

ISSN (Print) 2616-6836  
ISSN (Online) 2663-1296

Л.Н. Гумилев атындағы Еуразия ұлттық университетінің

# ХАБАРШЫСЫ

---

**BULLETIN**

of L.N. Gumilyov Eurasian  
National University

**ВЕСТНИК**

Евразийского национального  
университета имени Л.Н. Гумилева

**ФИЗИКА. АСТРОНОМИЯ** сериясы

**PHYSICS. ASTRONOMY** Series

Серия **ФИЗИКА. АСТРОНОМИЯ**

№1(126)/2019

1995 жылдан бастап шығады

Founded in 1995

Издается с 1995 года

Жылына 4 рет шығады

Published 4 times a year

Выходит 4 раза в год

Астана, 2019  
Astana, 2019

*Бас редакторы*  
ф.-м.ғ. докторы  
**А.Қ. Арынгазин** (Қазақстан)

*Бас редактордың орынбасары*

**А.Т. Ақылбеков**, ф.-м.ғ.д., профессор  
(Қазақстан)

*Редакция алқасы*

<b>Алдонгаров А.А.</b>	PhD (Қазақстан)
<b>Балапанов М.Х.</b>	доктор ф.-м.ғ.д., проф. (Ресей)
<b>Бахтизин Р.З.</b>	доктор ф.-м.ғ.д., проф. (Ресей)
<b>Гиниятова Ш.Г.</b>	ф.-м.ғ.к. (Қазақстан)
<b>Даулетбекова А.Қ.</b>	ф.-м.ғ.к. (Қазақстан)
<b>Ержанов Қ.К.</b>	ф.-м.ғ.к., PhD (Қазақстан)
<b>Жұмаділов Қ.Ш.</b>	PhD (Қазақстан)
<b>Здоровец М.</b>	ф.-м.ғ.к. (Қазақстан)
<b>Қадыржанов Қ.К.</b>	доктор ф.-м.ғ.д., проф. (Қазақстан)
<b>Кайнарбай А.Ж.</b>	ф.-м.ғ.к. (Қазақстан)
<b>Кутербеков Қ.А.</b>	ф.-м.ғ.д., проф. (Қазақстан)
<b>Лушик А.Ч.</b>	доктор ф.-м.ғ.д., проф. (Эстония)
<b>Морзабаев А.К.</b>	ф.-м.ғ.к. (Қазақстан)
<b>Мырзақұлов Р.Қ.</b>	ф.-м.ғ.д., проф. (Қазақстан)
<b>Нұрахметов Т.Н.</b>	ф.-м.ғ.д., проф. (Қазақстан)
<b>Сауытбеков С.С.</b>	ф.-м.ғ.д., проф. (Қазақстан)
<b>Тлеукенов С.К.</b>	ф.-м.ғ.д., проф. (Қазақстан)
<b>Усеинов А.Б.</b>	PhD (Қазақстан)

*Редакцияның мекенжайы:* 010008, Қазақстан, Астана қ., Сатпаев к-сі, 2,349  
б., Л.Н. Гумилев атындағы Еуразия ұлттық университеті.  
Тел.: +7(7172) 709-500 (ішкі 31-428)  
E-mail: vest\_phys@enu.kz

*Жауапты хатшы, компьютерде беттеген:* А. Нұрболат

**Л.Н. Гумилев атындағы Еуразия ұлттық университетінің хабаршысы.**  
**ФИЗИКА. АСТРОНОМИЯ сериясы**

Меншіктенуші: ҚР БжҒМ "Л.Н. Гумилев атындағы Еуразия ұлттық университеті" ШЖҚ РМК  
Мерзімділігі: жылына 4 рет.

Қазақстан Республикасының Ақпарат және коммуникациялар министрлігімен  
тіркелген. 27.03.2018ж. №16999-ж тіркеу куәлігі.

Тиражы: 25 дана

Типографияның мекенжайы: 010008, Қазақстан, Астана қ., Қажымұқан к-сі, 12/1, 349 б., Л.Н.  
Гумилев атындағы Еуразия ұлттық университеті. Тел.: +7(7172)709-500 (ішкі 31-428)

*Editor-in-Chief*  
Doctor of Phys.-Math. Sciences  
**A.K. Aryngazin** (Kazakhstan)

*Deputy Editor-in-Chief*

**A.T. Akilbekov**, Doctor of Phys.-Math. Sciences,  
Prof. (Kazakhstan)

*Editorial board*

<b>Aldongarov A.A.</b>	PhD (Kazakhstan)
<b>Balapanov M.Kh.</b>	Doctor of Phys.-Math. Sciences, Prof. (Russia)
<b>Bakhtizin R.Z.</b>	Doctor of Phys.-Math. Sciences, Prof. (Russia)
<b>Dauletbekova A.K.</b>	Candidate of Phys.-Math. Sciences, PhD (Kazakhstan)
<b>Giniyatova Sh.G.</b>	Candidate of Phys.-Math. Sciences (Kazakhstan)
<b>Kadyrzhanov K.K.</b>	Doctor of Phys.-Math. Sciences, Prof. (Kazakhstan)
<b>Kainarbay A.Zh.</b>	Candidate of Phys.-Math. Sciences (Kazakhstan)
<b>Kuterbekov K.A.</b>	Doctor of Phys.-Math. Sciences, Prof. (Kazakhstan)
<b>Lushchik A.</b>	Doctor of Phys.-Math. Sciences, Prof. (Estonia)
<b>Morzabayev A.K.</b>	Candidate of Phys.-Math. Sciences (Kazakhstan)
<b>Myrzakulov R.K.</b>	Doctor of Phys.-Math. Sciences, Prof. (Kazakhstan)
<b>Nurakhmetov T.N.</b>	Doctor of Phys.-Math. Sciences, Prof. (Kazakhstan)
<b>Sautbekov S.S.</b>	Doctor of Phys.-Math. Sciences, Prof. (Kazakhstan)
<b>Tleukenov S.K.</b>	Doctor of Phys.-Math. Sciences, Prof. (Kazakhstan)
<b>Useinov A.B.</b>	PhD (Kazakhstan)
<b>Yerzhanov K.K.</b>	Candidate of Phys.-Math. Sciences, PhD(Kazakhstan)
<b>Zdorovets M.</b>	Candidate of Phys.-Math. Sciences (Kazakhstan)
<b>Zhumadilov K.Sh.</b>	PhD (Kazakhstan)

*Editorial address:* L.N. Gumilyov Eurasian National University, 2, Satpayev str., of. 349, Astana,  
Kazakhstan, 010008  
Tel.: +7(7172) 709-500 (ext. 31-428)  
E-mail: vest\_phys@enu.kz

*Responsible secretary, computer layout:* A.Nurbolat

**Bulletin of L.N. Gumilyov Eurasian National University.**  
**PHYSICS. ASTRONOMY Series**

Owner: Republican State Enterprise in the capacity of economic conduct "L.N. Gumilyov Eurasian National University" Ministry of Education and Science of the Republic of Kazakhstan

Periodicity: 4 times a year

Registered by the Ministry of Information and Communication of the Republic of Kazakhstan.

Registration certificate №16999-ж from 27.03.2018.

Circulation: 25 copies

Address of printing house: L.N. Gumilyov Eurasian National University, 12/1 Kazhimukan str., Astana, Kazakhstan 010008;

tel.:+7(7172) 709-500 (ext. 31-428)

*Главный редактор*  
доктор ф.-м.н.  
**А.К. Арынгазин** (Казахстан)

*Зам. главного редактора*

**А.Т. Акилбеков**, доктор ф.-м.н.  
профессор (Казахстан)

*Редакционная коллегия*

<b>Алдонгаров А.А.</b>	PhD (Казахстан)
<b>Балапанов М.Х.</b>	ф.-м.н., проф. (Россия)
<b>Бахтизин Р.З.</b>	ф.-м.н., проф. (Россия)
<b>Гиниятова Ш.Г.</b>	кандидат ф.-м.н. (Казахстан)
<b>Даулетбекова А.К.</b>	кандидат ф.-м.н., PhD (Казахстан)
<b>Ержанов К.К.</b>	кандидат ф.-м.н., PhD (Казахстан)
<b>Жумадилов К.Ш.</b>	доктор PhD (Казахстан)
<b>Здоровец М.</b>	к.ф.-м.н. (Казахстан)
<b>Кадыржанов К.К.</b>	ф.-м.н., проф. (Казахстан)
<b>Кайнарбай А.Ж.</b>	кандидат ф.-м.н. (Казахстан)
<b>Кутербеков К.А.</b>	доктор ф.-м.н., проф. (Казахстан)
<b>Лущик А.Ч.</b>	ф.-м.н., проф. (Эстония)
<b>Морзабаев А.К.</b>	кандидат ф.-м.н. (Казахстан)
<b>Мырзакулов Р.К.</b>	доктор ф.-м.н., проф. (Казахстан)
<b>Нурахметов Т.Н.</b>	доктор ф.-м.н., проф. (Казахстан)
<b>Сауытбеков С.С.</b>	доктор ф.-м.н., проф. (Казахстан)
<b>Тлеукенов С.К.</b>	доктор ф.-м.н., проф. (Казахстан)
<b>Усеинов А.Б.</b>	PhD (Казахстан)

*Адрес редакции:* 010008, Казахстан, г. Астана, ул. Сатпаева, 2, каб. 349, Евразийский национальный университет имени Л.Н. Гумилева.  
Тел.: (7172) 709-500 (вн. 31-428)  
E-mail: vest\_phys@enu.kz

*Ответственный секретарь, компьютерная верстка:* А. Нурболат

**Вестник Евразийского национального университета имени Л.Н. Гумилева.**  
**Серия ФИЗИКА. АСТРОНОМИЯ**

Собственник РГП на ПХВ "Евразийский национальный университет имени Л.Н. Гумилева" МОН РК  
Периодичность: 4 раза в год

Зарегистрирован Министерством информации и коммуникаций Республики Казахстан.

Регистрационное свидетельство №16999-ж от 27.03.2018г.

Тираж: 25 экземпляров

Адрес типографии: 010008, Казахстан, г. Астана, ул. Кажимукана, 12/1, Евразийский национальный университет имени Л.Н. Гумилева. тел.: +7(7172)709-500 (вн. 31-428)

Л.Н. ГУМИЛЕВ АТЫНДАҒЫ ЕУРАЗИЯ ҰЛТТЫҚ УНИВЕРСИТЕТІНІҢ  
ХАБАРШЫСЫ. ФИЗИКА. АСТРОНОМИЯ сериясы

№1(126)/2019

МАЗМҰНЫ

<i>Балахаева Р., Акылбеков А., Даулетбекова А., Козловский А., Баймуханов З., Гиниятова Ш., Усеинов А., Садуова Б., Карим К.</i> SiO <sub>2</sub> /Si тректі темплэйтте екі типті электролит негізінде CdTe нанокластерлерін қалыптастыру	8
<i>Дукенов А.Б., Усеинов А.Б., Акылбеков А.Т., Даулетбекова А.К., Здоровец М.В., Ыбыраев Н.С., Оралбеков Н.Б.</i> Таза және кобальтпен легирленген MgF <sub>2</sub> -нің электрондық қасиеттерін Ab-initio есептеулері	15
<i>Доломатов М.Ю., Шуткова С.А., Шарипов Т.И., Бахтизин Р.З., Ишниязов З.З., Нураxметов Т.Н., Салиходжа Ж.М.</i> Мұнай асфальтені нанобөлшектерінің молекулалық және супрамолекулалық құрылымының ерекшеліктері	23
<i>Кайнарбай А. Ж., Нураxметов Т.Н., Юсупбекова Б., Кайнарбаева А., Турмаханбетова А., Базарбаева.Г.Е., Абдраман Б.</i> Биологиядан бастан күн энергетикасына шейін кең қолданыс табатын CdSe/CdS гетероқұрылымдардың алу әдістемесін жасау	32
<i>Мадиярова А.Е., Разина О.В., Цыба П.Ю.</i> f-эссенциялы Эйнштейн-Картан гравитация моделі	38
<i>Ногай А.С., Кутербеков К.А., Бекмырза К.Ж., Нураxметов Т.Н., Кабышев А.М., Кумисбек А., Жеткенбай А., Айдарбеков Н., Сулейменов А.</i> Жанармай жасушалары үшін кобальт халькогенидінің негізінде катализаторларды синтездеу және зерттеу	48
<i>Нураxметов Т.Н., Бахтизин Р.З., Салиходжа Ж.М., Жунусбеков А.М., Кайнарбай А.Ж., Дауренбеков Д.Х., Садыкова Б.М., Жанылысов К.Б., Юсупбекова Б.Н.</i> Сілтілі металл сульфаттарының зоналық құрылымы	56
<i>Санг Мей Ли, Босунг Шин, А.Сейтжан, А.Мырзагалиева, Б.Медеубаева</i> Брэгг торларына негізделген оптофлюидтық сенсорлар	67
<i>Саттинова З.К.</i> Құю қондырғысының сақиналы каналында бериллий тотығы термопласт шликерінің изотермиялық емес қату процесін модельдеу	81
<i>Тлеукенов С.К., Балабеков К.Н., Жалғасбекова З.К.</i> Ромбылық кристалдардағы топтық жылдамдық пен электромагниттік энергия ағыны	90

