A New Method for Obtaining Bistability

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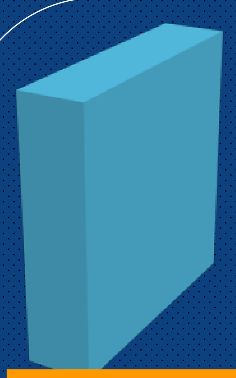
The optical bistability in a nonlinear dielectric film is closely related to the film thickness and linear refraction index. In this article, we present theoretical discussions and numerical simulations of the optical transmissivity and bistability of the metallic plates with periodic arrays of subwavelength 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.

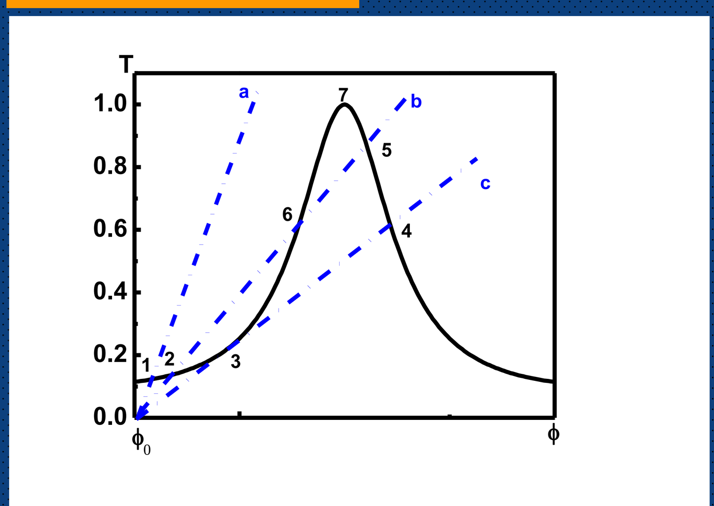
Dielectric film

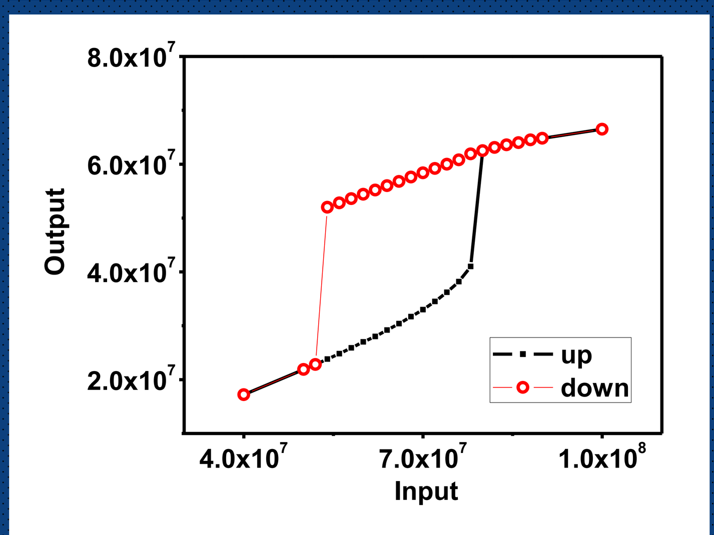


$$\varepsilon_h = \varepsilon_0 + \chi^{(3)} |E|^2$$

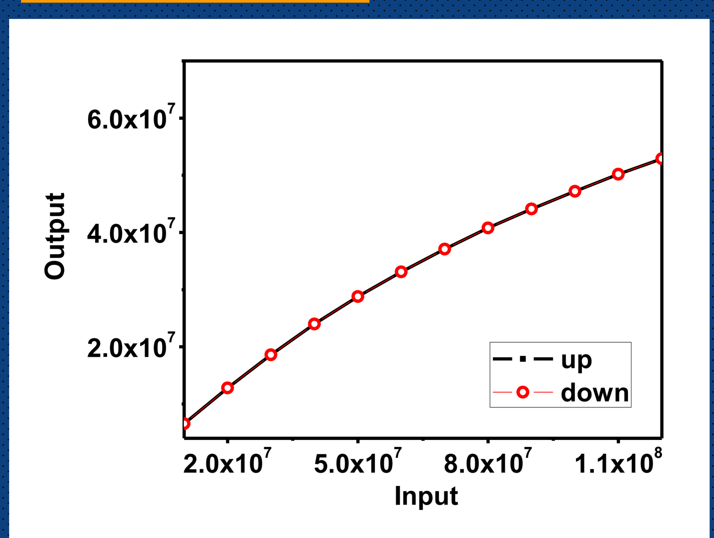
$$\chi^{(3)} = 1\times 10^{14} m^2 / V^2$$

