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Propagation characteristics of surface plasmon polariton modes in graphene layer with nonlinear magnetic cladding

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Abstract

We study the dispersion characteristics of surface plasmon polariton modes guided through a graphene monolayer bounded with a nonlinear magnetic cladding and linear substrate. Nonlinear cladding with permeability $\mu = \mu_1 + \mu_{nl}|\boldsymbol{H}|^2$ provides an extra hand for controlling guided mode behavior externally. The presence of graphene layer enhances nonlinearity in the waveguide configuration thereby changing position of the self-focused peak of field components in the nonlinear medium. Also the propagation length of the fundamental mode strongly depends on the chemical potential of graphene layer. An appreciable increase in propagation length with increase in input power is observed. Phase constant and propagation length of the fundamental mode are calculated as a function of input mode power and graphene layer chemical potential over midinfrared frequencies.

Keywords: graphene, surface plasmons, nonlinearity, plasmonic waveguide

(Some figures may appear in colour only in the online journal)

1. Introduction

Over the last few years graphene has been identified as a promising candidate for realizing subwavelength photonic and optoelectronic circuit elements. Graphene has attracted a significant amount of attraction among researchers due to its interesting optical and electrical properties, tunability, extreme light confinement ability, etc [1, 2]. Graphene layers support TM-polarized surface plasmon polaritons with extreme field concentration in the midinfrared and terahertz frequencies [3, 4]. Graphene plasmons were identified as more promising compared to metal-based conventional plasmonic elements due to their wide tunability achieved through electrostatic gating and chemical doping [4–6]. In recent years, a number of devices based on graphene have been realized over a wide frequency spectrum including sensors, polarizers, photodetectors, optical modulators, etc [2, 7, 8]. Further enhancement in graphene-based components can be achieved by integrating advanced materials in device structures.

Nonlinear materials have been incorporated into plasmonic devices to derive distinct optical phenomena including optical bistability, mode bifurcation, long interaction length, strong field confinement, etc [9–11]. Strong nonlinear effects in metal-based plasmonic structures have paved the way to realizing various optical components such as tunable filters, modulators, frequency converters, logical gates, directional couplers, etc [12–14]. In recent years, nonlinear materials have been identified as suitable candidates for molding-mode characteristics in graphene-based plasmonic devices. It has been reported that graphene plasmonic waveguides incorporating Kerr-type nonlinear medium exhibit enhanced propagation and localization characteristics [15]. Different structural configurations of graphene layers with Kerr-type nonlinear medium open up wide opportunities for controlling light in nanoscale, externally with the aid of electrical and optical signals [16]. The nonlinear response of graphene layer

