AlGaInAs/InP Hexagonal Resonator Microlasers with a Center Hole

H. Weng[1], Y. Yang[1], B. Liu[1], X. Ma[1]

[1]中 科 院半 究所 北京 中

Abstract

In the past decades, equilateral polygonal microcavity lasers with whispering-gallery modes (WGMs) have attracted great attentions due to their potential application in photonic-integrated circuits. Compared to the perfect microdisk without deformation, the polygonal microcavities such as triangle, square, hexagonal and octagonal can easily realize the light directional emission and single mode lasing by connecting an output waveguide to the position with weak field distribution. However, the lower output power due to the strong angular radiation limits their application in the practical engineering.
Mode characteristics are simulated numerically for regular hexagonal resonator with a center hole by the finite element method (FEM) technique. The introduction of a center hole will suppress the triangle propagation modes in the resonator because of the more uniform field distribution. However, the mode field patterns of the hexagonal resonant modes can be modificated and the quality factors (Q) will be enhanced several times with a suitable size of the hole. The optimized structural parameters are proposed for realizing the stronger resonance and unidirectional-emission single transverse mode lasing. We have fabricated the AlGaInAs/InP hexagonal resonator microlasers with a hole radii 0, 7.5, 9um and a 15 um side length connected to a 1.5 μm output waveguid. Higher coupled output power are observed for the devices with a center hole because the smaller current injection area and higher injection efficiency, which are agreement well with the simulation.
The 2-D FEM (the commercial software: using the eigenfrequency solver in the wave optics module of COMSOL Multiphysics®) computational domain under the symmetry or anti-symmetry conditions relative to the x axis is shown in Fig.2. (b). The resonator has a constant effective index of 3.2 and is surrounded by a confined layer with an index of 1.54. The side length of the resonator is 15μm and the radius of the center hole changes from R=0 to 9μm.The waveguide with 1.5 μm width is designed at a vertex for the directional output.
The simulation consults the Wave Optics Module-Veification Models-fabry perot and extends to the design of lasers.
We have using the finite element method (FEM) technique to simulate the mode characteristics for hexagonal resonator with a center hole. The introduction of a center hole will suppress the triangle propagation modes in the resonator because of the more uniform field distribution. However, the mode field patterns of the hexagonal resonant modes can be modificated and the quality factors (Q) will be enhanced several times with a suitable size of the hole. These results have profound guiding significance for the design of lasers. Higher coupled output power are observed in the experriment for the devices with a center hole because the smaller current

injection area and higher injection efficiency, which are agreement well with the simulation.

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Figures used in the abstract

Figure 1: Schematic diagram of 3-D hexagonal resonator with a center hole and an output waveguide at a vertex

Figure 2: Corresponding 2-D structure for the simulation

Figure 3: The calculated resonance wavelengths and quality factors in a hexagonal resonator with both symmetry conditions when R=0μm.(b)-(d) Intensity patterns of $|H_z|^2$ for antisymmetric TE modes marked as ①, ②, and ④ in Fig.3. (a), respectively.

Figure 4: The calculated resonance wavelengths and quality factors in a hexagonal resonator with both symmetry conditions when R=7.75μm. (b)-(d) Intensity patterns of $|H_z|^2$ for antisymmetric TE modes marked as ①, ②, and ③ in Fig.4. (a), respectively.