12th Optoelectronics and Communications Conference/16th International Conference on Integrated Optics and Optical Fiber Communication (OECC/IOOC2007)
Technical Digest, July 2007, Pacifico Yokohama

12P-17

Large Effective Area Photonic Crystal Fibers with Negative Dispersion and Ultra-Low Splicing Loss

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Abstract

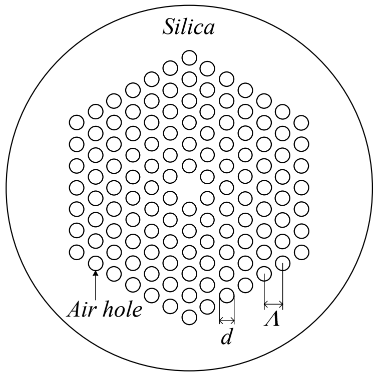
In this paper, we propose and demonstrate a novel type of PCF that has two cladding layers with Ge-Doped rods at the inner cladding. The authors numerically show that it is possible to design a single mode PCF with large negative dispersion in all telecommunication bands with both large effective area greater than 200μm^2 over the whole wavelength above 1.2μm and ultra low splicing loss of ~0.0dB per fusion-splicing to a conventional SMF.

Key words: *photonic crystal fiber (PCF), large effective area, Ge doped*

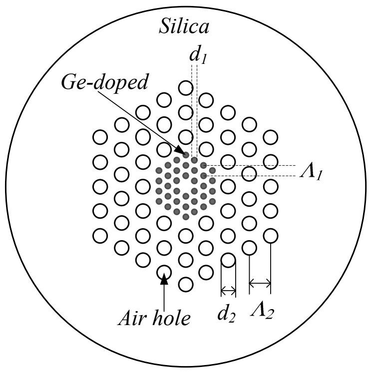
1 Introduction

In this paper, we will investigate a novel approach to manufacturing large-mode area fibers, namely that of micro-structuring the core instead of the cladding. The idea is to dope small areas in the core region to an index contrast which is large enough to be reproducible with small relative error. If the individual doped areas are sufficiently small, the light will experience a refractive index given by the average between the doped and silica/air interfaces. This idea has been explored in connection with micro-structured fibers lasers in order to control the doping level of the active core, but not as yet as a direct route to manufacturing LMA fibers.

An example of such a structure is shown in the Fig. 1(b). This design will obviously have the endlessly single mode property of the PCFs with micro-structured cladding. The advantage of the micro-structured-core design is that it should be much simpler to fabricate, since it has fewer elements and bigger silica/air interfaces in the final structure



(a)



(b)

Fig. 1 *Silica/air PCF with micro-structured cladding (left), and the proposed PCF with two cladding layers with Ge-Doped microstructure core (right).*

2 Structure and design of large mode area PCF (LMS-PCFs)

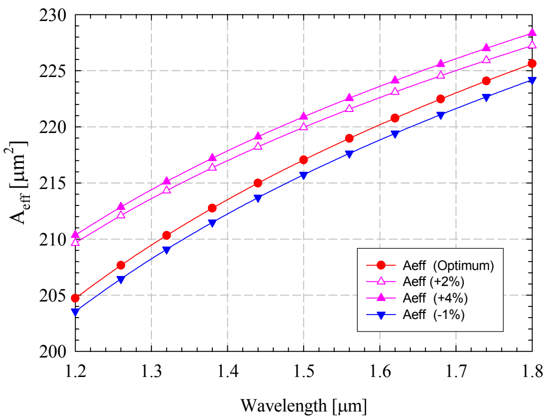
Fig. 1 shows cross section of conventional PCF and our proposed LMA-PCF. A conventional PCF has uniform air-holes of diameter d and pitch Λ. The LMA-PCF has two cladding layers with different indices. One is the inner cladding with a 2% Ge-Doped core of diameter of d_1 and a pitch of Λ_1, the other is the outer cladding with a hole diameter of d_2 and a pitch of Λ_2. Thus, by scaling up the physical size of the structure, the effective index contrast between two cladding can be made arbitrarily small, and the core size can be scaled up to the limit set by the tolerable micro- and macro-bending losses. In fact, due to the strong wavelength dependence of the effective cladding index, the fibers can be single-mode at all wavelengths.

Fig 2 show the effective area (A_{eff}) as a function of the wavelength of the proposed LMA-PCF, where (Λ_1= 1.9μm, d_1=0.7μm, Λ_2=6.5μm, d_2=1.56μm). From the results, it is seen that A_{eff} variation with -1%, +2% and +4% variation of all parameters. The A_{eff} of more than 200 μm^2 can be obtained over the whole wavelength range above 1.2 μm with large negative dispersion. Fig 2(b) shows that the dispersion tend to increase at the longer wavelengths and dispersion properties of proposed PCFs are insensitive with -1%, +2% and +4% variation of all parameters (Λ_1=1.9μm, d_1=0.7μm, Λ_2=6.5μm, d_2=1.56μm).

It can be seen from Fig 3 that although the field has confined mostly in Ge doped core region, noticeable penetration exits and spreads to the second core, thus leading to the large effective are of the proposed PCF. There is no leakage outside of the first innermost air-hole ring due to the contrast refractive index between the two cladding is very strong. From the experimental result, we can conclude that, by scale up and adjust the physical size of air-holes at the second cladding, larger effective area of the fiber can be achieved as well as the fiber can be single mode at all wavelength. Since the Modal Diameter-Petermann II is greater than 15μm above 1.2μm wavelength, the splice loss between the LMA-PCFs and conventional single mode fiber can be estimated to be 0dB utilizing overlap integral.

3 Conclusion

Novel photonic crystal fibers with two different air-holes and 2% Ge rod-core claddings geometries have been investigated, in order to design single-mode large mode area fibers. We show that the proposed LMA-PCFs could archive an effective area of more than 200μm^2 and with negative dispersion and no splicing losses. We believe that the proposed LMA-PCF will be beneficial for future ultra－broadband transmission application. The proposed LMA-PCF with flattened-dispersion is being investigated.



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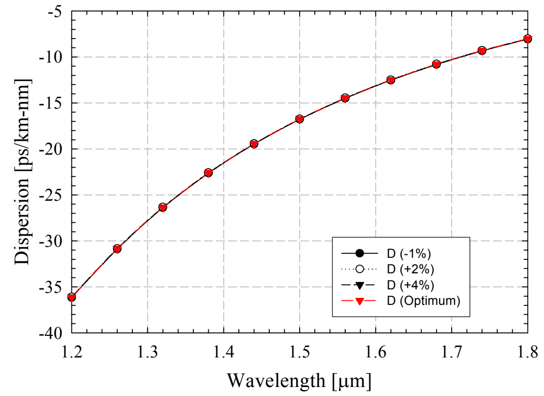

Fig. 2 *(a) Effective area, (b) Dispersion as a function of the wavelength*

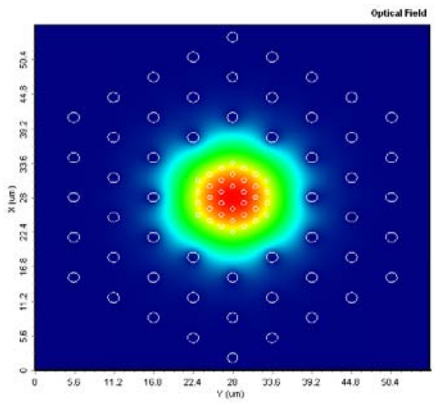

Fig. 3 *Modal-field distribution simulated at wavelength of 1550 nm*

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