BULLETIN OF L.N. GUMILYOV EURASIAN NATIONAL UNIVERSITY. PHYSICS.  
ASTRONOMY SERIES

№1(126)/2019

CONTENTS

---

<i>Balakhayeva R., Akilbekov A., Dauletbekova A., Kozlovskii A., Baimukhanov Z., Giniyatova Sh., Usseinov A., Saduova B., Karim K.</i> Creation of CdTe nanoclusters in SiO <sub>2</sub> /Si track templates using two types of electrolyte	8
<i>Dukenov A.B., Usseinov A.B., Akilbekov A.T., Dauletbekova A.K., Zdorovets M.V., Ybyraev N.S., Oralbekov N.B.</i> Ab-initio calculations of the electronic properties of pure and cobalt doped MgF <sub>2</sub>	15
<i>Dolomatov M.Yu., Shutkova S.A., Sharipov T.I., Bakhtizin R.Z., Ishniyazov Z.Z., Nurakhmetov T.N., Salikhodzha Z.M.</i> Band structure of alkali metal sulfates	23
<i>Kainarbai A.Zh., Nurakhmetov T.H., Usupbekova B., Kainarbaeva A., Turmakhanbetova A., Bazarbayeva.G., Abdraman B.</i> Wide application areas from biology until solar cell heterojunction CdSe/CdS synthesis method	32
<i>Madiyarova A.E., Razina O.V., Tsyba P.Yu.</i> Einstein-Cartan gravity model with f-essence	38
<i>Nogai A.S., Kuterbekov K.A., Bekmyrza K.Zh., Nurakhmetov T.N., Kabyshev A.M., Kumisbek A., Zhetkenbay A., Aidarbekov N., Suleimenov A.</i> Synthesis and Investigation of Catalysts Based on Cobalt Chalcogenide for Fuel Cells	48
<i>Nurakhmetov T.N., Bakhtizin R.Z., Salikhodja Z.M., Zhunusbekov A.M., Kainarbay A.Z., Daurenbekov D.H., Sadykova B.M., Zhangylysov K.B., Yussupbekova B.N.</i> Band structure of alkali metal sulfates	56
<i>Sang Mae Lee, Bosung Shin, A.Seitkan, A.Myrzagaliyeva, B.Medeubayeva</i> Optofluidic sensors based on bragg gratings	67
<i>Sattinova Z.K.</i> Simulation of the process of non-isothermal crystallization process of thermoplastic slurry BeO in the annular cavity of the casting plant	81
<i>Tleukenov S.K., Balabekov K.N., Zhalgasbekova Z.K.</i> Group velocity and flow of electromagnetic energy in rhombic crystals	90

ВЕСТНИК ЕВРАЗИЙСКОГО НАЦИОНАЛЬНОГО УНИВЕРСИТЕТА  
ИМЕНИ Л.Н.ГУМИЛЕВА. Серия ФИЗИКА. АСТРОНОМИЯ

№1(126)/2019

СОДЕРЖАНИЕ

<i>Балахаева Р., Акылбеков А., Даулетбекова А., Козловский А., Баймуханов З., Гиниятова Ш., Усеинов А., Садуова Б., Карим К.</i> Создание нанокластеров CdTe в трековых темплэйттах SiO <sub>2</sub> /Si с использованием двух типов электролита	8
<i>Дукенов А.Б., Усеинов А.Б., Акылбеков А.Т., Даулетбекова А.К., Здоровец М.В., Ыбыраев Н.С., Оралбеков Н.Б.</i> Ab-initio расчеты электронных свойств чистого и легированного кобальтом MgF <sub>2</sub>	15
<i>Доломатов М.Ю., Шуткова С.А., Шарипов Т.И., Бахтизин Р.З., Ишниязов З.З., Нурахметов Т.Н., Салиходжа Ж.М.</i> Особенности молекулярной и надмолекулярной структуры наночастиц нефтяных асфальтенов	23
<i>Кайнарбай А. Ж., Нурахметов Т.Н., Юсупбекова Б., Кайнарбаева А., Турмаханбетова А., Базарбаева.Г.Е., Абдраман Б.</i> Разработка методик получения гетероструктур CdSe/CdS широкого круга применения: от биологии до солнечной энергетики	32
<i>Мадиярова А.Е., Разина О.В., Цыба П.Ю.</i> Модель гравитации Эйнштейна-Картана с f-эссенцией	38
<i>Ногай А.С., Кутербекоев К.А., Бекмырза К.Ж., Нурахметов Т.Н., Кабышев А.М., Кумисбек А., Жеткенбай А., Айдарбеков Н., Сулейменов А.</i> Синтез и исследование катализаторов на основе халькогенида кобальта для топливных элементов	48
<i>Нурахметов Т.Н., Бахтизин Р.З., Салиходжа Ж.М., Жунусбеков А.М., Кайнарбай А.Ж., Дауренбеков Д.Х., Садыкова Б.М., Жанылысов К.Б., Юсупбекова Б.Н.</i> Зонная структура сульфатов щелочных металлов	57
<i>Санг Мей Ли, Босунг Шин, А.Сейтжан, А.Мырзагалиева, Б.Медеубаева</i> Оптофлюидные датчики на основе Брэгговских решеток	67
<i>Саттинова З.К.</i> Моделирование процесса неизотермического отверждения термопластичного шликера BeO в кольцевом канале установки литья	81
<i>Тлеуженов С.К., Балабеков К.Н., Жалгасбекова З.К.</i> Групповая скорость и поток электромагнитной энергии в ромбических кристаллах	90

Sang Mae Lee<sup>1,4</sup>, Bosung Shin<sup>2</sup>, A.Seitkan<sup>3</sup>, A.Myrzagaliyeva<sup>4</sup>, B.Medeubayeva<sup>5</sup>

<sup>1</sup> *Engineering Research Center for Net Shape and Die Manufacturing, Pusan, S. Korea*

<sup>2</sup> *College of Nanotechnology, Pusan National University, Pusan, S. Korea*

<sup>3</sup> *International Science Complex «Astana», Astana, Kazakhstan*

<sup>4</sup> *L.N.Gumilyov Eurasian National University, Astana, Kazakhstan*

<sup>5</sup> *S. Amanzholov East Kazakhstan State University, Ust-Kamenogorsk, Kazakhstan*  
(E-mail: <sup>1</sup> smlee@pusan.ac.kr, <sup>3</sup> seitkanainur.77@mail.ru, <sup>4</sup> anara\_vkgu@mail.ru)

### Optofluidic sensors based on bragg gratings

**Abstract:** This paper describes the optical planar waveguide Bragg grating including silica waveguide, polymeric waveguide, and silicon-on-insulator (SOI) waveguide in application for biosensors. Topic includes design and fabrication of the etched planar waveguide single Bragg grating and the polymeric & SOI planar waveguide Bragg grating Fabry-Perot cavity optical refractive index sensors. It is shown that the higher the refractive index of the medium, the more the resonance peak of a sensor moves. The Bragg grating cavity is more sensitive than the single Bragg grating at the same wavelength area. Therefore, a Bragg grating with a cavity area is more sensitive than the single Bragg grating. In addition, the shorter FP cavity waveguide could reveal much more sensitivity than the longer one, which will be promising to scale down the sensors to be so nanosized that extremely low concentration of molecules can be detected.

The sensor developed in this study shows much promise in the application of biomedical diagnostics such as a biosensor and/or environmental monitoring biochemical sensors.

**Keywords:** Fabry-Pérot Bragg gratings cavity, refractive index sensors, microfluidics

DOI: <https://doi.org/10.32523/2616-68-36-2019-126-1-68-81>

**Introduction.** The most common Bragg grating is induced in the core of a photosensitive fiber with a periodic index modulation exposed by the laser beam interference [1]. Similar techniques have been applied to form photoinduced Bragg gratings in integrated glass channel waveguides [2]. Planar optical waveguide gratings have been used in variety of applications for optical components like couplers, beam splitters, modulators, filters, and sensors, etc.[3,4] These devices are used to control lasers, spectrometers, and the measurement of the wavelength of light in a wide variety of fields. Since the 1990s, optical waveguide Bragg gratings have also been employed in optical sensors to measure both the mechanical and electrical conditions. This allows for the smaller footprint, lower weight, and simplification of measurement systems, in particular, because the resultant measurements can be encoded by Bragg resonant wavelength.

Author has recently developed high sensitivity and high selectivity fiber Bragg grating sensors [5-10]. For these sensors, the cladding and even part of the core of the fiber were completely removed. Sensors were characterized to have sensitivity to changes of the index of refraction of order  $7 \times 10^{-7}$ . The sensor was typically etched down to a diameter of 5  $\mu\text{m}$  and can be detected with a wavelength change of 1 pm or less in the center frequency of our Bragg grating sensor. This sensor was demonstrated to detect monolayer deposition of small molecules of mass of order 250 Da. In particular, we have studied the real-time attachment of one monolayer of 3-Aminopropyltriethoxysilane (APTES) and 3-aminopropyl-methyl diethoxysilane (APMDS) on the sensor and have demonstrated the formation of a water layer on the sensor. We have also studied the covalent monolayer attachment of glucose to the sensor and the hybridization of DNA. We extend this work by converting our fiber sensor to a planar single-mode ultra-high  $Q$  microcavity sensor on polymeric waveguides by forming a single-mode planar Bragg grating Fabry-Pérot (FP) cavities. In order to realize high finesse planar Bragg grating FP cavities, we will have to develop the technology for fabricating two spatially separated identical gratings.

With regard to biosensors, label-free biodetection is possible by measuring the varying effective refractive index of the optical waveguide that occurs from biointeraction between antibodies/probe and antigen/target molecules. This takes place on the surface of the core layer of the optical



waveguide. This occurs by means of the evanescent field penetrating the optical waveguide Bragg grating when light is incident on the optical waveguide Bragg grating. This sensor for biodetection can be made by carving the grating on the surface of the core layer of the optical waveguide to multiplex the Bragg grating wavelengths. Thus, the characteristics of Bragg grating sensors can be used to diagnose human diseases by detecting proteins in the human blood as biomarks. In addition, Bragg grating technology has the potential to be applied in a variety of other areas as well, such as the monitoring of food quality in manufacturing processes in the food industry, chemical and biological weapons-related measurement and detection activities in the military, and air and water quality measurements in the environmental protection industries.

The results from this investigation will also be used to develop a small sensor device with ultra-high sensitivity, which is achieved by forming an FP cavity between two Bragg gratings on the planar waveguide. The FP Bragg grating cavity structure allows for the development of ultra-high sensitive sensors. The sensitivity of the sensor has the potential to be further improved by generating sharper resonance peaks than a single Bragg grating. Shifts in optical resonant peaks due to the change of optical path length between two identical gratings arise from the change in the effective refractive index of an FP Bragg grating cavity. In this investigation, this is caused by binding immobilized antibodies and antigens, which can then be detected and measured.

In this study, FP Bragg grating cavity sensors will be designed, fabricated, and characterized so that the Bragg grating sensor has expanded to detect temperature and refractive index of medium surrounded planar waveguides such as an etched-silica core waveguide, a polymeric waveguide, and a silicon-on-insulator (SOI) planar waveguide Bragg grating.

**Theoretical Background.** A single planar waveguide Bragg grating This section provides the basic mathematical formalizing that will be used to design and perform data analyses of the proposed planar waveguide etched grating sensor. This section starts by providing the expressions needed to calculate the propagation constants for the slab waveguide in terms of the waveguide geometric and optical properties. Then the coupled mode equations are used to determine the grating properties are presented. The waveguide geometry of interest in this paper is illustrated in Figure 1, and consists of a core bounded by air above and core below. This waveguide is fabricated on a silicon substrate. The refractive indices of the air, and the core and cladding layers are denoted by  $n_1$ ,  $n_2$ , and  $n_3$ , respectively and core thickness is given by  $t_g$ . Also seen in Figure 1(a) are the etched corrugations of pitch and depth  $a$ .

The most important parameter in the design of Bragg grating in waveguides is effective index. This effective index is found in the usual way [11] by solving the wave equation and applying continuity boundary conditions at the respective core/cladding interfaces of the waveguide shown in Figure 1(a).

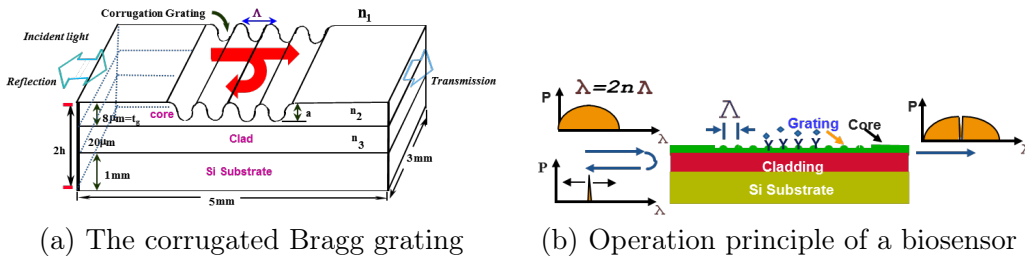


FIGURE 1 – Schematic of the corrugated Bragg grating on the silica planar waveguide as a biosensor

The guided modes have propagation constant  $\beta_s$  such that  $k_0 n_3 < \beta_s < k_0 n_2$ , where  $n_1 < n_3$ . This solution process leads to the following transcendental equation that yields the propagation constant:

$$\tanh t_g = \frac{p + q}{h(1 - pq/h^2)} \quad (1)$$

where  $h = (n_g k_0^2 - \beta_s^2)^{\frac{1}{2}}$ ,  $q = (\beta_s^2 - n_1^2 k_0^2)^{\frac{1}{2}}$ ,  $p = (\beta_s^2 - n_3^2 k_0^2)^{\frac{1}{2}}$  and  $k_0 = \bar{\omega}/c = 2\pi/\gamma$ .

