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RESEARCH ARTICLE

# Self-focusing of cosh-Gaussian laser beam in collisional plasma: effect of nonlinear absorption

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**Abstract** Self-focusing phenomenon of intense laser beams in underdense plasmas has been investigated theoretically. The mechanism of optical nonlinearity of plasma has been modeled by Ohmic heating of the plasma electrons resulting from their collisions with other species. The effect of nonlinear absorption of laser energy in plasma also has been incorporated. Formulation is based on finding a semi-analytical solution of the nonlinear wave equation for the slowly varying beam envelope. For this purpose, moment theory in W. K. B approximation has been invoked that converts nonlinear wave equation to an ordinary differential equation governing the evolution of spot size of the laser beam. The differential equation so obtained has been solved numerically to envision the effect of laser–plasma parameters on self-focusing of the laser beam

**Keywords** Self focusing · Cosh Gaussian · Plasma · Moment theory

## Introduction

Light has always fascinated man and investigation of interaction of light with matter is as old as human civilization. Ancient people used glass-made lenses to focus light to burn pieces of papers. However, with the debut of laser [1] in 1960, the twentieth century witnessed a dramatic shift in our perception and understanding of light. Due to its extraordinary properties of coherence, high intensity and monochromaticity, laser light revealed true beauty of light matter interactions. When laser was born, little did its inventors and aficionados realize that it would not only sweep that era of scientists off its feet, but would continue to challenge and mesmerize generations to come. With that high expectation as a benchmark, the laser has proved to be nothing short of a miracle. The laser has become ubiquitous in the almost every field of modern age science and technology. Even routine life applications are abound and still too many applications are in pipeline and are waiting for their turn.

Amelioration in laser technology fueled by the advent of chirp pulse amplification [2] (CPA) technique has led to a resurgence in the field of light matter interactions by giving birth to two entirely new areas of science, i.e., nonlinear optics and laser–plasma interactions. Interactions of intense coherent beams of light produced by modern laser systems with plasmas are rich in copious nonlinear phenomena those were not possible before the invention of laser. This includes a gamut from optical self-action effects like[3, 4] (self-focusing, self-guiding, self-phase modulation, etc.) to several frequency mixing processes[5, 6] like sum frequency generation, difference frequency generation, second harmonic generation (SHG), etc. Being extremely complex but rich in physics, these nonlinear effects have the potential to keep researchers busy for several upcoming years. Over past few years, veteran physicists are attempting to improve on the understanding of laser–plasma interactions by carrying out experimental as well as theoretical investigations. The major impetus behind these investigations on laser–plasma interactions was built by the proposal of initiating controlled nuclear fusion reaction by using ultra-intense laser beams [7]. Fusion is considered to be the cleanest source of energy that bears the promise to

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