Periodic Self-Accelerating Beams Along Convex Trajectories

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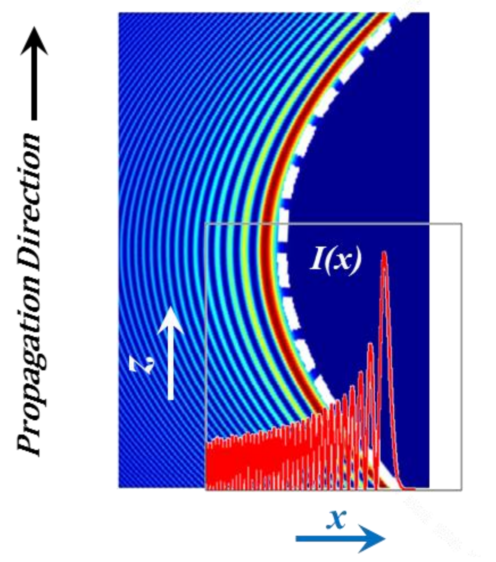
Introduction

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 diffracting.

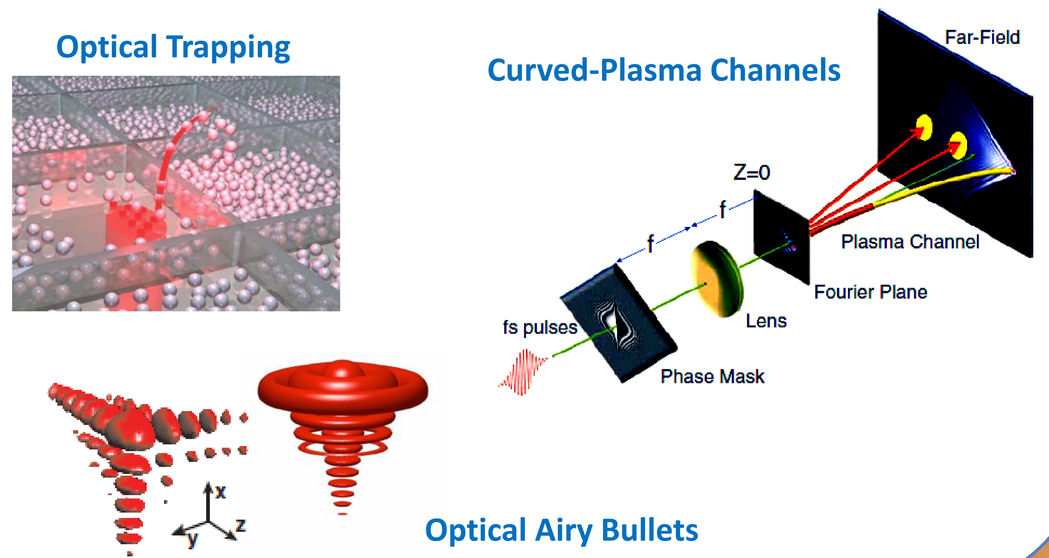
Airy Beam's Properties

- Non-diffractive propagation
- Bending trajectory
- Self-healing

1D Airy Beam



Airy Beam's Applications



References

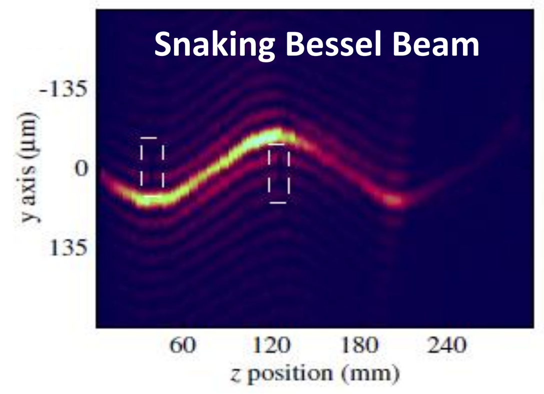
G. A. Siviloglou, *et al*, PRL 99, 213901 (2007)
J. Baumgartl, *et al*, Nat. Ph. 2, 675 (2008)
P. Polykin, *et al*, Science 324, 229 (2009)
A. Chong, *et al*, Nat. Ph. 4, 103 (2010)
A. D. Abdollahpour, *et al*, PRL 105, 253901 (2010)