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

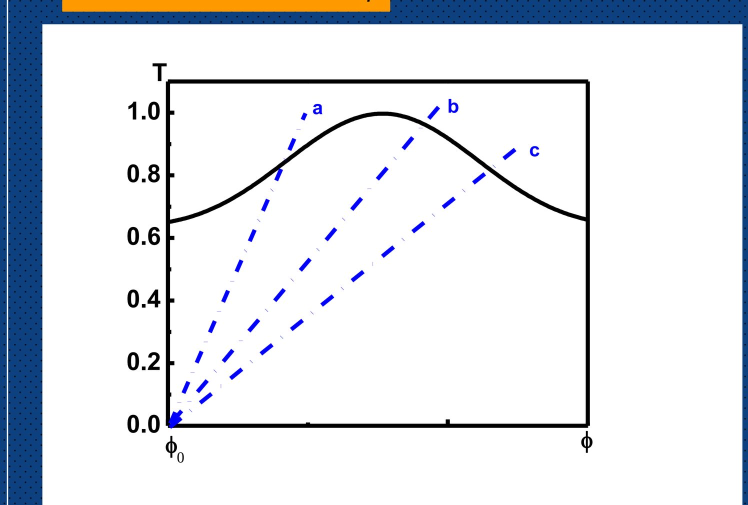


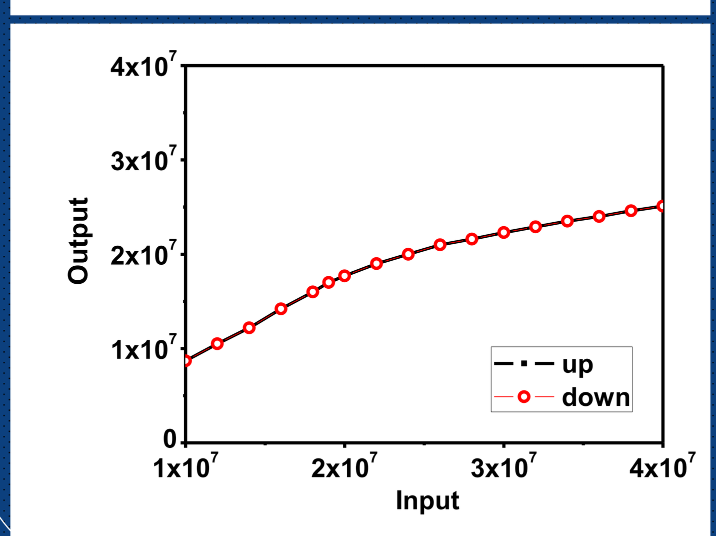


$\varepsilon_0 = 36, h = 0.1\lambda_f$ **No Bistability**



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





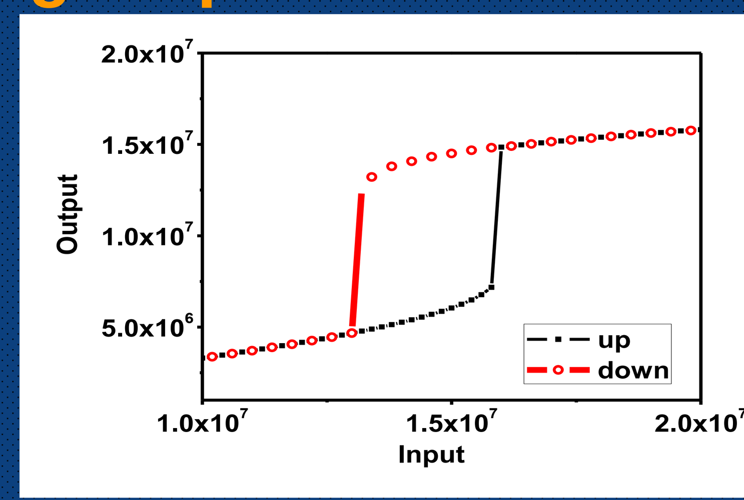
Metallic plates with periodic arrays of subwavelength aperture

