Realizing Single TE01 Mode Transmission in Hollow Core Fiber by Directional Lattices

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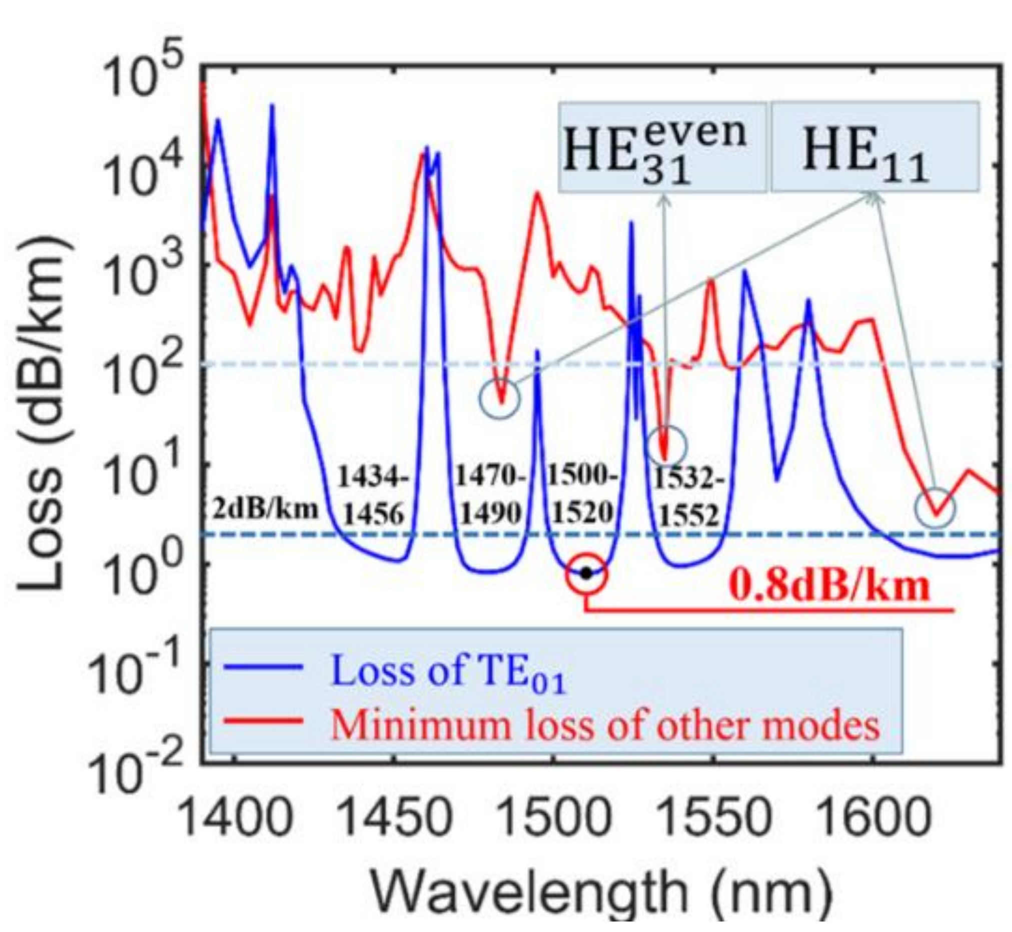
Introduction

- Transmission of controllable light wave in the air has been a research hotspot since 1999 when the hollow core photonics bandgap fiber was proposed . More than two decades of efforts have attempted to improve the purity and decrease the loss of the mode in such fiber. Due to the different light guiding mechanisms, the ideas that have been successful in solid-core fibers have encountered bottlenecks in hollow-core fibers. The best results so far are still not comparable to traditional optical fibers. New theoretical methods are urgently desired.
- In this work, we proposed a wave vector space that expresses the light wave state based on the basic principle of representation transformation, and give the mathematical form of the transformation between the position vector space and the wave vector space for arbitrary light wave state. The fiber eigenmode analysis based on the transformation gives the intrinsic difference among different modes.
- As proof of the principle, the modes in a 19-cell hollow core photonic bandgap fiber are selectively modulated, and only the transmission of the first-order angular polarization mode is allowed. The vector mode with large mode area, low loss and high purity has been obtained in the hollow core photonic bandgap fiber for the first time to the best of our knowledge.

Results

The blue curve represents the loss of TE_{01} and the red curve represents the minimum loss of other modes. The total loss diagram gives four transmission windows, including $1434-1456$ nm, $1470-1490$ nm, $1500-1520$ nm, and $1532-1552$ nm, in which the loss of TE_{01} is below 2 dB/km while losses of other modes are higher than 200 dB/km except for several indicated points.