Given a set of the refractive indices  $n_1$ ,  $n_2$ , and  $n_3$  and the waveguide thickness,  $t_g$ , of the planar waveguide, and the source wavelength,  $\gamma$ . Eq. (1) in general yields a number of solutions for the propagation constant,  $\beta_s$ . However, the source wavelength and the waveguide thickness are restricted in the present study such that only one propagation mode is supported, and therefore Eq. (1) has only one solution of interest. As a result, the effective index of the planar waveguide is given by  $n_{eff} = \beta_s \lambda / 2\pi$ .

The corrugated structure into the waveguide leads to a corresponding periodic perturbation of the refractive index distribution. Each groove of the grating acts like a weak mirror, and the cumulative effect of all of the weak reflectors results in a very strong combined reflection centered on what is known as the Bragg wavelength. The Bragg wavelength is related to the effective index calculated above and grating period,  $\Lambda$ , by [11]

$$\lambda_b = 2n_{eff}\Lambda \quad (2)$$

when expressed in terms of the propagation constant is given by

$$\lambda_b = \beta_s \lambda \Lambda / 2 \quad (3)$$

where  $\lambda_b$  is the Bragg wavelength and  $\lambda$  is the central wavelength of the optical source. The fraction of power couple to the backward-propagation mode ( $-\beta_s$ ), i.e. the grating reflectivity is given by [11]

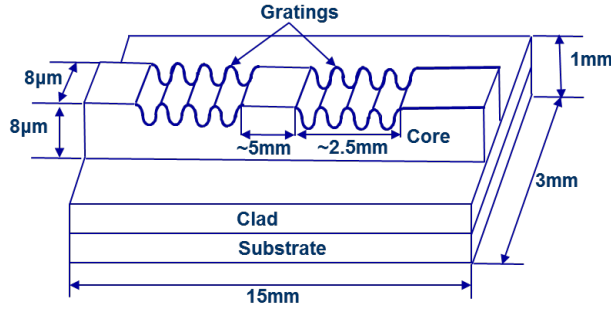
$$\mathfrak{R}_{max} = \tanh^2(\kappa L) \quad (4)$$

where  $L$  is the length of the Bragg grating and  $\kappa$  is the coupling coefficient.

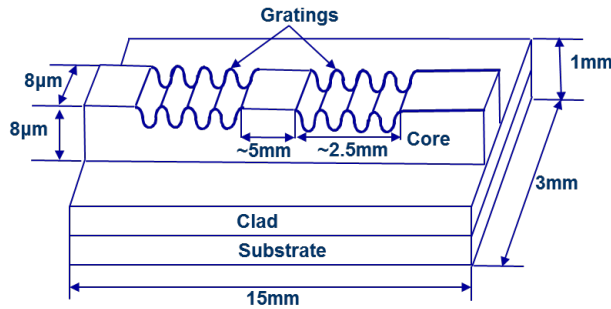
Figure 1(a) shows the principle of biosensor about how to detect biochemical. The antibody bound on the surface of the grating captures the antigen/target molecules surrounded on the Bragg grating, and then the Bragg grating wavelength due to change of effective refractive index of waveguide shifts in order to detect biochemical.

Planar waveguide Bragg grating Fabry–Pérot (FP) cavity

Figure 2 (a) illustrates a schematic of two identical gratings for forming the FP cavity. The length of a single Bragg grating inscribed on the single-mode core channel waveguide is 2.5 mm. The length of the FP Bragg grating cavity formed by the identical dual Bragg grating is 5 mm.



(a) The corrugated planar waveguide Bragg grating Fabry–Pérot (FP) cavity



(b) Operation principle of a biosensor

FIGURE 2 – Schematic of the corrugated planar waveguide Bragg grating Fabry–Pérot (FP) cavity

For the FP Bragg grating cavity formed by two identical planar waveguide Bragg gratings, we assume that the effective cavity length  $L_{FP}$  is constant and that the wavelength of a resonance mode,  $\lambda_R$ , must satisfy [11]

$$m\lambda_R/2 = n_{eff}L_{FP} \quad (5)$$

where  $m$  is the modal number. When the refractive index of the ambient medium on the bio-sensitive area, i.e., Fabry-Perot cavity area at which biochemical agent is bound to detect biochemical target, as shown in Figure 2(b), is changed, the effective index of the effective cavity length  $L_{FP}$  is changed and thus the resonance wave of  $m$ 'th mode is shifted.

The period of the single grating on the polymeric planar waveguide was designed to be 538 nm so that the Bragg wavelength of the single grating should be obtained to be around 1550 nm, whereas that of SOI waveguide was designed to be 228 nm. The length of the single grating was 2.5 mm, and the depth of the grating with a sine-waved pattern was designed to be  $\sim 150$  nm so that about 30% of the light can be reflected from the single grating

**Experiment.** Silica planar waveguide Bragg grating

The planar waveguides used in these studies are fabricated by Photonics Integrated Research, Inc (PIRI) using hydrolysis deposition. These waveguides are originally manufactured with an 8  $\mu\text{m}$  thick germanium doped silica core with a 20  $\mu\text{m}$  silica undercladding sitting on top of a 1 mm thick silicon substrate. The refractive indices of the core layer and underclad layer are 1.4495 and 1.4452 measured at 1550nm wavelength, respectively. The waveguide blank is diced parallel or perpendicular to the straight edge of the silicon substrate into 3 mm long x 5 mm wide waveguides.

Bragg gratings are produced in the planar waveguides using photoresist based optical lithography techniques. This process starts by first spin coating a 50 % dilution of Shipley S1400-17 photoresist onto the surface of the waveguide using 6000 rev/min for 30 seconds. The resulting  $\sim 220$  nm layer of photoresist is soft baked for 35 min at  $96^\circ\text{C}$  to ensure complete removal of thinning solvents. A phase mask printing method is then used to fabricate Bragg gratings. A phase mask is used to produce two equal amplitude interfering optical beams, as shown in Figure 3. The interfering pattern is expanded in size so that interference occurs in a 2 mm smaller diameter circular region. Grating are typically written in the planar waveguide coated by exposing the photoresist to the 244 nm UV light for 5 sec to 8 sec with a laser powers ranging from 2 mW to 3 mW. The phase mask used in this study had a pitch of 0.5278  $\mu\text{m}$  and 15.4 % transmission of zeroth order diffraction. This phase mask pitch corresponds to a Bragg wavelength somewhat near 1550 nm, depending on the effective index of the waveguide. Once exposed, the waveguides are baked for 12 min at  $120^\circ\text{C}$ .

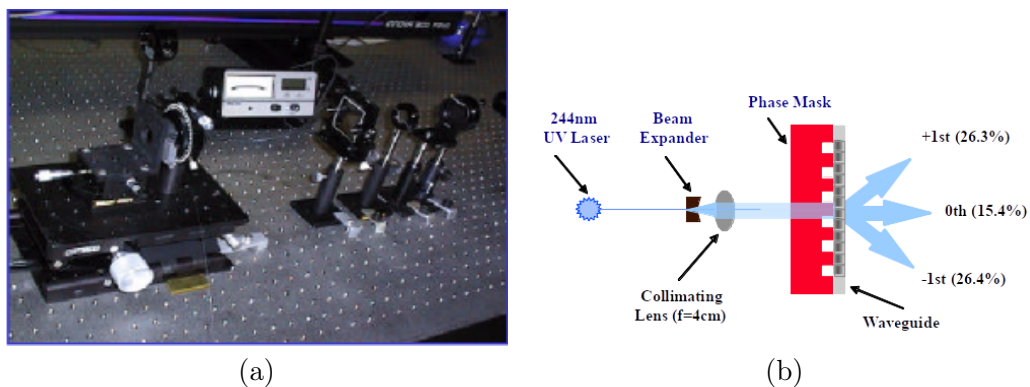


FIGURE 3 – (a) Photo and (b) schematic of phase mask direct imprinting of Bragg grating

Also seen in Figure 4 are the next step at which the grating fabrication process involves developing the photoresist for typically 12 sec with a developer made of one part Shipley Microposit Concentrate and one part deionized water to form resist gratings. The waveguide are then rinsed in deionized water for 30 sec and then blown dry with Nitrogen gas. After developing, the substrates are baked for 30 min at  $120^\circ\text{C}$ , and then are wet-chemically etched for 75 seconds to a depth of 130 nm to 200 nm using bufferd HF. The photoresist is next stripped using solvents such as Shipley S1165 remover or acetone.

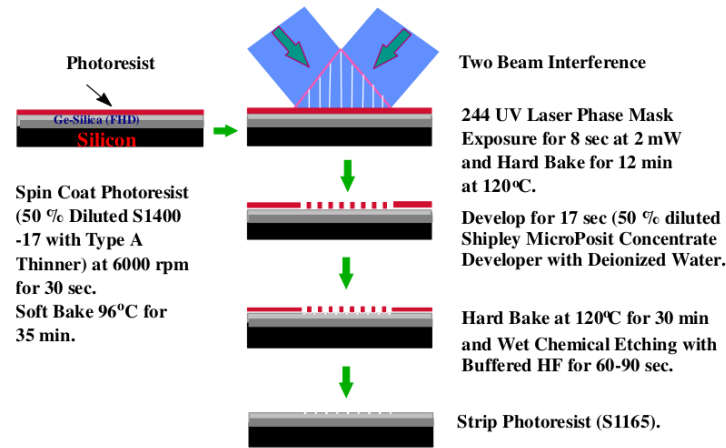


FIGURE 4 – Schematic of fabrication procedures for silica planar waveguide Bragg grating

### Polymeric planar waveguide Bragg grating

The period of the single grating was designed to be 538 nm so that the Bragg wavelength of the single grating should be obtained to be around 1550 nm. The length of the single grating was 2.5 mm, and the depth of the grating with a sine-waved pattern was designed to be  $\sim 150$  nm so that about 30% of the light can be reflected from the single grating.

Polymeric materials are used to form the planar optical waveguide which consists of the core layer (ZPU 13-440,  $n = 1.440$ , Chemoptic, South Korea) and the cladding layer (ZPU 13-436,  $n = 1.436$ , Chemoptic, South Korea). A cladding material, ZPU13-436, was spin coated on a 4 in. silicon wafer to be 20- $\mu\text{m}$  thick. After 3 min of UV curing under a Halogen lamp with  $9\text{ mW}/\text{cm}^2$  at 370 nm peak wavelength, the polymer was hard baked at  $160^\circ\text{C}$  for 30 min. An optical waveguide pattern was defined on the cladding layer by conventional photolithography using an AZ5214 photoresist. After the cladding layer with a thickness of 20  $\mu\text{m}$  was deposited on the silicon substrate, the core channel groove of 8  $\mu\text{m}$  wide and 8  $\mu\text{m}$  high on the clad layer was made by a reactive ion etching to implement single-mode optical waveguide. The etch rate of the AZ5214 was slower than that of the ZPU polymer. Then Chemoptic's material, ZPU 13- 440, was spin coated on the clad layer to form a core channel waveguide. The core layer was holographically exposed by two equal beams to form Bragg gratings on the core layer of the optical waveguide and then the exposed substrate was dry etched to form the corrugated gratings by the conventional lithographic technique, as shown in Figure 5.

### A Silicon-on-insulator (SOI) planar waveguide Bragg grating Fabry-Pérot (FP) cavity

SOI wafers were commercially available. SOI wafers consist of an oxide thickness of 1  $\mu\text{m}$  ( $n_2 = 1.46$ ) and a silicon thickness of 5  $\mu\text{m}$  ( $n_1 = 3.5$ ). The length of the single grating was 2.5 mm, and the Bragg grating with a depth of 150 nm is etched into the top of the ridge which is etched down to a depth of 3  $\mu\text{m}$ , so that about 30% of the light can be reflected from the single grating. The grating strength, coupling coefficient, depends upon the waveguide dimensions with a fixed grating depth.

The period of the single grating was designed to be 223 nm so that the Bragg wavelength of the single grating should be obtained to be around 1550 nm. Figure 6 outlines fabrication procedures of the ridge waveguide and the electron-beam lithographic sequence that was employed to pattern the Bragg gratings on the top of silicon ridge waveguides.

