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RESEARCH ARTICLE

Optical guiding of *q*-Gaussian laser beams in radial density plasma channel created by two prepulses: ignitor and heater

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Abstract Self-action effects (self focusing) and self phase modulation of *q*-Gaussian laser beam in plasma channel created by ignitor heater technique have been investigated theoretically. The ignitor beam causes tunnel ionization of air. The heater beam heats the plasma electrons and establishes a parabolic channel and also prolongs the channel life by delaying the electron ion recombination. The third beam (*q*-Gaussian beam) is guided in the plasma channel under the combined effects of density nonuniformity of the parabolic channel and relativistic mass nonlinearity of the plasma electrons. Formulation is based on finding the numerical solution of nonlinear Schrodinger wave equation (NSWE) for the fields of incident laser beams with the help of moment theory approach. Particular emphasis is put on dynamical variations of the spot size of the laser beams and longitudinal phase-shift of the guided beam with distance of propagation.

Keywords Self-Focusing · Self-Trapping · Phase Modulation · Bessel Gauss Lasers · Ponderomotive Force

Introduction

After the transistor, lasers [1] are considered to be one of the most successful inventions of 20th century science. When laser made its debut in 1960, some people called it solution in search of a problem. Today lasers have reserved their place in almost every aspect of life: consumer technologies like CD players, super market checkout scanners to higher end technologies. With the advent of chirped pulse amplification (CPA) technique [2], the turn of last century has witnessed a giant leap in laser technology leading to a renaissance in the field of light-matter interactions. This amelioration in laser technology has given birth to an entirely new field of science known as laser–plasma interactions. An agglomeration of nonlinear phenomena viz., parametric instabilities, [3, 4] higher harmonic generation, [5, 6] Self-focusing, [7] self-phase modulation [8], etc is ubiquitous in these laser plasma interactions.

A major impetus behind the investigations on laser plasma interactions was provided by the proposal of initiating fusion reactions [9, 10] for viable energy production by using intense laser beams. Fusion is considered to be the cleanest source of energy as there will be no emission of radioactive end products and green house gases. Thus, it bears the promise to quench humanity's endless thirst for energy without making any harm to global climate. Along the way the field of laser–plasma interactions has branched into a number of potential applications like laser-driven accelerators, [11, 12] X-ray lasers, [13, 14] higher harmonic generation [5, 6], etc. The ultimate breath of most of these applications depends on stable guiding of intense laser beams over longer distances, without significant energy loss. However, due to lights natural wave property of diffraction, a light beam traveling in vacuum or in a medium always broadens in the absence of an optical guiding mechanism. Diffraction broadening of the laser beam is thus the fundamental phenomenon that jeopardizes the feature of aforesaid applications by negating the efficiency of laser–plasma coupling. Hence, there is surging interest to explore the methods that may aid to increase the

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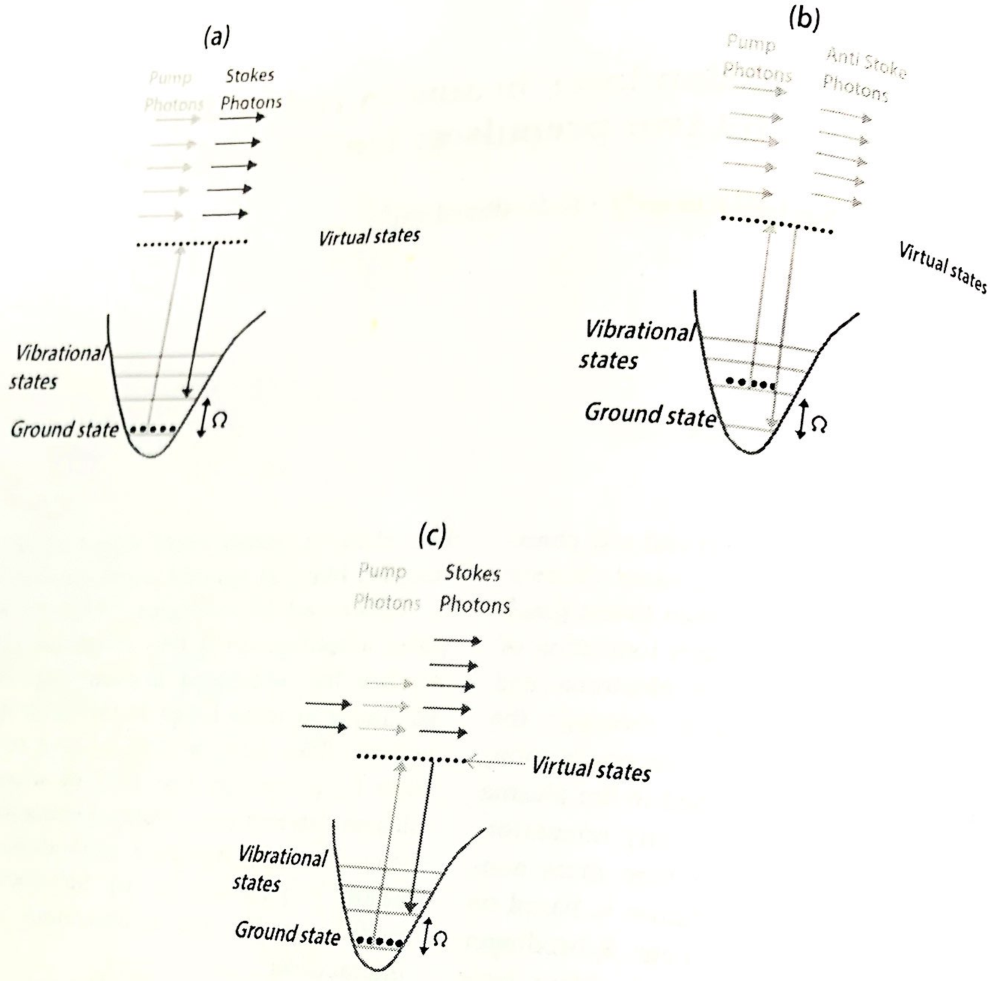

Figure 1. Raman scattering of light (a) Stoke's component (b) Anti Stoke's component (c) Stimulated Raman scattering.

nonlinear phenomena. These efforts have collectively laid the foundation of an entirely new branch of science known as laser plasma interactions.

Raman scattering occurs due to interaction of light with optical phonons. Equivalently we can see it is the scattering of light due to quantized molecular vibrations of the medium (Figure 1). Basically Raman scattering is an inelastic scattering in which an incident photon with energy $h\nu_L$ produces a scattered photon with energy $h\nu_S$ while the remaining energy $h(\nu_L - \nu_S){=}h\Omega$ results in the vibrational excitation of the molecule. Thus Stokes component of the Raman scattering corresponds to creation of an optical phonon. The frequency ν_S corresponding to the scattered photon is called Stokes frequency and is smaller than the incident light frequency by an amount equal to that of generated phonon.

In case the molecule is already in an excited state (Figure 1(b)), it may undergo a downward transition while producing the scattered photon. Hence, anti Stokes component of Raman scattering results in annihilation of an optical phonon. In that case the