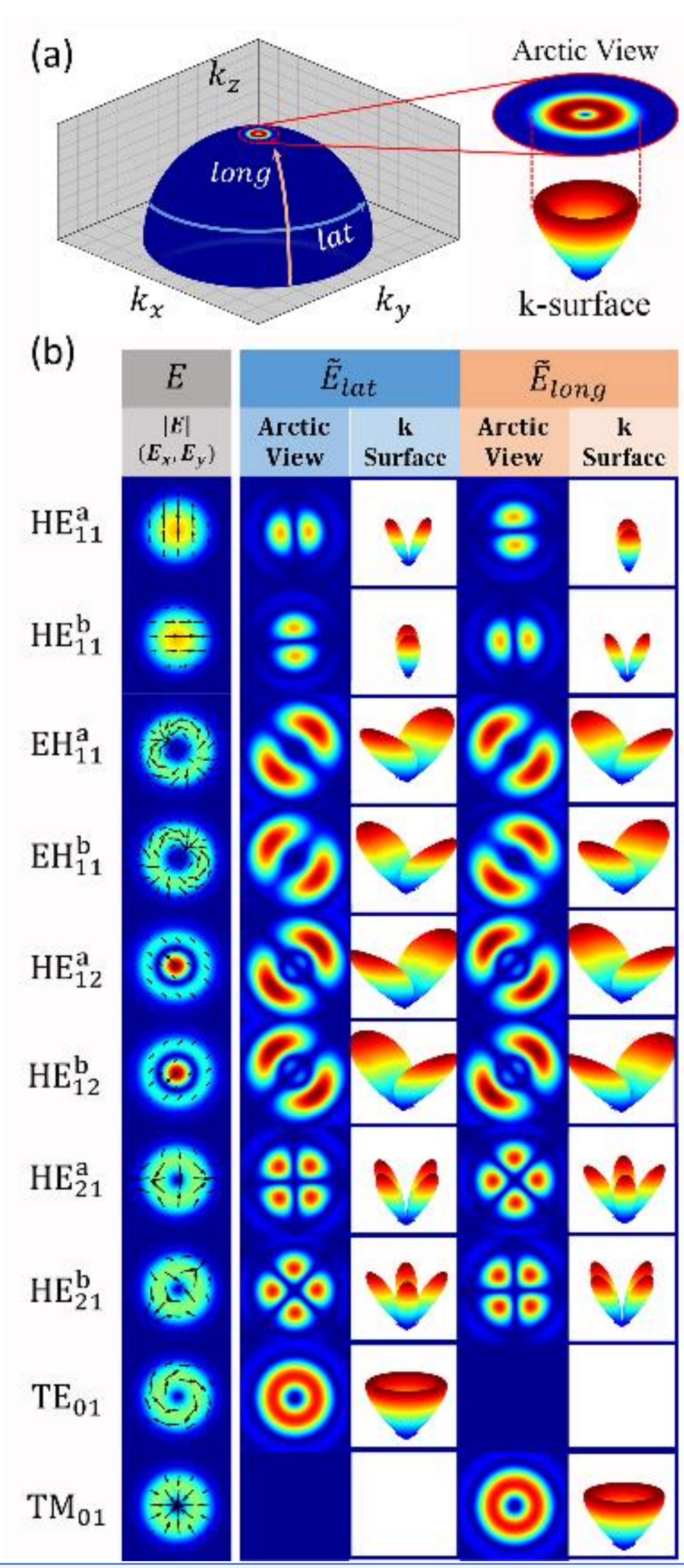


Methods

Analogous to the transformation of representation in quantum mechanics, we use the superposition of plane waves to represent the light wave field of the mode in the optical fiber. For a specific wave vector k, the component of **k** in the light field E is

$$\tilde{\mathbf{E}} = \iiint_{\infty} \mathbf{E}\exp\left[i\left(k_x x + k_y y + k_z z\right)\right] dxdydz$$

Then the vector $\tilde{\mathbf{E}}$ is plotted as the component $\tilde{E}_{long}$ perpendicular to the propagation direction and the component $\tilde{E}_{lat}$ perpendicular to both $\tilde{E}_{long}$ and **k** in Figure. It is obvious that TE mode contains almost no $\tilde{E}_{long}$. On the contrary, TM mode contains almost only $\tilde{E}_{long}$, while HE and EH modes contain $\tilde{E}_{lat}$ and $\tilde{E}_{long}$ equally.