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

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

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

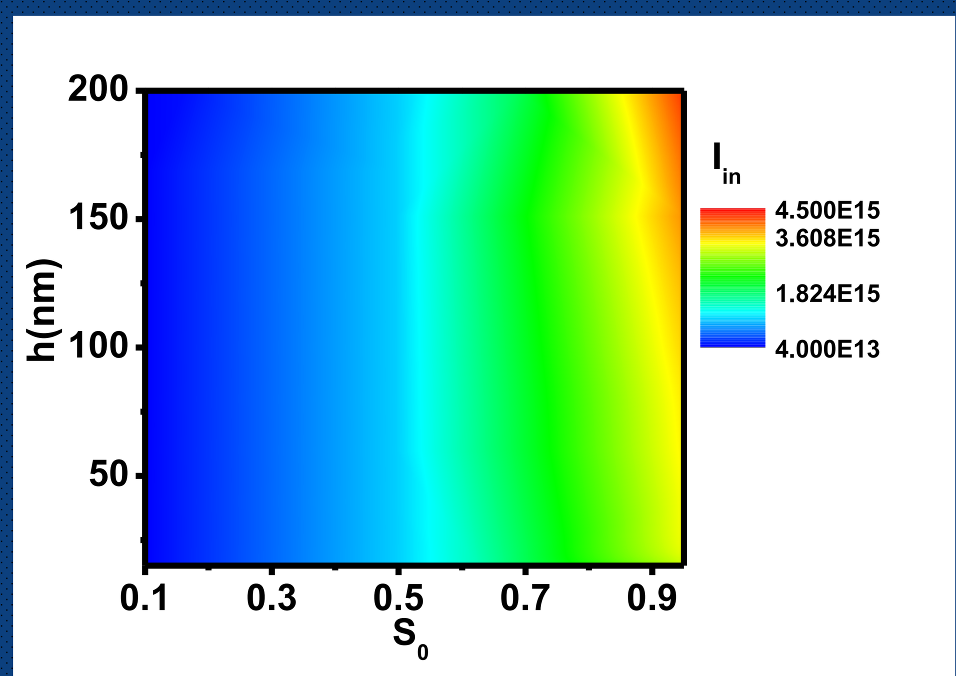
$$\varepsilon_h = \varepsilon_0 + \chi^{(3)} |T \bullet E_{in} / S_0|^2$$



