A New Method for Obtaining Bistability

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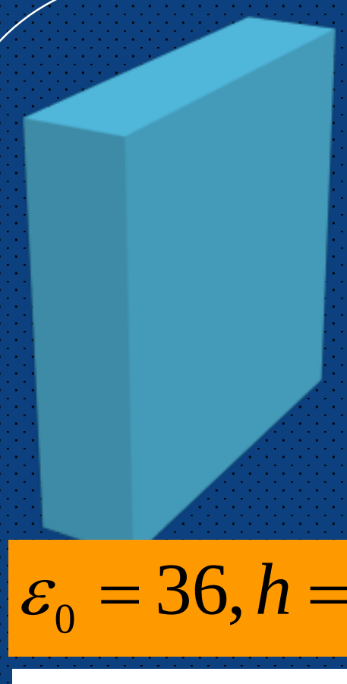
The optical bistability in a nonlinear dielectric film is closely related to the film thickness and linear refraction index. In this article, we present theoretical discussions and numerical simulations of the optical transmissivity and bistability of the metallic plates with periodic arrays of subwavelength aperture in different shapes. The fractal-shape aperture, which satisfies single-mode approximation, can get bistabilty when the film thickness and linear refraction index are very small. Also the threshold is much smaller in the fractal-shape aperture.