### The butt coupling technique

The final step in the grating sensor fabrication is to prepare the edges of the waveguides to facilitate coupling light into the sensor and to provide for visual inspection. This is done by first cleaning the diced waveguide with solvents (acetone and methanol) and then blowing to dry it with Nitrogen gas. The waveguide is mounted on a jig with the heat-melt wax and is polished using 1 micron and 0.3 micron aluminum oxide on a polishing wheel rotating at 1500 rev/min, respectively. The polishing is done using 0.1 micron diamond sheet. Visually inspection using a transmission

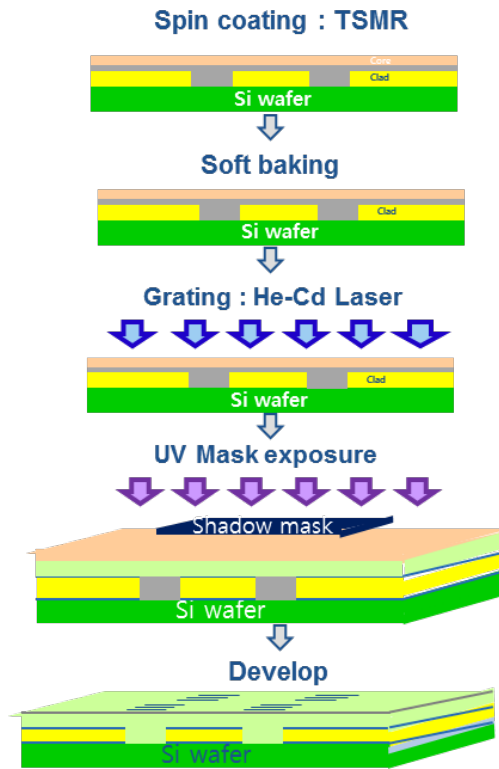


FIGURE 5 – Schematic of fabrication procedures for FP Bragg grating cavity

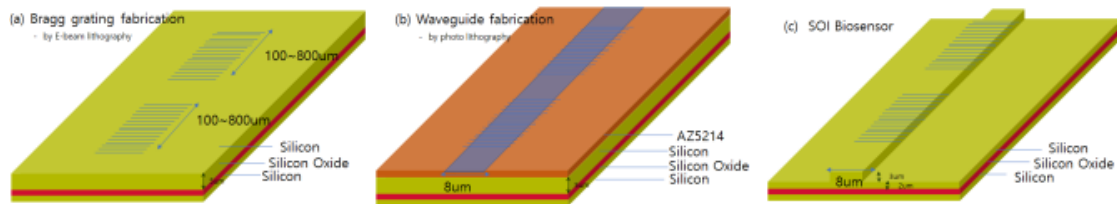


FIGURE 6 – Schematic of fabrication procedures of the ridge waveguide and the electron-beam lithographic sequence to pattern the FP Bragg grating cavity

optical microscope is used to control the surface roughness of the waveguide facet. Finally, the polished waveguide is thoroughly cleaned in acetone for 30 min at  $100^{\circ}C$  to remove residual wax.

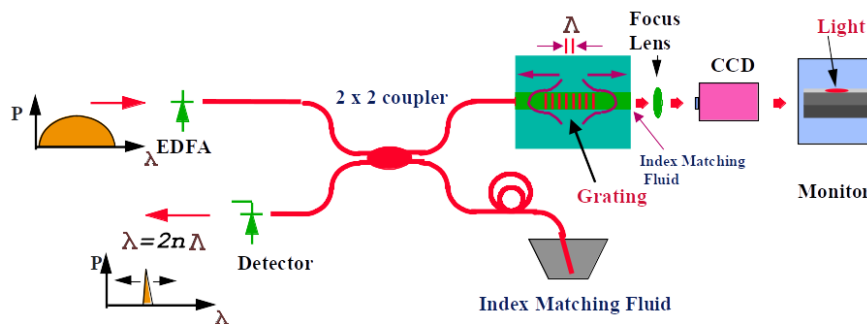


FIGURE 7 – The schematic of the coupling technique used to investigate spectral characteristics of planar waveguide Bragg gratings

The etched grating sensor is interrogated by using a single mode optical fiber to carry the light to and from the sensors. This means that efficient fiber to waveguide coupling techniques be used. Typical tolerance of lowest insertion loss are offset less than  $\pm 2 \mu m$  and an angular misalignment

less than  $0.5^\circ$ . The butt coupling technique shown schematically in Figure 7 was used to achieve the efficient fiber to waveguide coupling.

Amplified Spontaneous Emission (ASE) from an Erbium Doped Fiber Amplifier (EDFA) is launched into one arm of a 3 dB coupler fabricated with optical fiber having a mode field diameter of  $9.5 \mu\text{m}$ . One arm of the coupler is index matched to prevent back reflection and the other arm is butt coupled into the waveguide. Light reflected from the waveguide is directed by the  $2 \times 2$  coupler to an optical spectrum analyzer. The first step of the alignment process involves replacing the EDFA with a Helium Neon laser and imaging the transmitted near-field beam appearing at the back facet of the waveguide with a CCD camera. The Helium Neon laser is used because its wavelength falls within the spectral bandwidth of the CCD camera. The optical fiber and the planar waveguide are first aligned visually, and then a five degree of freedom monopositioning stage is used to adjust the location and orientation of the waveguide, while viewing the near field image on a video monitor. This process is stopped when the near-field image intensity is maximized, and its shape symmetric and centrally located. The He-Ne laser is then replaced with an EDFA, and the gap between the optical fiber and waveguide is reduced while monitoring the reflected spectrum in the optical spectrum analyzer. Optimum positioning is achieved when the spectrum associated with the air gap Fabry-Perot interferometer formed between the optical fiber and the waveguide facet is minimized. Index matching liquid (refractive index, 1.4587, Cargille Company) is applied to the back facet of the waveguide sensor to prevent a Fabry-Perot cavity from forming between the two waveguide facets.

To measure the shift in the optical Bragg grating wavelength when the single Bragg grating and the FP cavity sensor are covered by fluids to be measured, erbium-doped fiber amplifier (LiComm, South Korea) and optical spectrum analyzer (ANDO, Japan) with a 0.05-nm wavelength resolution were used. For the FP grating cavities, fluids were dropped by a pipette on the surface of the cavity between the FP grating cavities because of measuring the fluid- induced change in optical path length of FP cavity, whereas fluids were dropped on the surface of the Bragg grating..

### Results and Discussion. Silica planar waveguide Bragg grating

The gratings investigated here typically have a 537.8 nm period as measured using an atomic force microscopy (AFM) shown in Figure 8(a). It is noted that the distance between the phase mask and the planar waveguide has to be minimized without causing the damage of the phase mask to minimize the above noted multiple reflections.

The reflected spectrum produced by a grating 2 mm long, 200 nm deep (typical values) etched into a planar waveguide was measured with the optical spectrum analyzer as well, as shown in Figure 8(b). The reflected spectrum of the reflection from the planar waveguide gratings generally appeared bifurcated due to geometry-induced birefringence. Therefore, an output fiber polarizer is used to isolate the Bragg condition from one polarization mode. In order to examine temperature sensing performance of the etched planar waveguide Bragg grating sensor, the planar waveguide Bragg grating was heated with temperature ranging from  $20^\circ\text{C}$  to  $200^\circ\text{C}$  using the heating tape which folds the translating block mounting the planar waveguide. Figure 8(c) illustrates calculation leads to a proportionality factor between the change in wavelength and temperature of  $0.0137 \text{ nm}/^\circ\text{C}$ . For comparison, the proportionality factor for a  $\sim 1550 \text{ nm}$  photorefractive grating written in an optical fiber is  $0.0132 \text{ nm}/^\circ\text{C}$ .

#### Polymer planar waveguide Bragg grating

##### Single grating

Figure 9 shows the spectral change of a single Bragg grating. Each spectrum was measured in air ( $n = 1.00$ ), water ( $n = 1.33$ ), and IPA ( $n = 1.37$ ). The shifted wavelength was measured to be 1547.099, 1547.307, and 1547.341 nm in air, when water was dropped on the single grating, and in IPA, respectively. Water and IPA induced shifts in the wavelength to the right were measured to be  $\sim 0.208$  and  $0.242 \text{ nm}$ , respectively. The difference in wavelength between water and IPA-induced shifts was  $0.034 \text{ nm}$ . The sensitivity of a sensor ( $\Delta\lambda/\Delta n$ ), i.e., wavelength on the refractive index unit (RIU) between air and water, was  $0.63 \text{ nm} / \text{RIU}$ . The sensitivity between water and IPA was  $0.85 \text{ nm} / \text{RIU}$ .

#### B.2 Planar waveguide Bragg grating Fabry-Pérot (FP) cavity

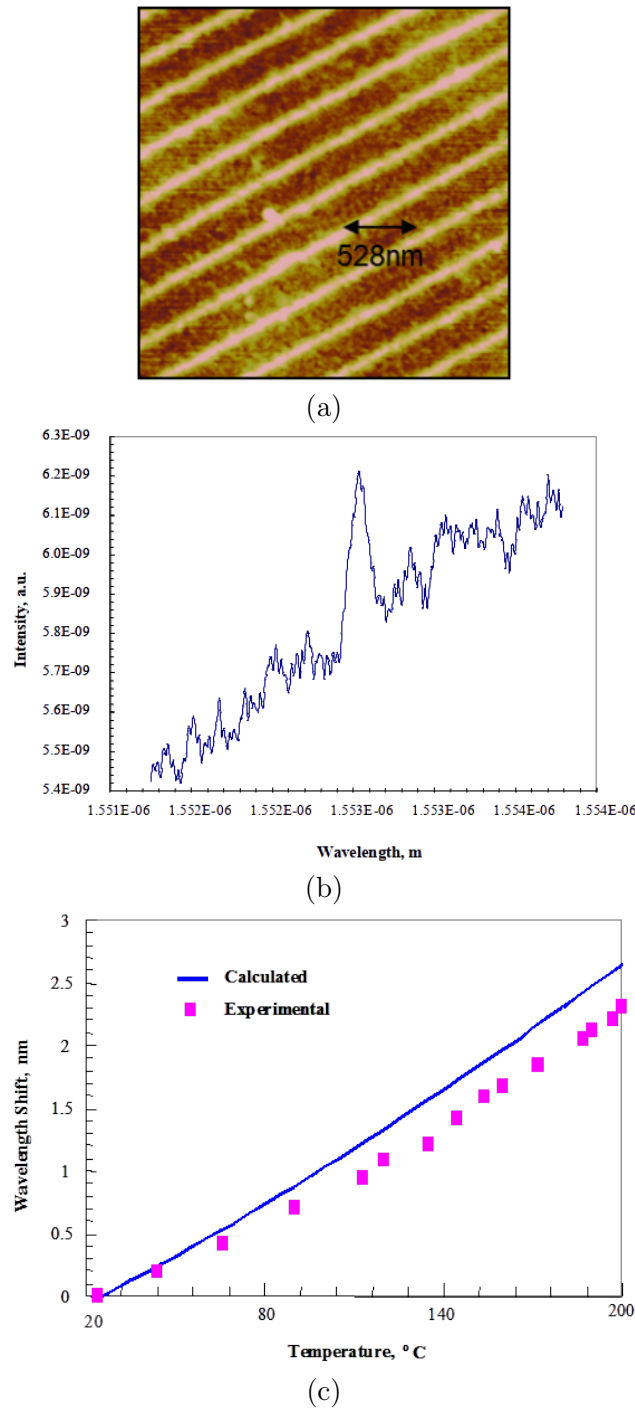


FIGURE 8 – (a) - AFM photo of the wet-etched grating (b) reflection spectrum of etched Bragg grating formed on the planar waveguide (c) shift in Bragg wavelength induced by temperature change

Figure 10 shows the photo of the fabricated FP cavity sensor. Atomic Force Microscopy (AFM) image of Bragg grating was also shown with magnification. The length of the FP cavity ( $L_{FP}$ ) formed by the two identical Bragg gratings is 5 mm. The reflected spectral resonance was measured by coupling the reflected light from the Bragg grating cavity to the detector through the  $2 \times 1$  optical fiber coupler. Before fabricating the 2.5-mm grating, the 5-mm grating was fabricated as a preliminary experiment. However, it was found that the long-length grating caused significant reflection of light from the first Bragg grating and thus the interference between two gratings could not be made without sufficient light transmission from the first grating. To overcome this problem, the Bragg grating length was designed to be 2.5 mm, preventing too much back-reflection from the

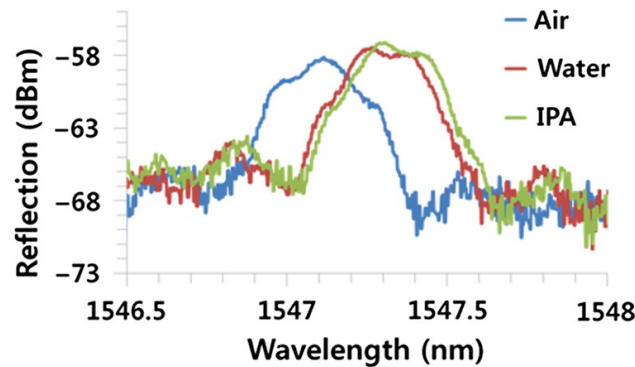


FIGURE 9 – Shift in wavelength of single-mode Bragg grating

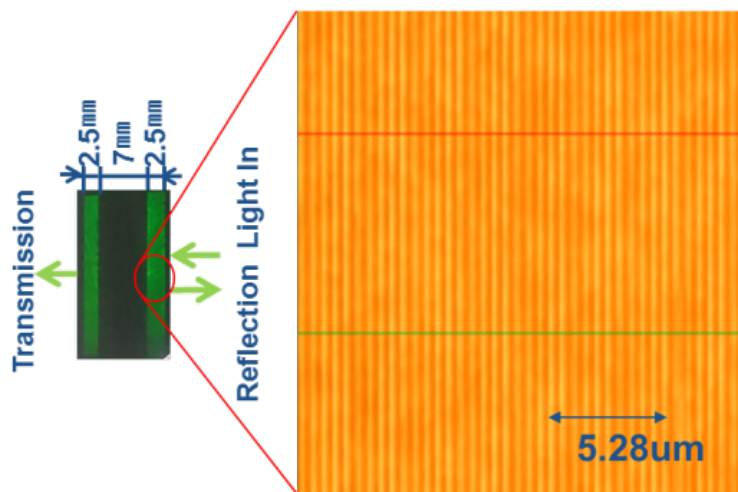


FIGURE 10 – Fabricated FP grating cavity and its AFM image of the grating with 528nm of a period

first grating and thus transmitting  $\sim 60\%$  to  $70\%$  of light from the first Bragg grating to the second Bragg grating. After passing the first Bragg grating, the light travels to the second Bragg grating and is then reflected to the first grating enough to have interference between two gratings, obtaining a high reflectivity from the FP cavity. The measured spectra of the fabricated FP Bragg grating cavity sensor were shown in Figure 11.