$\varepsilon_0 = 36$

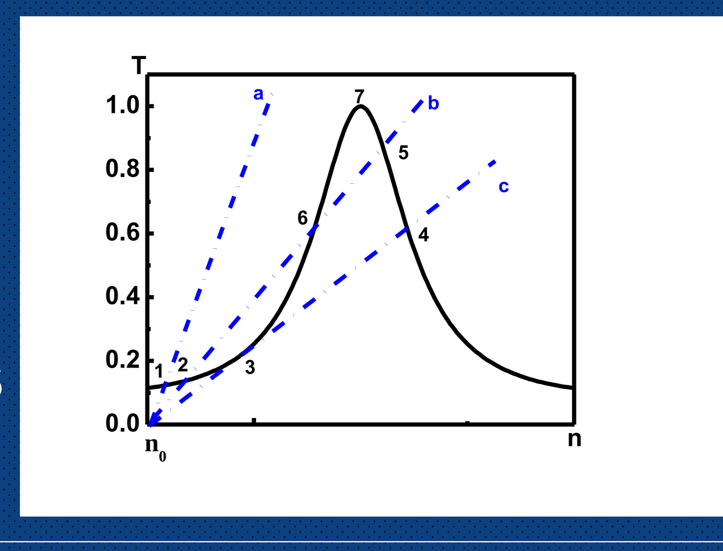
$S_0 = 0.47$

$\chi^{(3)} = 1\times 10^{14} m^2 / V^2$

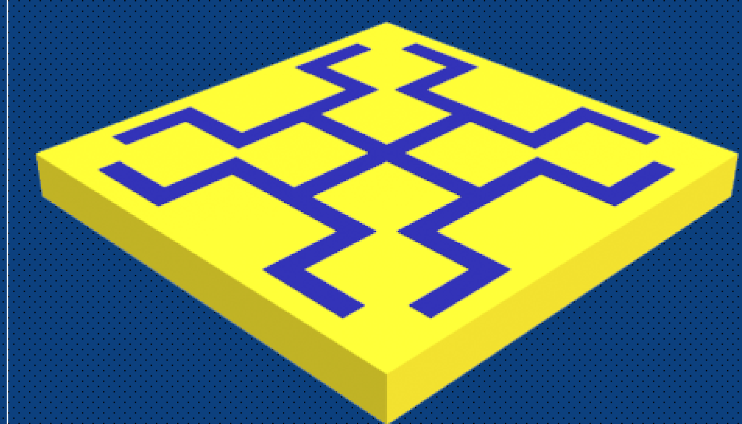


When $S_0 < 0.5$

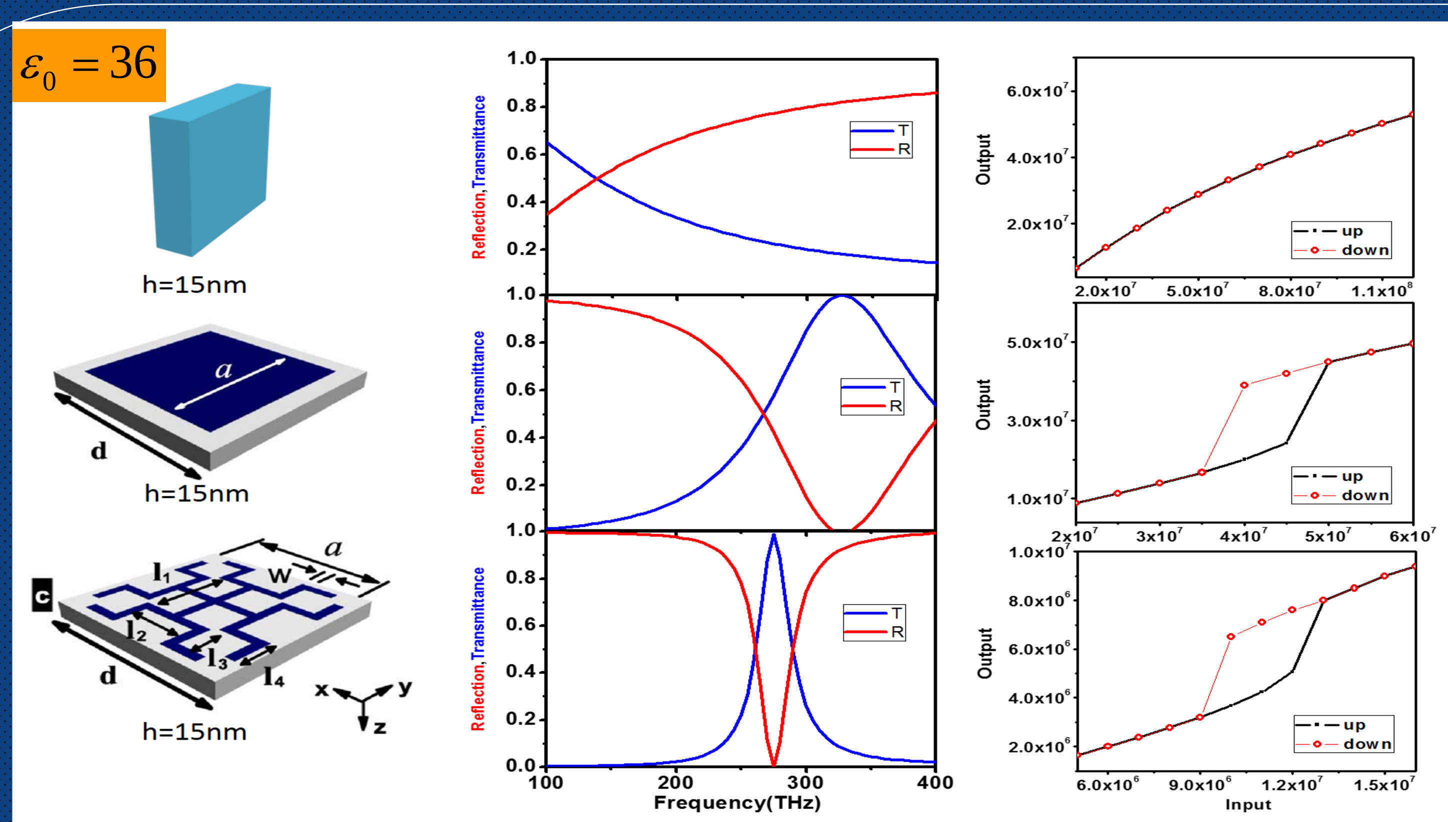
Bistability has nothing to do with film thickness



