Optics Communications 309 (2013) 26–29

Contents lists available at SciVerse ScienceDirect

Optics Communications

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

Effect of spectrum property on a focused supercontinuum laser

Runwu Peng*, Le Li, Yajie Li, Junlong Tang, Haiqing Xie, Liuming Dou

Department of Physics and Electronic Science, Changsha University of Science and Technology, Changsha 410114, China

ARTICLE INFO

Article history:
Received 18 June 2013
Accepted 2 July 2013
Available online 12 July 2013

Keywords:
Center wavelength
Spectrum
Focal shift
Supercontinuum

ABSTRACT

Fields of a focused supercontinuum laser with different center wavelength are studied near the focus in this paper. Effects of the spectrum property on the intensity distributions of the laser are analyzed in detail by numerical calculations. The results indicate that the maximum intensity is shifted toward the lens as the center wavelength decreases and it is deviated from the lens as the center wavelength shift to long wavelength. Influence of the center wavelength on the shift of the maximum intensity is smaller in the laser with broader bandwidth. Determined by the center wavelength, the focused supercontinuum laser presents positive focal shift or negative focal shift in the system with any truncated parameter. If appropriate center wavelength and bandwidth are chosen, the focal shift of the supercontinuum laser passing through a dispersive lens can be eliminated.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

The first white light spectra in the range from 400 nm to 700 nm were produced by Alfano and his coworker in 1970 [1,2]. As a new light source, the supercontinuum laser is finding applications in a diverse range of fields, including optical coherence tomography [3], frequency metrology [4], optical communications [5] and many others. In recent decades, the generation of the supercontinuum laser has been investigated extensively [6–15]. Ranka and his coworkers generated an almost rectangular spectrum with ultrabroadband continuum extending from 390 nm to 1600 nm in 2000 [6]. Halir et al generated a spectrum extending from 665 nm to 2025 nm with 160 pJ pulses by using a 4.3 cm-long waveguide last year [11]. In this year, Swiderski et al demonstrated a novel method of mid-infrared supercontinuum generation with the use of a 2 μm gain-switched selfmode-locked thulium-doped fiber laser and the source radiation ranging from ~1.9 to 3.8 μm wavelengths [15].

Li and Wolf reported focal shift effect in a focused laser firstly in 1981 [16,17] and then this effect has been studied in many beam models and optical systems [18–23]. Earlier this year, we researched the focal shift in the supercontinuum laser passing an apertured dispersion lens system in Ref. [22] at the first time. It is found that, apart from the conventional negative focal shift, the positive focal shift is also generated in the supercontinuum laser. As we investigate the propagation properties of the supercontinuum laser further, some new phenomena are found. In this paper, the intensity distributions of a focused supercontinuum laser with different center wavelength are studied and the variations of position of the maximum intensity with center wavelength are given.

2. Fields of a focused supercontinuum laser

Similar to investigations in Ref. [22], the model of a supercontinuum laser passing through an apertured dispersion lens is also studied and the transverse mode in one dimension is considered. It is also assume the space and the spectrum fields of the initial beam $E_1(x_1, 0, \omega)$ can be separated, i.e. $E_1(x_1, 0, \omega) = E_1(x_1, 0)S(\omega)$. The field of each frequency component of the supercontinuum laser after the apertured dispersive lens is obtained by using the Huygens–Fresnel diffraction integral as

$$E_2(x,z,\omega) = \frac{\exp(ikz)}{(i\lambda z)^{1/2}} \int_{-a}^{a} E_1(x_1,0,\omega)\exp\left\{\frac{ik}{2z}\left[-\frac{z-f(\lambda)}{f(\lambda)}x_1^2 - 2x_1x + x^2\right]\right\}dx_1 \tag{1}$$

where $k = 2\pi/\lambda$ is the wave number, a is half width of the rectangular aperture, and λ is wavelength. The focal length of the dispersion lens is given as $f(\lambda) = (n_0-1)f_0/[n(\lambda)-1]$, where n_0 and f_0 are the refractive index and the focal length of a set center wavelength, respectively, and $n(\lambda)$ is the refractive index of the frequency component with wavelength λ.