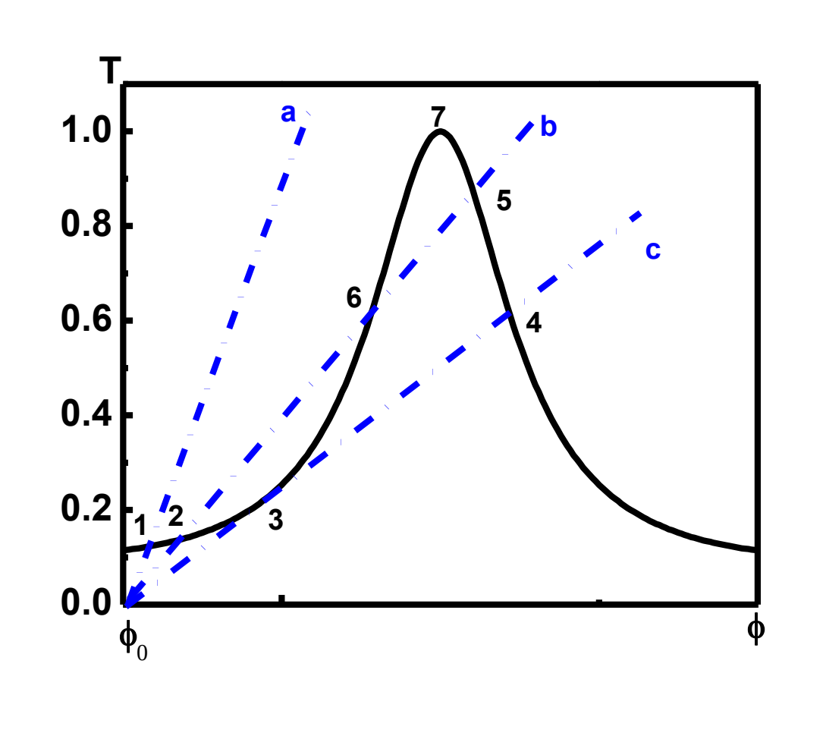


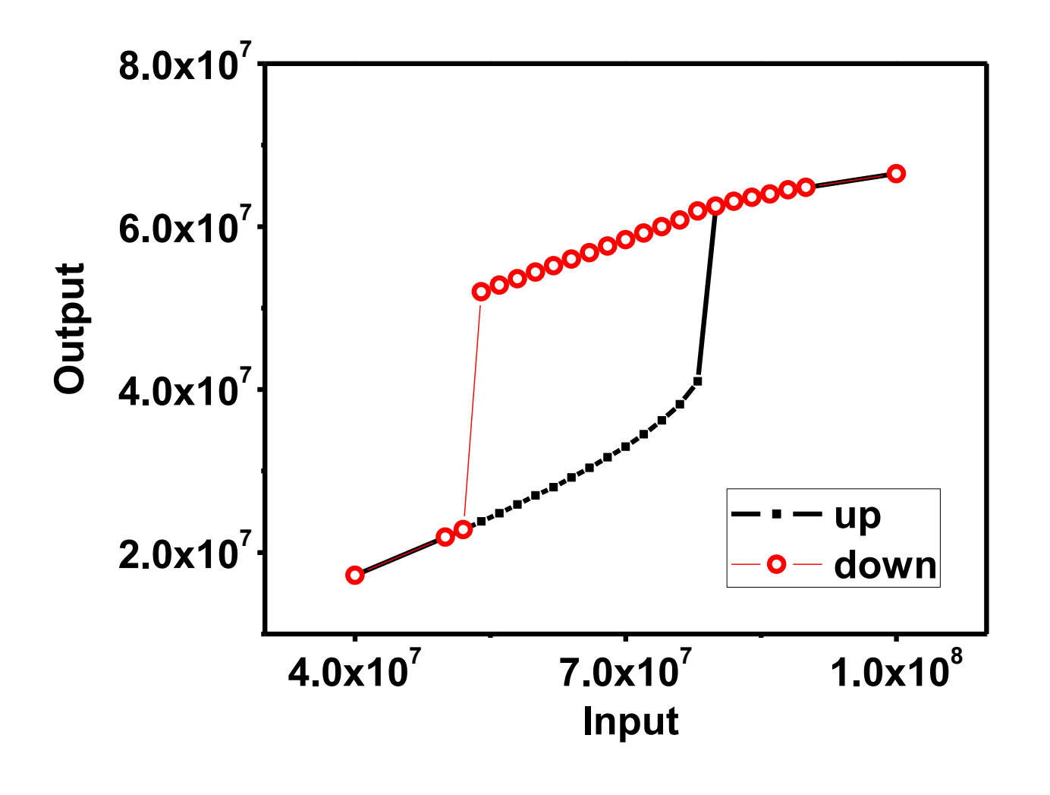
Dielectric film

$$\varepsilon_h = \varepsilon_0 + \chi^{(3)} |E|^2$$

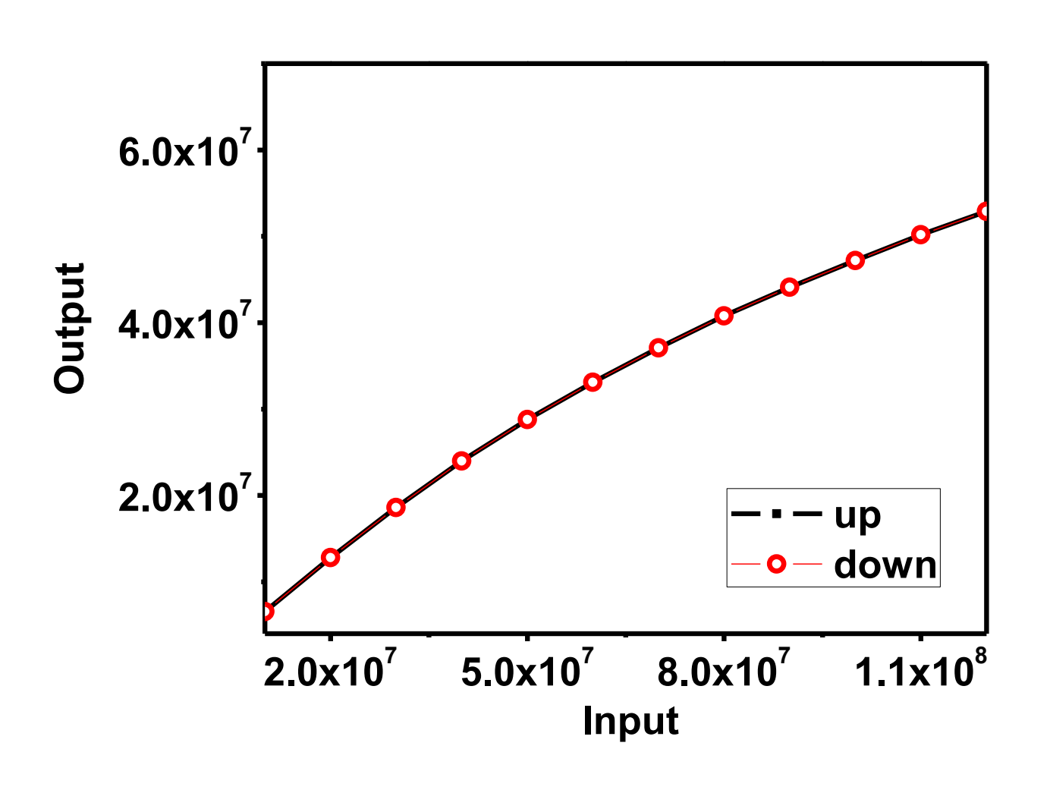
$$\chi^{(3)} = 1\times10^{14} m^2/V^2$$

$\varepsilon_0 = 36, h = 0.4\lambda_f$ **Get Bistability**

