

Demonstration of Digital Optical D Flip Flop based on Photonic Micro-ring Resonator

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Abstract— In this paper, we demonstrated an optical D-type flip-flop based on the electrooptic switching effect of silicon microring resonator. The operation of the flip flop has been verified by simulation using a clock signal of 10 Gbps and data signal of 1 Gbps. The results of the proposed flip-flop have been presented by the timing diagrams.

Index Terms—Optical; flip-flop; micro-ring resonator

I. INTRODUCTION

In the digital flip-flop technologies, D type flip-flop is one of the important and simplest functions, where it supports to store the data in outputs, the exact logic state as its input when a clocking signal is triggered to the circuit. This function makes this flip-flop as a one-bit digital memory; hence, it is also called Data Latch, Delay flip flop and D-type Bistable Circuit. Several ideas have been proposed to improve its efficiency such as reducing its power product or clock line capacitance, some also successfully print D flip-flop on single-walled carbon nanotubes (SWNTs) [1].

The development of the photonic microring resonator [2] and the breakthrough in photonic logic gates based on silicon micro-ring resonator such as micro-ring resonator based all-optical logic gates [3], photonic NOR logic gate using cascaded two micro-ring resonators have been demonstrated in the literature [4]. The Electro-optic directed logic operation has also been presented in [5-8]. In this paper, we proposed and demonstrated a digital optical D flip-flop based on micro-ring resonator. The circuit design is described and the flip-flop operation and results have been demonstrated.

II. DESIGN AND SIMULATION RESULTS OF OPTICAL D FLIP-FLOP

A general digital D flip-flop circuit is shown in Fig. 1 which is the base circuit for our optical flip-flop design. The logic block in Fig. 1 is designed by photonic microring resonator as shown in Fig. 2. A nonlinear silicon-based micro-ring resonator with the ring length of 60um, coupling gap of 300nm, waveguide loss of 6.03dB/cm. By applying the shift in resonance properties of the ring resonator, we can operated the

ring resonator device in such a way that it works as a digital switching device and performs logic gate functions to be used in the proposed flip-flop design.

The proposed circuit as shown in Fig. 2 is the optical replacement of the logic in Fig. 1. Replacing each of the digital logic gates existed inside the generic 4 NAND and 1 NOT D Flip-Flop design as shown in Fig. 1 into photonic devices, namely silicon micro-ring resonator tuned by the input electrical signal. The proposed flip flop circuit consists of four NAND ring resonators R2, R3, R4 and R5 and one NOT ring resonator R1. The D input signal and the Enable signals are connected to the data bit stream and the clock signal, respectively. The message signal is transmitted with the amplitude of 1.2V while the Clock signal is transmitted typically by the electrical pulse width modulated signal generator with a 50% duty cycle digital wave and the amplitude of 0.6V. All of these performed using simulation software.

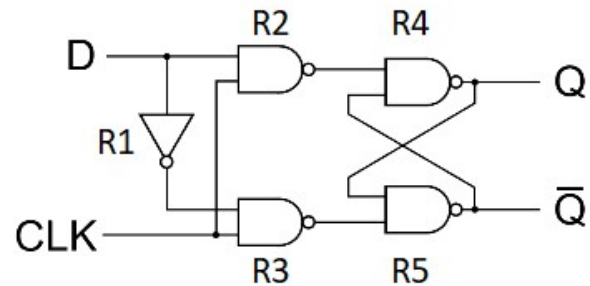


Fig. 1 D-type Flip-flop general diagrams using NAND and NOT logic.

In this circuit, there are several additional components required for required flip flop operation as shown in Fig. 2. The simulation software was a module named, "INTERCONNECT" of a commercially available software "Lumerical (www.lumerical.com). The parameters used in simulation are shown in Table 1.

TABLE 1. MICRO-RING MODULATOR PROPERTIES

Parameters	Values
Operating Frequency	1550nm
Ring Length	60um
Coupling Gap	300nm

Waveguide Loss	6.03dB/cm
Effective Index Coefficient	2.5
Group Index Coefficient	4.42
Waveguide Modes	TE, TM

The D input of the circuit is used with data signal of 1Gbps at the amplitude of 1.2V and the clock signal is injected at the data rate of 10Gbps with the amplitude of 0.6V. Both data and clock signals are from Non-Return Zero bit sequence generators, with the rise and fall time of 0.02ns. Each input is connected to an oscilloscope, while the optical Q and Inv(Q) outputs undergoes PIN photodetector where it converts the

optical signal to electrical signals. CW laser power delivers a single wavelength impulse light source of 5dBm at wavelength of 1547.95nm into the circuit as the resonance of the ring resonator is at the specified wavelength through initial simulation of the microring resonator. The D flip-flop results are presented in Fig 3. The data inputs, clock signal and the outputs of Q and Inv (Q) clearly verified the flip flop operation.

