ATOM PHYSICS AND PHYSICS OF CLUSTERS AND NANOSTRUCTURES

Conference materials
UDC 535.372:621.315.592
DOI: https://doi.org/10.18721/JPM.183.123

Investigation of microdisks lasers with an InGaN/GaN quantum well in the active region at elevated temperatures

D.A. Masyutin [1] ✉, A.A. Rudnev [1], E.I. Moiseev [1], A.G. Vainilovich [2], E.V. Lutsenko [2], A.F. Tsatsulnikov [3], A.V. Sakharov [3, 4], D.S. Arteev [3, 4], A.E. Nikolaev [4], A.A. Pivovarova [4], E.E. Zavarin [3, 4], N.D. Il'inskaya [4], L.K. Markov [4], I.P. Smirnova [4], N.V. Kryzhanovskaya [1], A.E. Zhukov [1]

[1] National Research University Higher School of Economics, St. Petersburg branch, St. Petersburg, Russia;
[2] Stepanov Institute of Physics of NAS Belarus, Minsk, Belarus;
[3] Submicron Heterostructures for Microelectronics, Research & Engineering Center, RAS, St. Petersburg, Russia;
[4] Ioffe Institute, St. Petersburg, Russia;
✉ dmasyutin@hse.ru

Abstract. In this work, we present results on high-temperature operation microdisk lasers with an active region based on InGaN/GaN quantum wells. The diameter of the microdisks was 5 μm. The photoluminescence spectra measured in the temperature range from 25 °C to 100 °C. The temperature stability lasing is demonstrated.

Keywords: GaN, InGaN/GaN quantum wells, microdisk resonator, WGM

Funding: The article was prepared during the research within the framework of the project "International Academic Cooperation" of the National Research University Higher School of Economics.

Citation: Masyutin D.A., Rudnev A.A., Moiseev E.I., Vainilovich A.G., Lutsenko E.V., Tsatsulnikov A.F., Sakharov A.V., Arteev D.S., Nikolaev A.E., Pivovarova A.A., Zavarin E.E., Il'inskaya N.D., Markov L.K., Smirnova I.P., Kryzhanovskaya N.V., Zhukov A.E., Investigation of microdisks lasers with an InGaN/GaN quantum well in the active region at elevated temperatures, St. Petersburg State Polytechnical University Journal. Physics and Mathematics. 18 (3.1) (2025) 125–128. DOI: https://doi.org/10.18721/JPM.183.123

Материалы конференции
УДК 535.372:621.315.592
DOI: https://doi.org/10.18721/JPM.183.123

Исследование микродисковых лазеров с InGaN/GaN квантовой ямой в активной области при повышенных температурах

Д.А. Масютин [1] ✉, А.А. Руднев [1], Э.И. Моисеев [1], А.Г. Войнилович [2], Е.В. Луценко [2], А.Ф. Цацульников [3], А.В. Сахаров [3, 4], Д.С. Артеев [3, 4], А.Е. Николаев [4], А.А. Пивоварова [4], Е.Е. Заварин [3, 4], Н.Д. Ильинская [4], Л.К. Марков [4], И.П. Смирнова [4], Н.В. Крыжановская [1], А.Е. Жуков [1]

[1] Национальный исследовательский университет «Высшая школа экономики»,
Санкт-Петербургский филиал, Санкт-Петербург, Россия;
[2] Институт физики им. Б.И. Степанова НАН Беларуси, г. Минск, Беларусь
[3] НТЦ микроэлектроники РАН, Санкт-Петербург, Россия;
[4] Физико-технический институт им. А.Ф. Иоффе РАН, Санкт-Петербург, Россия
✉ dmasyutin@hse.ru

Аннотация. В работе представлены результаты исследования высокотемпературных характеристик микродисковых лазеров с активной средой на основе квантовых ям InGaN/GaN. Исследовались спектры фотолюминесценции микродисков диаметром 5 мкм в диапазоне температур от 25 °C до 100 °C. Продемонстрирована высокая температурная стабильность лазерной генерации.

Ключевые слова: GaN, InGaN/GaN квантовые ямы, микродиск, МШГ

Финансирование: Статья подготовлена в ходе проведения исследования в рамках проекта «Международное академическое сотрудничество» НИУ ВШЭ.

Ссылка при цитировании: Масютин Д.А., Руднев А.А., Моисеев Э.И., Войнилович А.Г., Луценко Е.В., Цацульников А.Ф., Сахаров А.В., Артеев Д.С., Николаев А.Е., Пивоварова А.А., Заварин Е.Е., Ильинская Н.Д., Марков Л.К., Смирнова И.П., Крыжановская Н.В., Жуков А.Е. Исследование микродисковых лазеров с InGaN/GaN квантовой ямой в активной области при повышенных температурах // Научно-технические ведомости СПбГПУ. Физико-математические науки. 2025. Т. 18. № 3.1. С. 125–128. DOI: https://doi.org/10.18721/JPM.183.123

Introduction

The growing demand for high-speed data transmission in integrated photonic systems has driven the development of compact and efficient on-chip light sources. III-nitride semiconductors have emerged as promising candidates due to their direct bandgap, high thermal and chemical stability, and wide spectral tunability from ultraviolet to near-infrared [1]. GaN microdisk lasers integrated on silicon substrates are of particular interest, as they combine the optical advantages of III-nitrides with the scalability and integration with other silicon devices [2].

