各位、

東北大学電気通信研究所
ブロードバンド工学研究部門
超ブロードバンド信号処理研究室
教授 尾辻 泰一

第 104 回ナノ・スピン工学研究会
「トポロジカル三次元材料および二次元ヘテロ接合材料の新奇特性とそのテラヘルツ機能応用」
の開催について

拝啓、
時下ますますご清祥のこととお慶び申し上げます。

さて、添付の通り、9月6日（木）に、
第 104 回ナノ・スピン工学研究会「トポロジカル三次元材料および二次元ヘテロ接合材料の新奇特性とそのテラヘルツ機能応用」
を開催いたします。

大学院生向けの特別講義として企画いたしました。
皆様多数ご参集下さいますようご案内申し上げます。

敬具、

日 時：2018年9月6日（木）15:00〜17:50
会 場：東北大学電気通信研究所 片平北キャンパス
ナノ・スピン総合研究棟4階 A401 会議室
言 語：英語

プログラム:
15:00〜16:20
講師1：Dr. SENSALÉ RODRÍGUEZ, Berardi, Assist. Prof., The University of Utah, Salt Lake City, UT 84112, USA
題 目：Strong terahertz plasmonic resonances in Cd3As2: a 3D topological dirac semimetal
内 容：添付ファイルの通り
16:20〜16:30 休息
16:30〜17:50
講師2：Dr. MOROZOV, Sergey, Prof., Institute for Physics of Microstructures of RAS, 603950 Nizhny Novgorod, Russia
題 目：HgCdTe-based heterostructures for THz emitters
内 容：添付ファイルの通り

主 催：東北大学電気通信研究所 ナノ・スピン工学研究会
問合せ先：尾辻 泰一（電気通信研究所 教授）
TEL&FAX：022-217-6104
Email: otsuji@rie.c.tohoku.ac.jp
104th Nano-Spin Engineering Seminar

"Novel Properties of Topological 3D Materials and Graphene-Based Atomically-Thin 2D Heterostructures and Their Terahertz Applications"

Dear all,

You are cordially invited to the 104th Nano-Spin Engineering Seminar
"Novel Properties of Topological 3D Materials and Graphene-Based Atomically-Thin 2D Heterostructures and Their Terahertz Applications."
The details are in the following.

The seminar is planned for master/doctor students. Your attendance is greatly appreciated.

Sincerely yours,

Date & time: 15:00-17:50, 6th September, 2018 (Thursday).
Place: A401 Meeting Room, 4F Floor, RIEC Nano-Spin Laboratory Building, Katahira-Campus, Tohoku University
Language: English

Program:
15:00-17:50
1st Lecturer: Dr. SENSALE RODRIGUEZ, Berardi, Assist. Prof., The University of Utah, Salt Lake City, UT 84112, USA
Title: Strong terahertz plasmonic resonances in Cd3As2: a 3D topological dirac semimetal
Content: As in attached file
16:20-16:30  Break
16:30-17:50
2nd Lecturer: Dr. MOROZOV, Sergey, Prof., Institute for Physics of Microstructures of RAS, 603950 Nizhny Novgorod, Russia
Title: HgCdTe-based heterostructures for THz emitters
Content: As in attached file

Organizer: Nano-Spin Engineering Seminar, RIEC, Tohoku University

Contact: Taiichi Otsuji (Professor, RIEC)
TEL&FAX: 022-217-6104
Email: otsuji@riec.tohoku.ac.jp
Three-dimensional semimetals have been predicted and demonstrated to have a wide variety of interesting properties associated with its linear energy dispersion. In analogy to 2D Dirac-materials, such as graphene, Cd$_3$As$_2$ has also shown to exhibit ultra-high mobility, with values exceeding 15,000 cm$^2$/V.s at room-temperature and much higher mobility at low temperatures. Furthermore, based on ARPES data Cd$_3$As$_2$ has been shown to exhibit a very large Fermi velocity, $v_F \sim 1.5 \times 10^6$ m/s, which is much higher than that in graphene ($\sim 1 \times 10^6$ m/s) or topological insulators. We experimentally demonstrate synthesis of high-quality large-area Cd$_3$As$_2$ thin-films through thermal evaporation and molecular beam epitaxy as well as the realization of plasmonic structures consisting of periodic arrays of Cd$_3$As$_2$ disks and stripes. These arrays exhibit sharp plasmonic resonances at terahertz frequencies ($\sim 1$ THz) with associated quality-factors $\sim 5$. These quality-factors, which to the best of our knowledge are among the largest reported to-date at room-temperature in semiconductor-based plasmonic structures in the terahertz range, is a direct result of the long relaxation-time in Cd$_3$As$_2$, which in our films approaches 1 ps at room-temperature. Moreover, ultrafast tunable response is demonstrated through excitation of photo-induced carriers in optical pump / terahertz probe experiments. Our results evidence that the 3D nature of Cd$_3$As$_2$ provides for a more robust platform for terahertz plasmonic applications than what is otherwise possible in 2D Dirac-materials such as graphene. Overall, these observations can pave a way for the development of a myriad of terahertz optoelectronic devices based on Cd$_3$As$_2$, benefiting from strong coupling of terahertz radiation, ultrafast transient response, magneto-plasmon properties, etc.; moreover, the long Drude scattering time, thus large kinetic inductance in Cd$_3$As$_2$ also holds enormous potential for the re-design of passive elements such as inductors and hence can have a profound impact in the field of RF integrated circuits.

