GaN Ultraviolet laser based on Bound States in the Continuum (BIC)

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In recent years, a new type of optical mode for light confinement named bound states in the continuum (BICs) has attracted lots of attention in optical physics.[1] In these BICs, light is in completely localized states within the continuous spectrum of the environment with radiative losses fully suppressed. Therefore, BICs are recognized to achieve light confinement with dramatically enhanced quality factor (*Q*) in periodic structures. To date, optical BICs have been widely discussed and utilized in wave systems. The quasi-BIC effect was firstly reported in passive systems which contain periodic structures such as dielectric gratings, metasurfaces, and photonic elements.[2-3]. Subsequently, active devices based on BIC modes were reported to support out-of-plane and narrow-linewidth lasing with small device sizes down to a few dozen periods of the periodic structure. This allows the lasing device to be integrated with high density onto a chip. Due to these advantages, lasers based on BIC with emissions in the near-infrared (NIR) and the visible range were realized.[4-5] However, an ultraviolet (UV) laser based on BIC has not been reported. Since ultra-small UV light sources hold important applications in high-resolution bio-imaging, laser therapy, spectroscopy, lithography, and optical storage, UV nanolasers with high throughputs and narrow linewidths are highly required. The utilization of BIC is a promising solution to realize compact lasing devices with highly directional emissions.

In this work, we demonstrate a BIC-based UV laser with directional emission and tunable emission wavelength that is fabricated on a standard GaN thin film without any etching step. A one-dimensional (1-D) periodic dielectric structure supporting the BIC mode was fabricated directly on the GaN thin film by a single-step electron-beam (e-beam) lithography process. Due to the strong light confinement of the BIC mode, the lasing action at 376 nm with a narrow linewidth of full-width at half-maximum (FWHM) of 0.10 nm and a beam divergence of 1.5° was observed. The value is among the smallest in the reported GaN-based single-mode UV lasers. Also, we demonstrate the potential of the laser for practical application under relatively high-temperature environments by raising the temperature to 383K. Furthermore, the control of the emission wavelength in a step of 0.45 nm over a wide range was achieved by adjusting the structure period and the operating temperature. It is noted that single-mode UV lasers with good monochromaticity and accurate wavelength control are highly desired for practical applications Last but not least, we demonstrate that lasing can still be achieved even if the device size is shrunk to 8 μm in length, showing that the high-*Q* BIC mode paves the way for the realization of compact UV light sources.

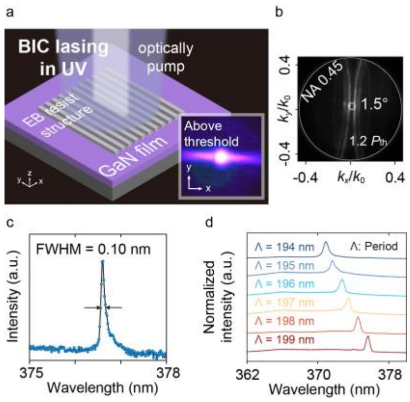

Figure 1. GaN ultraviolet laser based on bound states in the continuum (BIC). (a) The schematic of the designed laser which contains an e-beam resist line-and-space structure on the GaN film. The inset shows the optical image of the laser. (b) The collected far-field image of lasing showing a beam divergence of 1.5°. (c) The high-resolution spectrum of the lasing showing an FWHM of 0.10 nm. (d) Achieved wavelength control in a step of 0.45 nm by changing the structure period.

Reference

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