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Beam steering and coupling in tunable hollow waveguide with narrow air core

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Abstract

We present the new function of tunable hollow waveguides with a variable air core. A possibility of wide-angle beam steering from the hollow waveguide and efficient tilt-coupling in narrow air core hollow waveguides is suggested.

1. Introduction

Tunable hollow waveguides [1] based on Bragg reflector waveguides [2] exhibit various unique features such as wide tunability of propagation constants, temperature insensitivity, and slow light propagation in narrow air cores. We have demonstrated various device applications of tunable hollow waveguides [3-6]. The small air core hollow waveguide gives us giant tuning characteristics [5]. Propagation characteristics including slow light in sub-wavelength narrow air cores are still open for discussions. Also, the coupling issue for such narrow air cores is an important issue.

In this paper, we discuss a possibility of wide-angle beam steering from tunable hollow waveguides and efficient coupling in narrow air core hollow waveguides.

2. Radiation and beam steering

Figure 1 shows the model of hollow waveguides for calculating the radiation from the hollow waveguide. The top mirror is terminated and thus the radiation takes place in an upper side. We used a full-vectorial Mxwell's solver (FIMMWAVE, provided by Photon Design Company), which is based on a film-mode-matching method [7], for calculating field distributions. Figure 2 shows the calculated field distribution of the radiation from hollow waveguides with an air core of (a) 3 μm, (b) 1.5 μm and (c) 1 μm, respectively. It is noted that we are able to realize wide beam steering of over 40 degrees with small displacement of air cores. Figure 3 shows the radiation angle versus the air core thickness of hollow waveguides. The result shows a possibility of continuous and wide angle beam steering, which results from the wide tunability of propagation constants.

Figure 4 shows the calculated insertion loss as a function of air core thicknesses, indicating an increase of loss for small air cores, which can be understood by the reflection at the edge of the terminated top mirror as shown in Fig. 5. If the core thickness is closed to a cut-off condition, the guided light in the hollow waveguide is perfectly reflected at the edge as shown in Fig. 5.

3. Tilt-coupling into narrow air-core waveguide

Figure 4 shows a possibility of low loss coupling into a narrow air core by tilting an input beam as shown in Fig. 6. The incident angle and spot size of an input beam are 40 degree and 2 μm, respectively. Figure 6 shows the calculated field distribution. The insertion loss is 2.5 dB, while the structure is not optimized yet.

4. Conclusion

We present wide-angle beam steering from the tunable hollow waveguide and efficient tilt-coupling in a narrow air core. Wide tunability in sub-wavelength air cores enables us to realize new functions of tunable hollow waveguides.

References

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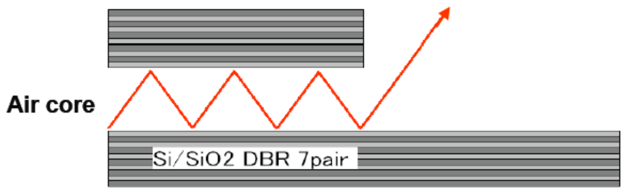

Fig.1 Model of hollow optical waveguides for beam steering.

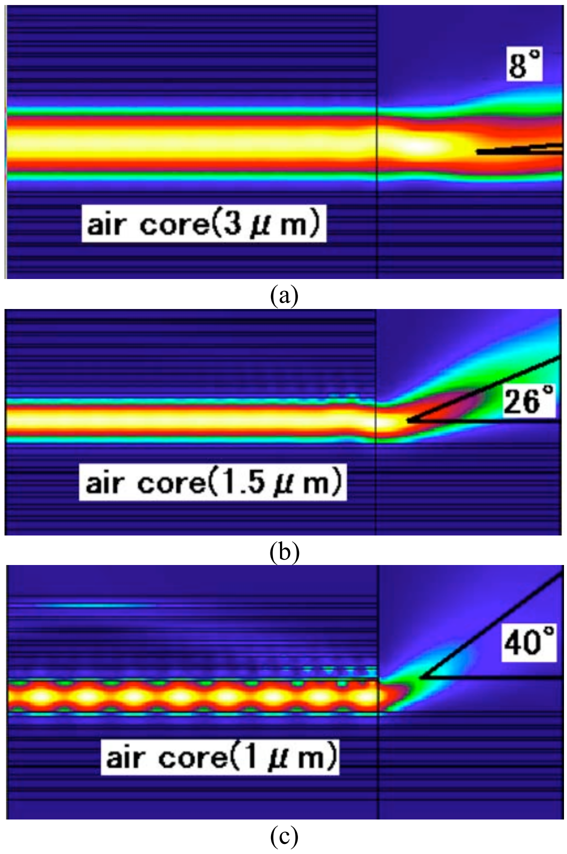

Fig. 2 Calculated field distribution of radiation from hollow waveguide with an air core of (a) 3 μm, (b) 1.5 μm and (c) 1 μm.