The full-width at half maximum (FWHM) of the highest peak of spectrum formed by multiple reflection arisen from Bragg grating FP cavity was measured to be  $0.036$  nm with maximum reflectivity of  $20$  dB at wavelength of  $1547.9$  nm, whereas that of the single grating was  $0.228$  nm. Free spectral range of FP cavity was measured to be about  $0.12$  nm, which was made by interference between the optical waves from the first Bragg grating and the second Bragg grating. In addition, the spectrum was formed symmetrically around the highest peak, as shown in Figure 11.

To measure the sensitivity of the sensor, shifts in the wavelength of the FP cavity sensor were measured when dropping water and methanol on the region (so called the biosensitive area) between the two Bragg gratings. At this moment, no surrounding liquid was dropped on the surface of the grating. A shift in wavelength of spectral resonant peak can be induced by changing the effective refractive index of optical waveguide due to varying the surrounding medium.

The sensitivity of a sensor ( $\Delta\lambda/\Delta n$ ), i.e., wavelength on the RIU between air and water, was  $0.48$  nm / RIU. The sensitivity between water and IPA was  $2.58$  nm / RIU. It is shown that the closer the refractive index of the medium to that of the waveguide, the larger the movement of the peak. This phenomenon is more dominant for an FP cavity than a single grating.

The shifts in wavelength for the single Bragg grating and FP cavity sensors have a similar movement in water, but FP cavity sensors revealed more rapid movement than the single Bragg grating



in methanol. Through these movements, when the refractive index of the surrounding medium approaches closer to the effective refractive index of the waveguide, the wavelength of the FP cavity sensors could be rapidly changed. FP Bragg grating cavity sensors revealed a rapid change of resonant wavelength compared to the single Bragg grating sensor. In addition, a shorter cavity length sensor showed more sensitivity than a longer cavity length sensor.

The planar waveguide with high difference in refractive index between the core and clad layers was made by using the ZPU12-480 (core layer,  $n = 1.480$ ) and ZPU13-436 (clad layer,  $n = 1.436$ ). Figure 11(a) shows the spectral reflectance of the FP cavity sensor with 5 mm of length with a high difference refractive index between core and clad layers when surrounded by air, methanol, and water. The shifted wavelength at the highest value for each spectral reflectance was 1578.332 nm in air, 1579.24 nm in methanol, and 1579.321 nm in water, respectively. This result indicated a 10 times greater shift than low refractive difference cavity sensor by air and water, Figure 11(b) shows the plot of shifts in wavelength of FP Bragg grating cavity sensors by air ( $n = 1$ ), methanol ( $n = 1.326$ ), and water ( $n = 1.33$ ). The curve of sensor sensitivity sharply increases between methanol and water because the refractive indices of surrounding media get close to that of the sensor.

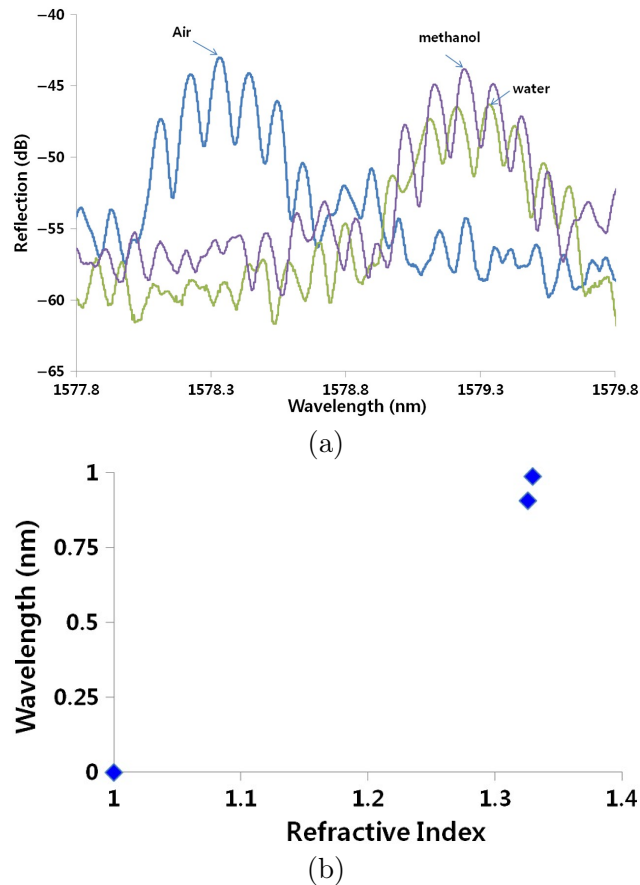


FIGURE 11 – Shift in wavelength of FP Bragg grating cavity sensor with high difference in refractive index between core and clad layers (a) shifts in spectra of FP grating cavity (b) plot of shifts in grating wavelength

The FP Bragg grating cavity may have much better sensitivity than the single Bragg gratings. These results indicate that an FP Bragg grating cavity sensor may detect low volume of molecules with higher sensitivity as biological sensors when employing the immune-sensing schemes such as antibody and antigen reactions.

#### SOI planar waveguide Bragg grating FP cavity

Silicon is transparent at photon energies below the bandgap (i.e., for wavelengths longer than about  $1.2 \mu\text{m}$ ). Although the high refractive index contrast between silicon and oxide or air seems to imply a small mode size, relatively large optical modes can be confined in silicon-ridge waveguides

without sacrificing single-mode operation [12, 13]. Single-mode SOI ridge waveguides with propagation losses as low as 0.1 dB/cm and fiber coupling losses as low as 0.17 dB per facet have been reported [14]. A relatively shallow grating atop the ridge would constitute a very weak perturbation, and would not be suitable for most integrated filter applications, the structure should offer reasonable grating strength with a relatively large mode size [15]. For sensor application, however, the structure shown in Figure 12 offers appropriate grating strength with a mode size to couple the optical fiber.

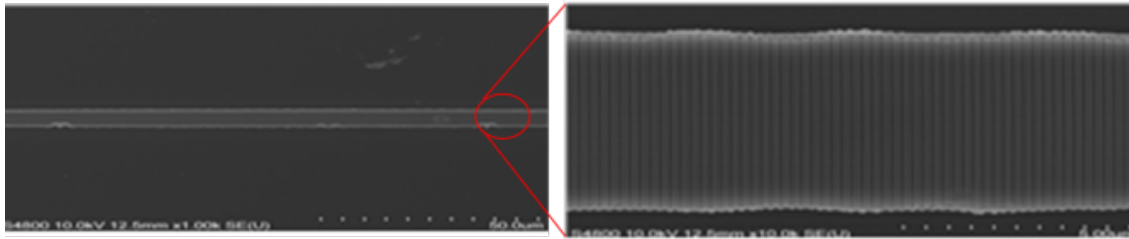


FIGURE 12 – Photos for FP grating cavity on SOI planar waveguide

Figure 12 illustrates the SOI ridge waveguide and Bragg grating patterned on the SOI ridge waveguide. The characterization of SOI planar waveguide Bragg grating FP cavity structure is under investigation.

**Conclusion.** The purpose of this study is to develop biologically compatible high-sensitivity sensors for the detection of a biomedical substance for medical diagnostics through telemedicine via a body-mountable tiny small biochip and environmental monitoring. Etched-silica planar waveguide single Bragg grating was characterized to have Bragg wavelength shift with change in temperature, as a result, the temperature-induced fractional Bragg wavelength shift measured in this experiment is  $0.0132 \text{ nm}/^\circ\text{C}$ . It has a potential to be used in a biosensor. A polymeric optical planar waveguide was made was fabricated the sample which has a grating length of 5 mm. As a result, it was confirmed that the shallower depth and the shorter grating length could develop the interference arisen from multiple reflections between two identical Bragg gratings.

We fabricated two single gratings to form a FP Bragg grating cavity with 5 mm of cavity length. The Bragg wavelength of the single grating that forms the FP Bragg grating cavity was designed to be a 1550-nm wavelength. As a result, spectral characteristics for the 5 mm of the Bragg grating cavity revealed a sharp-pointed peak that is finger shaped, whereas the single Bragg grating has a round-shaped peak. In addition, reflectivity of the single Bragg grating is about 10 dB, but that of the 5 mm of Bragg grating FP cavities have about 20 dB, which is two times larger than the single Bragg grating. Furthermore, the resonance spectra of the FP Bragg grating cavity sensors with the 5 Bragg grating cavity have 0.036 nm of FWHM as compared to 0.316 nm of FWHM for the single Bragg grating. This fact confirms that the resolution of the FP Bragg grating cavity sensor could be enhanced by 10 to 20 times over that of the single Bragg grating.

It is shown that the higher the refractive index of the medium, the more the resonance peak of a sensor moves. The Bragg grating cavity is more sensitive than the single Bragg grating at the same wavelength area. Therefore, a Bragg grating with a cavity area is more sensitive than the single Bragg grating. In addition, the shorter FP cavity waveguide could reveal much more sensitivity than the longer one, which will be promising to scale down the sensors to be so nanosized that extremely low concentration of molecules can be detected.

All the planar waveguide Bragg gratings have a potential in application for bio/chemical sensing such as biomedical diagnostics and environmental monitoring, etc.

**Acknowledgments.** This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2014R1A1A2059472), and supported by the project for nanomold-based customer -designed fusion products of Nanocenter funded by the Ministry of Trade, Industry and Energy Project Number: N0002310).

## References

- 1 Othonos A. Fiber Bragg gratings // Rev. Sci. Instrum – 1997. – Vol. 68. No. 12. – P. 4309-4341.
- 2 Strasser T. A., Erdogan T., White A. E., Mizrahi V., and Lamaire P. J. Ultraviolet laser fabrication of strong, nearly polarization-independent Bragg reflectors in germanium doped silica waveguides on silica substrates // Appl. Phys. Lett. – 1994. - Vol. 65, No. 26,- P. 3308-3310.
- 3 Flanders D. C. et al. Grating filters for thin-film optical waveguides // Appl. Phys. Lett. – 1974. – Vol.24. No. 4. P. 194-196.
- 4 Hong C. S. and Shellan J. B. Broad band grating filters for thin film optical waveguides // Appl. Phys. Lett. – 1977. – Vol.31. -No. 4.- P. 276-278.
- 5 Chryssis A. N. et al. High sensitivity evanescent field fiber bragg grating sensor // IEEE Photonics Technol. Lett. – 2005. – Vol.17.- No.6.- P.1253-1255.
- 6 Chryssis A. et al. Increased sensitivity and parametric discrimination using higher order modes of etched core fiber bragg grating sensors // IEEE Photonics Technol. Lett. – 2006. –Vol.18.- No.1.- P.178.
- 7 Saini S.S. et al. Monolayer detection of biochemical agents using etched core fiber Bragg grating sensors // IEEE Photonics Technol. Lett. – 2007. – Vol.19.- No.18. -P.1341-1343.
- 8 Stanford C. J. et al. Real-time monitoring of siloxane monolayer film formation on silica using a fiber Bragg grating // Curr. Anal. Chem. – 2008. – Vol.4. No. 4. P.356-361.
- 9 Dagenais M. and Stanford C. J. Evanescent fiber Bragg grating bio sensors, in VLSI Micro- and Nanophotonics // Science, Technology, and Applications, E. H. Lee et al., Eds., Taylor and Francis, London, UK, 2009.
- 10 Stanford C. J. et al. Covalent attachment of carbohydrate derivatives to an evanescent wave fiber Bragg grating biosensor // J. Sensors 2009. P.1-7.
- 11 Yariv A. Coupled Mode Theory for Guided Wave Optics // IEEE Journal of Quantum Electronics. – 1973. – Vol. 9. P.919-933.
- 12 Schmidtchen J., Splett A., Schüppert B., and Petermann K. Low loss single mode optical waveguides with large cross section in silicon oninsulator // Electron. Lett. – 1991. – Vol. 27. P.1486-1488.
- 13 Soref R. A., Schmidtchen J., and Peterman K. Large single-mode rib waveguides in GeSi Si and Si on SiO // J. Quantum Electron. – 1991. – P.1971-1973.
- 14 Fischer U., Zinke T., Kropp J. R., Arndt F., and Peterman K. 0.1 dB. cm waveguide losses in single mode SOI rib waveguides // IEEE Photon. Technol. Lett. – 1996. – Vol. 8. P.647-648.
- 15 Thomas Edward Murphy, Jeffrey Todd Hastings and Henry I. Smith. Fabrication and Characterization of Narrow Band Bragg Reflection Filters in Silicon on Insulator Ridge Waveguides // J. Lightwave Technology. – 2001. P.1938-1942.