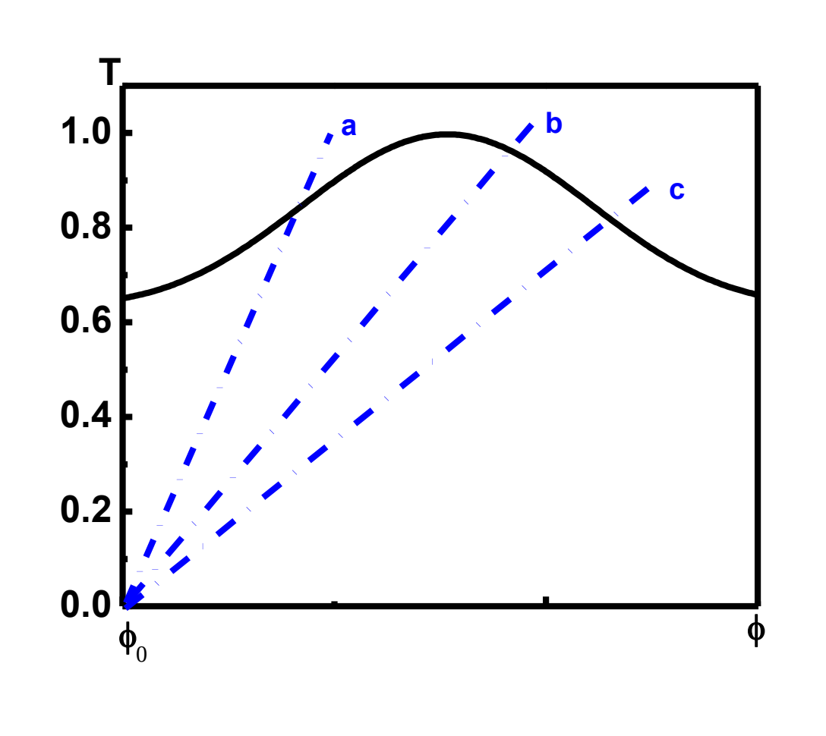


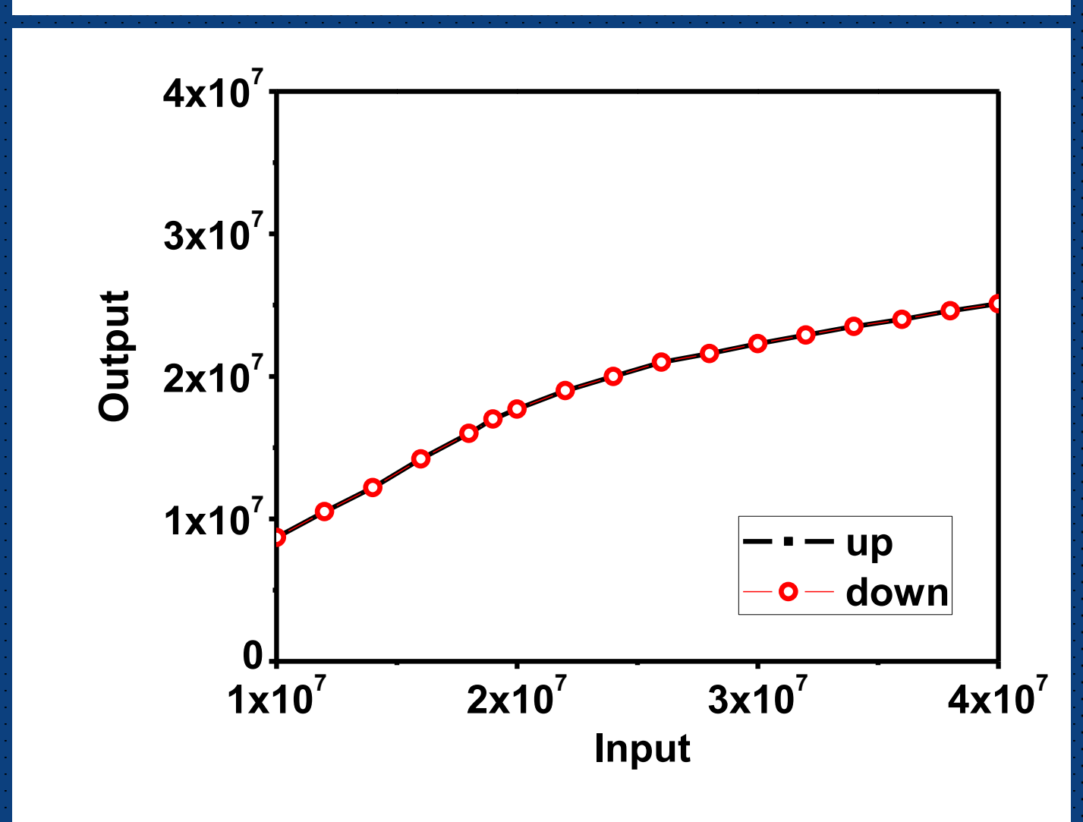


$\varepsilon_0 = 36, h = 0.1\lambda_f$ **No Bistability**



$\varepsilon_0 = 4, h = 0.4\lambda_f$ **No Bistability**





Metallic plates with periodic arrays of subwavelength aperture

