Hybrid optical-electrical pumping in GaN ridge polariton lasers: a step toward full electrical injection

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Exciton-polariton laser is characterized by its operation mode, which relies on the stimulated relaxation of polaritons from an exciton reservoir into a final polaritonic state. Unlike conventional diode lasers, localized pumping on only part of the cavity is possible. Moreover, the laser regime transitions from continuous-wave (CW) operation at low temperatures [1] to a mode-locking regime as the temperature rises [2]. These demonstrations were conducted in an optically pumped GaN waveguide.

In our current study, we take a step toward electrical injection in GaN ridge waveguides. The structures are grown on c-plane sapphire substrates using MOVPE, incorporating a 163 nm GaN active layer confined within P- and N-doped AlGaN claddings forming a PIN junction. The laser cavities are defined by vertical Bragg reflectors (R > 80%) at each end of the ridge (lengths: 60–600 µm), fabricated through a six-step electron-beam lithography process. Key fabrication challenges will be discussed.

These cavities were studied under CW and pulsed electrical injection, but no laser effect was observed. To deepen our understanding, we explored a hybrid pumping scheme combining synchronized quasi-continuous optical and electrical excitation. This was implemented on cavities where the P-type contact metal covered only 20% of the total cavity length. At 300 K, we analyzed how electrical injection influenced the system when added to near-threshold optical pumping. When the optical power was slightly below threshold, the additional electrical current enabled the system to cross the threshold and exhibit clear lasing behavior (see Figure 1(a)). Conversely, when the optical pump alone was sufficient to induce the laser effect, the extra electrical injection increased the emission intensity and induced a spectral redshift of about 5 meV (see Figure 1(b)). Since this shift does not scale with injected current, a purely thermal origin is unlikely, suggesting the involvement of other physical mechanisms. This hybrid approach marks a significant step toward the realization of fully electrically driven polariton lasers and the integration of multifunctional components on a single polaritonic chip.

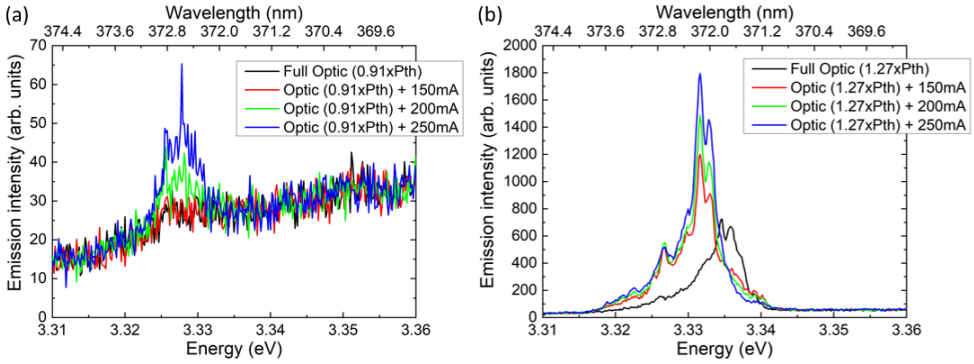

Figure 1: Emission spectra recorded at the DBR position at T = 300 K for a 200 µm-long cavity under hybrid excitation. (a) Optical excitation below threshold at 0.91 × Pth; (b) Optical excitation above threshold at 1.27 × Pth, with spectral changes shown as a function of the injected electrical current.

Acknowledgments

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References

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