This study investigates the impact of microdisk laser heating on lasing threshold power and wavelength shift, which are crucial for ensuring the stability of the laser operation.

Materials and Methods

The studied heterostructure was fabricated by metal-organic chemical vapor deposition (MOCVD) on misoriented (111) Si-substrate. The structure contains a 200 nm thick AlN layer, a composition of AlGaN buffer layers of variable composition with a total thickness of 770 nm, a 200 nm thick GaN waveguide layer, 5x $In_{0.1}Ga_{0.9}N$/GaN quantum wells (QWs) of 2 nm thickness each, separated from each other by 8 nm thick GaN layers, and a 200 nm thick GaN cover layer. Mesas with a diameter of 5 μm were formed by plasma chemical etching method.

Microphotoluminescence (μPL) spectroscopy was used to investigate the optical properties of heterostructures. The sample was placed on heater, the temperature in which varied from 25 °C to 100 °C. Optical pumping was carried out by a pulsed laser (λ = 355 nm, pulses 9 ns, frequency 10 kHz) with an acousto-optic modulator. The pump laser beam was directed along the normal to the substrate and focused onto a single microlaser using a Thorlabs LMU-5X-NUV objective (NA 0.12). Radiation from the microlaser was collected with a Mitutoyo Plan Apo NUV 50X microobjective (NA 0.42), located at an angle of ~30° relative to the substrate plane. Detection of the microlaser emission spectra was performed using a Thorlabs CCS200/M spectrometer.

Results and Discussion

μPL spectra over a wide temperature range were investigated. The room temperature photoluminescence spectra of the microdisk laser at optical pump powers of 205 uW, 253 uW, and 314 uW ($0.8P_{th}$, P_{th}, $1.25P_{th}$) are shown in Fig. 1, *a*.

At low pumping, the photoluminescence spectrum of microlaser has a form characteristic of spontaneous emission. The emission maximum of the main optical transition was at room temperature at a wavelength of 427 nm. With increasing pumping power, a narrow line appears on the short-wave slope of the emission peak, corresponding to one of the modes of the whispering gallery of the microresonator. For the resonance line (420 nm), the transition to the lasing mode is observed, as evidenced by the threshold dependence of the integral intensity (Fig. 1, *b*). The threshold of lasing is 249 uW for room temperature.

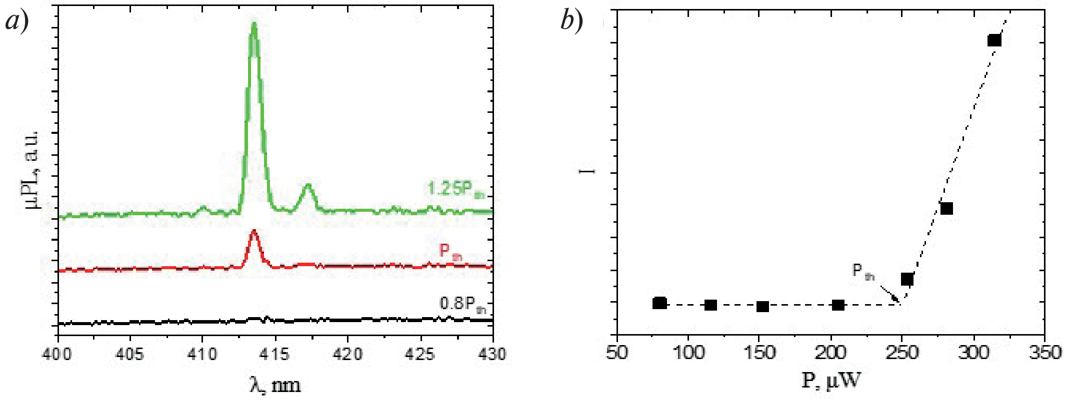

Fig. 1. μPL spectra of microdisk laser at room temperature (*a*) and L-L curves for 5 um microdisk (*b*)

Figure 2, *a* shows the μPL spectra of the laser at 25 °C and 100 °C at an optical pump power of 314 uW. High-temperature lasing is observed, it's confirmed by a defense of mode intensity on pump power (the inset of Fig. 2, *a*). The threshold power is slightly variable between 245 uW and 255 uW (Fig. 2, *b* black) and lasing continued to be observed with a slight long-wavelength shift from 413 nm to 415 nm (Fig. 2, *b* red) in the temperature range from 25 °C to 100 °C. We assume that the additional optical losses at high temperatures are caused by enhanced absorption of free carriers in the waveguide layer of the laser [3].

