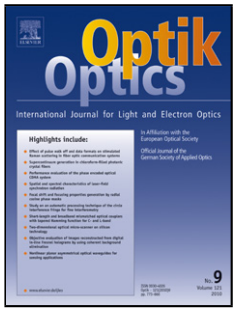

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Complete Solutions of Finite Airy Beams in Free Space and Graded Index Media with Fourier Analysis

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In order to analyze the far-field propagation characteristics of the new non-diffractive Airy beams theoretically and deeply on the condition of finite energy, the Fourier analysis method was utilized. The analytical solution to paraxial wave equation which described one-dimensional Airy beams' propagation dynamics in free space was given. Furthermore, a new analytical solution to the modified paraxial wave equation which described one-dimensional Airy beams' linear propagation dynamics in graded index media was also given, which was different from the known one. The far-field propagation characteristics of one-dimensional and two-dimensional Airy beams in free space were studied by utilizing the acquired analytical solution. In addition, the influence of different parameters on non-diffractive propagation and transverse acceleration characteristics of Airy beams were studied in detail. The non-diffractive propagation distances would become longer if the decay factor became smaller when the arbitrary transverse scale kept invariant. Moreover, the Airy beams would accelerate faster if the arbitrary transverse scale became smaller when the decay factor kept invariant. The linear propagation characteristics of one-dimensional Airy beams in the graded index media was also analyzed. Interesting phenomena were observed ,and it was found the trajectory of the Airy beams could be modulated arbitrarily if the parameters of the media were selected properly.

OCIS codes: **(***070.0070) Fourier optics and signal processing ; (070.2580) Paraxial wave optics; (350.5500) Propagation.*

Keywords: Fourier optics and signal processing; Paraxial wave optics; Propagation

1. INTRODUCTION

In 1979 Berry and Balazs firstly demonstrated that the Schrödinger equation existed a special solution which was called "Airy packet" in the context of quantum mechanics [1]. The special wave packet had the unique and fantastic characteristics of non-diffraction and self-acceleration. However, the achievement didn't attract enough attention as the ideal Airy packet carried infinite energy, which couldn't be realized in the experiments. In 2007 it was found the Airy function truncated by exponentially decaying was also a particular solution to the Schrödinger equation [2], which helped to make the energy of the Airy packet become finite. Subsequently, the fascinating Airy beams which had the characteristics of non-diffraction, self-acceleration and self-healing were firstly realized by utilizing liquid crystal spatial light modulator in the experiments [3]. The study on the new Airy beams and other non-diffractive beams has become a hot area during the past few years. Recently, most attention has been concentrated on the generation of Airy beams[4-8], particular Airy beams[9-13], control of particular beams and the potential application of these beams, such as directional control of particles[17] and generation of light bullets[18,19].

It could be seen the most accomplished work was focused on the study of Airy beams' characteristics and their application by utilizing the known results. Can we study the characteristics of Airy beams deeply with starting from the initial conditions by utilizing traditional methods? Will we acquire some different results? It is rarely mentioned in other references. Therefore, we start our study from the initial one-dimensional (1D) Schrödinger equation which governs the propagation dynamics of particles in free space by utilizing the classic Fourier analysis method. The electric field envelope which follows the Airy function was acquired with complete derivation. Furthermore, we continue our study on the propagation characteristics of Airy beams in the graded index media from the modified paraxial wave equation with same method. The corresponding solution to the equation was also deduced. Interestingly, the solution we acquired was different from the known one in Ref. [20]. In addition, we studied the non-diffraction and self–acceleration characteristics of 1D and 2D Airy beams by utilizing the acquired solutions in detail and interesting phenomena were observed in our study.

2. THEORETICAL STUDY WITH FOURIER ANALYSIS

The Schrödinger equation which governs the propagation dynamics of 1D Airy beams could be described as:

$$i\frac{\partial \phi}{\partial \xi}+\frac{1}{2}\frac{\partial^2 \phi}{\partial s^2}=0 \qquad (1)$$