The transverse mode of the laser is Gaussian shape and the beam waist is located at the same plane of the lens, i.e. $E_1(x_1, 0) = A_0\exp(-x_1^2/w_0^2)$, where w_0 is the width of the beam waist and A_0 is a complex constant. Considering the fields on z axis only, i.e. $x = 0$, and performing integral calculation of Eq. (3), it is obtained

$$E_2(0,z,\omega) = -A_0\exp(ikz)\left[\frac{N_w F_\lambda}{N_w(z_f - F_\lambda) - iz_f F_\lambda \xi}\right]^{1/2} \operatorname{erf}\left[\frac{iN_w\delta}{\xi}\left(\frac{1}{F_\lambda} - \frac{1}{z_f}\right) + \delta\right]^{1/2} S(\omega), \tag{2}$$

* Corresponding author. Tel.: +86 73185258224.
E-mail address: pengrunwu@163.com (R. Peng).

0030-4018/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.optcom.2013.07.004

where $\delta=(a/w_0)^2$ is truncated parameter and $N_w=w_0^2/\lambda_0 f_0$ is Fresnel number related with the laser beam, $F_\lambda=f(\lambda)/f_0=(n_0-1)/[n(\lambda)-1]$ and $z_f=z/f_0$, $\xi=\lambda/\lambda_0$, erf( ) is error function. The fields can be obtained as

$$E(0,z)=\int_{-\infty}^{\infty} E_2(0,z,\omega)\, d\omega, \tag{3}$$

and the intensity is given by $I(0, z)=|E(0, z)|^2$.

3. Effects of the spectrum property on intensity distributions

We have known in Ref. [22] that the intensity distributions of the focused supercontinuum laser with Gaussian spectrum shape and rectangle spectrum shape differ from each other. In this paper, the supercontinuum laser with Gaussian spectrum profile is also considered but the center frequency is not located at a set center frequency in Ref. [22]. The spectrum is in the form of

$$S(\omega)=\exp\left\{-2\ln 2\frac{[\omega-(\omega_0+\omega')]^2}{\Delta\omega^2}\right\}, \tag{4}$$

where the $\Delta\omega$ is the spectrum width of the supercontinuum laser and ω' is the shift of the center frequency related to the set center frequency. We also consider that the dispersion lens is made of the fused silica, whose refractive index $n(\lambda)$ is given in Ref. [22]. In the following calculation, $N_w=125$ and a set center wavelength λ_0 of 800 nm is considered and the focus is related to the set center wavelength.

Normalized intensity distributions of the focused supercontinuum laser on z axis near the focus are given in Fig. 1 with $\delta=0.25$ and the bandwidth of 10 nm in Fig. 1(a) and the bandwidth of 400 nm in Fig. 1(b). The solid line is the laser with center wavelength of 600 nm, the dashed line is that of 800 nm and the dotted line is that of 1000 nm. The figures show that the maximum intensity is shifted toward the lens as the center wavelength decreases, and it is deviated from the lens as the center wavelength shift to long wavelength. The maximum intensity even exceeds the focus and the negative focal shift turns to positive focal shift as the center wavelength increases. Compared with Fig. 1(a) and (b), it is also found that the maximum intensity shifts smaller in the laser with broader bandwidth.

Fig. 2 depicts the normalized intensity distributions on z axis near the focus with $\delta=4$ and the bandwidth of 10 nm in Fig. 2 (a) and the bandwidth of 400 nm in Fig. 2(b). The solid line is the laser with center wavelength of 600 nm, the dashed line is that of 800 nm and the dotted line is that of 1000 nm. Variations of the maximum intensity's position with center wavelength are similar to those in Fig. 1. It is known that the focal shift of the supercontinuum laser passing through a dispersive lens is positive as $\delta=4$ in Ref. [22]. However, the maximum intensity shifts toward the lens and the laser even presents negative focal shift as the center wavelength decrease. The Fig. 2(a) and (b) also shows that shift of the center wavelength has larger effect on the variation of