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



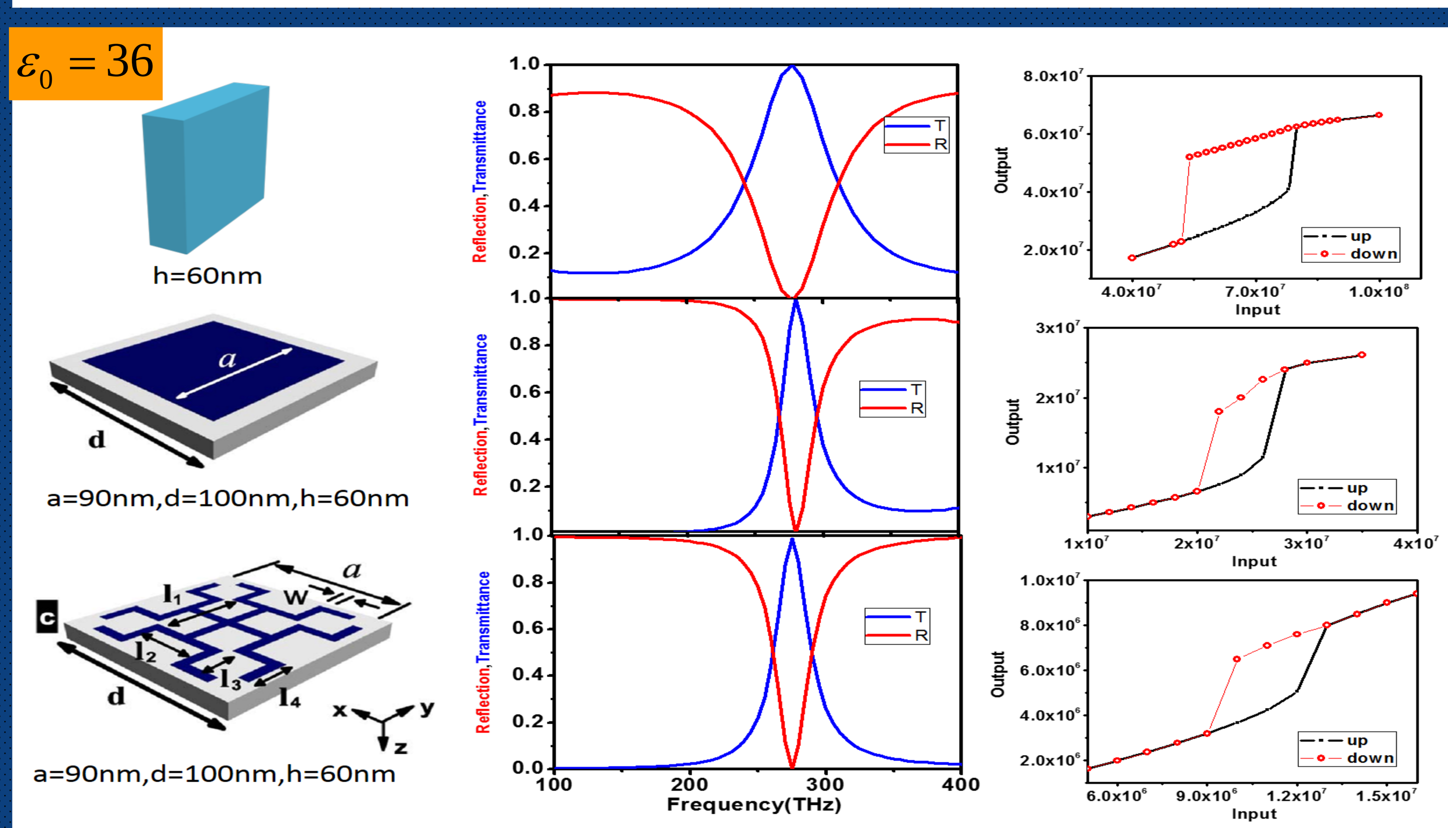
No bistability in thin film

$S_0 = 0.81 > 0.5$

single-mode approximation not valid only if n large enough

$S_0 = 0.47 < 0.5$

single-mode approximation valid



Sensitive to thickness h

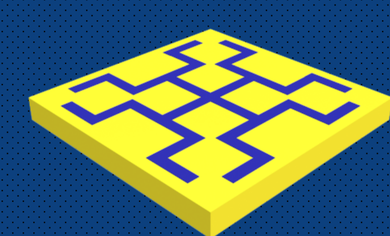
Also change with the thickness h

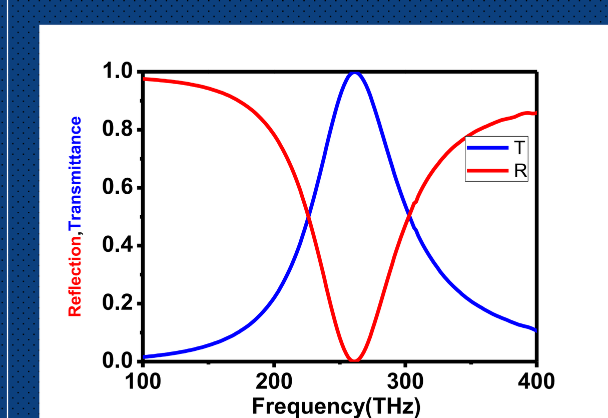