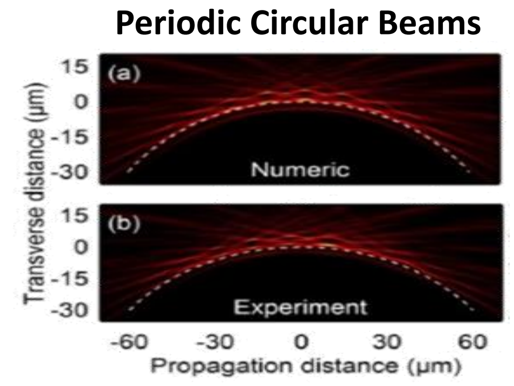
Motivations

- **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 periodical self-accelerating beams by engineering the Fourier spectrum.**

References

E. Greenfield, *et al*, FiO/LS, Tech. Dig. OSA, paper FW1A2, (2012)
J. Morris, *et al*, J. Opt. 12, 124002, (2010)
A. Mathis, *et al*, arXiv:1304.3469
J. Rasen, *et al*, Opt. Lett. 20, 2042 (1995)
J. Zhao, *et al*, Opt. Lett. 38, 498, (2013)



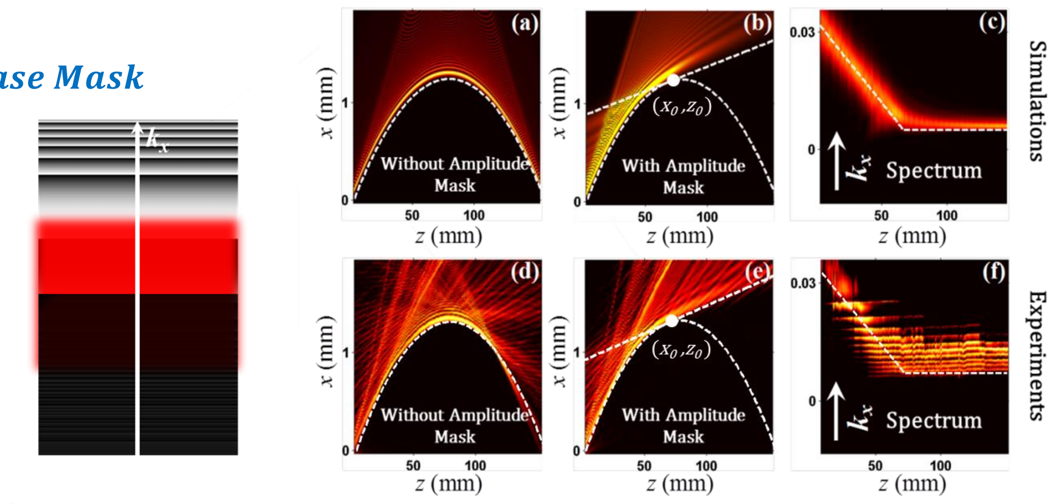


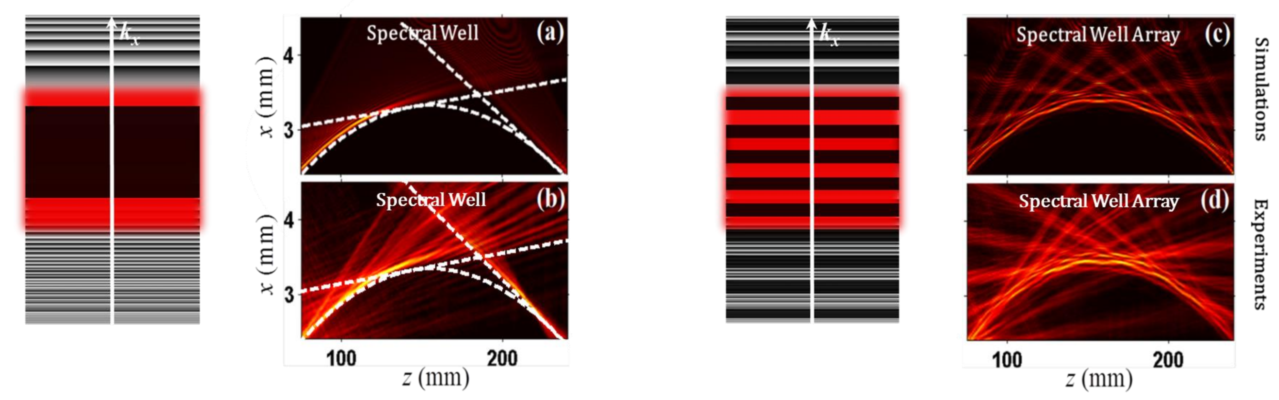
Experimental Results

Paraxial Periodic Self-accelerating Beams

Spectral Cubic Phase Mask

$$\rho(k_x) = \left(\alpha \frac{k_x}{k}\right)^3$$





