Extended First Integral Method for Investigating Nonlinear Surface Plasmon Polaritons in Dielectric-Metal-Nonlinear Slab Waveguides

Ajith Ramachandran[1] and Vincent Mathew[2,a)]

[1]*Department of Physics, Indian Institute of Science Education and Research (IISER) Bhopal, Bhopal, Madhya Pradesh, 462066, India*
[2]*Department of Physics, Central University of Kerala, Kasaragod, Kerala, 671314, India*

[a)]Corresponding author: vincent@cukerala.ac.in

Abstract. The extended first integral method is used to study the complete propagation characteristics of nonlinear surface plasmon polaritons in a multilayer slab waveguide. The method has an advantage of simultaneously obtaining dispersion relation as well as field profile of the propagating mode in the guiding structure. The dispersion characteristics have been found to depend on the input field intensity. Soliton - like nature for the electric field in the focussing nonlinear medium has been found to enhance the propagation length of the wave propagating through the waveguide.

Introduction

Surface Plasmon Polaritons (SPP) are surface charge oscillations coupled to an electromagnetic wave and posses certain momentum and propagate along the interface between two media have opposite sign for permittivity [1, 2]. SPP based waveguides have been well studied in the past as such waveguides are the only possibility to guide light below sub-wavelength regime [3]. The research has further advanced in the direction of designing an all-optical chip with each constituting elements are now optical element and the control of each element is also managed by light fields itself. In that direction, one important element is the tunable SPP based waveguides, where the tuning is also performed with the aid of optical waves. The all-optical tunable waveguides in the nanoscale can be designed using SPP based waveguides which possess a nonlinear medium to assist the tuning function [4, 5, 6]. Nonlinear properties of material depends on the field intensity of the electromagnetic wave and since SPP has the characteristics of having high field intensity concentrated at the nanoscale region between metal and the dielectric, the nonlinear effects are naturally enhanced and nonlinear effects become significant in the propagation of light [7, 8, 9].

First integral method has been widely used for studying the dispersion characteristics of the nonliniear SPP [10, 11]. One disadvantage of the method is that final dispersion relation is, in most cases, obtained as a function of the electric field intensity at one interface of the structure. In addition, a clear understanding of the relation between the input field intensity and the field intensity at the interface is not evident in many cases. To overcome this issue, first integral method can be combined with another well known method called field based method to self consistently solve the dispersion problem to obtain both dispersion characteristics as well as field profile.

In the present study, the dispersion characteristics of nonlinear surface plasmon polaritons supported by nonlinear-metal-linear slab waveguide has been explored using the extended first integral method. Next section explains the theoretical basics of the method followed by the major results and discussions. The final section concludes the major results.

Theory

The waveguide considered consists of a thin metal film sandwiched in between one dielectric linear medium and a dielectric nonlinear medium. In the presence of an incident electromagnetic wave, the nonlinear medium can be

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