1、Nothing to do with the thickness h

2、The threshold much lower

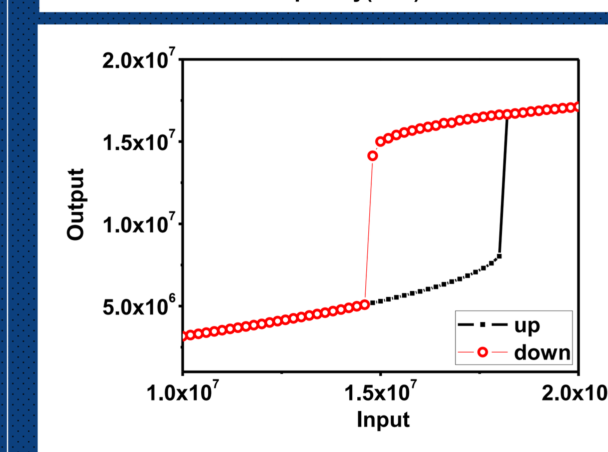
$\varepsilon_0 = 4$

$h = 0.1\lambda_f$

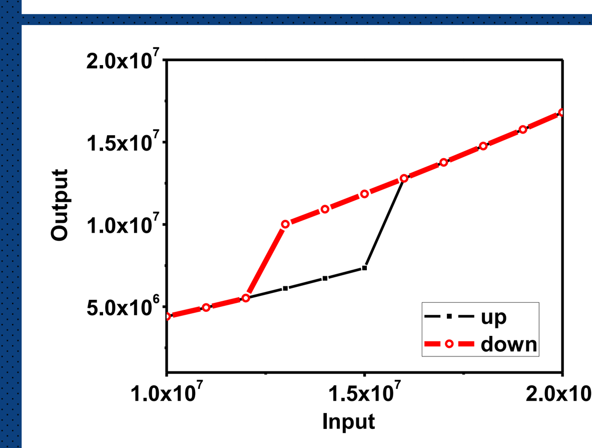




$S_0 = 0.59$



Theoretical Calculation



FDTD Calculation

Can also get bistability

References:

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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).