Experimental results corresponding to an amplitude modulation applied to a spectral cubic phase mask. Three different amplitude distributions have been employed: an Heaviside amplitude distribution (up panel), a "Spectral well" amplitude distribution and a array of "Spectral well" distributions (down panel). Applying an amplitude mask the bending trajectory is affected by the amplitude modulation. In particular, beam follows a periodic path propagating along a convex trajectory when an array of "Spectral well" amplitude distribution is used to modulate the amplitude in spectral regime, thus generating periodic self-accelerating beams

Non-Paraxial Periodic Self-accelerating Beams

The spectral evolution is described by:

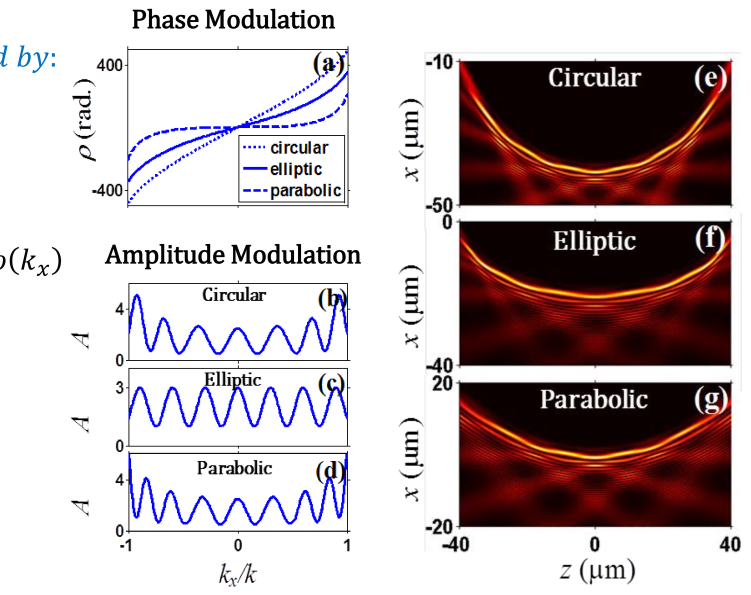
$$E(k_x, z) = A(k_x)\, exp[i\mu(k_x, z)]$$

