

Ridge polariton laser: towards a short laser on chip for integration

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Polaritons in waveguides offer novel potentialities for their application in optoelectronics, based on the concept of the polariton laser. Unlike a conventional semiconductor laser, polariton laser does not require any population inversion in order to stimulate the light emission, which potentially allows the creation of laser components operating with short injection sections and a much larger gain.

The wide band gap materials, like nitrides GaN and ZnO, with their robust excitons and large oscillator strength, offer the possibility of a strong coupling regime stable up to room temperature. The first polariton laser and amplifier based on a bulk ZnO waveguide, where cavities are accidentally formed between cracks, was recently realized [1]. In the present work, we can control the cavity which is carried out on the top-down design. The laser cavities are GaN etched ridge structures with Distributed Bragg Reflectors (inset Fig.1(a)) operating under strong coupling [2] up to 300K with a 66 ± 10 meV Rabi splitting.

The cavities are optically pumped with a line-shaped spot, resonantly pumping the exciton reservoir. Below threshold, the PL spectra exhibits Fabry-Perot (FP) modes over a large energy (Fig.1(a)). The nonlinearity of the emission and the spectral narrowing beyond threshold evidence the laser operation of the device. In order to assess the strong coupling regime between photons and excitons in a waveguide geometry, we can measure and model the cavity free spectral range (FSR) (Fig.1(b)). Consequently, we demonstrate the operation of a CW polariton laser and we propose to explore the impact of the pump length in order to emphasize the specificities of the polariton laser and, in particular, the absence of reciprocity between the processes leading to gain and loss. The polariton laser is operated for an exciton reservoir length of just 15% of the cavity length (Fig.1(c)) [3]. It is worth noting that this would not be possible in a conventional ridge laser with population inversion (Fig.1(d)). Such a short injection section offers the opportunity to include additional functionalities within the cavity, such as a tunable absorber for sensing or modulation.

The experimental results are compared to numerical simulations, based on semiclassical Boltzmann equations, of the dynamics of the exciton reservoir and the polariton population along the LPB (Fig.1(c)) [4][5]. The measured gain reaches 7000 cm^{-1} , one order of magnitude larger than in conventional GaN or InGaN-based ridge laser, paving the way to very short laser cavities.

References

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Supplementary information

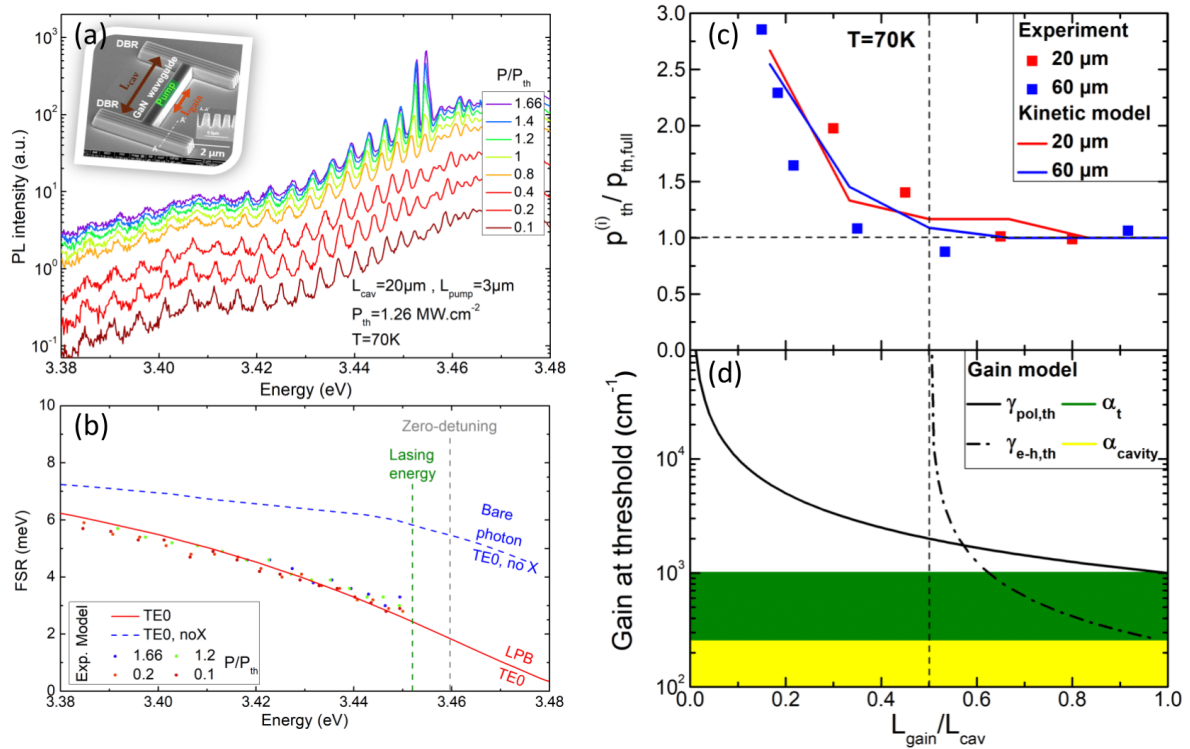


Figure 1: (a) Power-dependent PL spectra across the lasing threshold, for a $20\mu\text{m}$ -long cavity at $T=70\text{K}$; Inset: SEM image of a $5\mu\text{m}$ polariton ridge waveguide; (b) Experimental FSR of the FP modes (dots) versus energy and calculated FSR (plain line) from corresponding LPB dispersions. The dispersion in the absence of strong coupling is indicated as a dashed blue line; (c) Laser power at threshold $p_{th}^{(i)}$, integrated along the whole excitation length, vs gain length, normalized to its value $p_{th,full}^{(i)}$ for $L_{pump}=L_{cav}$; (d) Modeling of the modal gain at threshold calculated vs gain length, for a polariton laser (plain line) and semiconductor lasers (dash-dotted line); the cavity losses, common to both models, are indicated in yellow, whereas the absorption of the active layer, specific to polaritons, is indicated in green.