Abstract – A novel graded index microstructured polymer THz fiber, whose graded index profile is achieved by a hexagonal subwavelength air-hole array with graded diameters, is studied. The simulation results show that this geometry design can reduce the dispersion and the confinement loss significantly.

I. INTRODUCTION AND BACKGROUND

Traditional graded-index polymer optical fiber (GI-POF) has been previously developed for numerous applications [1-3]. However, the technology behind conventional GI-POF is very inconvenient for applications, since a near-perfect parabolic index profile is very hard to be achieved by using the doping method. To solve this problem, R. Lwin et. al. reported new GI-POFs based on microstructured polymer optical fibers for broadband transmission [4]. In these new designs, graded index profile had been achieved by using microstructured cladding with varying air-holes diameter.

In this paper, we demonstrate a novel graded-index microstructured polymer optical fiber with subwavelength air-holes for terahertz applications. Comparing to R. Lwin et. al.’s design, our fiber has a hexagonal subwavelength air-hole array with varying diameters in the whole fiber cross-section, as shown in Fig. 1. This design can not only reduce the transmission loss but also decrease the fiber size, especially in THz regime.

II. RESULTS

Fig. 1 shows the cross-section of fiber fabricated from this design. This fiber was made of low density polyethylene (LDPE), which had been proved to be a great raw material for terahertz optical devices, because of its low absorption coefficient and material dispersion in terahertz region [5].

In order to obtain a similar index profile as the conventional GI-POF, we used both graded air-hole-diameter \( d = 72, 84, 96, 108 \) and inconsistent lattice constants \( \Lambda \). Following power-law graded azimuthal average refractive index could be achieved by this arrangement.

\[
\tilde{n} (\theta) = n_0 (1 - 2a (r/R)^g)^{1/2}
\] (1)

\( n(r) = n_0 (1 - 2a (r/R)^g)^{1/2} \) (1)

Fig. 2. (a) The dispersions of fundamental modes of mPOFs with graded diameter air- with different g holes (solid lines) and traditional mPOF with uniform diameter air-holes (dotted line). The dashed line is the dispersion of the real structure shown in Fig. 1(c). (b) The modified standard deviation \( (\sigma) \) as a function of parameter g.
where \( a \) is refractive index difference between the fiber core and the outmost air-hole layer, \( R \) is the radius of this fiber. The average refractive index of each layer is given as

\[
\bar{n}_k = \eta \bar{n}_{\text{air}} + (1 - \eta) \bar{n}_{\text{polymer}}
\]

(2)

where \( \eta \) is the air filling fraction at each layer. Fig. 1(b) shows the refractive index profile along the dashed line in Fig. 1(a).

Chromatic dispersion is the most important property for this fiber. In order to show the effect of this modified index profile, we compare dispersions of the proposed GI-mPOF with different \( g \) parameters. As shown in Fig. 2(a), the dispersion has been reduced significantly. In order to show how the parameter \( g \) effects on dispersion properties, we also calculated a modulated standard deviations (\( \sigma \)) of dispersions with different \( g \), where we used zero to replace the average values of dispersion. As shown in Fig. 2(b), with a bigger \( g \), the standard deviation is smaller, which means the dispersion is more flattened and more close to zero. When \( g \) is bigger than 6, the standard deviation will increase slightly. The dashed line in Fig. 2(a) is the dispersion of the fiber we fabricated, which is calculated based on the structure shown in Fig. 1(c). As the microstructure of this GI-mPOF was degenerated during the drawing process, the dispersion calculated based on real structure is much bigger, which would be caused by the deformation of air-holes.

Confinement loss, which can be deduced from the imaginary part of the complex effective mode index, is another important property for this fiber. Fig. 3 demonstrates the comparison of confinement loss between the GI-mPOFs with different \( g \) parameters (solid lines) and the conventional mPOF with uniform diameter air-holes (dotted line). The confinement losses of GI-mPOFs are much smaller than their competitor of conventional mPOF. At the same time, the confinement ability has been improved if \( g \) parameter become bigger. To explain this phenomenon, we also demonstrate the mode distribution of fundamental mode of GI-mPOF (\( g=2 \)) and the conventional mPOF. As shown in Fig. 4, the fundamental mode field of GI-mPOF is confined in the central region very well because of higher index contrast between the central region and the outer air-hole-layers. Meanwhile, for the conventional mPOF, more mode energy has been leaked and so high confinement loss is presented.

### III. CONCLUSION

We have present a novel GI-mPOF for terahertz applications. The graded index profile of this fiber is achieved by its nonuniform air-hole distribution: both the air-hole diameter and pitch change along the radial direction. According to the simulation results, both the dispersion and the confinement loss have been reduced significantly comparing to the conventional mPOF with uniform air-holes.

### REFERENCE