ('1') to the mean value of peak power of low level ('0'). We have found C.R. 18.71 dB for SUM and 26.65 dB for CARRY of the half adder.

The Q value expressed as[10]

$$Q = \frac{P^1_{Mean} - P^0_{Mean}}{sd^1 + sd^0} \qquad (9)$$

which is found to be 73.44 for SUM and 27.74 for CARRY.

The eye-opening is defined as following formula[6]

$$OP = \frac{P^1_{Min} - P^0_{Max}}{P^1_{Min}} \qquad (10)$$

We have calculated REOP for SUM is 95.4% and CARRY is 99.6% of the half adder. We choose the parameter as I =

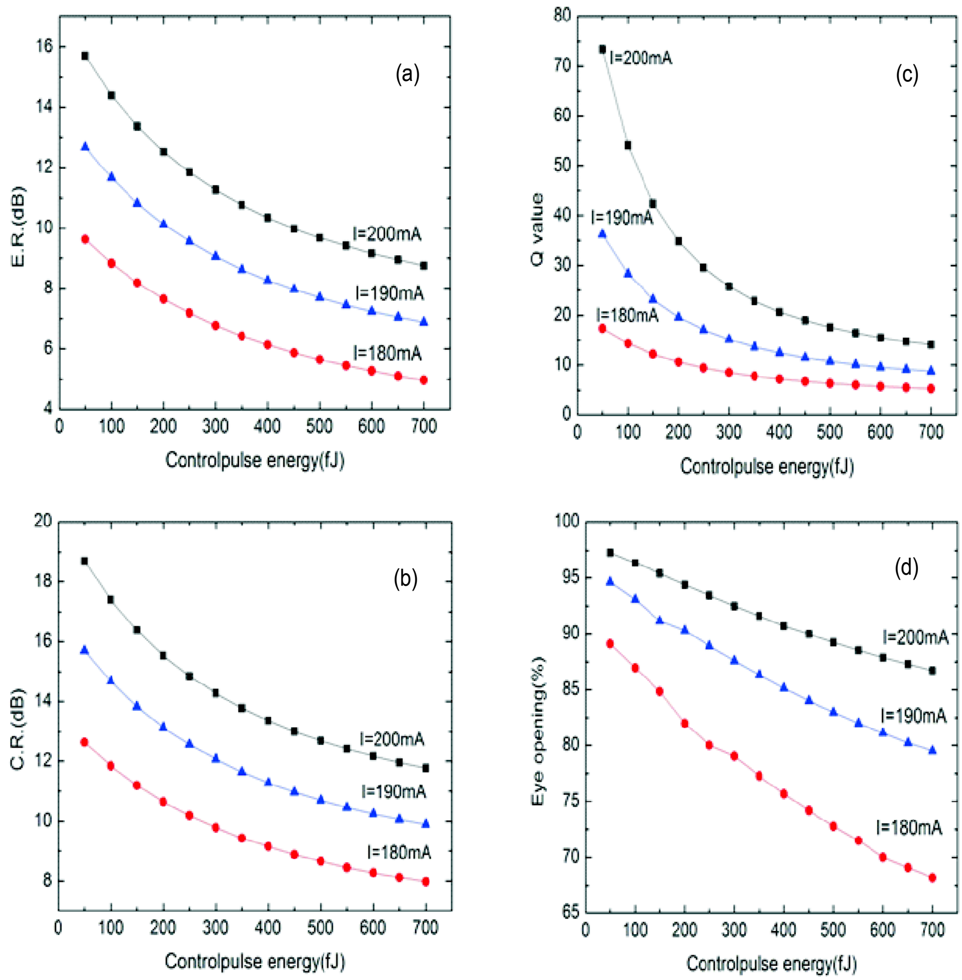


Fig. 4. Plots of (a) ER versus E_c, (b) CR versus E_c, (c) Q versus E_c and (d) eye-opening versus E_c for SUM output.

200 mA, t_e = 75 ps, E_c = 50 fj, and τ_{fwhm} = 1 ps and we found ER = 15.70 dB, CR = 18.71 dB, OP = 95.4%, quality factor (Q) = 73.44 and bit-error-rate (BER) is zero for SUM and ER = 24.16 dB, CR = 26.65 dB, OP = 99.6% and Q value 27.74 for CARRY of the half adder circuit. The plots of the output ER, CR, Q value and eye-opening with E_c when injection current (I) is kept constant is shown in Fig. 4(a) to Fig. 4(d) for SUM and the plots of the output ER, CR, Q value and eye-opening with E_c when injection current (I) is kept constant is shown in Fig. 5(a) to Fig. 5(d) for CARRY of the half adder circuit.

Eye diagram with large eyes represents clear transmission. High value of relative eye-opening (95.4% and 99.6%) represents good response of the half adder circuit. In Fig. 4 and Fig. 5 indicates ER, CR, Q value and eye-opening reduces with raising the control pulse energy due to gain compression effect. Also, since lower biasing current implies less unsaturated gain the maximum values of the ER and CR also decreases with decreasing biasing current. High values of Q values indicate error less transmission of the half adder circuit.

