AGREEMENT TO CREATE THE INTERNATIONAL ASSOCIATED LABORATORY

"Laboratory of Terahertz and Mid-Infrared Collective Phenomena in Semiconductor Nanostructures "

(LIA TERAMIR)

The **CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE** (French National Center for Scientific Research), hereinafter referred to as **"CNRS"**, a public scientific and technological organization, headquartered at 3, rue Michel-Ange, 75794 Paris Cedex 16 (France), represented by its President, Professor **Alain FUCHS**,

Acting in its own name and on behalf of the following joint research units:

- Laboratoire Charles Coulomb (L2C), UMR 5221 (CNRS - UM2), directed by Dr Jean-Louis SAUVAJOL,
- Laboratoire Matériaux et Phénomènes Quantiques (MPQ), UMR 7162 (CNRS – UPD), directed by Prof. Carlo SIRTORI,
- Laboratoire National des Champs Magnétiques Intenses (LNCMI), UPR 3228 (CNRS), directed by Dr Gerardus RIKKEN,

The CNRS acting by power of attorney also on behalf of the UNIVERSITÉ MONTPELLIER 2 - SCIENCES ET TECHNIQUES, hereinafter referred to as "UM2", on behalf of the L2C joint research unit.

And

The **UNIVERSITÉ PARIS DIDEROT,** hereinafter referred to as **"UPD"**, a public institution for higher education and research, headquartered at 5 rue Thomas Mann, 75205 Paris Cedex 13 (France), represented by its President, Professor **Christine CLERICI,**

Acting in its own name and on behalf of the following joint research unit:
- Laboratoire Matériaux et Phénomènes Quantiques (MPQ), UMR 7162 (CNRS - UPD), directed by Prof. Carlo SIRTORI

And

The **INSTITUTE OF HIGH PRESSURE PHYSICS of the POLISH ACADEMY OF SCIENCES,** hereinafter referred to as **"IHPP PAS"**, a public research performing institution, headquartered at Sokołowska 29/37, 01-142 Warsaw (Poland), represented by its Director, Professor **Izabella GRZEGORY,**

And

The **INSTITUTE FOR PHYSICS OF MICROSTRUCTURES of the RUSSIAN ACADEMY OF SCIENCES,** hereinafter referred to as **"IPM"**, a public research performing institution, headquartered at 7, Akademicheskaya ul, Afonino, Kstovskii raion, Nizhny Novgorod oblast, 607680, Russian Federation, represented by its Director, Prof. **Zakhary F. KRASILNIK ,**

Acting in its own name and on behalf of the following research unit:
- Laboratory "Physics of semiconductor heterostructures and superlattices, directed by Prof. Vladimir GAVRILENKO

And

The A.V. RZHANOV INSTITUTE OF SEMICONDUCTOR PHYSICS of the SIBERIAN BRANCH of the RUSSIAN ACADEMY OF SCIENCES, hereinafter referred to as **"ISP"**, a public research performing institution, headquartered at pr. Lavrentieva 13, 630090 Novosibirsk, (Russian Federation), represented by its Director, Professor **Alexander V. LATYSHEV,**

Acting in its own name and on behalf of the following research unit:
- Laboratory of Epitaxial Technology from Molecular Beams of A2B6 compounds, directed by Dr. Sergey DVORETSKY

And

The **RUSSIAN FOUNDATION FOR BASIC RESEARCH**, hereinafter referred to as **"RFBR"**, a public funding research organization, headquartered at Leninsky Prospect 32a, 117334 Moscow (Russian Federation), represented by its Chairman of the Board, Academician **Vladislav PANCHENKO.**

Hereinafter referred to collectively as the "Parties" or individually as the "Party."

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IN ACKNOWLEDGMENT OF

- The agreement on scientific cooperation between the Government of the French Republic and the Government of the Republic of Poland signed in Warsaw, on May 28th, 2008;

- The agreement for scientific cooperation between the CNRS and the PAS, signed on January 16th, 2012 in Paris;

- The agreement on Cultural Cooperation between the Governments of the Russian Federation and of the French Republic, signed in Paris on February 6, 1992;

- The agreement on Scientific and Technical Cooperation between the Governments of the Russian Federation and of the French Republic, signed in Moscow on July 28, 1992;

- The agreement for scientific cooperation between CNRS and the RFBR, signed in Paris, on May 24, 2012;

- The agreement for Scientific Cooperation between CNRS and the Russian Academy of Sciences, renewed in Moscow on June 25, 2010;

- The agreement between CNRS and UM2; UM2's rights and obligations, stemming from the present LIA TERAMIR agreement, will automatically be transferred to the new university to be created by the merger of universities Montpellier 1 and Montpellier 2.

