Periodic Self-Accelerating Beams Along Convex Trajectories

Yi Hu\(^1\), Domenico Bongiovanni\(^1\), Zhigang Chen\(^2\), and Roberto Morandotti\(^1\)

\(^1\)Université du Québec, Institut National de la Recherche Scientifique, Varennes, Quebec J3X 1S2, Canada
\(^2\)Department of Physics & Astronomy, San Francisco State University, San Francisco, CA 94132, US

\*bongiovanni@emt.inrs.ca

Introduction

Self-accelerating beams are optical beams featured by a transversely bending trajectory. Among them Airy beams have the unique characteristic of freely accelerating along parabolic trajectory without diffraction.

Airy Beam's Properties
- Non-diffractive propagation
- Bending trajectory
- Self-healing

Airy Beam's Applications
1D Airy Beam
- Optical Trapping
- Curved-Plasma Channels
- Optical Airy Bullets

Motivations
- Nowadays self-accelerating beams can be engineered to propagate along arbitrary trajectories. However, most of researches deal with those beams propagating along smooth trajectories.
- In other optical configurations, such as Bessel beams, “snaking beams” have been realized.
- Very recently, periodic self-accelerating beams taking the forms of a snake-like trajectory have been also demonstrated. Here, we present a new different approach for generating periodic self-accelerating beams by engineering the Fourier spectrum.

References

Theory

1D Self - Accelerating Beam

Mapping Spectrum to Space

The spectral evolution is:

\[ E(k_x, z) = A(k_x) \exp(i \phi(k_x, z)) \]

where:

\[ \phi(k_x, z) = \frac{\omega_0}{k_0} z \left( \frac{k_x}{k_0} \right)^2 + \phi_{\text{dif}}(k_x, z) \]

Experimental Results

Paraxial Periodic Self-accelerating Beams

Spectral Cubic Phase Mask

Non-Paraxial Periodic Self-accelerating Beams

The spectral evolution is described by:

\[ E(k_x, z) = A(k_x) \exp(i \phi(k_x, z)) \]

where:

\[ \phi(k_x, z) = \frac{\omega_0}{k_0} z \left( \frac{k_x}{k_0} \right)^2 + \phi_{\text{dif}}(k_x, z) \]

In our research, 1D self-accelerating beams are generated in the real space by amplitude- and phase-modulating a Gaussian beam, in the spectral domain, and by computing the Fourier transformation through a cylindrical lens (see setup). We found the existence of a mapping between spectrum and propagation distance. When only a phase modulation is applied, different positions in the trajectory are mapped by different frequencies in the spectrum. Introducing a large amplitude modulation, the spectrum is mapped to a straight line, tangent to the trajectory, thus bringing the beam to propagate along a straight trajectory and losing the curved propagation.

Setup

In the non-paraxial regime, the described spectral amplitude modulation analysis is still applicable and periodic self-accelerating beams can be also generated beyond the paraxial limit.

Conclusion

We have studied the combined effects of spectral phase and amplitude modulations on the dynamics of self-accelerating beams and found that:

- Large amplitude modulation, such as a Heaviside amplitude distribution, greatly changes the beam path where the straight and convex trajectories co-exist.
- Periodic self-accelerating beams are obtained by employing arrays of Heaviside amplitude distributions.

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