Design

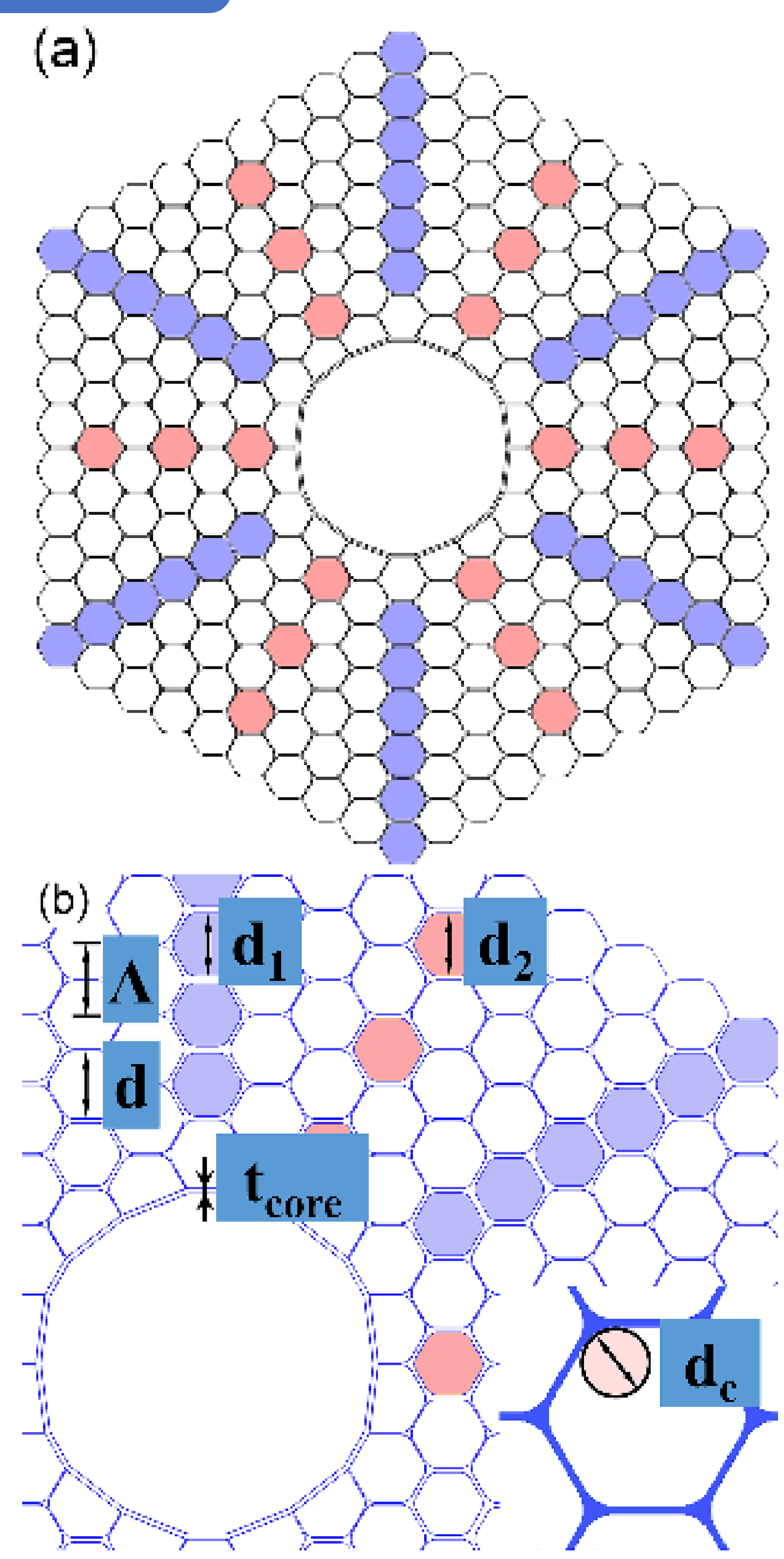


Figure (a) shows a diagram of the 19-cell HC-PBGF. Light is imprisoned in a cage of the periodic cladding by the out of plane photonic bandgap. In such bandgap, the probability of the light escaping from the defect is close to zero regardless of the wave vector direction, thereby all the modes (generally about dozens of them for a 19-cell HC-PBGF) are well confined. However, in this work, only one cylindrical vector mode is supported in such 19-cell HC-PBGF by tiny changes on the typical structure. The photonic lattice in a specific direction is modulated to construct a multilayer air-medium interface arranged at an appropriate interval, which will exhibit high transmittance for $\tilde{E}_{long}$, but low transmittance for $\tilde{E}_{lat}$. Thus, $\tilde{E}_{lat}$ and $\tilde{E}_{long}$ suffer different losses in a definite direction. As shown in Figure (b), the colored lattices located on the 12 symmetry axes of the fiber are shrunk evenly to provide high $\tilde{E}_{long}$ loss in these directions, thereby TE mode with only $\tilde{E}_{lat}$ can obtain better confinement, and other modes with $\tilde{E}_{long}$ component along the modulated direction will suffer higher losses.

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