- The agreement between CNRS and UPD;

- The power of attorney conferred on the CNRS to sign the present Agreement on behalf UM2, empowering CNRS to negotiate, sign and manage the agreement for the creation of the LIA TERAMIR on its behalf.

- The French decree n°2009-645 of June 9, 2009 on the management between the French public institutions of the industrial property of the results from research conducted by French state-employees, and which determines a French public mandatory responsible for the protection and exploitation of said results.

PREAMBLE

The International coordination network (GDRI) "Semiconductor sources and detectors of THz frequencies" supported in France by CNRS came into existence in 2005 with following development from GDR to GDRI through European network GDRE. During 8 years of its activity many international and national events have been organized: workshops, PhD thesis, researchers' exchanges resulting in collaborations and joint publications.
GDRI helped also in identification and establishing many strong bilateral collaborations focused on more specific projects. The most developed of them are the collaborations of the teams leaded by French GDRI coordinators of (C.Sirtori and W.Knap) and two east European countries – Poland and Russia. These collaborations are the basis of present LIA.

Below we present some important facts/agreements about collaboration in the past. We would like to stress that all these common research, publications, joint international theses, exchange visits and other actions allow constructing solid basis for LIA project.

♦ 2005-2007 PICS 3208 "

"Oscillations Terahertz de plasma bidimensionnel dans les systemes semiconducteurs aux dimensions nanometriques" ; between University Montpellier and Institute for Physics of Microstructures, Nizhny Novgorod, Russia and A.F.Ioffe Physical-Technical Institute, St. Petersburg, Russia.

Joint research have been carried out on several subjects: (i) Tunable terahertz detection by 50 nm gate length AlGaAs/InGaAs HEMTs ; (ii) Terahertz emission at T=4.2 K by InGaAs/InAlAs and GaAs/AlGaAs HEMTs (iii) Hole cyclotron resonance in strained InGaAs/GaAs QW heterostructures (iv) Cyclotron resonance in InAs/AlSb quantum well heterostructures in quantizing magnetic fields up to 13 T.

◆ **2005 - now, GDR 2987** "Détecteurs et Emetteurs de Radiations TéraHertz à Semiconducteurs" was created in 2005 and had in its initial form 22 participants from France and abroad (Russia, Poland, Germany, Lithuania etc) from universities, different research organizations and industry.

◆ **2006-2010 GDRE**. "Semiconductor sources and detectors of THz frequencies" between some French laboratories and laboratories in Lithuania, Poland and Russia. It was apparent after the first GDR meeting that some specific collaborations with well defined research subjects between some French laboratories and laboratories in Lithuania , Poland and Russia could be proposed. To allow the possibility and support of such international THz research actions, CNRS-DRI proposed the GDR-E agreement (with well defined intellectual property rights) between a very limited number of teams.

◆ **2010-2013 GDRI**. "Semiconductor sources and detectors of THz frequencies" between some French laboratories and laboratories in Japan, Lithuania, Poland and Russia.

Strong collaboration between French, Russian and Polish laboratories resulted from these networks supported by CNRS in France, in Russia and Poland collaboration was supported by Russian and Polish Academies of Science and Russian Foundation for Basic Research.

Visiting and exchanges between laboratories of France, Poland and Russia

Visits to L2C, UMR 5221 du CNRS and University Montpellier 2 of stay duration from one week to one month have been organized:

- From Institute for Physics of microstructures , RAS, Nizhny Novgorod, Russia: 7 persons, 12 months in total.