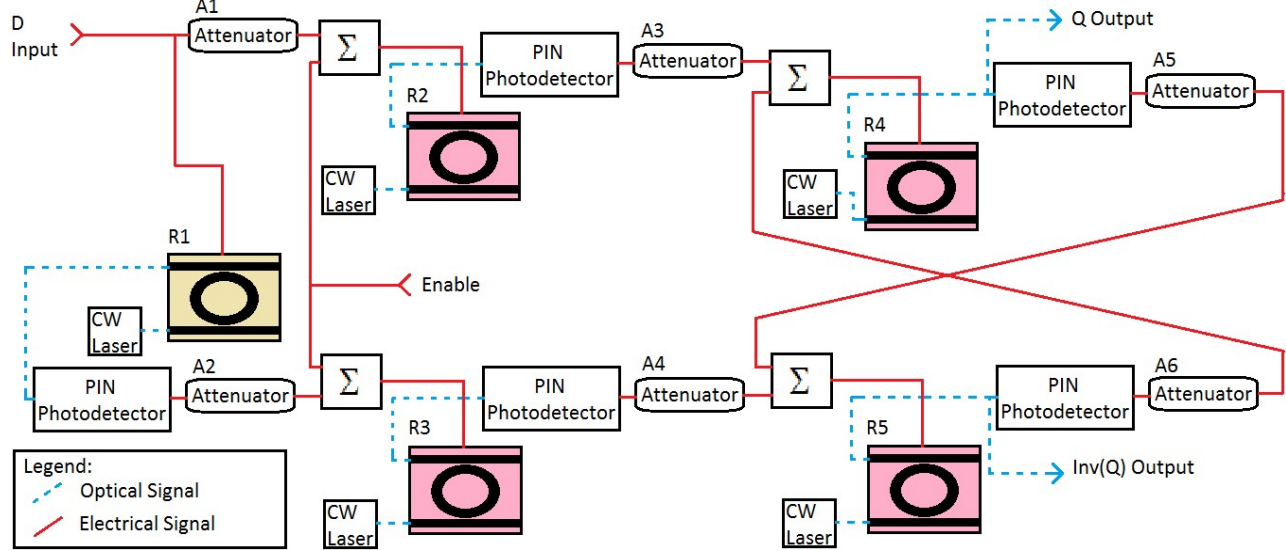


Fig. 2. Schematic circuit diagram of the optical D Flip-Flop.

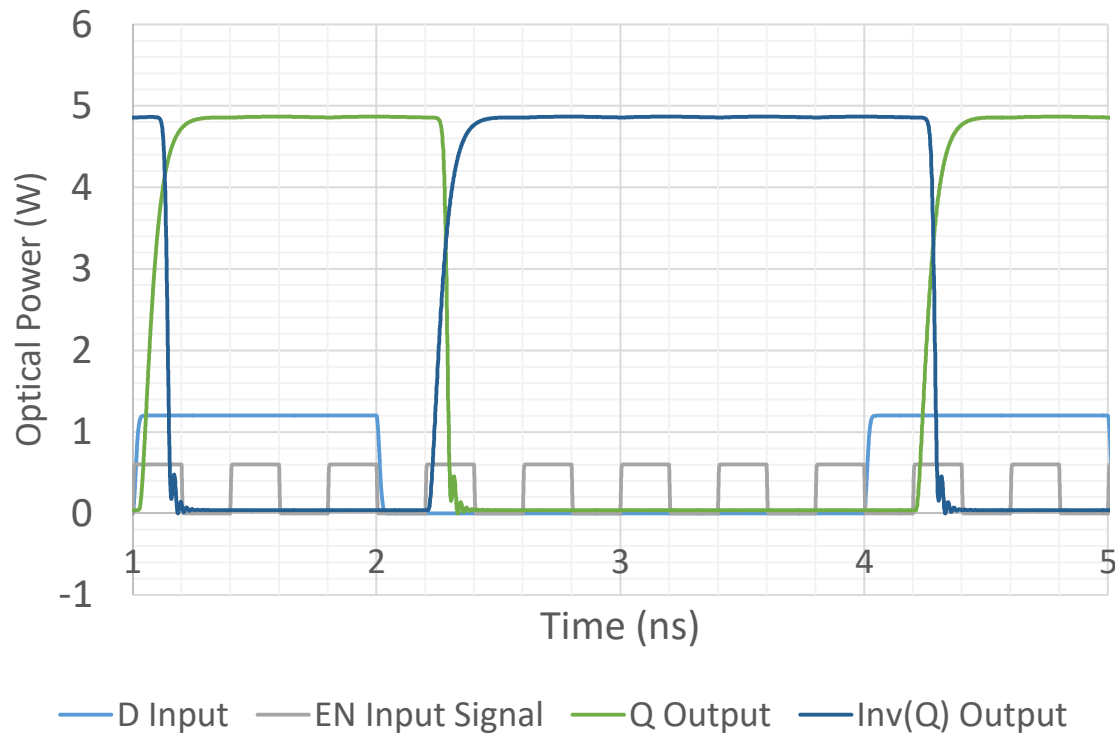


Fig. 3 Optical D- flip flop input and output timing diagrams.

III. CONCLUSION

In this paper we have demonstrated the concept design of an optical D-Flip-Flop using the switching mechanism of silicon micro-ring resonators. We have demonstrated the circuit design and operation of the designed circuit using the electrooptic resonance shift properties of the ring resonator. The demonstrated optical D flip-flop circuit includes NAND equivalent four ring resonators and 1 NOT equivalent ring resonator. We justified the operation of the proposed D flip-flop using simulation and demonstrated the results in timing diagrams with 10 Gbps clock signals and 1 Gbps data signals.

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