Airy Beams on Incoherent Background

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Abstract—We present a class of diffraction-free partially coherent beams, each member of which comprises a finite-power, non-accelerating Airy bump residing on a statistically homogeneous, Gaussian-correlated background. We examine free-space propagation of soft apertured realizations of the proposed beams and show that their evolution is governed by two spatial scales: the coherence width of the background and the aperture size. A relative magnitude of these factors determines the practical range of propagation distances over which the novel beams can withstand diffraction.

Keywords—airy beams; partially coherent beams; incoherent background; gaussian aperture

I. INTRODUCTION

Partially coherent beams (PCBs) have attracted a great deal of interest over the years due to their intriguing properties [1, 2]. The majority of PCBs have been statistically homogeneous. In particular, propagation invariant random fields manifest themselves as bumps or dips residing atop a statistically homogeneous background. Such statistical diffraction-free beams have been shown to possess universal self-similar asymptotic propagation properties in random media [3]. In this presentation, we demonstrate how a family of genuine diffraction-free, partially coherent Airy sources can be constructed such a way that any member of the family is represented by an Airy bump situated on a Gaussian correlated uniform background.

II. RESULTS AND DISCUSSION

We first derive the intensity of a softly apertured Airy beam on incoherent background (ABIB) with the aid of a Gaussian amplitude mask using Fresnel transform [4]:

\[
I(x, z) = \left(\frac{k_0}{2\pi}\right)^2 \int dx_1 \int dx_2 W^{(0)}(x_1, x_2) e^{ik_0(x_2-x_1)^2/2\sigma^2} e^{-k_0(x-\bar{x})^2/2\sigma^2},
\]

where \(W^{(0)}\) is the cross-spectral density of the apertured ABIB source and \(k_0\) is the carrier wavenumber. The transverse scales governing free-space propagation of finite-power ABIBs are illustrated in Fig. 1.

Then, we examine free-space paraxial propagation of the Gaussian apertured ABIB [5]. The evolution of the apertured Airy bump on a nearly incoherent background is depicted in Fig. 2 for three propagation distances measured in units of 

\[ z_c = \sqrt{2k_0\sigma_c w_0}, \]

which sets the scale for diffraction. Here, we consider two cases: very large and moderately sized apertures.

In the wide aperture limit where \(\varepsilon = \sigma_c/w_0 = 0.01\), the ABIB remains nearly diffraction free as shown in Fig. 2(a). However, as the aperture size is reduced to satisfy \(\varepsilon \leq 0.1\) condition, the ABIB gradually transfers the power from its main lobe into the tails according to Fig. 2(c). Interestingly, over long enough propagation distances where \(z \geq 3\sigma_c\), the sidelobes virtually disappear, for both tightly and loosely apertured ABIB profiles.

As demonstrated, the actual distance over which any finite-power ABIB defies diffraction is determined by the interplay of the coherence width of the random background \(\sigma_c\) and the aperture size \(w_0\).

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