OWTNM 2016 | 24TH INTERNATIONAL WORKSHOP ON OPTICAL WAVE & WAVEGUIDE THEORY AND NUMERICAL MODELLING

Optical Bistability and Self-Pulsation with Long-Range Hybrid Plasmonic Disk Resonators

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Optical bistability and self-pulsation with disk resonators based on the Long-Range Hybrid Plasmonic Waveguide (LRHPW) are studied using a theoretical framework combining perturbation theory, Coupled Mode Theory (CMT) and the Finite Element Method (FEM). The physical system is designed for Kerr bistability with minimum power threshold and high Extinction Ratio (ER). It is moreover shown to support spontaneous oscillations with high Modulation Depths (MD).

Nonlinear phenomena in resonant systems are known to lead in bistable behaviour due to positive feedback [1]. Importantly, the intensity build-up in the resonator lowers the power needed for nonlinearity manifestation. The nonlinear response can be studied by means of a CMT framework [2] taking into account all relevant phenomena: Kerr, two photon absorption and free carrier effects. By properly tuning the carrier lifetime τ_c by means of carrier sweeping we can demonstrate both Kerr-induced bistability for memory/switching operations and self-pulsation for tunable optical clock applications.

Figure 1(a) depicts a travelling-wave resonator, side-coupled to a bus waveguide. The physical implementation is based on the LRHPW with the gaps occupied by a highly nonlinear $\chi^{(3)}$ polymer (DDMEBT). Through rigorous 3D FEM simulations we find that R = 1.158 μm and g = 400 nm lead to Kerr bistability at minimum power levels and maximum ER [2]. Specifically, by reducing τ_c to 8 ps we demonstrate bistable action with an input power of 40 mW and an ER of 22 dB [Fig. 1(b)]. The system can switch between states in less than 50 ps, and is thus suitable for ultrafast memory applications. On the other hand, when τ_c lies around 45 ps we observe self-pulsation [Fig. 1(c)] with high modulation depth (> 0.8) and an oscillation frequency which can vary between 7.15-9 GHz when tuning the input power in the range of 25-45 mW.

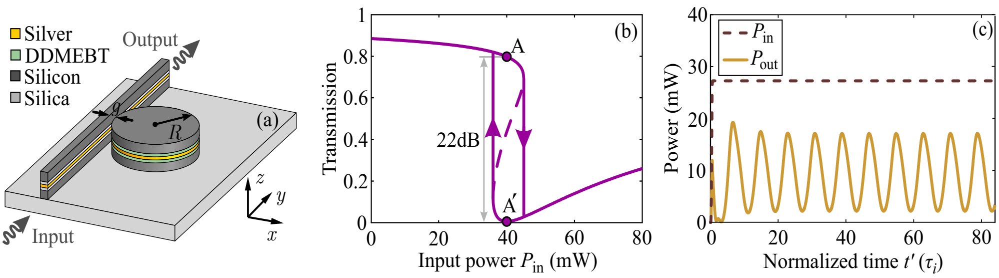

Fig. 1. (a) LRHPW-based disk resonator, side-coupled with a bus waveguide. (b) Bistability curve leading to bistable states at P_{in} = 40 mW with ER = 22 dB after suppressing free carriers (τ_c = 8 ps). (c) Self-pulsing behaviour at P_{in} = 27 mW (τ_c = 45 ps), with $f = 7.5$ GHz and MD = 0.8.

References
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