$$T^{TE}(k_x) = \frac{4Y_0^{TE} Y_{hole} e^{iq_z h}}{\left(Y_0^{TE} + Y_{hole}\right)^2 - \left(Y_0^{TE} - Y_{hole}\right)^2 e^{2iq_z h}}$$

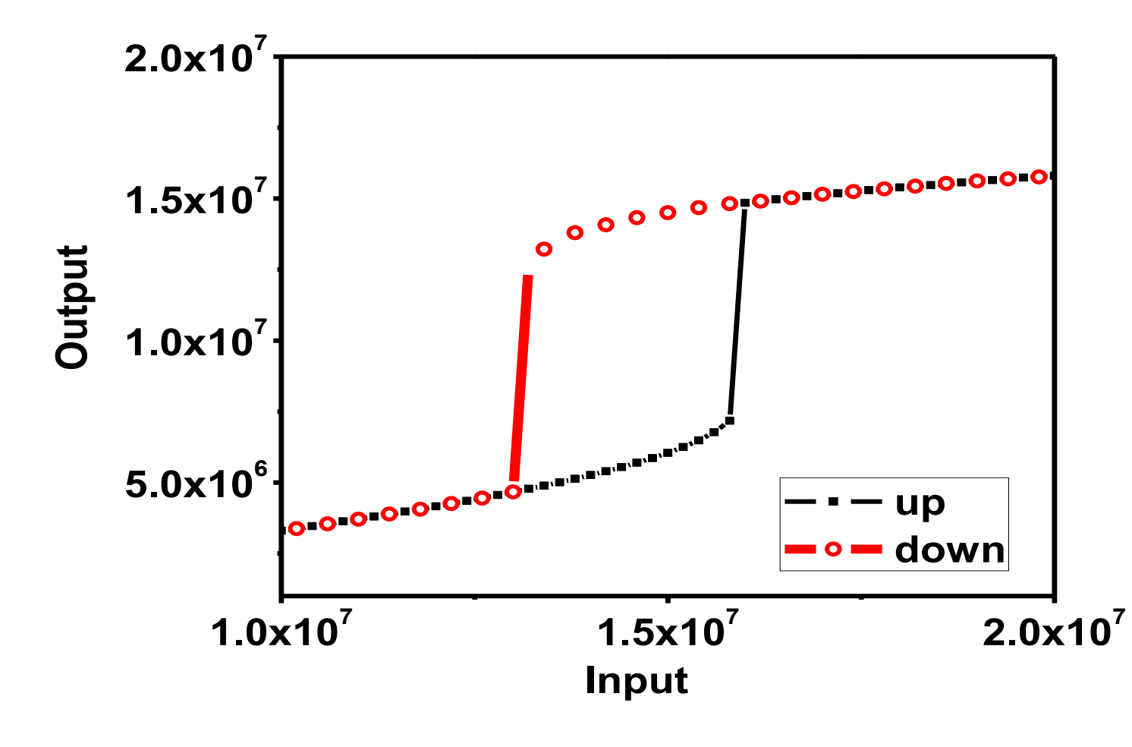
$$T^{TM}(k_x) = \frac{4Y_0^{TM} Y_{hole} e^{iq_z h}}{\left(Y_0^{TM} + Y_{hole}\right)^2 - \left(Y_0^{TM} - Y_{hole}\right)^2 e^{2iq_z h}}$$