where: $\mu(k_x, z) = \sqrt{k^2 - {k_x}^2}\, z + \rho(k_x)$

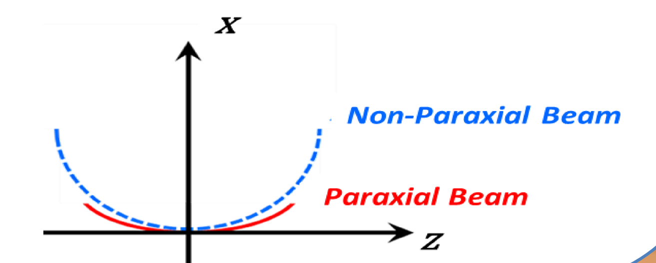
k_x *Spatial angular frequency*

k *Wavenumber*

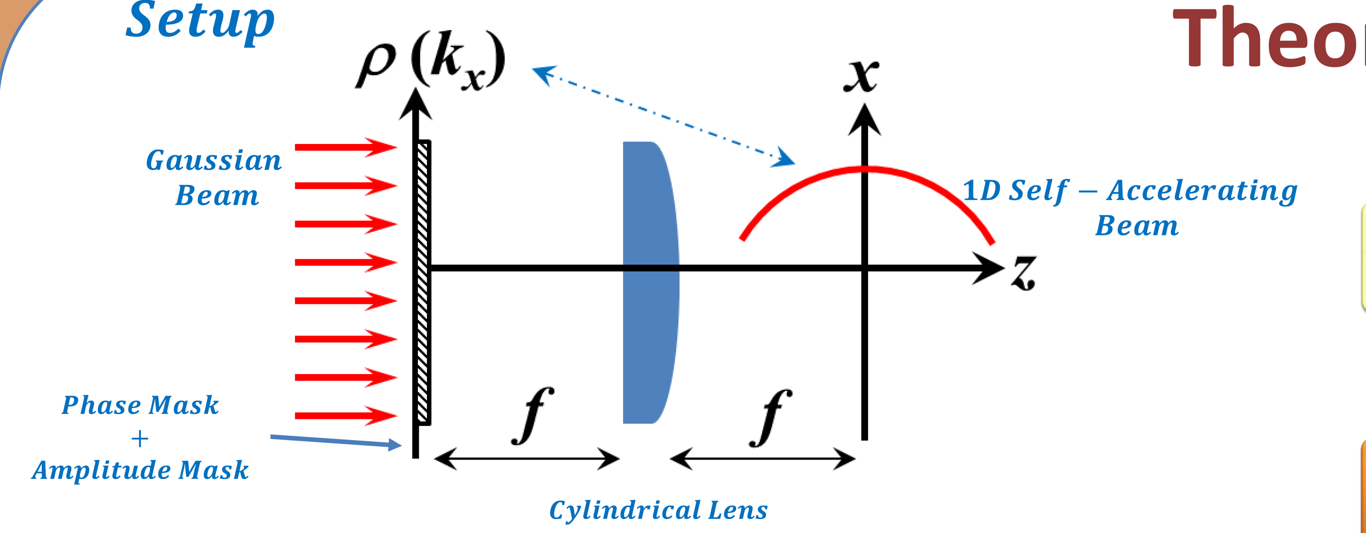
$\rho(k_x)$ *Phase Modulation*



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.



Setup



The spectral evolution is :

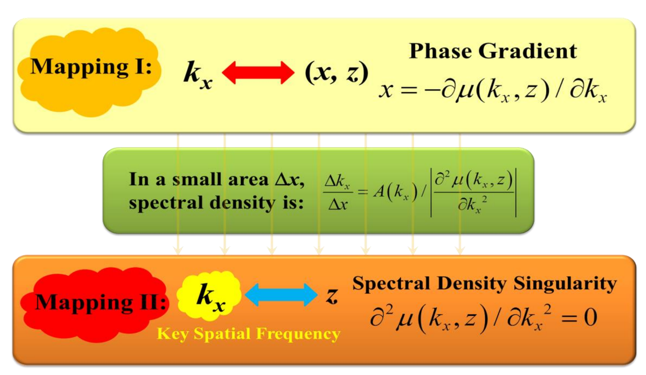
$$E(k_x, z) = A(k_x) exp[i\mu(k_x, z)]$$

where: $\mu(k_x, z) = -\frac{({k_x}^2)}{2k} z + \rho(k_x)$

Diffraction Term — *Imposed Phase*

Theory

Mapping Spectrum to Space



Phase Mask ⟷ Trajectory

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.

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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