Санг Мей Ли<sup>1,4</sup>, Босунг Шин<sup>2</sup>, А.Сейткан<sup>3</sup>, А.Мырзағалиева<sup>4</sup>, Б.Медеубаева<sup>5</sup>

<sup>1</sup> Таза кескіндеме және бояу өндірісі бойынша инженерлік зерттеулер орталығы, Пусан, Корея

<sup>2</sup> Нанотехнология колледжі, Пусан ұлттық университеті, Пусан, Корея

<sup>3</sup> Астана халықаралық университеті, Астана, Қазақстан

<sup>4</sup> Л.Н.Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан

<sup>5</sup> С. Аманжолова Шығыс Қазақстан мемлекеттік университеті, Өскемен, Қазақстан

### Брэгг торларына негізделген оптофлюидтық сенсорлар

**Аңдатпа:** Бұл мақалада оптикалық жазық толқынжетектегіш брэгг торын биосенсорларда қолдану тарапынан сипатталады. Сипатталған брэгг торы кремнийлік толқынжетектегіш, полимерлік толқынжетектегіш және кремний-диэлектрикте (SOI) толқынжетектегіштерінен тұрады. Мақалада Фабри-Перо резонаторының оптикалық сыну датчиктері үшін жазық біртұтас толқынжетектегіш Брэгг торларын, полимерлі және кремний-диэлектрикті Брэгг торларын дайындау және өндіру тақырыптары қарастырылған.

Ортаның сыну көрсеткіші неғұрлым жоғары болса, датчиктің резонанстық шыңы соғұрлым жоғары болады. Қуысты Брэгг торы бірдей толқын ұзындығы аймағында бірыңғай Брэгг торына қарағанда аса сезімтал. Сондықтан, ұғымалық қуысты Брэгг торы бірыңғай Брэгг торына қарағанда сезімтал. Сонымен қатар, қысқа FP толқындық қуысының сезімталдығы ұзақ толқындық қуысқа қарағанда әлдеқайда жоғары, бұл датчиктерді наноөлшемді етіп жасай отырып, молекулалардың өте төмен концентрациясын анықтауға мүмкіндік туғызады.

Осы зерттеуде әзірленген датчиктің биомедициналық диагностикада қолдану болашағы зор, мысалы биосенсорлар немесе қоршаған орта мониторингінде қолданылатын биохимиялық датчиктері.

**Түйін сөздер:** Fabry-Perot Bragg қуысты тор, сыну көрсеткіштерінің сенсорлары, микрофлюидтер.

Санг Мей Ли<sup>1,4</sup>, Босунг Шин<sup>2</sup>, А.Сейткан<sup>3</sup>, А.Мырзагалиева<sup>4</sup>, Б.Медеубаева<sup>5</sup>

<sup>1</sup> Инженерно-исследовательский центр по созданию и производству штампов

<sup>2</sup> Колледж нанотехнологий, Пусанский национальный университет, Пусан, Южная Корея

<sup>3</sup> Международный университет Астана, Астана, Казахстан

<sup>4</sup> Евразийский национальный университет им.Л.Н.Гумилева, Астана, Казахстан

<sup>5</sup> Восточно-Казахстанский государственный университет им. С. Аманжолова, Усть-Каменогорск, Казахстан

### Оптофлюидные датчики на основе Брэгговских решеток

**Аннотация:** В данной работе описывается оптическая плоская волноводная брэгговская решетка, которая включает в себя кремниевый волновод, полимерный волновод и волновод кремний-на диэлектрике (КНД) в применении для биосенсоров. Темы настоящей статьи включают в себя проектирование и изготовление протравленной плоской волноводной одиночной брэгговской решетки и полимерной и кремний-на диэлектрике (КНД) плоской волноводной брэгговской решетки датчиков оптического преломления резонатора Фабри-Перо. Показано, что чем выше показатель преломления среды, тем больше изменяется резонансный пик датчика. Полость решетки Брэгга более чувствительна, чем одиночная брэгговская решетка в той же области длины волны. Поэтому брэгговская решетка с полостью более чувствительна, чем единственная брэгговская решетка. Кроме того, более короткая волноводная полость ФР может обнаруживать гораздо большую чувствительность, чем более длинная, что будет перспективным для того, чтобы уменьшить датчики настолько наноразмерно, что можно обнаружить чрезвычайно низкую концентрацию молекул.

Датчик, разработанный в данном исследовании, демонстрирует большую перспективность для применения в биомедицинской диагностике, такой как биосенсор и / или биохимические датчики мониторинга окружающей среды.

**Ключевые слова:** полость решетки Фабри-Перо Брэгга, датчики показателя преломления, микрофлюиды

### References

- 1 Othonos A. Fiber Bragg gratings, Rev. Sci. Instrum, 68, (12), 4309-4341 (1997).
- 2 Strasser T. A., Erdogan T., White A. E., Mizrahi V., and Lamaire P. J. Ultraviolet laser fabrication of strong, nearly polarization-independent Bragg reflectors in germanium doped silica waveguides on silica substrates, Appl. Phys. Lett. 65, (26), 3308-3310 (1994).
- 3 Flanders D. C. et al. Grating filters for thin-film optical waveguides, Appl. Phys. Lett, 24, (4), 194-196 (1974).
- 4 Hong C. S. and Shellan J. B. Broad band grating filters for thin film optical waveguides, Appl. Phys. Lett, 31, (4), 276-278 (1977).
- 5 Chryssis A. N. et al. High sensitivity evanescent field fiber bragg grating sensor. IEEE Photonics Technol. Lett. 17, (6), 1253-1255, 2005.
- 6 Chryssis A. et al. Increased sensitivity and parametric discrimination using higher order modes of etched core fiber bragg grating sensors, IEEE Photonics Technol. Lett, 18, (1), 178 (2006).
- 7 Saini S.S. et al. Monolayer detection of biochemical agents using etched core fiber Bragg grating sensors. [IEEE Photonics Technol. Lett] 19, 18, 1341-1343 (2007) (in Eng).
- 8 Stanford C. J. et al. Real-time monitoring of siloxane monolayer film formation on silica using a fiber Bragg grating. [Curr. Anal. Chem]. 4, 4, 356-361 (2008) (in Eng).
- 9 Dagenais M. and Stanford C. J. Evanescent fiber Bragg grating bio sensors, in VLSI Micro- and Nanophotonics. [Science, Technology, and Applications] (Taylor and Francis, London, UK, 2009). (in Eng).
- 10 Stanford C. J. et al. Covalent attachment of carbohydrate derivatives to an evanescent wave fiber Bragg grating biosensor, J. Sensors, 1-7(2009).
- 11 Yariv A. Coupled Mode Theory for Guided Wave Optics. [IEEE Journal of Quantum Electronics], 9, 919-933 (1973).
- 12 Schmidtchen J., Splett A., Schüppert B., and Petermann K. Low loss single mode optical waveguides with large cross section in silicon on insulator. [Electron. Lett.], 27, 1486-1488 (1991). (in Eng).
- 13 Soref R. A., Schmidtchen J., and Peterman K. Large single-mode rib waveguides in GeSi Si and Si on SiO<sub>2</sub>, J. Quantum Electron, 1971-1973 (1991).
- 14 Fischer U., Zinke T., Kropp J. R., Arndt F., and Peterman K. 0.1 dB. cm waveguide losses in single mode SOI rib waveguides, IEEE Photon. Technol. Lett, 8, 647-648 (1996).
- 15 Thomas Edward Murphy, Jeffrey Todd Hastings and Henry I. Smith. Fabrication and Characterization of Narrow Band Bragg Reflection Filters in Silicon on Insulator Ridge Waveguides, J. Lightwave Technology, 1938-1942 (2001).

#### Сведения об авторах:

Санг Мэй Ли - Философия докторы, Пусан Ұлттық университетінің профессоры, Пусан Корея.

Босунг Шин - Философия докторы, Пусан Ұлттық университетінің профессоры, Пусан Корея.

Сейтқан А.- Философия докторы, бас ғылыми қызметкер, «Астана» халықаралық ғылыми кешені, Қабанбай батыр даңғылы, 8, Астана, Қазақстан.

Мырзагалиева А.Б. - биология ғылымдарының докторы, профессор, Л.Н.Гумилев атындағы Еуразия ұлттық университеті, Қажымұқан көш. 13, Астана, Қазақстан.

Балжан Медеубаева – химия магистрі, химия кафедрасының аға оқытушысы, С. Аманжолов атындағы Шығыс Қазақстан мемлекеттік университеті, 30-Гвардиялық дивизиясы көш. 34, Өскемен, Қазақстан.

Sang Mae Lee – Doctor of Philosophy, Professor, Pusan National University, Pusan, Korea.

*Bosung Shin* – Doctor of Philosophy, Professor, Pusan National University, Pusan, Korea.

*Ainur Seitkan* – Doctor of Philosophy, Senior Researcher, International Science Complex «Astana», Astana, Kazakhstan, Kabanbay batyr avenue, 8, Astana, Kazakhstan.

*Anar Myrzagaliyeva* – Doctor of Biology, Professor, L.N.Gumilyov Eurasian National University, Kazhyimukan str., 13, Astana, Kazakhstan.

*Balzhan Medeubayeva* – Master of Chemistry, Senior Lecturer of Chemistry Department, S. Amanzholov East Kazakhstan State University, 30-Gvardejskaya diviziya street, 34, Ust-Kamenogorsk, Kazakhstan.

*Поступила в редакцию 14.12.2018*

«Л.Н. Гумилев атындағы Еуразия ұлттық университетінің Хабаршысы. Физика. Астрономия сериясы»  
журналында мақала жариялау ережесі

Журнал редакциясы авторларға осы нұсқаулықпен толық танысып, журналға мақала әзірлеу мен дайын мақаланы журналға жіберу кезінде басшылыққа алуды ұсынады. Бұл нұсқаулық талаптарының орындалмауы сіздің мақалаңыздың жариялануын кідіртеді.

1. **Журнал мақсаты.** Физика мен астрономия салаларының теориялық және эксперименталды зерттелулері бойынша мұқият тексеруден өткен ғылыми құндылығы бар мақалалар жариялау.

2. Баспаға (барлық жариялаушы авторлардың қол қойылған қағаз нұсқасы және электронды нұсқа) журналдың түпнұсқалы стильдік файлының міндетті қолданысымен LaTeX баспа жүйесінде дайындалған Tex- пен Pdf-файлындағы жұмыстар ұсынылады. Стильдік файлды *bulphysast.enu.kz* журнал сайтынан жүктеп алуға болады. Сонымен қатар, автор(лар) ілеспе хат ұсынуы керек.

3. Автордың қолжазбаны редакцияға жіберуі мақаланың Л.Н. Гумилев атындағы Еуразия ұлттық университетінің хабаршысында басуға келісімін, шетел тіліне аударылып қайта басылуына келісімін білдіреді. Автор мақаланы редакцияға жіберу арқылы автор туралы мәліметтің дұрыстығына, мақала көшірілмегендігіне (плагиаттың жоқтығына) және басқа да заңсыз көшірмелердің жоқтығына кепілдеме береді.

4. Мақаланың көлемі 18 беттен аспауға тиіс (6 беттен бастап).

ГТАМРК <http://grnti.ru/>

Автор(лар)дың аты-жөні

Мекеменің толық атауы, қаласы, мемлекеті (егер авторлар әртүрлі мекемеде жұмыс жасайтын болса, онда әр автор мен оның жұмыс мекемесі қасында бірдей белгі қойылу керек)

Автор(лар)дың E-mail-ы

Мақала атауы

**Аннотация** (100-200 сөз; күрделі формулаларсызсыз, мақаланың атауын мейлінше қайталамауы қажет; әдебиеттерге сілтемелер болмауы қажет; мақаланың құрылысын (кіріспе мақаланың мақсаты/ міндеттері /қарастырылып отырған сұрақтың тарихы /зерттеу /әдістері нәтижелер/талқылау, қорытынды) сақтай отырып, мақаланың қысқаша мазмұны берілуі қажет).

**Түйін сөздер** (6-8 сөз не сөз тіркесі. Түйін сөздер мақала мазмұнын көрсетіп, мейлінше мақала атауы мен аннотациядағы сөздерді қайталамай, мақала мазмұнындағы сөздерді қолдану қажет. Сонымен қатар, ақпараттық-ізвестіру жүйелерінде мақаланы жеңіл табуға мүмкіндік беретін ғылым салаларының терминдерін қолдану қажет).

**Негізгі мәтін** мақаланың мақсаты/ міндеттері/ қарастырылып отырған сұрақтың тарихы, зерттеу әдістері, нәтижелер/талқылау, қорытынды бөлімдерін қамтуы қажет.

5. **Таблица, суреттер** – Жұмыстың мәтінінде кездесетін таблицалар мәтіннің ішінде жеке нөмірленіп, мәтін көлемінде сілтемелер түрінде көрсетілуі керек. Суреттер мен графиктер PS, PDF, TIFF, GIF, JPEG, BMP, PCX форматындағы стандарттарға сай болуы керек. Нүктелік суреттер кеңейтілімі 600 dpi кем болмауы қажет. Суреттердің барлығы да айқын әрі нақты болуы керек.

Мақаладағы **формулалар** тек мәтінде оларға сілтеме берілсе ғана номерленеді.

Жалпы қолданыста бар **аббревиатуралар** мен **қысқартулардан** басқалары міндетті түрде алғаш қолданғанда түсіндірілуі берілуі қажет. **Қаржылай көмек туралы** ақпарат бірінші бетте көрсетіледі.

