Optics and Laser Technology 98 (2018) 46–55

Contents lists available at ScienceDirect

Optics and Laser Technology

journal homepage: www.elsevier.com/locate/optlastec

Full length article

Influence of coma aberration on aperture averaged scintillations in oceanic turbulence

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ARTICLE INFO

Article history:
Received 20 October 2016
Received in revised form 21 May 2017
Accepted 14 July 2017

Keywords:
Aperture averaged scintillation
Coma aberration
Oceanic turbulence

ABSTRACT

The influence of coma aberration on aperture averaged scintillations in oceanic turbulence is studied in detail by using the numerical simulation method. In general, in weak oceanic turbulence, the aperture averaged scintillation can be effectively suppressed by means of the coma aberration, and the aperture averaged scintillation decreases as the coma aberration coefficient increases. However, in moderate and strong oceanic turbulence the influence of coma aberration on aperture averaged scintillations can be ignored. In addition, the aperture averaged scintillation dominated by salinity-induced turbulence is larger than that dominated by temperature-induced turbulence. In particular, it is shown that for coma-aberrated Gaussian beams, the behavior of aperture averaged scintillation index is quite different from the behavior of point scintillation index, and the aperture averaged scintillation index is more suitable for characterizing scintillations in practice.

1. Introduction

The coma aberration is one of the main aberrations in optical systems, and it causes the degradation of image quality [1]. It is important to study the influence of coma aberration on beam characteristics for many applications. González-Galicia et al. analyzed the effect of primary coma aberration in the focusing of ultrashort pulses for Gaussian illumination and experiment [2]. Vo et al. compared the beam characteristics between an Airy beam and a Seidel coma-aberrated beam [3]. Mendoza-Yero and Alda obtained an analytical solution for the irradiance of a Gaussian laser beam diffracted by a circular aperture and affected by coma aberration [4]. Chen and Pu showed that in the presence of coma aberration, the vortex beams contain not only the original orbital angular momentum (OAM) component but also other components [5]. Wang et al. presented a method for characterizing the coma aberrations in the projection lens using a phase-shifting mask and a transmission image sensor [6]. In addition, Li et al. studied the behavior of polarization state of a stochastic electromagnetic affected by the astigmatic aberration in turbulence [7]. However, the influence of coma aberration on beam characteristics in turbulent media hasn't been investigated.

When an optical beam propagates through turbulent media, the random phase modulation causes scintillations which degrade ratio of signal to noise [8]. In recent years, some studies were carried out concerning scintillation reduction in atmospheric turbulence [9–20]. Since recently the interest in active optical underwater communications, imaging and sensing appeared [21], it has become important to deeply understand how the oceanic turbulence affects beam characteristics [22–27]. In addition, the scintillations in oceanic turbulence were studied, but these studies were only restricted to plane, spherical and Gaussian waves [28–31]. It is noted that the above studies [9–20,28–31] were restricted to the point scintillations.

As the receiving aperture size increases beyond the irradiance correlation width, the receiver "sees" several correlation patches and the scintillation level begins to decrease, which is called the aperture averaging effect [8]. In the 1950s, the decrease in scintillation associated with increasing telescope collecting area was recognized in early astronomical measurements [32]. In recent decades, aperture averaging effects were studied in the context of laser beam propagation through atmospheric turbulence [33–37].

In this paper, we design a computer code of a Seidel coma-aberrated Gaussian beam through oceanic turbulence by using the random phase screen method and the discrete Fourier transform (DFT) method, and study the influence of coma aberration on aperture averaged scintillations in oceanic turbulence by using the numerical simulation method. The results obtained in this paper will be useful in the applications of communications, imaging and sensing systems involving oceanic turbulence channels.

