Chapter 4 Results and Discussion

4.1 Distribution of Optical Bottle Beam

Figure 4.1 shows the 3D and the intensity profiles of supercontinuum white light bottle beam taken by the *WinCamD* in the region of bottle beam a specific distance z behind the lens from Z_1 to Z_2,. The bottle beam's distributions, ring-shaped, is gradually changing as propagating that its ring-diameter increases from Z_1 to Z_b and then decreases from Z_b to Z_2.

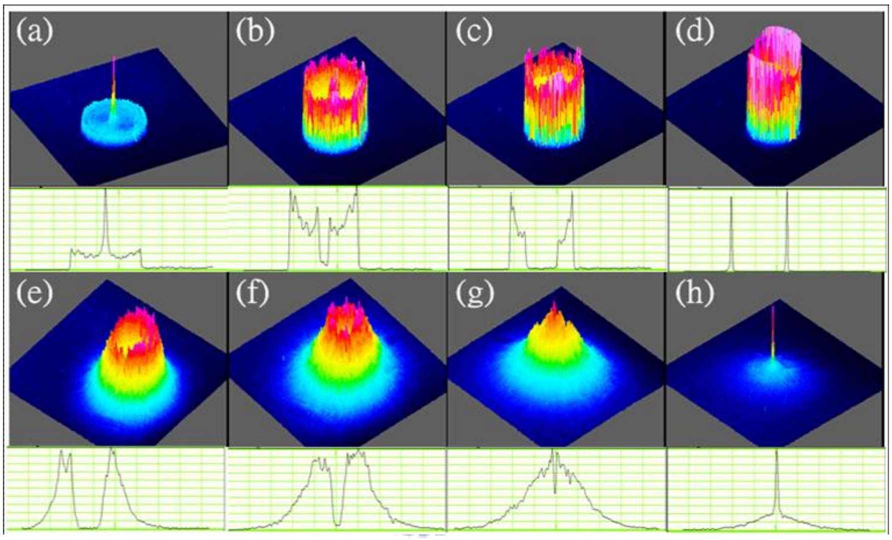

Fig. 4.1 1D intensity profiles and 3D Images of the bottle beam.

We can see in Fig. 4.1 (d) the ring at the position Z_b is the thinnest. At first we observed the distribution is a peak in Fig. 4.1 (a), peak is disappearing but with a dip between at the center of a plateau in Fig. 4.1 (b). At the same time, the ring-diameter gradually increases until reaching the thinnest ring at the position Z_b. On the contrary, the reverse process occurs with increasing ring thickness from Figs. 4.1 (d) to (g) as increasing z. At last, the peak is restoring in Fig. 4.1 (h) at z = Z_2. It can be also clearly seen from the false color images in Fig. 4.2. Once again, we observed the ring diameter linearly changes with propagating distance from the positive lens.

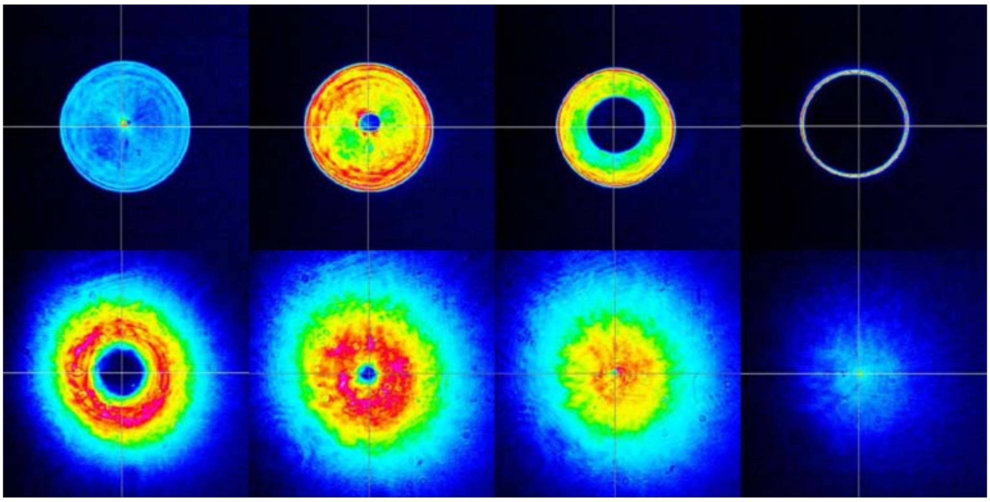

Fig. 4.2 2D images of bottle beam.

4.2 Comparisons of Experimental and Theoretical Results

From the experimental data of beam profiler through a distance z behind the positive lens, we obtained the relations between ring diameter and distance z at specific wavelengths central wavelength at 532nm, 670nm, and 780nm, respectively. From these experimental results of different central wavelengths and supercontinuum, the diagram of relations between ring-diameter and propagating distance behind the lens at within 532nm (green) and 670nm (red) is shown in Figure 4.3. The insets on the top of Figure 4.3 are the pictures of thinnest rings at the position Z_b for central wavelengths 532nm and 670nm, and the thinnest ring diameter is defined as D_b. By linearly fitting the data of both 532nm and 670nm, we can obtain the ranges of optical bottle beam. Therefore the experimental data of ring diameter with propagating distance z at these four central wavelengths are shown in Table 4.1 (a), (b), (c), and (d), respectively.

Table 4.1 Optical bottle beam parameters for various central wavelengths and white light supercontinuum: (a) Central wavelength at 532nm source.

