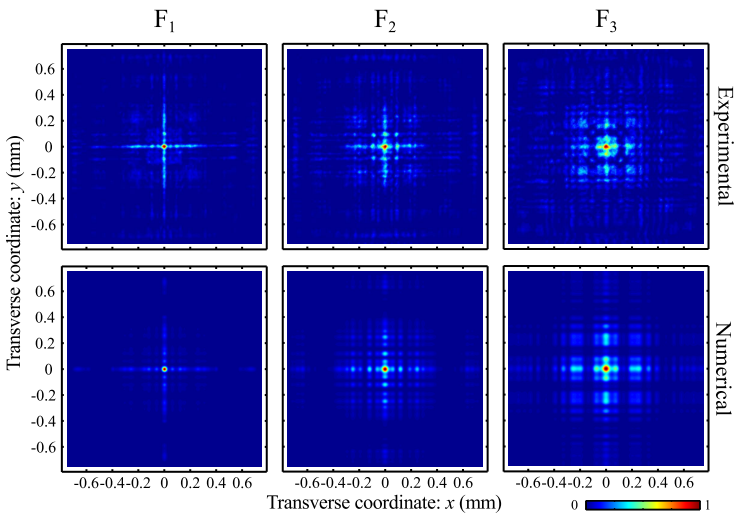

Fig. 5. Experimental transverse irradiance (top) compared with the analytically obtained irradiance (bottom) for a fractal order $S = 3$ CDZP. Transversal planes belong to the first order focus shown in Fig. 4(b) located at $z = 10.4$ cm and two secondary foci at $z = 11.3$ cm and $z = 13.6$ cm.

at two subsidiary foci ($z = 11.3$ cm and $z = 13.6$ cm) can be compared with the analytical results calculated using Eq. (5) for the order $S = 3$. In all cases, the irradiance has been normalized to its own maximum value. In spite of that the experimental images are affected by noise and by the aberrations of both, L3 and the microscope objective, a very good agreement with the numerical simulation is obtained. A characteristic two-arms-cross pattern at the main focus, extended to the subsidiary foci, can also be observed, so this behavior can be interpreted as an extension of depth of focus.

5. Conclusions

A new fractal diffractive optical element a CDZP is proposed. The focusing properties of this novel kind of lenses are analytically and experimentally investigated. The axial irradiances provided by these elements have been computed for different fractal stages obtaining a self-similar behavior. Moreover, under a monochromatic illumination, a CDZP gives rise a focal volume containing a delimited sequence of two-arms-cross patterns which are axially distributed according to the self-similarity of the lens. One potential application of CDZP is to generate a reference pattern in optical alignment and calibration of 3D systems. A spiral phase mask superposed to the CDZP pupil function —Eq. (2)— can be used for generating hollow rectangular beams [19]. Moreover, CDZP could be applied in THz communications given that Fresnel zone plates have been proved to be valuable elements for improving the performance in infrared antennas [20]. On the other hand, its cross-shaped focal pattern and its enhanced focal depth could be also helpful to perform parallel photopolymerisation in three-dimensional microstructure fabrication [21]

Acknowledgments

We acknowledge the financial support from Ministerio de Economía y Competitividad (grants FIS2011-23175 and TRA2009-0215), Generalitat Valenciana (grant PROMETEO2009-077), and Universitat Politècnica de València (PAID-05-11), Spain.