Modelling Optical Bistability with Hybrid Silicon-Plasmonic Resonators

Odysseas Tsilipakos*, Thomas Christopoulos, Georgios Sinatkas, Emmanouil E. Kriezis
Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki, Greece
* otsilipa@auth.gr

Optical bistability with hybrid silicon-plasmonic resonators is studied with a theoretical framework combining perturbation theory, coupled mode theory and the finite element method. Each physical system is designed so as to exhibit minimum power threshold and maximum extinction ratio between bistable states.

Introduction

Nonlinear phenomena based on the third-order susceptibility or free-carrier effects can be a favorable approach towards designing functional plasmonic components featuring fast response and all-optical operation. When combined with resonant structures, nonlinearity can lead to optical bistability, offering a route towards memory or switching elements. Importantly, the intensity build-up in the resonator leads to reduced power requirements compared to non-resonant approaches.

Results

Figure 1(a) depicts a travelling-wave (disk) resonator comprising a $\chi^{(3)}$ nonlinear polymer (DDMEBT) side-coupled to an access waveguide. The physical implementation is based on the nonlinear conductor-gap-silicon (NLCGS) hybrid plasmonic waveguide [1] which allows for nanonscale confinement and at the same time low propagation loss, thus favoring the manifestation of optical bistability. By conducting rigorous 3D simulations we find that R=1 μm minimizes the power required for bistability and g=225 nm results in critical disk-waveguide coupling maximizing the extinction ratio (ER) between bistable states [2]. The corresponding hysteresis loop is depicted in Fig. 1(b). Bistability manifests for optical powers just above 1W with the ER being theoretically infinite. Importantly, the instantaneous nature of $\chi^{(3)}$ nonlinearity permits the system to switch between states in less than 5 ps, rendering the proposed structure suitable for ultrafast memory/switching applications. Carrier-induced bistability with travelling- or standing-wave hybrid plasmonic resonators [Fig. 1(c)] is also examined since a Si layer is present in the structure giving rise to two-photon absorption. Such implementations lead to reduced power thresholds of few mW but are associated with ns response times due to the relatively slow process of carrier diffusion.

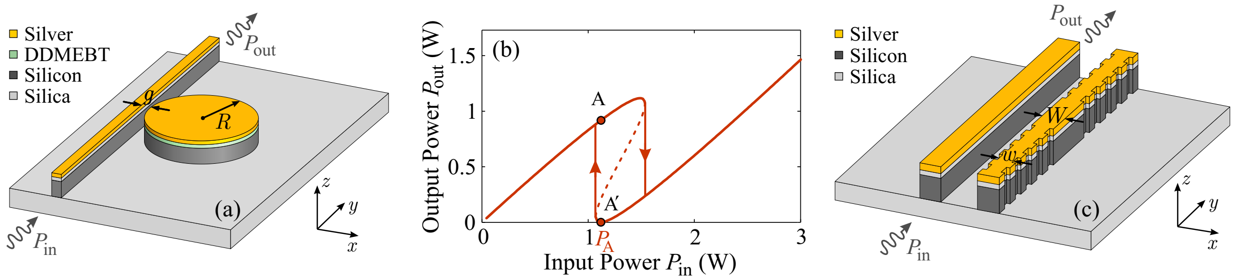

Fig. 1. (a) NLCGS-based disk resonator coupled to CGS access waveguide. (b) Bistability curve for a disk-waveguide system with R=1 μm and g=225 nm. For P_{in}=P_A=1.12 W the system exhibits bistable states with theoretically infinite ER. (c) Standing wave resonator with Bragg reflectors for carrier-induced bistability.

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References

[1] A. Pitilakis, O. Tsilipakos and E. E. Kriezis, *ICTON 2012*, paper 6254436.

[2] O. Tsilipakos and E. E. Kriezis, *J. Opt. Soc. Am. B* **31**, 1968-1705, 2014.