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Published in:
Frontiers in Optics 2018

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):

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Mode-Group Selective Air-Clad Photonic Lantern

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Abstract: A new method for fabrication of mode group selective photonic lanterns is experimentally demonstrated. The design is very simple, using only a tapered fiber bundle and an air-cladding. Good mode group selectivity is demonstrated.

OCIS codes: (060.2340) Fiber optics components, (060.4230) Multiplexing.

1. Introduction

Photonic Lanterns (PL) is a promising mode multiplexer technology which allows simultaneous (de)multiplexing of several modes, potentially with low loss and high mode selectivity [1]. A new fabrication technique for PL has been reported [2]. In this technique the input fibers of the lantern are stranded together, (without using a capillary tube) down-tapered, spliced to the output few mode fiber, and finally coated with a polymer with lower refractive index than the cladding of the fibers. In [2] no mode selectivity was demonstrated. Here we demonstrate a mode group selective lantern. Furthermore, it is shown that the polymer cladding can be exchanged with an air cladding. Getting rid of the polymer coating not only make the fabrication simpler and cheaper, but also gives lower loss, as our current polymer coating method is found to add loss.

2. Design

A mode-group selective lantern for LP_{01} and the LP_{11} mode groups for a OFS two mode step index fiber (TMF) is designed using a standard single mode fiber (SSMF) and two low cut off fibers (Corning HI1060). The performance of the PL has been modeled using a 2D-scalar mode solver. The scalar approximation is expected to give some error on the results due to the very high index contrast between silica and air. However, such a model is used to get the general trends and the obtained results agree well with the experimental results. The simulation results are summarized in Fig 1. The evolution of the first 6 lantern modes along down taper is shown in Fig 1(a). Lantern mode 1 starts in the SSMF, while modes 2 and 3 start in the HI1060 fibers. Mode 4 and up are unused (guided) cladding modes. If the difference between the effective index is sufficiently large and the down taper is sufficiently slow, the power stays within the...
mode, i.e. the power coupled into the SSMF stays in mode 1 while the power coupled to the two HI1060 stays within modes 2 and 3. The calculated loss from the coupling between the taper end and the two mode fiber is shown in fig 1(b). The loss is observed to be minimum for a taper diameter around 23 µm. Offset in the coupling between the taper and two mode fiber is a source of loss [2]. Fig 1(c) shows the simulated effect of this offset on crosstalk. Generally, the crosstalk is higher for the LP01 mode compared to the LP11 mode.

3. Experimental Results

The tapered fiber bundle is aligned with the TMF and the loss on both directions is measured scanning the input polarization to find the extremes for loss and crosstalk. For the multiplexing loss, light is coupled to each of the input fibers and the power output at the TMF end is measured. As shown in Table 1, a higher multiplexing loss is measured on the HI1060 fibers, which agrees with the lower overlap of LP11 modes as shown in Fig 1(b). For the de-multiplexing loss measurements, the LP01 mode is launched into the TMF through an SMF splice and the output power of SSMF is 13 dB higher than that out of the HI1060 fibers. Similarly, LP11 mode is launched to the TMF using a LPG and the sum of the two HI1060 output is 7 dB higher than out of SSMF, thus showing selectivity between the two mode groups. This is further confirmed by spatial and spectral imaging (S2) of the output modes using a tunable laser and an infrared camera. In this S2 method, the Fourier-filter based analyzing technique [3], which assumes a dominant mode, is used. The method works well, as long as the crosstalk is less than -10 dB. When the light is launched to SSMF, the dominant mode in the TMF is LP01 with low crosstalk to the LP11 mode as shown in Table 1. With light at each of the HI1060 fibers, LP11 is the dominant mode, also with even lower crosstalk with the LP01 mode as predicted in fig 1(c).

Table 1. Loss measurements and S2 imaging of the output modes in the multiplexing direction showing polarization dependence in the fabricated lantern

<table>
<thead>
<tr>
<th>Multiplexing Loss</th>
<th>SSMF Input</th>
<th>first HI1060 Input</th>
<th>second HI1060 Input</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 dB - 3.3 dB</td>
<td>5.5 dB - 6.4 dB</td>
<td>4.9 dB - 5.2 dB</td>
</tr>
<tr>
<td>Dominant mode</td>
<td>Crosstalk</td>
<td>Dominant mode</td>
<td>Crosstalk</td>
</tr>
<tr>
<td></td>
<td>-14.4 dB</td>
<td>-16.8 dB</td>
<td>-19.9 dB</td>
</tr>
<tr>
<td></td>
<td>-15.6 dB</td>
<td>-15.9 dB</td>
<td>-13.9 dB</td>
</tr>
<tr>
<td></td>
<td>-16.1 dB</td>
<td>-17.8 dB</td>
<td>-14.4 dB</td>
</tr>
</tbody>
</table>

4. Conclusion

We demonstrate the fabrication of a mode selective photonic lantern without the use of a low index cladding. Using S2 imaging a crosstalk around -15 dB is measured for multiplexing. By launching the LP01 and LP11 one after the other into the few mode fiber, a crosstalk around -10 dB is measured for de-multiplexing.

Acknowledgements

The Danish Council for Independent research, grant DFF-4184-00433 is acknowledged for the financial support.

References