6. Жұмыста қолданылған әдебиеттер тек жұмыста сілтеме жасалған түпнұсқалық көрсеткішке сай (сілтеме беру тәртібінде немесе ағылшын әліпбиі тәртібі негізінде толтырылады) болуы керек. Баспадан шықпаған жұмыстарға сілтеме жасауға түйым салынады.

Сілтемені беруде автор қолданған әдебиеттің бетінің нөмірін көрсетпей, келесі нұсқаға сүйеніңіз дұрыс: тараудың номері, бөлімнің номері, тармақтың номері, теораманың (лемма, ескерту, формуланың және т.б.) номері көрсетіледі. Мысалы: қараңыз [3; § 7, лемма 6]», «...қараңыз [2; 5 теорамандағы ескерту]». Бұл талап орындалмаған жағдайда мақаланы ағылшын тіліне аударғанда сілтемелерде қателіктер туындауы мүмкін.

**Қолданылған әдебиеттер тізімін рәсімдеу мысалдары**

1 Воронин С. М., Карацуба А. А. Дзета-функция Римана. –М: Физматлит, –1994, –376 стр. – **кітап**

2 Баилов Е. А., Сихов М. Б., Темиргалиев Н. Об общем алгоритме численного интегрирования функций многих переменных // Журнал вычислительной математики и математической физики –2014. –Т.54. № 7. –С. 1059-1077. - **мақала**

3 Жубанышева А.Ж., Абикенова Ш. О нормах производных функций с нулевыми значениями заданного набора линейных функционалов и их применения к поперечниковым задачам // Функциональные пространства и теория приближения функций: Тезисы докладов Международной конференции, посвященной 110-летию со дня рождения академика С.М.Никольского, Москва, Россия, 2015. – Москва, 2015. –С.141-142. – **конференция еңбектері**

4 Нургазина К. Рыцарь математики и информатики. –Астана: Каз.правда, 2017. 19 апреля. –С.7. – **газеттік мақала**

5 Кыров В.А., Михайличенко Г.Г. Аналитический метод вложения симплектической геометрии // Сибирские электронные математические известия –2017. –Т.14. –С.657-672. doi: 10.17377/semi.2017.14.057. – URL: <http://semr.math.nsc.ru/v14/p657-672.pdf>. (дата обращения: 08.01.2017). - **электронды журнал**

7. Әдебиеттер тізімінен соң автор өзінің библиографиялық мәліметтерін орыс және ағылшын тілінде (егер мақала қазақ тілінде орындалса), қазақ және ағылшын тілінде (егер мақала орыс тілінде орындалса), орыс және қазақ тілінде (егер мақала ағылшын тілінде орындалса) жазу қажет. Соңынан транслиттік аударма мен ағылшын тілінде берілген әдебиеттер тізімінен соң әр автордың жеке мәліметтері (қазақ, орыс, ағылшын тілдерінде – ғылыми атағы, қызметтік мекенжайы, телефоны, e-mail-ы) беріледі.

8. Редакцияға түскен мақала жабық (анонимді) тексеруге жіберіледі. Барлық рецензиялар авторларға жіберіледі. Автор (рецензент мақаланы түзетуге ұсыныс берген жағдайда) үш күн аралығында қайта қарап, қолжазбаның түзетілген нұсқасын редакцияға қайта жіберуі керек. Рецензент жарамсыз деп таныған мақала қайтара қарастырылмайды. Мақаланың түзетілген нұсқасы мен автордың рецензентке жауабы редакцияға жіберіледі.

**9. Төлемақы.** Басылымға рұқсат етілген мақала авторларына төлем жасау туралы ескертіледі. Төлем көлемі 2018 жылы 4500 тенге – ЕҰУ қызметкерлері үшін және 5500 тенге басқа ұйым қызметкерлеріне.

**Реквизиттер:**

"Евразийский национальный университет им. Л.Н.Гумилева" МОН РК

Столичный филиал АО "Цеснабанк"

КБЕ 16

БИН 010140003594

БИК TSES KZ KA

Счет в кодировке IBAN-

KZ91998ВТВ0000003104-

"За публикацию ФИО авторов"

**Provision on articles submitted to the journal "Bulletin of L.N. Gumilyov Eurasian National University. Physics. Astronomy series"**

*The journal editorial board asks the authors to read the rules and adhere to them when preparing the articles, sent to the journal. Deviation from the established rules delays the publication of the article.*

**1. Purpose of the journal.** Publication of carefully selected original scientific.

2. The scientific publication office accepts the article (in electronic and printed, signed by the author) in Tex- and Pdf-files, prepared in the LaTeX publishing system with mandatory use of the original style log file. The style log file can be downloaded from the journal website *bulphysast.enu.kz*. And you also need to provide the cover letter of the author(s).

Language of publications: Kazakh, Russian, English.

**3. Submission of articles to the scientific publication office means the authors' consent to the right of the Publisher, L.N. Gumilyov Eurasian National University, to publish articles in the journal and the re-publication of it in any foreign language. Submitting the text of the work for publication in the journal, the author guarantees the correctness of all information about himself, the lack of plagiarism and other forms of improper borrowing in the article, the proper formulation of all borrowings of text, tables, diagrams, illustrations.**

4. The volume of the article should not exceed 18 pages (from 6 pages).

**5. Structure of the article**

**GRNTI** <http://grnti.ru/>

**Initials and Surname of the author (s)**

**Full name of the organization, city, country** (if the authors work in different organizations, you need to put the same icon next to the name of the author and the corresponding organization)

**Author's e-mail (s)**

**Article title**

**Abstract** (100-200 words, it should not contain a big formulas, the article title should not repeat in the content, it should not contain bibliographic references, it should reflect the summary of the article, preserving the structure of the article - introduction/ problem statement/ goals/ history, research methods, results /discussion, conclusion).

**Key words** (6-8 words/word combination. Keywords should reflect the main content of the article, use terms from the article, as well as terms that define the subject area and include other important concepts that make it easier and more convenient to find the article using the information retrieval system).

**The main text of the article** should contain an introduction/ problem statement/ goals/ history, research methods, results / discussion, conclusion. Tables, figures should be placed after the mention. Each illustration should be followed by an inscription. Figures should be clear, clean, not scanned.

Tables are included directly in the text of the article; it must be numbered and accompanied by a reference to them in the text of the article. Figures, graphics should be presented in one of the standard formats: PS, PDF, TIFF, GIF, JPEG, BMP, PCX. Bitmaps should be presented with a resolution of 600 dpi. All details must be clearly shown in the figures.

In the article, only those **formulas** are numbered, to which the text has references.

All **abbreviations**, with the exception of those known to be generally known, must be deciphered when first used in the text.

Information on **the financial** support of the article is indicated on the first page in the form of a footnote.

**6.** The list of literature should contain only those sources (numbered in the order of quoting or in the order of the English alphabet), which are referenced in the text of the article. References to unpublished issues, the results of which are used in evidence, are not allowed. Authors are recommended to exclude the reference to pages when referring to the links and guided by the following template: chapter number, section number, paragraph number, theorem number (lemmas, statements, remarks to the theorem, etc.), number of the formula. For example, "..., see [3, § 7, Lemma 6]"; "..., see [2], a remark to Theorem 5". Otherwise, incorrect references may appear when preparing an English version of the article.

### Template

1 Воронин С. М., Карацуба А. А. Дзета-функция Римана. -М: Физматлит, -1994, -376 стр.-**book**

2 Баиллов Е. А., Сихов М. Б., Темиргалиев Н. Об общем алгоритме численного интегрирования функций многих переменных // Журнал вычислительной математики и математической физики -2014. -Т.54. № 7. -С. 1059-1077. - **journal article**

3 Жубанышева А.Ж., Абикенова Ш. О нормах производных функций с нулевыми значениями заданного набора линейных функционалов и их применения к поперечниковым задачам // Функциональные пространства и теория приближения функций: Тезисы докладов Международной конференции, посвященная 110-летию со дня рождения академика С.М.Никольского, Москва, Россия, 2015. - Москва, 2015. -С.141-142. - - **Conferences proceedings**

4 Нургазина К. Рыцарь математики и информатики. -Астана: Каз.правда, 2017. 19 апреля. -С.7. **newspaper articles**

5 Кыров В.А., Михайличенко Г.Г. Аналитический метод вложения симплектической геометрии // Сибирские электронные математические известия -2017. -Т.14. -С.657-672. doi: 10.17377/semi.2017.14.057. - URL: <http://semr.math.nsc.ru/v14/p657-672.pdf>. (дата обращения: 08.01.2017). - **Internet resources**

**7.** At the end of the article, after the list of references, it is necessary to indicate bibliographic data in Russian and English (if the article is in Kazakh), in Kazakh and English (if the article is in Russian) and in Russian and Kazakh languages (if the article is English language). Then a combination of the English-language and transliterated parts of the references list and information about authors (scientific degree, office address, telephone, e-mail - in Kazakh, Russian and English) is given.

**8. Work with electronic proofreading.** Articles received by the Department of Scientific Publications (editorial office) are sent to anonymous review. All reviews of the article are sent to the author. The authors must send the proof of the article within three days. Articles that receive a negative review for a second review are not accepted. Corrected versions of articles and the author's response to the reviewer are sent to the editorial office. Articles that have positive reviews are submitted to the editorial boards of the journal for discussion and approval for publication.

**Periodicity of the journal:** 4 times a year.



**9. Payment.** Authors who have received a positive conclusion for publication should make payment on the following requisites (for ENU employees - 4,500 tenge, for outside organizations - 5,500 tenge):

**Requisites:**

L.N. Gumilyov Eurasian  
National University"  
JSC "Tsesnabank:"  
Tsesnabank КБЕ  
КБЕ 16  
БИН 010140003594  
БИК TSES KZ KA  
Счет в кодировке IBAN-  
KZ91998ВТВ0000003104-  
-За публикацию фио

**Положение о рукописях, представляемых в журнал «Вестник Евразийского национального университета имени Л.Н.Гумилева. Серия: Физика. Астрономия»**

Редакция журнала просит авторов ознакомиться с правилами и придерживаться их при подготовке работ, направляемых в журнал. Отклонение от установленных правил задерживает публикацию статьи.

1. Цель журнала. Публикация тщательно отобранных оригинальных научных работ по актуальным проблемам теоретических и экспериментальных исследований в области физики и астрономии.

2. В редакцию (в бумажном виде, подписанном всеми авторами и в электронном виде) представляются Tex- и Pdf-файлы работы, подготовленные в издательской системе LaTeX, с обязательным использованием оригинального стилевого файла журнала. Стилиевой файл можно скачать со сайта журнала *bulphysast.enu.kz*. Автору (авторам) необходимо предоставить сопроводительное письмо.

**Язык публикаций:** казахский, русский, английский.

3. Отправление статей в редакцию означает согласие авторов на право Издателя, Евразийского национального университета имени Л.Н. Гумилева, издания статей в журнале и переиздания их на любом иностранном языке. Представляя текст работы для публикации в журнале, автор гарантирует правильность всех сведений о себе, отсутствие плагиата и других форм неправомерного заимствования в рукописи, надлежащее оформление всех заимствований текста, таблиц, схем, иллюстраций.

4. Объем статьи не должен превышать 18 страниц (от 6 страниц).

5. Схема построения статьи

**ГРНТИ** <http://grnti.ru/>

**Инициалы и фамилия автора(ов)**

**Полное наименование организации, город, страна** (если авторы работают в разных организациях, необходимо поставить одинаковый значок около фамилии автора и соответствующей организации)

**E-mail** автора(ов)

**Название статьи**

**Аннотация** (100-200 слов; не должна содержать громоздкие формулы, по содержанию повторять название статьи; не должна содержать библиографические ссылки; должна отражать краткое содержание статьи, сохраняя структуру статьи – введение/ постановка задачи/ цели/ история, методы исследования, результаты/обсуждение, заключение/выводы).

**Ключевые слова** (6-8 слов/словосочетаний. Ключевые слова должны отражать основное содержание статьи, использовать термины из текста статьи, а также термины, определяющие предметную область и включающие другие важные понятия, позволяющие облегчить и расширить возможности нахождения статьи средствами информационно-поисковой системы).

**Основной текст статьи** должен содержать введение/ постановку задачи/ цели/ историю, методы исследования, результаты/обсуждение, заключение/выводы.

Таблицы включаются непосредственно в текст работы, они должны быть пронумерованы и сопровождаться ссылкой на них в тексте работы. Рисунки, графики должны быть представлены в одном из стандартных форматов: PS, PDF, TIFF, GIF, JPEG, BMP, PCX. Точечные рисунки необходимо выполнять с разрешением 600 dpi. На рисунках должны быть ясно переданы все детали.

В статье нумеруются лишь те **формулы**, на которые по тексту есть ссылки.

Все **аббревиатуры и сокращения**, за исключением заведомо общеизвестных, должны быть расшифрованы при первом употреблении в тексте.

Сведения о **финансовой поддержке** работы указываются на первой странице в виде сноски.

6. Список литературы должен содержать только те источники (пронумерованные в порядке цитирования или в порядке английского алфавита), на которые имеются ссылки в тексте работы. Ссылки на неопубликованные работы, результаты которых используются в доказательствах, не допускаются.