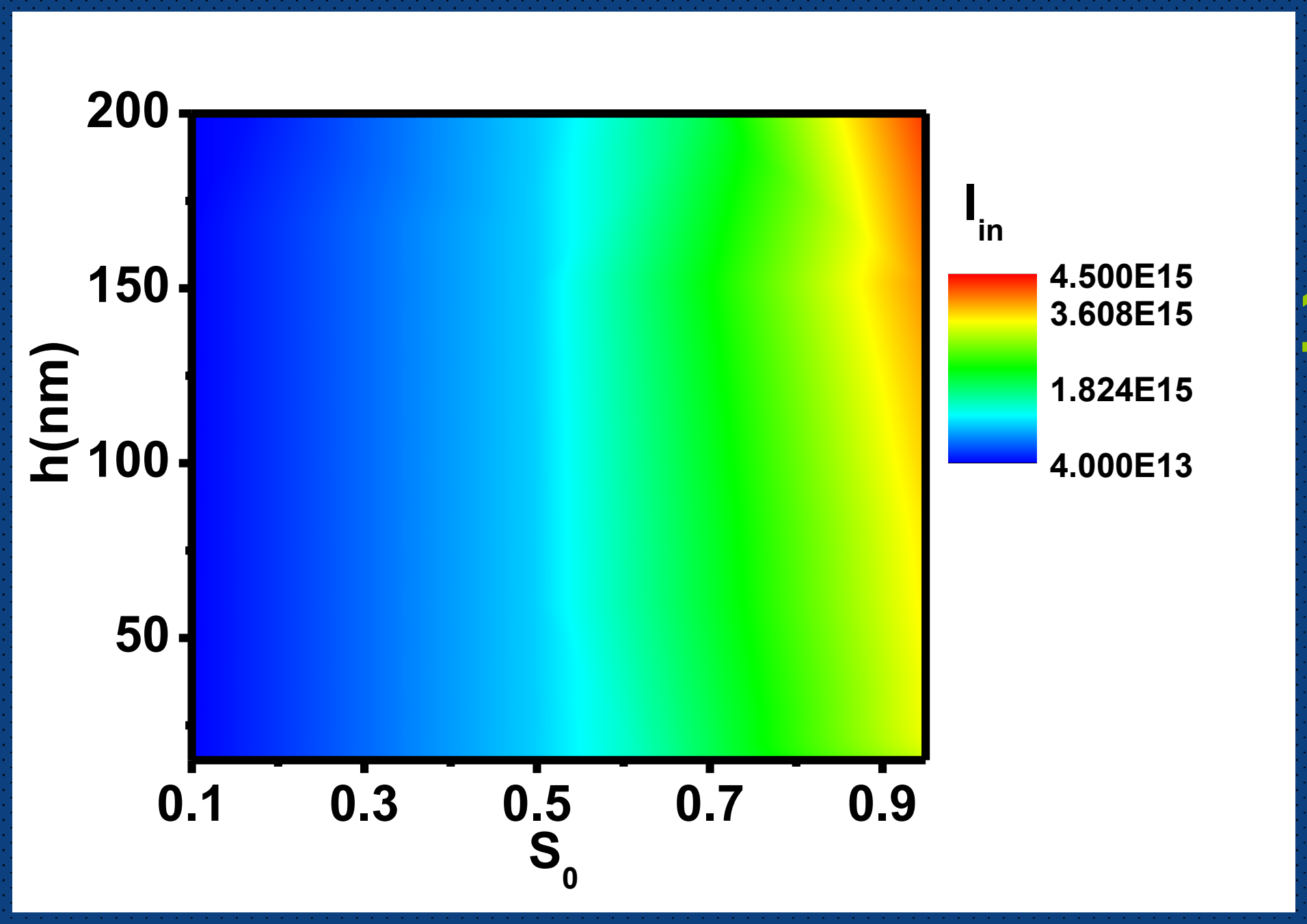
$$S_0 = \frac{\int_{hole} E_y^{inc*} E_y^{wg}\, dxdy}{\int_{hole} (|E_x^{wg}|^2 + |E_y^{wg}|^2)\, dxdy}$$