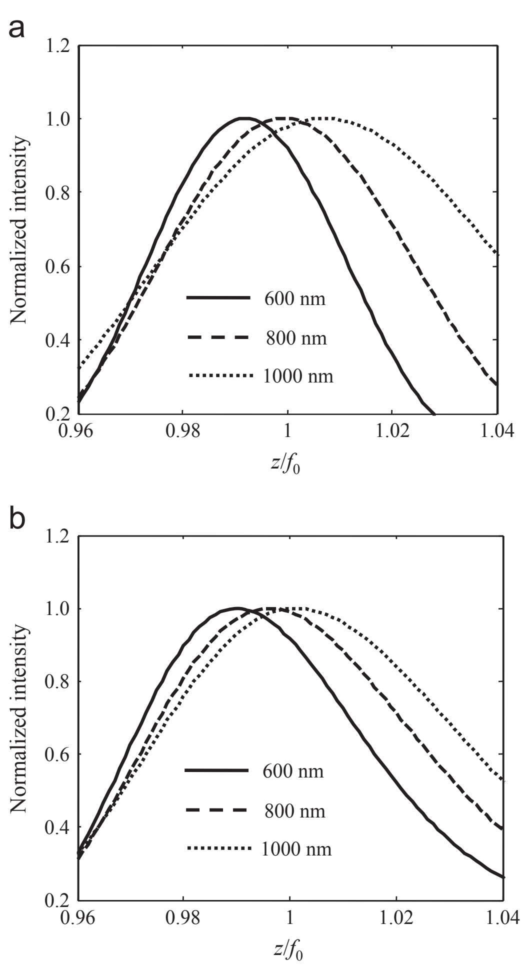

Fig. 1. Normalized intensity distributions on z axis near the focus with $\delta=0.25$. The solid line is the laser with center wavelength of 600 nm, the dashed line is that of 800 nm and the dotted line is that of 1000 nm.(a) 10 nm bandwidth and (b) 400 nm bandwidth.

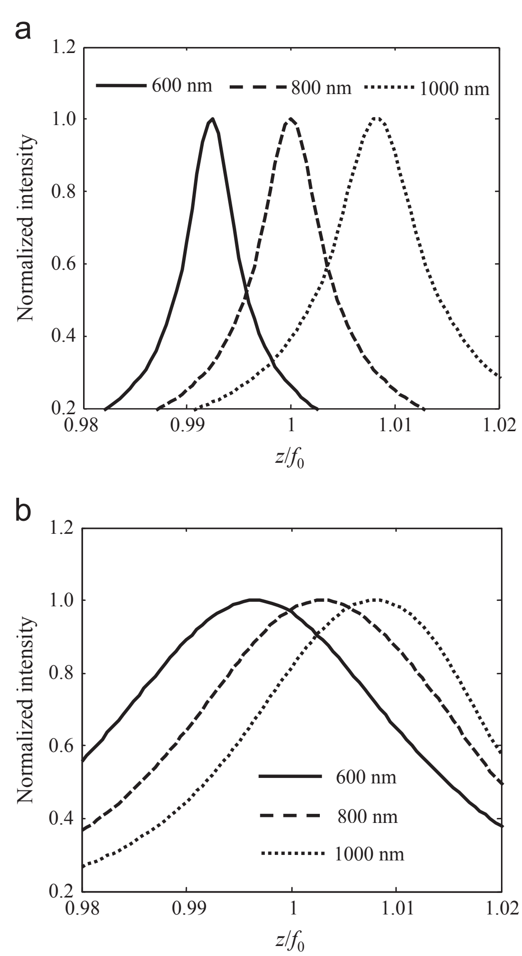

Fig. 2. Normalized intensity distributions on z axis near the focus with $\delta=4$. The solid line is the laser with center wavelength of 600 nm, the dashed line is that of 800 nm and the dotted line is that of 1000 nm. (a) 10 nm bandwidth and (b) 400 nm bandwidth.

Download English Version:

https://daneshyari.com/en/article/7932242

Download Persian Version:

https://daneshyari.com/article/7932242

Daneshyari.com