Bio-sketch: Dr. Sensale-Rodriguez is a tenure-track Assistant Professor at the University of Utah, with an appointment with the Department of Electrical & Computer Engineering. He joined the faculty at the University of Utah in 2013, after earning his Ph.D. in Electrical Engineering from the University of Notre Dame (UND). During his research career, he has received the National Science Foundation (NSF) CAREER Award, the Eli J. and Helen Shaheen Graduate School Award in Engineering at UND, and the Best Student Paper Award at the 37th International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW-THz). Sensale-Rodriguez's research and teaching interests are in the area of (opto)electronic devices and materials. His research projects involve (i) simulation and design of electronic and photonic devices, in particular employing emerging materials, (ii) growth, fabrication and characterization of electronic and optical materials and devices, (iii) system integration of these devices.
HgCdTe-based heterostructures for THz emitters

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e-mail more@ipmras.ru

The problem of developing terahertz (THz)/long-wavelength emitters is one of the hottest topics in the applied physics. For many spectroscopy related applications, it would be favorable to employ compact semiconductor lasers as the sources of long wavelength radiation. Quantum cascade lasers (QCLs) demonstrate remarkable performance in the spectral range from 1THz to 5 THz and above 15 THz. In $\lambda=20–25\mu$m range, operation of the QCLs has been demonstrated only for several specific wavelengths. However, their output power and operation temperature are limited by the growth technology. There are alternative semiconductor systems that allow one to come close to the graphene-like energy-momentum law, but leave a finite bandgap. Unlike graphene, HgTe/CdHgTe QW allow tailoring the bandgap by simply changing the QW width. Modern molecular beam epitaxy (MBE) delivers high quality HgCdTe epitaxial structures not only for native CdZnTe substrates, but for “alternative” GaAs substrates as well. In this work we demonstrate stimulated emission (SE) from HgCdTe QW structures at wavelengths as long as 19.5μm, which is the margin of the spectral “gap” where QCLs are not available [Applied Physics Letters, 2017, 111(19): p. 192101; Appl. Phys. Lett., 2016, Vol. 108, P. 092104].

As shown, the Auger recombination can be suppressed in narrow HgTe/CdHgTe QWs, like in the long-wavelength lead salt lasers. Despite the fact that the threshold pumping intensity has increased by 50 times with twofold increase in the SE wavelength, the absolute values remain feasible, roughly following the trend predicted in our earlier works. Since we used “below bandgap” pumping, only a minor part of the pumping photons was absorbed in the QWs. Being recalculated to the equivalent threshold current for illustrative purposes, the threshold is only 500A/cm2 for $\lambda=20\mu$m. In principle, such low threshold current density allows development of diode lasers, taking into account that the technology of p-n junction in HgCdTe is constantly developing. While n-type doping of HgCdTe with indium is well understood and controllable, p-type doping has some problems to solve. In particular, mercury vacancies, which are double acceptors commonly used for p-type “doping” of HgCdTe, are in fact defects; therefore, they are also carrier lifetime “killers.” Consequently, diode lasers would most likely require another dopant, e.g., arsenic. However, further increase in wavelength is even more tantalizing route, which seems feasible at low temperature (20K–40K), at least in the spectral range from 20 to 30μm wavelength, where only free carrier absorption is present and gain can be achieved with relatively weak pumping, avoiding the carrier heating. Also we report stimulated emission in 2.8 – 3.5 μm wavelength range from HgTe/CdHgTe quantum well (QW) heterostructures at temperatures available with thermoelectric cooling around 260K (~13°C0). The structures were designed to suppress the Auger recombination by implementing narrow (1.5 – 2 nm) QWs. We conclude that Peltier cooled operation is feasible in lasers based on such structures, making them of interest for spectroscopy applications in the atmospheric transparency window from 3 to 5 μm.

Dr. Sergey Morozov is a Head of lab "Physics of semiconductor heterostructures and superlattices" at the Institute for Physics of Microstructures Russian Academy of Sciences (Nizhniy Novgorod, Russia). He joined the Institute for Physics of Microstructures Russian Academy of Sciences in 2001, after earning his Ph.D. in Department of Physics, Nizhny Novgorod State University. His key words of projects involve narrow-gap semiconductors; experimental study of semiconductor lasers emission spectra; life-time study in semiconductors; spectroscopy of quantum-size heterostructures; emission and detection of THz radiations in low-dimensional semiconductor structures.