$$\varepsilon_h = \varepsilon_0 + \chi^{(3)} |T \bullet E_{in} / S_0|^2$$

$\varepsilon_0 = 36$ $S_0 = 0.47$

$\chi^{(3)} = 1\times10^{14} m^2/V^2$

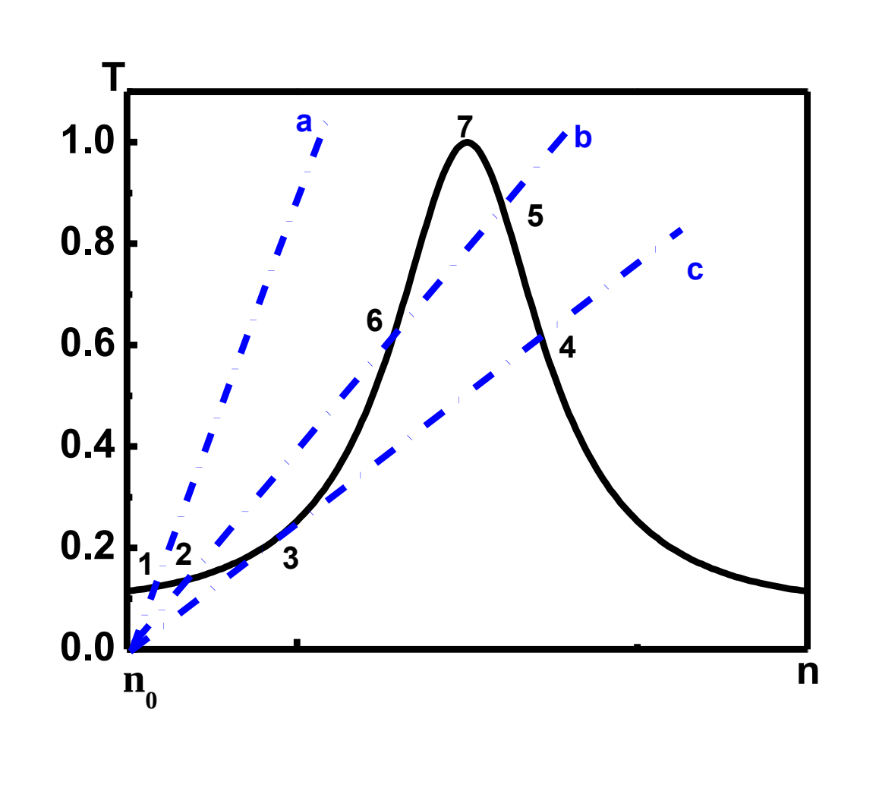




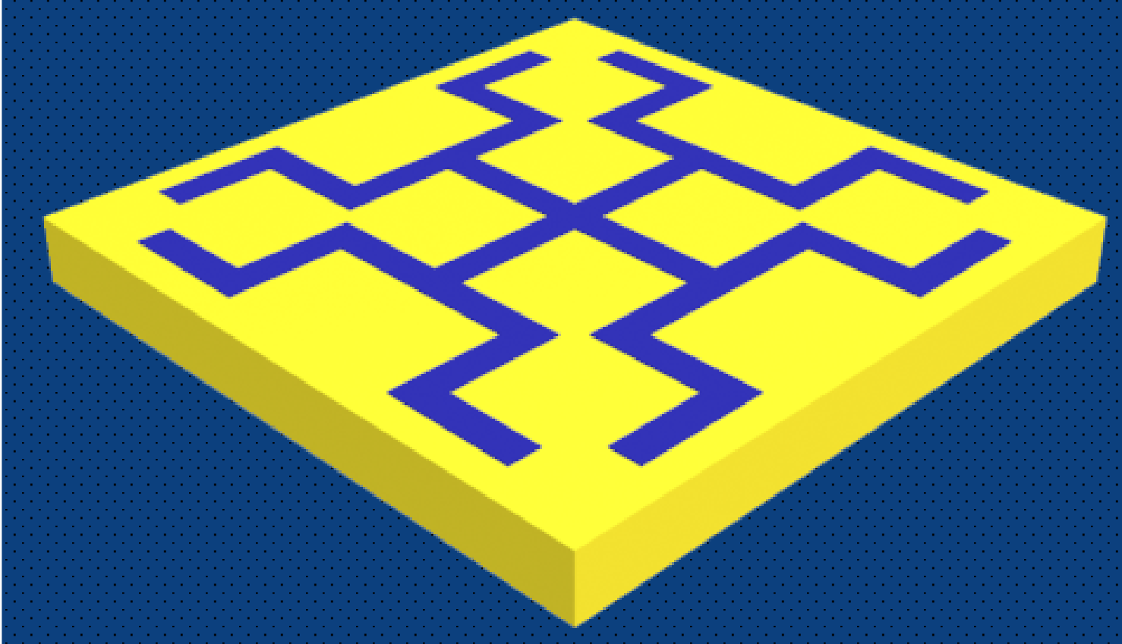
1、When $S_0 < 0.6$

Bistability has nothing to do with film thickness

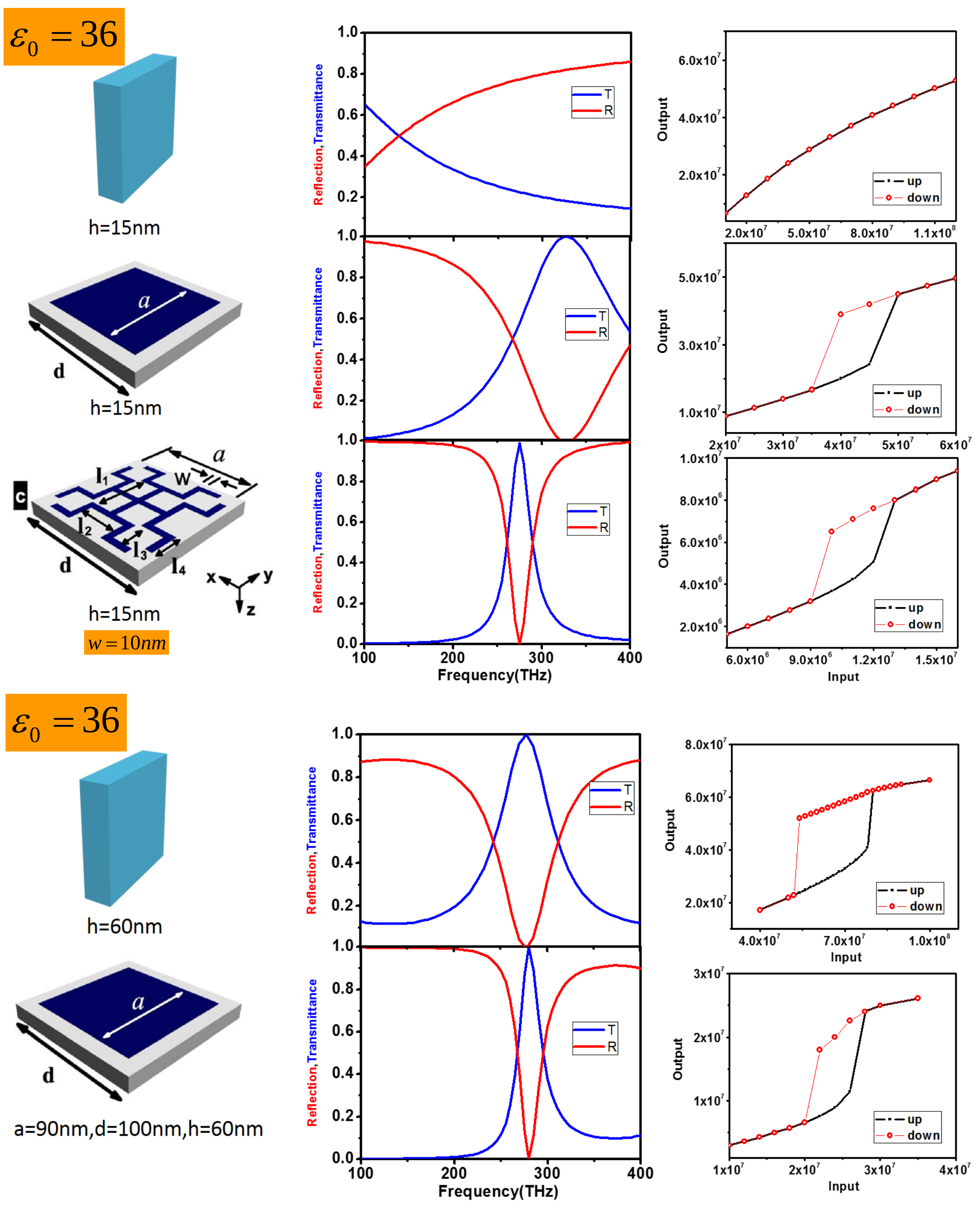
2、The threshold decrease when S_0 is small

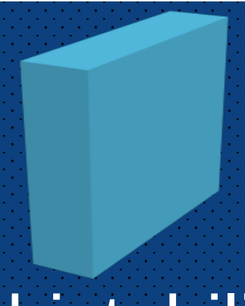


Fractal Structure

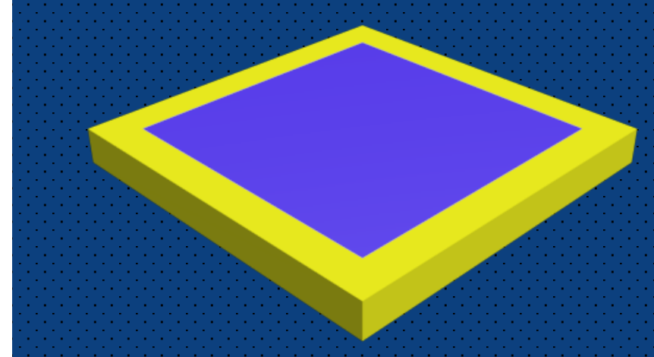


- The transmission is robust against film thickness
- The transmission phase is nearly zero
- The single-mode approximation is valid
- Have small S_0