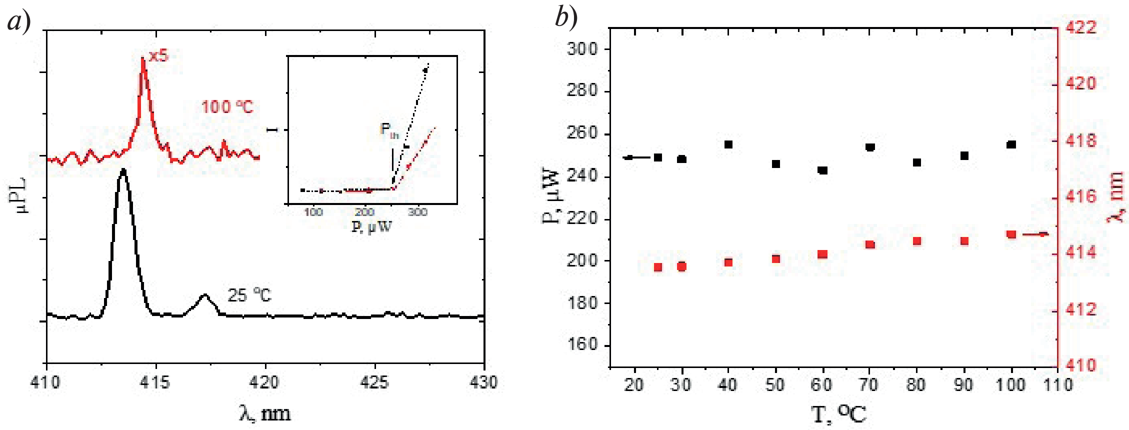

Fig. 2. μPL spectra of microdisk laser and L-L curves (insert) at temperatures 25 °C (black) and 100 °C (red) (*a*), temperature dependence of the threshold power density (black, left axis) and lasing peak position (red, right axis) (*b*)

Conclusion

For the first time, lasing has been demonstrated at elevated temperatures (up to 100 °C) for InGaN/GaN microdisk with QW in the active region. The laser shows line and threshold power stability with a temperature range from 25 °C to 100 °C. The results obtained represent a significant contribution to the progress of technologies integration III-N lasers with Si devices.

Acknowledgments

The work was carried out using the large-scale research facility No. 2087168 “Complex optoelectronic stand”.

REFERENCES

1. **Baten M.Z., Alam S., Sikder B., Aziz A.,** III-Nitride Light-Emitting Devices, Photonics. 8 (2021) 430.

2. **Tabataba-Vakili F., Doyennette L., Brimont C., Guillet T., Rennesson S., Frayssinet E., Damilano B., Duboz J.-Y., Semond F., Roland I., El Kurdi M., Checoury X., Sauvage S., Gayral B., Boucaud P.,** Blue Microlasers Integrated on a Photonic Platform on Silicon, ACS Photonics. 5 (2018) 3643–3648.

3. **Kryzhanovskaya N.V., Moiseev E.I., Polubavkina Y.S., Maximov M.V., Mokhov D.V., Morozov I.A., Kulagina M.M., Zadiranov Y.M., Lipovskii A.A., Tang M., Liao M., Wu J., Chen S., Liu H., Zhukov A.E.,** Elevated temperature lasing from injection microdisk lasers on silicon, Laser Phys. Lett. 15 (2018) 015802.

THE AUTHORS

MASYUTIN Dmitriy A.
dmasyutin@hse.ru
ORCID: 0009-0005-4578-7550

RUDNEV Artem A.
aarudnev@edu.hse.ru
ORCID: 0009-0004-6609-9741

MOISEEV Eduard I.
emoiseev@hse.ru
ORCID: 0000-0003-3686-935X

VAINILOVICH Aliaksei G.
a.vainilovich@ifanbel.bas-net.by
ORCID: 0009-0009-5699-2751

LUTSENKO Evgenii V.
e.lutsenko@ifanbel.bas-net.by
ORCID: 0000-0003-2333-7776

TSATSULNIKOV Andrey F.
andrew@beam.ioffe.ru
ORCID: 0000-0002-5078-8946

SAKHAROV Alexei V.
val.beam@mail.ioffe.ru
ORCID: 0000-0002-9976-999X

ARTEEV Dmitri S.
ArteevDS@mail.ioffe.ru
ORCID: 0000-0003-4447-8789

NIKOLAEV Andrey E.
aen@mail.ioffe.ru
ORCID: 0000-0001-6522-4484

PIVOVAROVA Antonina A.
pivovarova.antonina@gmail.com
ORCID: 0000-0002-2313-9051

ZAVARIN Evgenii E.
EZavarin@mail.ioffe.ru
ORCID: 0000-0001-8380-3172

IL'INSKAYA Natalya D.
Natalya.Ilynskaya@mail.ioffe.ru
ORCID: -

MARKOV Lev K.
l.markov@mail.ioffe.ru
ORCID: 0000-0001-7293-1320

SMIRNOVA Irina P.
irina@quantum.ioffe.ru
ORCID: 0000-0001-5313-0640

KRYZHANOVSKAYA Natalia V.
nkryzhanovskaya@hse.ru
ORCID: 0000-0002-4945-9803

ZHUKOV Alexey E.
zhukale@gmail.com
ORCID: 0000-0002-4579-0718

Received 05.08.2025. Approved after reviewing 12.08.2025. Accepted 26.09.2025.