Авторам рекомендуется при оформлении ссылок исключить упоминание страниц и руководствоваться следующим шаблоном: номер главы, номер параграфа, номер пункта, номер теоремы (леммы, утверждения, замечания к теореме и т.п.), номер формулы. Например, "..., см. [3; § 7, лемма 6]"; "..., см. [2; замечание к теореме 5]". В противном случае при подготовке англоязычной версии статьи могут возникнуть неверные ссылки.

**Примеры оформления списка литературы**

1 Воронин С. М., Карацуба А. А. Дзета-функция Римана. -М: Физматлит, -1994, -376 стр. - **книга**

2 Баилов Е. А., Сихов М. Б., Темиргалиев Н. Об общем алгоритме численного интегрирования функций многих переменных // Журнал вычислительной математики и математической физики -2014. -Т.54. № 7. -С. 1059-1077. - **статья**

3 Жубанышева А.Ж., Абикенова Ш. О нормах производных функций с нулевыми значениями заданного набора линейных функционалов и их применения к поперечниковым задачам // Функциональные пространства и теория приближения функций: Тезисы докладов Международной конференции, посвященной 110-летию со дня рождения академика С.М.Никольского, Москва, Россия, 2015. - Москва, 2015. -С.141-142. - **труды конференции**

4 Нуртазина К. Рыцарь математики и информатики. -Астана: Каз.правда, 2017. 19 апреля. -С.7. - **газетная статья**

5 Кыров В.А., Михайличенко Г.Г. Аналитический метод вложения симплектической геометрии // Сибирские электронные математические известия -2017. -Т.14. -С.657-672. doi: 10.17377/semi.2017.14.057. - URL: <http://semr.math.nsc.ru/v14/p657-672.pdf>. (дата обращения: 08.01.2017). - **электронный журнал**

7. После списка литературы, необходимо указать библиографические данные на русском и английском языках (если статья оформлена на казахском языке), на казахском и английском языках (если статья оформлена на русском языке) и на русском и казахском языках (если статья оформлена на английском языке). Затем приводится комбинация англоязычной и транслитерированной частей списка литературы и сведения по каждому из авторов (научное звание, служебный адрес, телефон, e-mail - на казахском, русском и английском языках).

8. **Работа с электронной корректурой.** Статьи, поступившие в Отдел научных изданий (редакция), отправляются на анонимное рецензирование. Все рецензии по статьям отправляются автору. Авторам в течение трех дней

необходимо отправить корректуру статьи. Статьи, получившие отрицательную рецензию, к повторному рассмотрению не принимаются. Исправленные варианты статей и ответ автора рецензенту присылаются в редакцию. Статьи, имеющие положительные рецензии, представляются редколлегии журнала для обсуждения и утверждения для публикации.

**Периодичность журнала:** 4 раза в год.

**9. Оплата.** Авторам, получившим положительное заключение к опубликованию, необходимо произвести оплату по следующим реквизитам (для сотрудников ЕНУ – 4500 тенге, для сторонних организаций – 5500 тенге):

## Мақаланы рәсімдеу үлгісі

МРНТИ 27.25.19

А.Ж. Жубанышева<sup>1</sup>, Н. Темиргалиев<sup>2</sup>, А.Б. Утесов<sup>3</sup>

<sup>1</sup> *Институт теоретической математики и научных вычислений Евразийского национального университета имени Л.Н.Гумилева, Астана, Казахстан*

<sup>2</sup> *Актюбинский региональный государственный университет имени К. Жубанова, Актюбе, Казахстан*

(Email: <sup>1</sup> *axaulezh@mail.ru*, <sup>2</sup> *ntmath10@mail.ru*, <sup>3</sup> *adilzhan\_71@mail.ru*)

**Численное дифференцирование функций в контексте Компьютерного (вычислительного) перечника**

### Введение

Текст введения...

Авторам не следует использовать нестандартные пакеты LaTeX (используйте их лишь в случае крайней необходимости)

### Заголовок секции

#### 1.1 Заголовок подсекции

Окружения.

**Теорема 1.** ...

**Лемма 1.** ...

**Предложение 1.** ...

**Определение 1.** ...

**Следствие 1.** ...

**Замечание 1.** ...

**Теорема 2** (Темиргалиев Н. [2]). *Текст теоремы.*

**Д о к а з а т е л ь с т в о.** Текст доказательства.

### 2. Формулы, таблицы, рисунки

$$\delta_N(\varepsilon_N; D_N)_Y \equiv \delta_N(\varepsilon_N; T; F; D_N)_Y \equiv \inf_{(l^{(N)}, \varphi_N) \in D_N} \delta_N \left( \varepsilon_N; \left( l^{(N)}, \varphi_N \right) \right)_Y, \quad (51)$$

где  $\delta_N(\varepsilon_N; (l^{(N)}, \varphi_N))_Y \equiv \delta_N(\varepsilon_N; T; F; (l^{(N)}, \varphi_N))_Y \equiv$

$$\equiv \sup_{\substack{f \in F \\ |\gamma_N^{(\tau)}| \leq 1 (\tau=1, \dots, N)}} \left\| Tf(\cdot) - \varphi_N \left( l_N^{(1)}(f) + \gamma_N^{(1)} \varepsilon_N^{(1)}, \dots, l_N^{(N)}(f) + \gamma_N^{(N)} \varepsilon_N^{(N)}; \cdot \right) \right\|_Y.$$

Таблицы, рисунки необходимо располагать после упоминания. С каждой иллюстрацией должна следовать надпись.

### 3. Ссылки и библиография

Для ссылок на утверждения, формулы и т. п. можно использовать метки. Например, теорема 2, Формула (51)

Таблица 1 – Название таблицы

Простые	Не простые
2, 3, 5, 7, 11, 13, 17, 19, 23, 29	4, 6, 8, 9, 10, 12, 14



Рисунок 1 – Название рисунка

Для руководства по  $\LaTeX$  и в качестве примера оформления ссылок, см., например, *Львовский С.М.* Набор и верстка в пакете  $\LaTeX$ . Москва: Космосинформ, 1994.

Список литературы оформляется следующим образом.

### Список литературы

- 1 Локуциевский О.М., Гавриков М.Б. Начала численного анализа. –М.: ТОО "Янус", 1995. –581 с. - **книга**
- 2 Темиргалиев Н. Компьютерный (вычислительный) поперечник как синтез известного и нового в численном анализе // Вестник Евразийского национального университета имени Л.Н. Гумилева –2014. –Т.4. №101. –С. 16-33. doi: ... (при наличии) - **статья**
- 3 Жубанышева А.Ж., Абикинова Ш. О нормах производных функций с нулевыми значениями заданного набора линейных функционалов и их применения к поперечниковым задачам // Функциональные пространства и теория приближения функций: Тезисы докладов Международной конференции, посвященная 110-летию со дня рождения академика С.М.Никольского, Москва, Россия, 2015. – Москва, 2015. –С.141-142. - **труды конференций**
- 4 Курмуков А.А. Ангиопротекторная и гипополипидемическая активность леукомизина. –Алматы: Бастау, 2007. –С. 3-5 - **газетные статьи**
- 5 Кыров В.А., Михайличенко Г.Г. Аналитический метод вложения симплектической геометрии // Сибирские электронные математические известия –2017. –Т.14. –С.657-672. doi: 10.17377/semi.2017.14.057. – URL: <http://semr.math.nsc.ru/v14/p657-672.pdf>. (дата обращения: 08.01.2017). - **электронный журнал**

**А.Ж. Жубанышева**<sup>1</sup>, **Н. Темиргалиев**<sup>1</sup>, **А.Б. Утесов**<sup>2</sup>

<sup>1</sup> Л.Н.Гумилев атындағы Еуразия ұлттық университетінің теориялық математика және ғылыми есептеулер институты, Астана, Қазақстан

<sup>2</sup> Қ.Жубанов атындағы. Ақтөбе өңірлік мемлекеттік университеті, Ақтобе, Қазақстан

#### Компьютерлік (есептеуіш) диаметр мәнінде функцияларды сандық дифференциалдау

**Аннотация:** Компьютерлік (есептеуіш) диаметр мәнінде Соболев класында жататын функцияларды олардың тригонометриялық Фурье-Лебега коэффициенттерінің ақырлы жиынынан алынған дәл емес ақпарат бойынша жуықтау есебі толығымен шешілді [100-200 сөздер].

**Түйін сөздер:** жуықтап дифференциалдау, дәл емес ақпарат бойынша жуықтау, шектік қателік, Компьютерлік (есептеуіш) диаметр [6-8 сөз/сөз тіркестері].

**A.Zh.Zhubanysheva**<sup>1</sup>, **N. Temirgaliyev**<sup>1</sup>, **A.B. Utesov**<sup>2</sup>

<sup>1</sup> Institute of theoretical mathematics and scientific computations of L.N. Gumilyov Eurasian National University, Astana, Kazakhstan

<sup>2</sup> K.Zhubanov Aktobe Regional State University, Aktobe, Kazakhstan

#### Numerical differentiation of functions in the context of Computational (numerical) diameter

**Abstract:** The computational (numerical) diameter is used to completely solve the problem of approximate differentiation of a function given inexact information in the form of an arbitrary finite set of trigonometric Fourier coefficients. [100-200 words]

**Keywords:** approximate differentiation, recovery from inexact information, limiting error, computational (numerical) diameter, massive limiting error. [6-8 words/word combinations]

## References

- 1 Lokucievskij O.M., Gavrikov M.B. *Nachala chislennogo analiza* [Elements of numerical analysis] (Yanus, Moscow, 1995). [in Russian]
- 2 Temirgaliyev N. Komp'yuternyj (vychislitel'nyj) poperechnik kak sintez izvestnogo i novogo v chislennom analize [Computational (numerical) diameter as a synthesis of the known and the new in numerical analysis], *Vestnik Evrazijskogo nacional'nogo universiteta imeni L.N. Gumileva* [Bulletin of L.N. Gumilyov Eurasian National University], 4 (101), 16-33 (2014). [in Russian]
- 3 Zhubanysheva A.Zh., AbikenovaSh.K. O normah proizvodnyh funkcionov s nulevymi znachenijami zadannogo nabora linejnyh funkcionov i ih primeneniya k poperechnikovym zadacham [About the norms of the derivatives of functions with zero values of a given set of linear functionals and their application to the width problems]. Tezisy dokladov Mezhdunarodnoj konferencii, posvjashhennaja 110-letiju so dnja rozhdenija akademika S.M.Nikol'skogo "Funkcional'nye prostranstva i teorija priblizhenija funkcionov" [International conference on Function Spaces and Approximation Theory dedicated to the 110th anniversary of S. M. Nikol'skii]. Moscow, 2015, pp. 141-142. [in Russian]
- 4 Kurmukov A. A. Angioprotekornaja i gipolipidemicheskaia aktivnost' leukomycina [Angioprotective and lipid-lowering activity of leukomycin] (Bastau, Almaty, 2007, P. 3-5). [in Russian]
- 5 Kyrov V.A., Mihajlichenko G.G. Analiticheskij metod vlozhenija simplekticheskoj geometrii [The analytic method of embedding symplectic geometry], *Cibirskie jelektronnye matematicheskie izvestija* [Siberian Electronic Mathematical Reports], 14, 657-672 (2017). doi: 10.17377/semi.2017.14.057. Available at: <http://semr.math.nsc.ru/v14/p657-672.pdf>. [in Russian]. (accessed 08.01.2017).

### Сведения об авторах:

*Жубаньшева А.Ж.* - Старший научный сотрудник Института теоретической математики и научных вычислений, Евразийский национальный университет имени Л.Н.Гумилева, ул. Сатпаева, 2, Астана, Казахстан.

*Темиргалиев Н.* - Директор Института теоретической математики и научных вычислений, Евразийский национальный университет имени Л.Н.Гумилева, ул. Сатпаева, 2, Астана, Казахстан.

*Утесов А.Б.* - кандидат физико-математических наук, доцент кафедры математики, Актыобинский региональный государственный университет имени К. Жубанова, пр. А.Молдагуловой, 34, Актобе, Казахстан.

*Zhubanysheva A.Zh.* - Senior researcher of the Institute of theoretical mathematics and scientific computations, L.N. Gumilyov Eurasian National University, Satpayev str., Astana, Kazakhstan.

*Temirgaliyev N.* - Head of the Institute of theoretical mathematics and scientific computations, L.N. Gumilyov Eurasian National University, Satpayev str., Astana, Kazakhstan.

*Utesov A.B.* - candidate of physical and mathematical sciences, Associate Professor of the Department of Mathematics, K.Zhubanov Aktobe Regional State University, A.Moldagulova Prospect, 34, Aktobe, Kazakhstan.

*Поступила в редакцию 15.05.2017*

Редакторы: А.Қ. Арынгазин  
Шығарушы редактор, дизайн: А. Нұрболат

Л.Н. Гумилев атындағы Еуразия ұлттық университетінің  
Хабаршысы. Физика. Астрономия сериясы.  
-2019 - 1(126) - Астана: ЕҰУ. 107-б.  
Шартты б.т. - 9,375 Таралымы - 25 дана.

Мазмұнына типография жауап бермейді.

Редакция мекен-жайы: 010008, Астана қ.,  
Сәтбаев көшесі, 2.  
Л.Н. Гумилев атындағы Еуразия ұлттық университеті  
Тел.: +7(7172) 70-95-00(ішкі 31-428)

Л.Н. Гумилев атындағы Еуразия ұлттық университетінің баспасында басылды