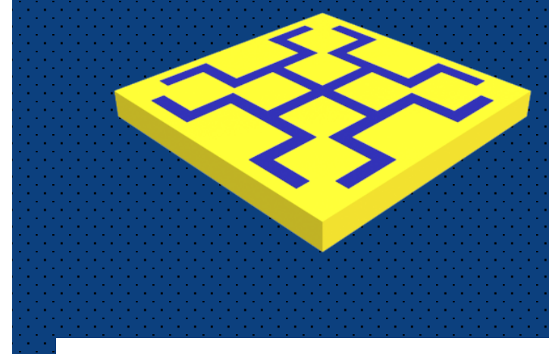


No bistability
in thin film
Sensitive to thickness h



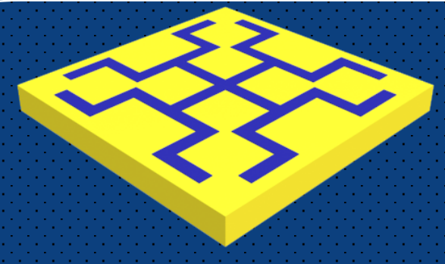
$S_0 = 0.81 > 0.6$

single-mode approximation not valid only if n large enough



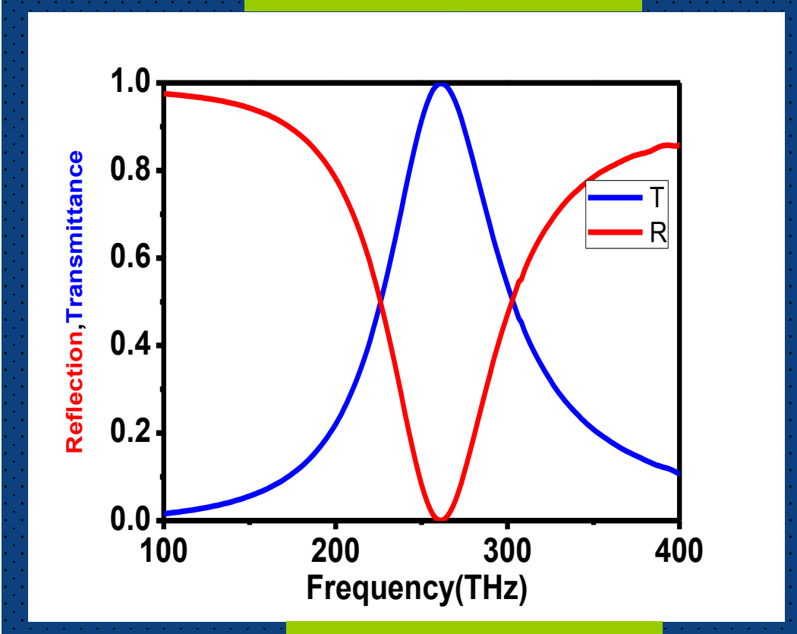
$S_0 = 0.47 < 0.6$

S_0 becomes smaller when h increases
The threshold much lower than other structures