- From Laboratory of Semiconductors, Institute of High Pressure Physics of the Polish Academy of Sciences and Warsaw University: 4 persons, 2.5 years in total

PhD thesis

ORLOV Michael, 2004-2008, "Physics of emission and detection of electromagnetic waves of Thz frequencies in the transistors of submicron dimensions";

thesis en co-tutelle between Laboratoire Charles Coulombs (L2C), UMR 5221 du CNRS et Université Montpellier 2 and Laboratory of Physics of semiconductor heterostructures and superlattices, Institute for Physics of microstructures , Russian Academy of Science

KLIMENKO Oleg, 2007-2009, "Generation and detection of terahertz radiation in semiconductors and low-dimensional semiconductor structures";

thesis en co-tutelle between Laboratoire Charles Coulombs (L2C), UMR 5221 du CNRS et Université Montpellier 2 and P.N.Lebedev Physical Institute of Russian Academy of Sciences, Moscow

KRISHTOPENKO Sergey, 2009-2011 «Spin splitting and collective effects in InAs/AlSb quantum well heterostructures»

thesis en co-tutelle between Université Toulouse III – Paul Sabatier and Laboratory of Physics of semiconductor heterostructures and superlattices, Institute for Physics of Microstructures, Russian Academy of Science, Nizhniy Novgorod.

ZHOLUDEV Maksim, 2010-2013, « Spectroscopie Térahertz des systèmes semi-conducteurs bidimensionnels: résonance cyclotron, états résonants des impuretés peu profondes et effets dépendants du spin »

thesis en co-tutelle between Laboratoire Charles Coulombs (L2C), UMR 5221 du CNRS et Université Montpellier 2 and Laboratory of Physics of semiconductor heterostructures and superlattices, Institute for Physics of microstructures , Russian Academy of Science

Workshops organized in the frame of GDR, GDRE and GDRI:

GDR-I Workshop, December, 2013, Montpellier, France

7th THz days and GDR-I Workshop, March 25-27, 2013, Cargèse, Corsica, France

International Workshop on Optical Terahertz Science and Technology, April 1 -5, 2013, Kyoto, Japan

GDR-I Workshop, Avril 24-27, 2012, Tignes, France
GDR-I Workshop, March 29-April 1, 2011, Tignes, France
WITH project meeting, April 1-2, 2011, Tignes, France
GDR-I Workshop, September 27-28, 2010, Paris, France
Colloque "Rencontres scientifiques CNRS/Academie de Science de Russie", September 29-30 Paris, France
GDR-E Workshop, 16-17 November, 2009, Montpellier, France
GDR-E Workshop, 25-26 September, 2008, Paris, France
Meeting of the Steering Committee, 4 June, 2007, Paris, France
GDR-E Workshop, 1-2 June, 2007, Bombannes, France
GDR-E Scientific Committee Meeting, 4 December, 2006, Montpeller
Journées couplées GDR Ondes & GDR THz,5-6 Decembre 2006, Montpellier
The 2nd meeting, 9 May, 2006, Paris
The 1rst meeting,27-28 Juin, 2005, Montpeller

In order to consolidate the network that we have constructed in the past, we propose to focalize the joint research of a few laboratories on very specific/hot subject related to collective/plasma excitations in semiconductor nanostructures with special emphasis on nitrides, tellurides and graphene like based nanostructures.

Main actions
a) Research: theory, growth, processing and TERA-MIR investigations of novel structures using semiconductor nanostructures with emphasis on Dirac like energy dispersion systems.
b) Organization – of national and international workshops/meetings – (possible support from EC- COST 1024 action)
c) Exchange visits of PhDs students and researchers (also possible help of COST 1024)

Summarizing: the TERAMIR-LIA laboratory will have a very high scientific and technological potential because it will merge the "know how" of French teams on THz and Mid Infrared properties of nanostructures with "know-how" of east European countries and their unique technologies:
1) technology of extremely high mobility HgTe based quantum nanostructure (Rzhanov ISP SB RAS, Russia)
2) technology of GaN/AlGaN dislocation free, high pressure synthesized GaN bulk based epitaxial nanostructures (UNIPRESS-Poland)
Such technologies are not available in France and both are foreseen as potential candidates to revolutionary/new semiconductor - Graphene – like or "better then Graphene" nanostructures.
The activity of this LIA laboratory should be devoted to both: i) basic science and ii) applications.

Consequently, the Parties agree, on the basis of this Agreement, to form an "International Associated Laboratory - LIA" devoid of legal status and governed by the following provisions.

