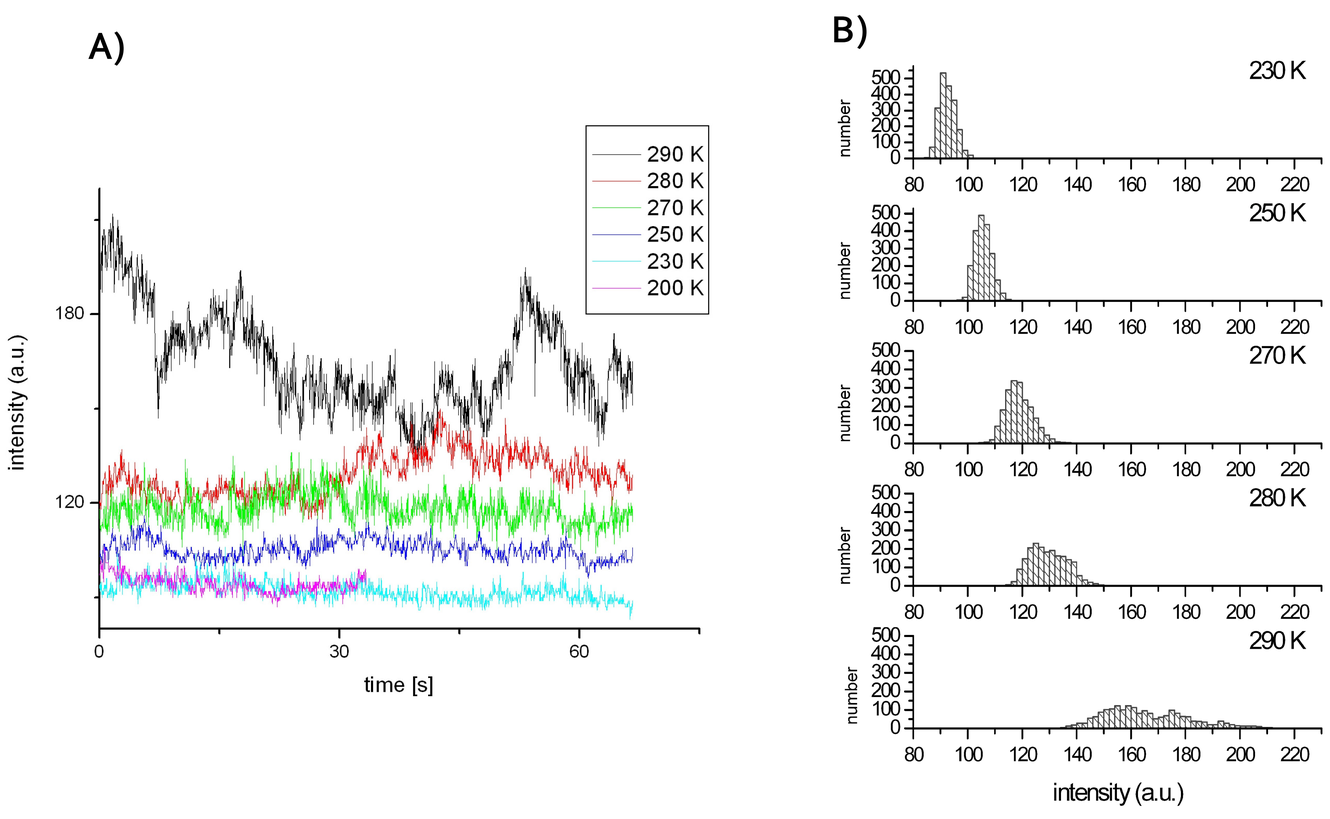
InGaN デバイスの点滅発光現象の研究

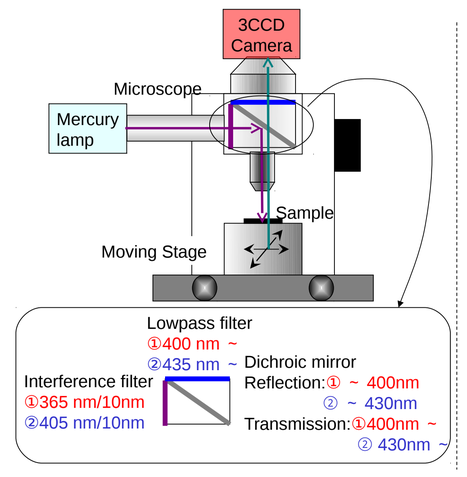
ミケレット・ルジェロ [1)]、後藤 秀樹 [2)]
[1] 横浜市立大学 生命ナノシステム科学研究科、 [2] エー・イー・テック株式会社

概要:
The blinking of InGaN optical devices is studied in high details. We propose here a new model to explain the optical process that causes the blinking. We consider that the optical intensity observable from a device is proportional to the number of recombination of carrier per unity of time. This recombination rate is dependent on several factors in the quantum well. We made a model that takes in account the nanoscale thermal vibrations that occur in the quantum well and that actually shift the quantum well thickness. The variation of the thickness occurs at very high frequencies and in not-coherent way, however the interaction of adjacent vibration produce interference that results in observable random beating of much lower frequencies.