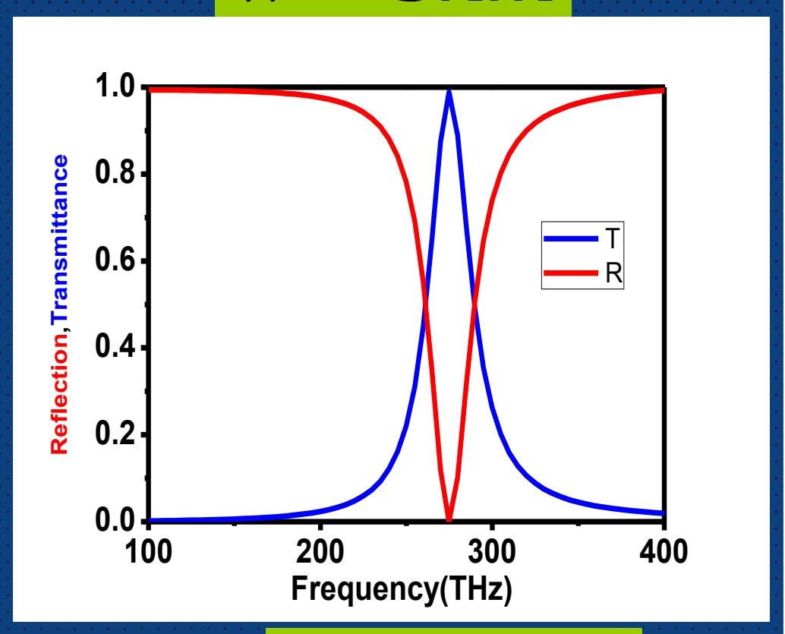


$h = 0.1\lambda_f$ $\varepsilon_0 = 4$

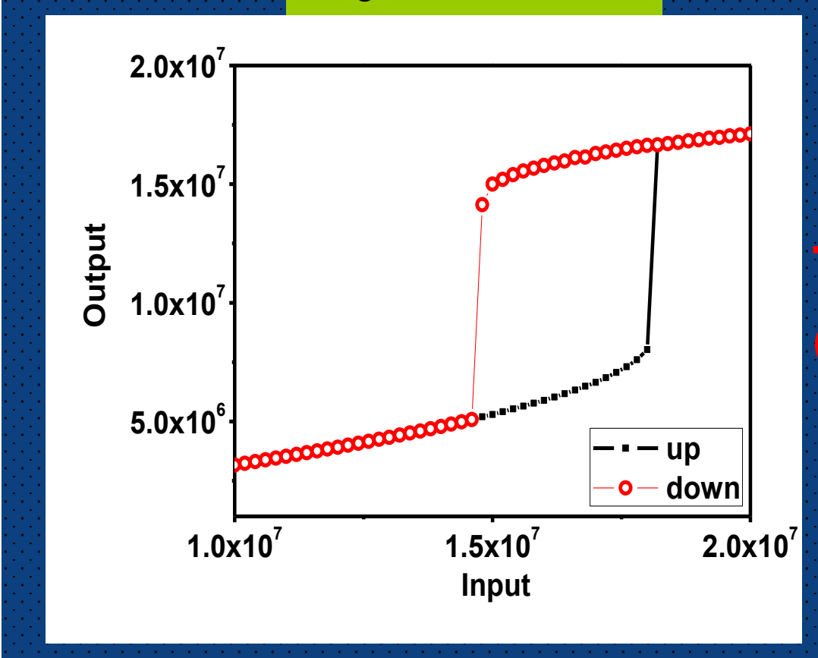
$w = 10nm$



$w = 5nm$

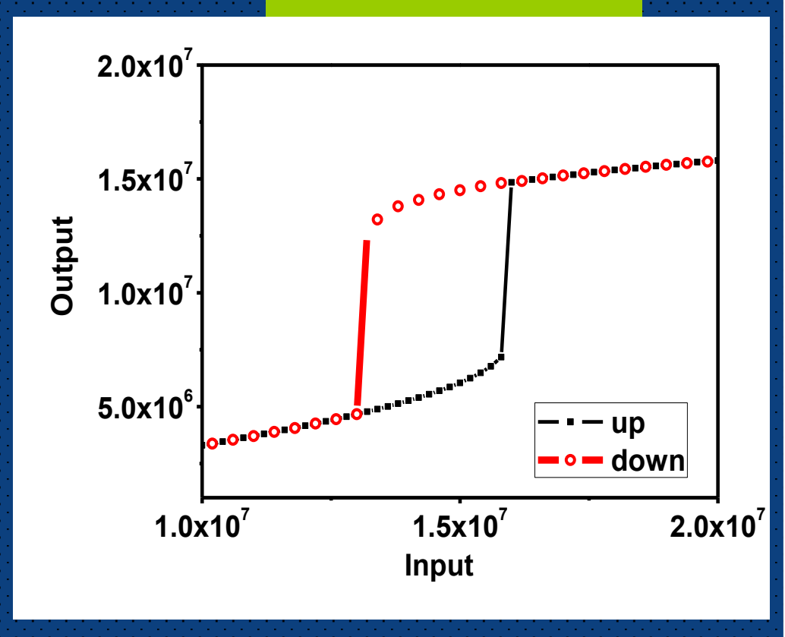


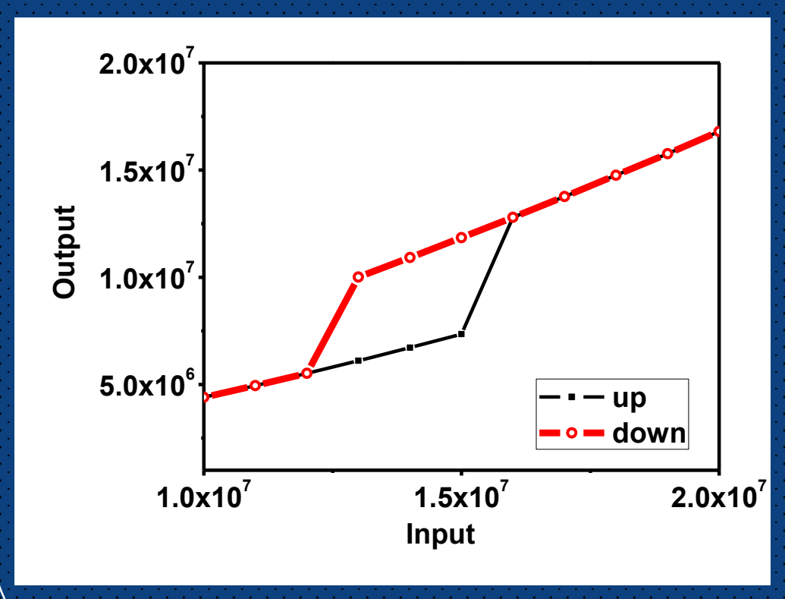
$S_0 = 0.59$



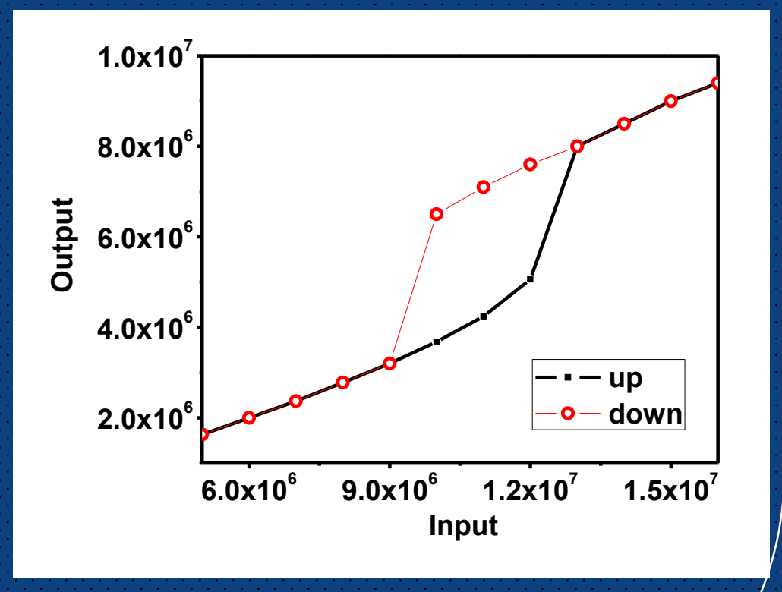
Theoretical Calculation

$S_0 = 0.46$





FDTD Calculation



1、Can also get bistability when n is small
2、S_0 becomes smaller when w decreases

References: 1. S. Y. Xiao, Q. He, X. Q. Huang, L. Zhou, Metamaterials 5, 112 (2011)
2. W. Chen and D. L. Mills, Phys. Rev. B 35,524 (1987)
3. M. Born and E. Wolf, 1970, Principles of Optics, 4th Ed. (Pergamon Press, Elmsford, NY).