TITLE I – CREATION, TERM, NAME, PURPOSE AND COMPOSITION OF THE LIA

Article 1 - Creation and term

The International Associated Laboratory (LIA) **"Laboratory of Terahertz and Mid-Infrared Collective Phenomena in Semiconductor Nanostructures"**, abbreviated as "TERAMIR", hereinafter referred to as "LIA" or "LIA TERAMIR", shall be effective on **January 1st 2015** for a term of four (4) years, renewable once.

Article 2 - Purpose

The purpose of the LIA is to carry out the research project described in Annex 1 attached hereto in the field of Terahertz and Mid-Infrared Collective Phenomena in Semiconductor Nanostructures.

Article 3 - Composition

The LIA TERAMIR consists of the following laboratories:

- Laboratoire Charles Coulomb (L2C), UMR 5221 CNRS- UM2, Montpellier, directed by Dr Jean-Louis SAUVAJOL,
- Laboratoire Matériaux et Phénomènes Quantiques (MPQ), UMR 7162, CNRS-UPD, Paris, directed by Prof. Carlo SIRTORI,
- Laboratoire National des Champs Magnétiques Intenses (LNCMI), UPR 3228 CNRS, Grenoble directed by Dr Gerardus RIKKEN,
- Institute of High Pressure Physics of the Polish Academy of Sciences, Warsaw, Poland, directed by Professor Izabella GRZEGORY,
- Laboratory of Physics of semiconductor heterostructures and superlattices, Institute for Physics of Microstructures, Russian Academy of Sciences, Nizhny Novgorod, directed by Professor Vladimir GAVRILENKO,
- Laboratory of Epitaxial Technology from Molecular Beams of A2B6 compounds, Rzhanov Institute of Semiconductor Physics, Siberian Branch of Russian Academy of Sciences, Novosibirsk, directed by Dr. Sergey DVORETSKY,

The personnel and teams list (hereinafter referred to as "LIA Members"), as of January 1st 2015, is set out in Annex 2.A.

According to the research program realised in the framework of the LIA, researchers from other laboratories can participate in the LIA research. If deemed necessary, their participation will be subject to a specific Agreement or to an Amendment to the Agreement according to article 16.

Article 4 – Type of cooperation

The LIA has no legal status or capacity.

This Agreement neither sets out to nor results in, nor should anything in it be construed as either forming, creating, implementing or recognizing the creation of a joint company, agency relationship, corporation, interest group or any other type of commercial grouping or entity or de facto company by the Parties.

TITLE II - ORGANIZATION

Article 5 – Co-directors

The LIA is ran by three (3) Co-directors, one per country. The management of the LIA is jointly provided by:

- Dr Wojciech KNAP, for France,
- Dr. Czeslaw SKIERBISZEWSKI, for Poland
- Prof. Vladimir GAVRILENKO, for the Russian Federation,

hereinafter referred to as "Co-directors".

In accordance with the practice of their home institutions, the Co-directors jointly assume responsibility for the scientific program and each one individually manages his part of the LIA. As necessary, they shall establish the rules of procedure for the LIA Members.

The Co-directors shall prepare the research program, provisional budget and annual financial and scientific reports to be submitted to the Steering Committee and to the Parties.

The directors of the French Joint Research Units (UMR) participating in the LIA are solely responsible administratively with regard to staff management and use of funding resources allocated to the LIA vis-à-vis the Parties overseeing their unit.

The Co-directors may delegate the scientific management of the LIA to a Scientific Management Committee composed of thematic group leaders selected among the LIA researchers. The list of members of the Scientific Management Committee as of January 1st 2015 is set out in Annex 2.B.

Article 6 – Steering Committee

6.1. – Composition

A Steering Committee for the LIA TERAMIR is constituted. This Committee shall be composed of 2 representatives per country, chosen from outside the staff of those laboratories making up the LIA:

- 2 representatives of the French Parties:
  - the Director of the Institute of Physics of CNRS (INP), or his/her representative
  - the Vice-President for Research of UPD, or his/her representative

- 2 representatives of the Polish Parties:
  - the Director of the International Relations Office of the PAS, or his/her representative
  - the Director of the IHPP PAS, or his/her representative

- 2 representatives of the Russian Parties:
  - the Director of the IPM, or his/her representative
  - the Director of the International Relations Department of RFBR, or his/her representative

All members possess equal voting rights.