Z(mm)	26.89	27.74	28.78	29.63	30.98	32.25	33.50	34.51	35.64
Diameter(mm)	0.40	0.80	1.27	1.60	2.07	2.43	2.66	2.53	2.47

z(mm)	37.59	39.19	42.39	46.10	52.11	59.60
Diameter(mm)	2.37	2.23	2.07	1.47	1.20	0.40

(b) Central wavelength at 670nm source.

z(mm)	27.90	28.81	29.50	30.76	32.10	33.02	34.12	36.03	36.99
Diameter(mm)	0.63	1.03	1.30	1.77	2.20	2.47	2.65	2.47	2.40

z(mm)	38.99	42.37	45.00	49.02	55.84	59.43
Diameter(mm)	2.27	2.03	1.90	1.50	1.00	0.47

(c) Central wavelength at 780nm source.

z(mm)	28.00	29.04	29.86	30.82	31.98	32.97	34.35	36.30	37.89
Diameter(mm)	0.57	1.00	1.37	1.70	2.13	2.37	2.63	2.47	2.37

z(mm)	39.48	41.52	43.78	46.58	49.97	59.11
Diameter(mm)	2.23	2.07	1.83	1.53	1.23	0.80

(d) Supercontinuum white light source.

z(mm)	28.23	29.41	30.36	31.12	32.09	33.39	34.58	36.55	38.44
Diameter(mm)	0.50	1.03	1.43	1.70	2.03	2.40	2.62	2.50	2.33

z(mm)	40.27	42.32	44.67	49.19	54.29	59.12
Diameter(mm)	2.20	1.90	1.70	1.30	0.87	0.53

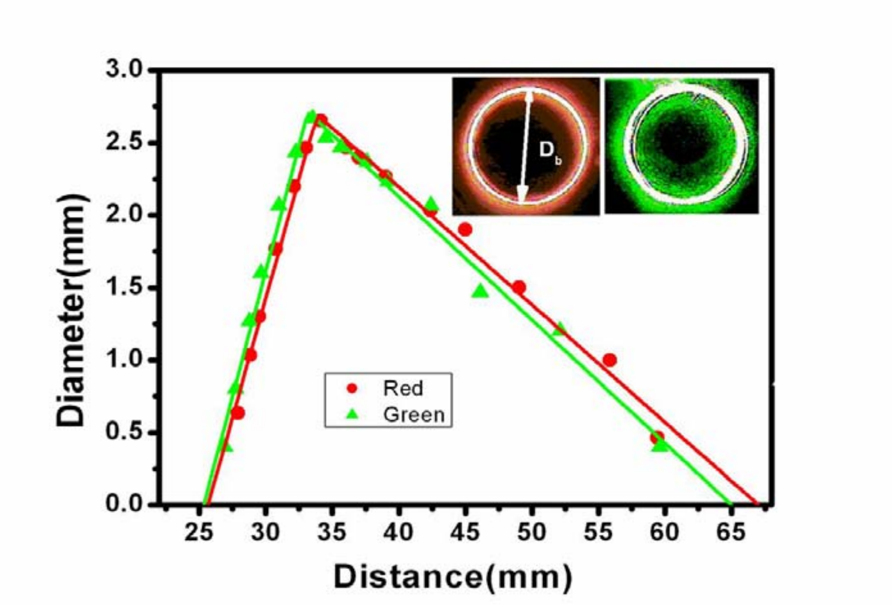

Fig. 4.3 Diagram of ring-diameter versus propagation distance at 532 nm and 670 nm, respectively.

We estimated the positions of bottle beam at started and ended points by *Fresnel-Kirchhoff's diffraction integral* with the given input field source at different central wavelengths. The results of experiment and theoretical calculation are shown in Table 4.2. Z_1, Z_2, and $\triangle Z = Z_2 - Z_1$ are the start, the ended positions, and the overall range of the bottle beam, respectively, Z_b is the position of the thinnest ring with diameter D_b. The values with parentheses in Table 4.2 are the results of theoretical calculation that are closed to the experimental results.

Table 4.2 Results of experiment and theoretical calculation.

	Z_1(mm)	Z_b(mm)	D_b(mm)	Z_2(mm)	$\triangle Z$(mm)
Green/532 nm Exp.(Cal.)	25.34 (25.33)	33.50	2.66	65.01 (65.79)	39.67 (40.06)
Red /670 nm Exp.(Cal.)	25.66 (25.57)	34.12	2.65	67.01 (66.84)	41.35 (41.27)
IR /780 nm Exp.(Cal.)	25.93 (25.71)	34.35	2.63	67.59 (67.27)	41.66 (41.56)
Supercontinuum	26.31	34.58	2.62	64.41	38.10

4.3 Discussion

From the single wavelength results of experiment and theoretical calculation, we observed an interesting tendency of the positions of bottle beam. The start and the end positions Z_1 and Z_2 of the bottle beam are different at the different central wavelengths. As the central wavelength increases, not only these two points but also the position Z_b shift farther away from the positive lens with reducing ring diameter D_b. It is obviously due to dispersion of different central wavelengths. On the other hand, the results of supercontinuum light are more interested to us. From Table 4.2, we find that the range of the bottle beam for the supercontinuum light is the smallest. It means that the starting point is farther than that of single line wavelength at 780nm and the end point is nearer than the single line wavelength at 532nm. Because the spectrum of supercontinuum covers from 460 nm to 1530 nm, the results can be considered as is the superposition of all the single wavelengths. Therefore, the range and the ring diameter at Z_b are both smaller than the individual wavelengths, and position of Z_b is farther than others.