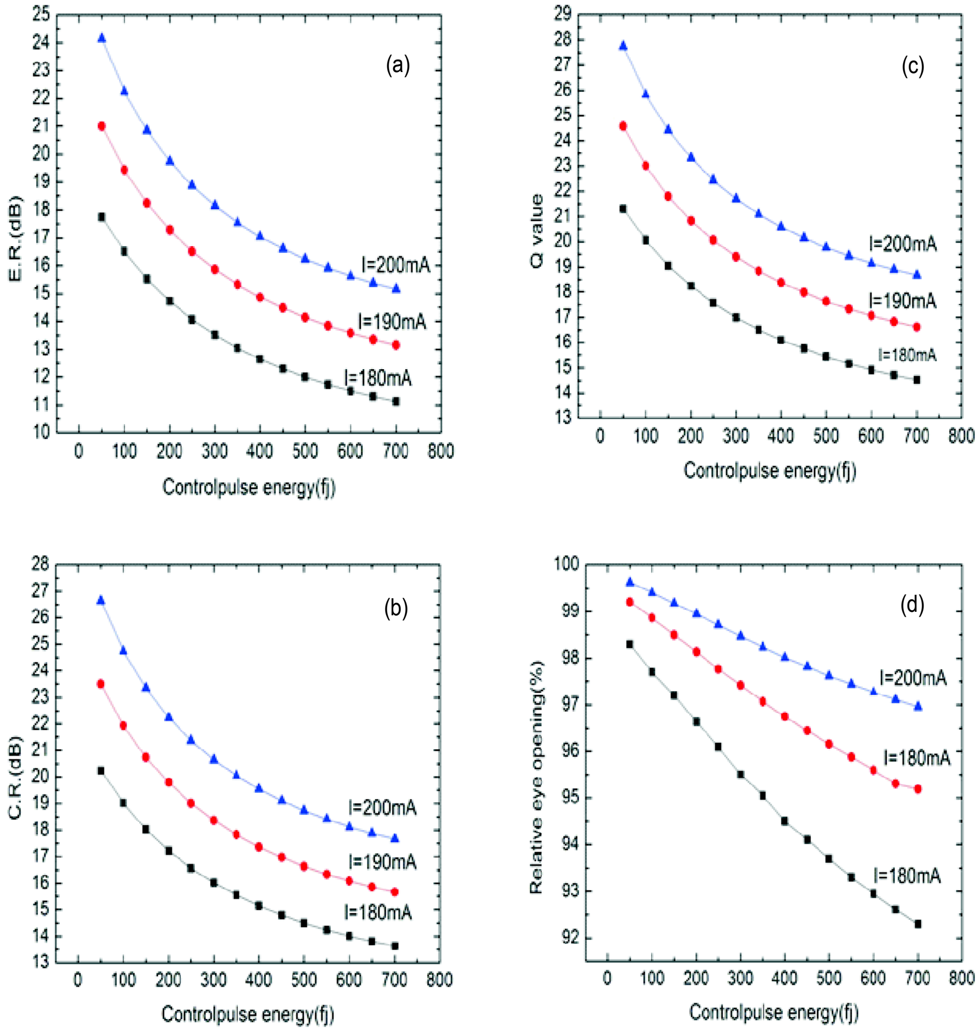


Fig. 5. Plots of (a) ER versus E_c, (b) CR versus E_c, (c) Q versus E_c and (d) eye-opening versus E_c for CARRY output.

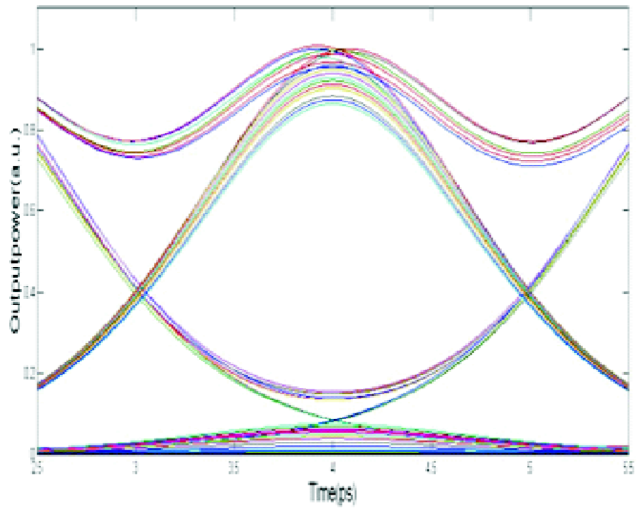


Fig. 6. Eye-diagram of SUM output.

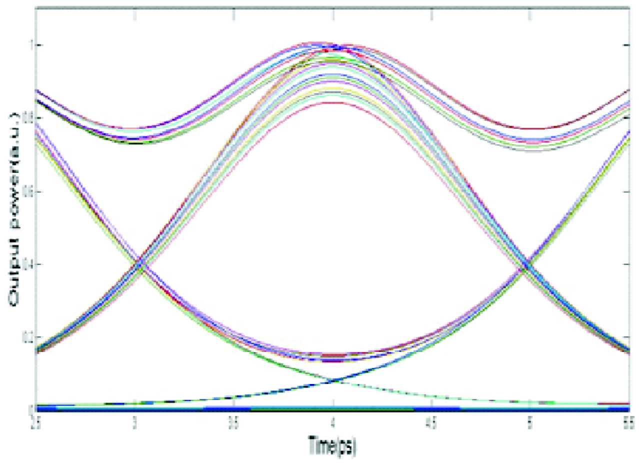


Fig. 7. Eye-diagram of CARRY output..

Conclusions

A novel all optical half adder circuit is designed and simulated using RSOA. ER, CR, Q factor and eye diagram show satisfactory performance and reliability of the device. Large Q value and eye opening ensure errorless operation. The half adder can be extended to design a full adder with some additional circuits.

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