Subject to the execution of a nondisclosure agreement, all Parties may invite members of their administrative organization and/or outside parties, to attend the Steering Committee meetings. Such invited guests shall sit in a consultative capacity.
The list of representatives as of January 1st 2015 is set out in Annex 2.C.

The LIA Co-directors shall attend the Steering Committee meetings in a consultative capacity.

6.2. - Chairperson

The Parties appoint one of the Steering Committee members as Chairperson in rotation for two years in order to preside the Steering Committee.

The Chairperson as of January 1st 2015 is the Director of the CNRS INP.

6.3. – Meetings and decisions

The Steering Committee shall meet at least once every two (2) years and, at the initiative of its Chairperson and at the request of its members or the Co-directors, as often as required by the interests of the LIA.

Decisions require the unanimity of members either present or represented, the quorum being reached at $^5/_6$ of its members.
In the event of practical impossibility of a physical meeting, the Steering Committee may meet via teleconferencing or any other means.

6.4. – Role

The Steering Committee:
- formulates recommendations on the project presented by the Co-directors and the state and direction of the research carried out by the LIA;
- approves the funding necessary to run the LIA;
- may make recommendations or propose reorientations;
- defines the collaboration policy of the LIA taking into account the Parties' interests;
- defines the Party in charge of negotiation of research contracts;
- provides an opinion on any modification of the LIA structure and on the admission of new laboratories or Parties to the LIA;
- provides an advice as to the renewal of the LIA based on the evaluation reports;
- may also study any matter relating to the LIA.

Meeting minutes for all Steering Committee meetings shall be provided by the Chairperson to all Parties within 30 days.

Article 7 – Scientific evaluation

The LIA activities shall be assessed regularly and in any case before its expiration date by the relevant authorities of all Parties, in accordance with the applicable procedures of these bodies. The Parties may also propose to form an *Ad Hoc* Committee, particularly prior to LIA renewal, in order to evaluate its scientific activities and issue recommendations on the LIA scientific orientation and functioning.
Evaluation reports shall be addressed to the Steering Committee and the Parties.

TITLE III – FINANCIAL AND HUMAN RESOURCES

Article 8 – Funding provisions

Every calendar year, the budget required to carry out the LIA research is prepared and submitted by the LIA Co-directors to the Steering Committee for approval.

Annex 3 attached hereto, sets out the projected budget allocated by the Parties as of the date the LIA enters into effect. This budget is updated annually by the LIA Co-directors, following a vote by the Steering Committee.

Each LIA Party shall manage its respective resources, such as the internal budget allocation for the LIA purposes or external resources.

Resources obtained jointly within the framework of agreements concluded on behalf of the LIA shall be shared and managed by the Parties in accordance with their participation in such projects.

A report is provided annually by each Party to the others on the resources it allocated over the past year (including equipment, premises and tenured or temporary personnel).

Moreover, the funds allocated to the LIA and managed by three LIA Co-directors are subject to the customary monitoring mechanisms in their respective countries to verify their legitimate use in relation to the purpose of this Agreement.

Article 9 – Personnel

Personnel assigned to contribute to the LIA shall remain administratively dependent on their original institution and unit and shall carry out its work under the administrative supervision of their unit director.

Annexes 2 and 3 summarize the schedule and extent of the participation of personnel in the joint scientific project.

The exchange of personnel (secondment, etc.) is subject to execution of an agreement setting out in particular terms and conditions of compensation, ownership of results and subordination.

While on assignment, visitors are subject to the bylaws and procedures of the hosting laboratory.

Article 10 – Facilities and equipment

LIA members shall have access to the facilities and/or equipment listed in Annex 4 throughout the term of this Agreement for purposes of carrying out the research project described in Annex 1.

The Party, in whose possession the facilities and/or equipment are located, remains liable therefore.

For information purposes, the amount of depreciation allowance for facilities and equipment made available to the LIA must be provided (according to the terms in effect for each Party).

The use of facilities and/or equipment is subject to the safety and security rules in force.

The Parties' premises are made available to LIA use subject to compliance with the bylaws and procedures of the owner Party and the execution of a hosting agreement.

In the event of a loan or rental of facilities and equipment, a loan agreement shall be executed by the Parties concerned, including reference to the purpose and term, any applicable fees, the Parties' liabilities and the terms of maintenance and return of the property.