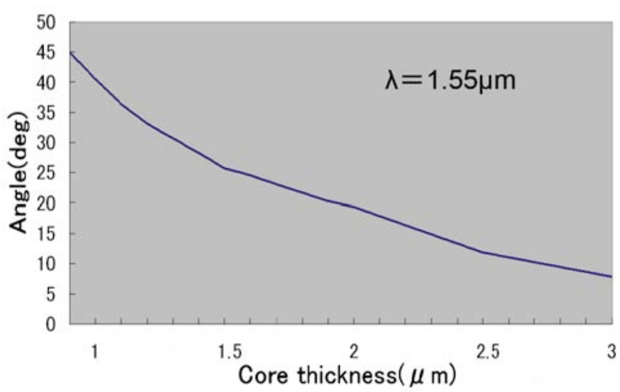

Fig. 3 Calculated radiation angle from the hollow waveguide versus air core thickness.

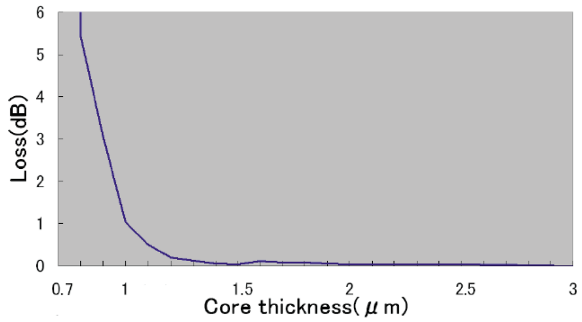

Fig. 4 Calculated insertion loss as a function of air core thickness.

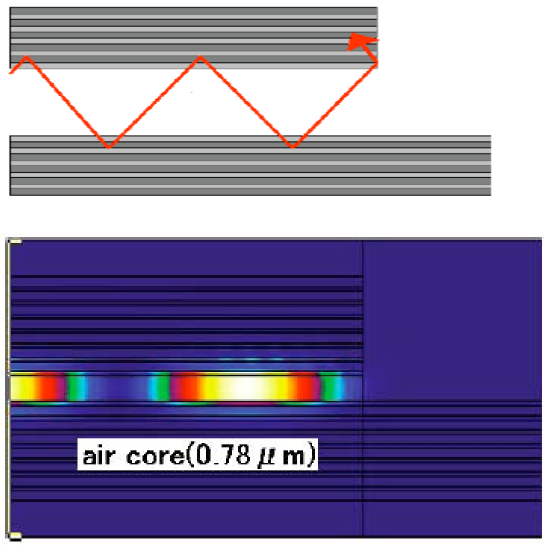

Fig. 5 Perfect reflection at the edge of hollow waveguide with 0.78 μm air core.

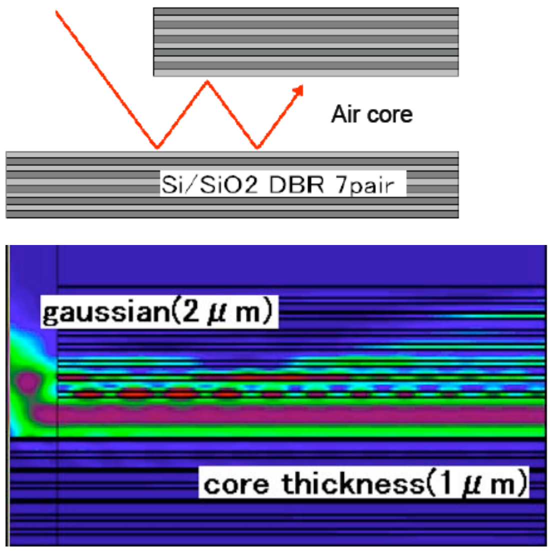

Fig.6 Schematic and calculated field distribution of hollow waveguide with tilt-coupling scheme.