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Impact of mode-hopping noise on InGaN edge emitting laser RIN properties

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In this study we report through a comparative analysis of optical spectrum, L-I curve and relative intensity noise (RIN) measurement, the impact of mode hopping on the overall intensity noise dynamics of InGaN edge emitting lasers. We reveal that this mode hopping contributes to the enhancement of the laser RIN with variation as large as 20 dB for pumping level above twice the laser threshold. The coexistence of longitudinal modes with modal gain in excess of the gain threshold induces few modes lasing and then mode competition. The subsequent enhancement of the RIN can be detrimental for applications where the intensity stability of InGaN lasers is a key parameter.

Our experimental setup based on Fourier transformation of the measured photocurrent allow us to deepen the study of RIN measurement through continuous noise analysis in frequency domain. Simultaneous measurements of the optical spectrum, Radio Frequency (RF) intensity noise in function of the pump current fluency give access to the rich dynamics of those lasers. The structure is described in details [1]. Figure 1 a) shows the static response of the laser based on L-I curve measurement. Related to this L-I curve, Figure 1 b) to d) show the optical spectrum dynamics for different pump current. Figure 1 b) displays the optical spectrum below the threshold ($I_{pump}=40$ mA) corresponding to the amplified spontaneous emission from which we can extract the gain profile. This ripple corresponds to the effective FSR of the structure. Increasing the pump current above the threshold ($I_{pump}=90$ mA), the laser behaves in single mode operation. Incrementing the pump current to 160 mA ($2.5I_{pump}$) the laser behaves in bi-mode regime with two adjacent modes. We then record continuously the optical spectrum of the laser and the RIN behaviour in function of the pump current above the threshold (Figure 2). A comparative study of Figure 2 a) - b) permit to identify the impact of lasing regime on RIN properties. Just above the laser threshold [$I_{pump}=90$ mA], the laser behaves in single mode regime. The corresponding RIN measurement is presented on Figure 2 b). The RIN behaviour is specific from a Class B laser in single mode operation with constant low noise RIN around -140 dB/Hz at intermediate frequencies [1-1000] MHz. For a pump current at twice the threshold [$I_{pump}=120$ mA], bimode operation of mode (2) and (3) occurs, featuring an enhancement of the RIN amplitude for intermediate frequencies. Indeed, in bimode lasing operation, two successive modes having similar intensity amplitude can compete to suck the gain through stimulated emission. This two modes, being of similar amplitude, have difficulties to equally share the available gain contributing to intensity fluctuations and even mode switching. Thus, "bimode operation" is not stable at all and temporally behave either as single mode (mode (2) or (3)) or noisy bimode operation.

This nonlinear behavior is driven by strong interplay between spontaneous emission and nonlinear cross saturation gain. This study reveal that for certain pump current the InGaN laser manifests strong intensity dynamics that can even be detrimental for specific purposes. Currently, only external cavity lasers can offer single mode operation in the blue range of the spectrum. Efforts have to be done to obtained commercially available monolithic single mode InGaN lasers

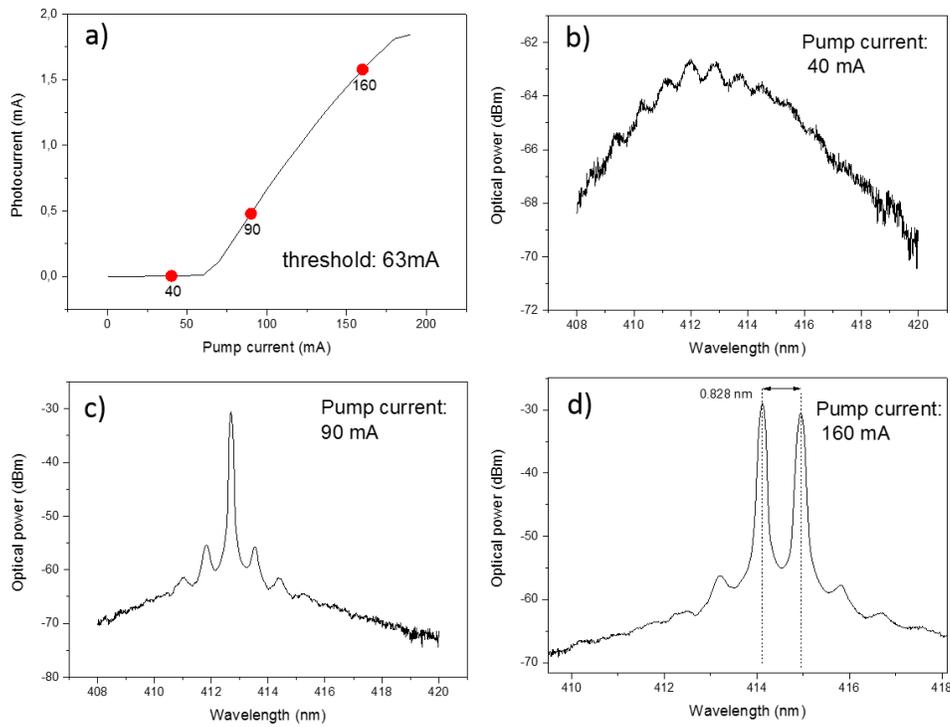


Figure 1 a) L-I curve of the laser. Optical spectra of the diode below ($I=40$ mA) b), above ($I=90$ mA) c) and far above ($I=160$ mA) d) the laser threshold ($I=65$ mA).

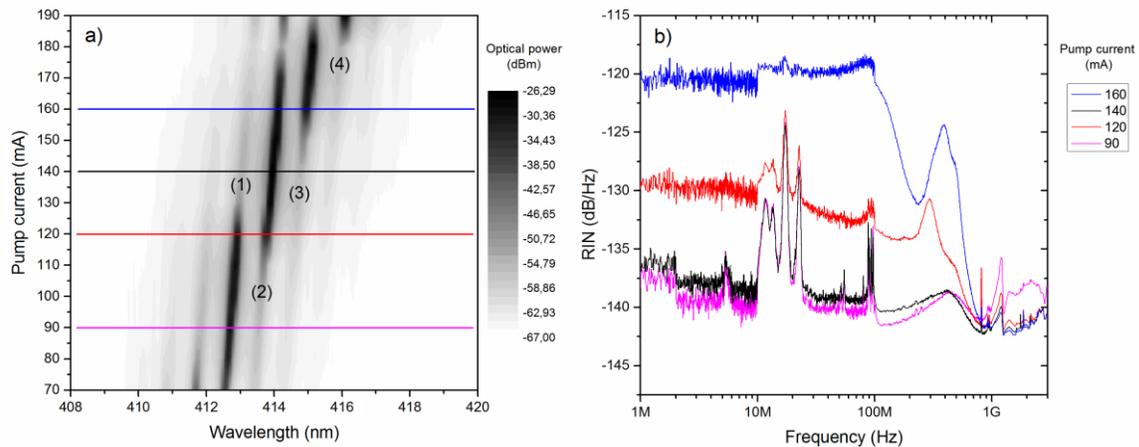


Figure 2 a) Optical spectrum evolution in function of the pump current above the laser threshold. b) RIN measurement for specific current values revealing the impact of mode hopping competition in InGaN laser. Strong peaks between 10 and 30 MHz are contributions from electromagnetic perturbations of the setup

- [1] L. Sulmoni, J.-M. Lamy, J. Dorsaz, a. Castiglia, J.-F. Carlin, W. G. Scheibenzuber, U. T. Schwarz, X. Zeng, D. L. Boiko, and N. Grandjean, J. Appl. Phys. **112**, 103112 (2012).