Design of a surface plasmon resonance based S-R latch circuit

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INTRODUCTION: In this work, we model the design an all-optical version of an S-R latch. More specifically, we extend the approach detailed in [1] to obtain a waveguiding structure that operates as that digital circuit. The performance of the circuit is discussed in terms of its spectral response, considered as the square magnitude of the S parameters between a specified input-output pair, $|S_{ij}|^2$, computed using the 2D Wave Optics module of COMSOL Multiphysics.

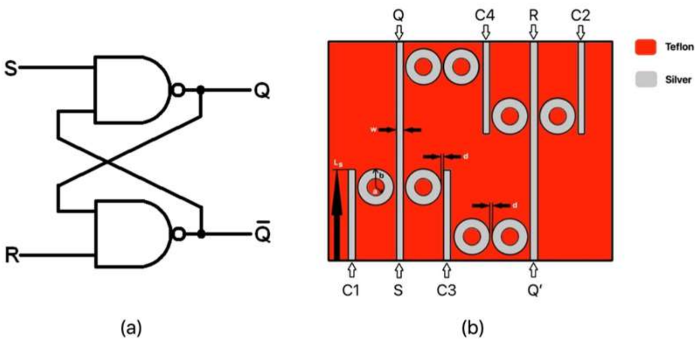

Figure 1. Diagram of a S-R latch configuration with NAND (b) Plasmonic waveguide to emulate the S-R latch

COMPUTATIONAL METHODS: The study is centered on the propagating plasmonic modes in the waveguide. The 2D Wave Optics module with EWFD interface of COMSOL Multiphysics was applied for the modeling of the circuit. The ultimate goal is to compute the mode fields by solving numerically the following frequency-domain equation:

$$\nabla \times (\nabla \times \boldsymbol{E}) - k_0^2 \varepsilon_r \boldsymbol{E} = 0$$

A parametric sweep in the frequency domain study is implemented to compute the S-parameters for the wavelength range [800 nm, 2000 nm].

The circuit diagram for the S-R latch (Figure 1(a)) shows that only one pair of inputs is required to set a high or low logic level at the output Q (and the opposite at Q'). On the other hand, the physical realization of the circuit by the plasmonic waveguide shown in Figure 1(b) needs a set of auxiliary ports in order to provide the proper field coupling that allows the correct input-output relationship. These control ports are designated as C1, C2, C3 and C4.

RESULTS: To define when the output state is ON or OFF, a threshold magnitude of the transmission spectrum of 0.25 is used to distinguish the outputs states, according to [1]. More specifically, if the optical power is greater than 0.25 the output represents bit 1, otherwise the transmitted signal corresponds to bit 0. Table 1 summarizes the states of each control port in each simulation state. The two last columns are the output state of the proposed structure and the NAND port S-R latch, respectively. The transmission spectrum results for each state are in Figures 2 to 4.

Table 1. Relation between excitations in input and control ports and the respective outputs

Input Ports (W)	Control Ports (W)	T_{Tresh}	T	Output Structure	Output S-R Latch
R = 0 S = 0	C1 = 1 C2 = 1 C3 = 0 C4 = 0	0.25	Q = 0.04 Q' = 0.02	Q = OFF Q' = OFF	Invalid state
R = 0 S = 1	C1 = 1 C2 = 1 C3 = 1 C4 = 0	0.25	Q = 0.04 Q' = 0.35	Q = OFF Q' = ON	Q = OFF Q' = ON
R = 1 S = 0	C1 = 1 C2 = 1 C3 = 0 C4 = 1	0.25	Q = 0.45 Q' = 0.09	Q = ON Q' = OFF	Q = ON Q' = OFF
R = 1 S = 1	C1 = 1 C2 = 1 C3 = 1 C4 = 1	0.25	Q = 0.47 Q' = 0.1	Q = ON Q' = OFF	Previous state remains

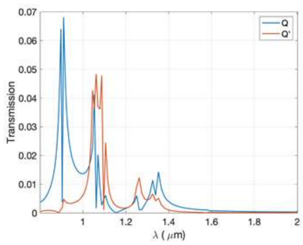

Figure 2.Trasmission spectrum for S=0 and R=0

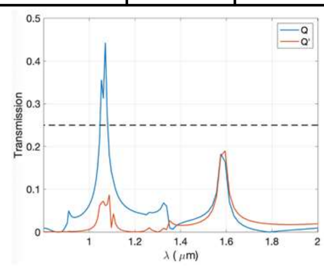

Figure 3.Trasmission spectrum for S=0 and R=1

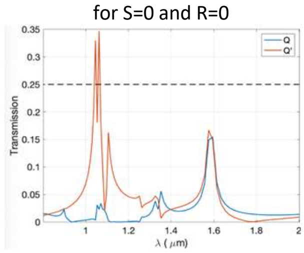

Figure 4.Trasmission spectrum for S=1 and R=0

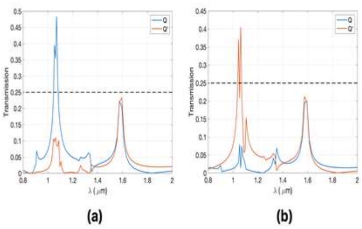

Figure 5.Trasmission spectrum for S=1 and R=1 (a) where the previous state are S=0 and R=1 and (b) the previous state is S=1 and R=0

CONCLUSIONS: In this work, the simulation results indicate that the arrangement of silver nanoribbons and rings can provide a spectral response that resembles the operation of a S-R latch. Further investigations will be focused on the optimization of the structure. Particularly, a greater transmission ratio between the outputs is required in order to enhance the bit detection.

REFERENCE:

1. ABDULNABI, Saif H., ABBAS, Mohammed N., All-optical logic gates based on nanoring insulator-metal-insulator plasmonic waveguides at optical communications band, Journal of Nanophotonics 13(1), 016009 (2019).