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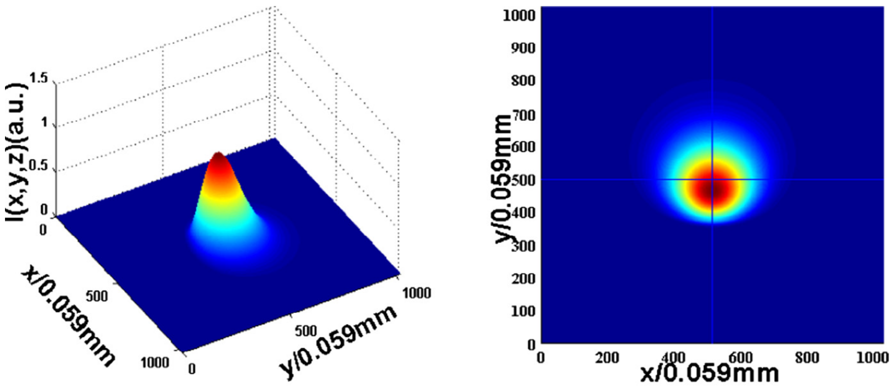
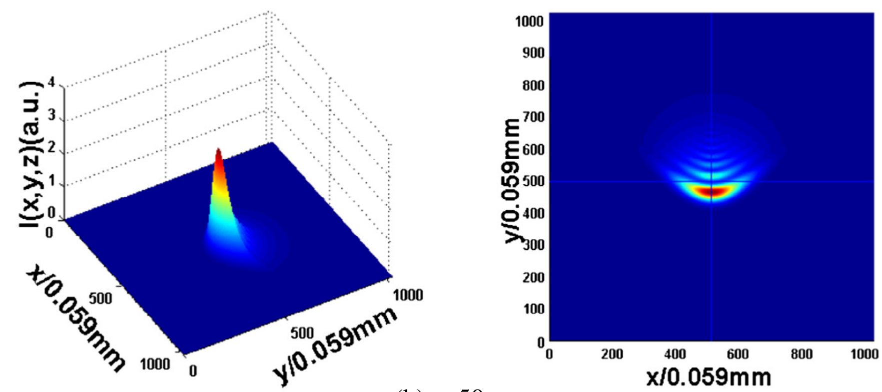
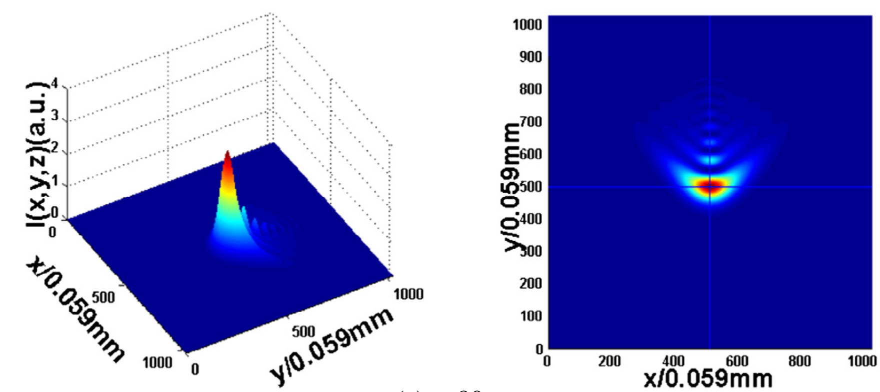
http://dx.doi.org/10.1016/j.optlastec.2017.07.019
0030-3992/



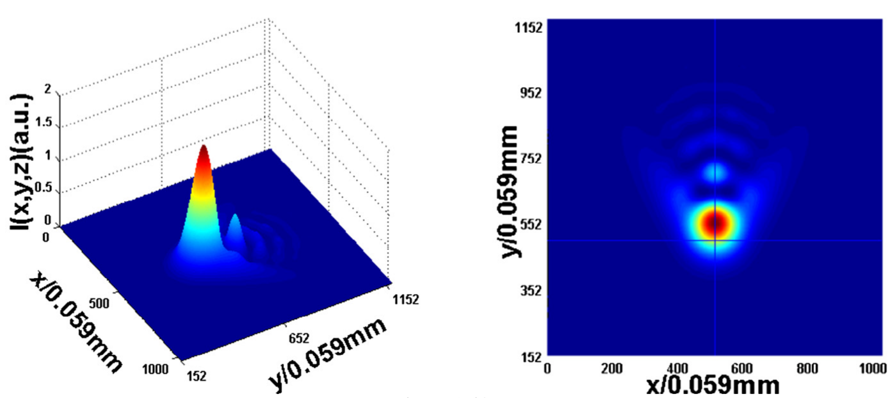
(a) z=20m



(b) z=50m



(c) z=80m



(d) z=150m

Fig. 1. 3D intensity distribution and its counter lines at different propagation distance z in free space, $kC_3 = 5$.