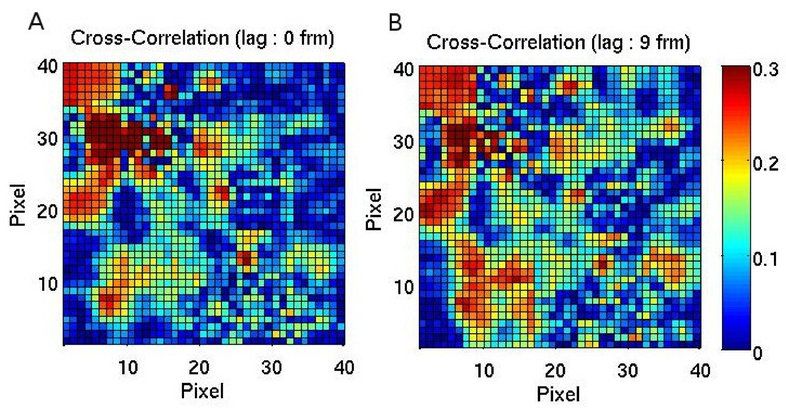
ミケレット・ルジェロ、 ruggero@yokohama-cu.ac.jp
後藤秀樹、 hgoto@adscorp.jp



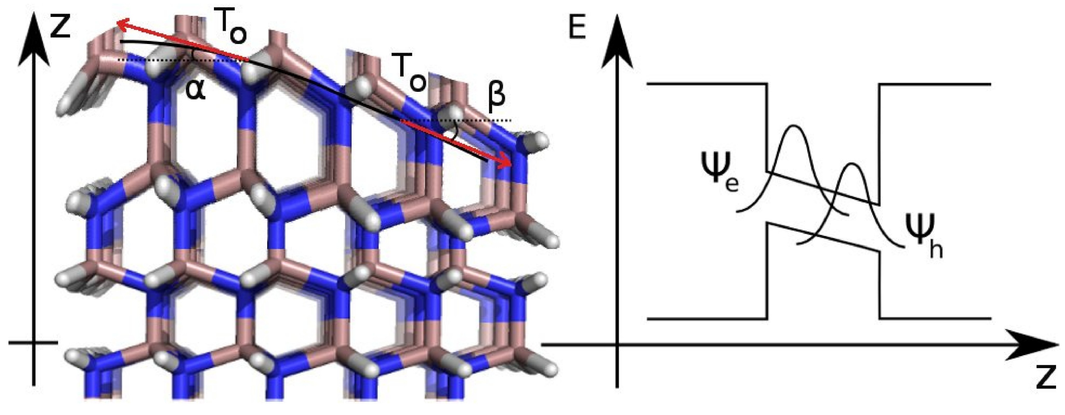
A) The Intensity of single points in the InGaN device is plotted against time at different temperatures. It is obvious that the optical fluctuations (blinking) are more dominant near room temperature, while they tend to disappear at lower temperatures. **B)** Histograms of the blinking intensity for different temperatures. Whereas the optical emission appears to be stable at 230K, the overall intensity increases and its spread widens as the temperature rises.



The schematic representation of our minimalistic experimental apparatus, a CCD camera is mounted over an excitation selective microscope. The InGaN sample is excited at 325nm to induce blinking. Blinking is recorder and its behavior analyzed pixel by pixel for correlation and other properties.



The time behaviour of the optical fluctuations is analized by a correlation study. Each pixel detected by the CCD camera records a single time series of intensity data. For each pixel the correlation coefficient relative to a reference point is determined and plotted in the map (A). The second map (B) is obtained in the same way, with same points and reference, however there is a time lag inserted in the time serie to check for diffusion. Points with high correlation with the target appear to expand and diffuse along the sample suggesting a propagation mechanism.



An exaggerated scheme in which the Wurtzite structure is stretched along the crystal growth direction Z (left) and the corresponding Energy density diagram (right). The mechanical stress along the line of adjacent atoms indicated by the line, is represented by the tension T_o shown in two arbitrary points tangent with the deformation line with angles alpha and beta. The deformation along the Z axis modifies the overlap of electron-hole wave functions, this results in observable photo-luminescence variations, see text for details [1].

We have been awarded a collaborative research project in which we seek a method to use the blinking phenomena to estimate quality of marketable devices.

AETech は 2010 年 5 月に設立されたベンチャー企業です。半導体生産プロセス開発の経験豊富なチームが、「ワンステップ HVPE 法」による GaN 基板の量産技術の開発を行っております。基本技術は、東北大学八百隆文名誉教授によって開発された窒化ガリウム（ GaN ）基板の製造技術（各国特許取得済み）を基にしており、共同開発を行っております。
2011 年 10 月には茨城県土浦市に開発用の研究開発センターを開設し、本格的な開発をスタートさせています。

結論

We have realized a simple model and experimental tests that suggest that the optical instabilities in InGaN quantum wells are caused by mechanical beats of thermal vibrations associated with the quantum well lattice. These beats have been observed experimentally through monitoring with CCD camera the photoluminescence and making a time resolved correlation analysis. Furthermore the thermal dependence of the phenomena is compared with a Boltzmann distribution of an harmonic oscillating lattice, resulting in good match and agreement with the original hypothesis.

[1] Observation of lattice waves through observation of the photoluminescence Blinking in InGaN Quantum Well devices, R. Micheletto, K. Oikawa, C. Feldmeier, arXiv:1202.5368v1 [physics.optics](24 Feb 2012)