Article 11 – Research contracts

All research contracts that shall be executed with third-party bodies, public or private, within the framework of the LIA, require approval of and signature by all Parties, and are subject to the paragraph 6.4 on the role of the Steering Committee.

They shall be negotiated by the Party having express authority to so act, in accordance with the Co-directors' proposition and the agreement of the other Parties. The authorized Party shall keep the other Parties informed of the results of all negotiations. The latter shall dispose of fifteen (15) working days to respond, after which the negotiation is deemed approved.

The use of LIA TERAMIR title by the Parties must include that LIA is devoid of legal personality and the LIA Parties are financially and legally independent and separate liable partners.

The nondisclosure clauses included in such research contracts must not preclude the concerned researchers from including their research in activity reports or the students to defend their PhD dissertation.

The contracts shall make explicit provisions for reimbursing overheads associated with activities developed under said contracts which have been paid by the Party involved in the research. The corresponding amounts, determined by agreement between the Parties, shall be allocated to the budgetary contribution of said Party.

TITLE IV – PUBLICATIONS, CONFIDENTIALITY, INTELLECTUAL PROPERTY AND VALORISATION

Article 12 – Mutual informing and Publications

Each Party undertakes to share with the other Parties all information needed to carry out the joint research work. The publication of scientific results shall be made according the usual custom and practice of the scientific community, Parties' recommendations on scientists' affiliation and with prior consent of all scientific contributors to the results and entitled Parties.

Publications related to the joint research efforts of the LIA research projects shall include reference to the LIA Parties or other French overseeing authorities and bearing the mandatory statement *"Research conducted in the scope of the TERAMIR International Associated Laboratory (LIA)"*

Throughout the term of the LIA and for a subsequent period of two (2) years, each Party shall request the consent of the other Party for its own publication related to the LIA. Such consent may not be unreasonably withheld.

In any case, a publication cannot be delayed beyond nineteen (19) months from the date of receipt of a notice by the Parties. Where a publication or paper contains important information of an industrial, commercial or strategic nature related to the activities of certain Parties the decision regarding the nature and term of nondisclosure shall be taken by the Steering Committee (allowed: activity reports by personnel, closed session dissertation defenses).The Steering Committee shall make its decision known within a maximum period of one (1) month as from the receipt date of the enquiry. This decision can consist in:

a) Accepting the publication unreservedly; or
b) Requesting that the publication or communications project be postponed, owing to real and serious reasons in particular if specific information must be subject to protection under intellectual property provisions. In such case, the Parties agree to either remove the objecting Party's Confidential Information or to delay the planned publication for a period of up to a maximum of eighteen (18) months after objection to allow for protection or other appropriate steps.

Article 13 – Non-disclosure

Within the framework of information exchange necessary to carry out the joint research work, the Parties shall refrain from disclosure, protection (patent) or exploitation of commercial or industrial nature of any confidential information belonging to the other Party,

Information (of any kind, contained in any medium) is confidential when explicitly identified as "confidential".

The period of confidentiality runs for the term of the LIA and a subsequent five (5)-year period.

The Parties are responsible for ensuring compliance with duty of non-disclosure by their employees during LIA and following expiration of its term or following termination of their employment, as well as by hosted personnel.

However, this clause shall not impede Parties' researchers from fulfilling their obligation of producing an activity report, which shall not constitute disclosure within the meaning of the laws governing industrial property, nor students from defending their doctoral thesis or internship report relating to the work conducted under this cooperative activity. If necessary, the examination may take place behind closed doors.

Exceptions in which the Confidentiality obligations shall not apply:

- if the confidential information becomes publicly available by means other than a breach of the recipient's confidentiality obligations;
- if the disclosing party subsequently informs the recipient that the confidential information is no longer confidential;
- if the confidential information is communicated to the recipient without any obligation of confidence by a third party who is in lawful possession thereof and under no obligation of confidence to the disclosing party;
- if the confidential information, at any time, was developed by the recipient completely independently of any such disclosure by the disclosing party; or
- if the confidential information was already known to the recipient prior to disclosure.
- if a Party is required, to disclose confidential information in order to:
    - comply with applicable laws or regulations or with a court or administrative order, provided however that it shall, to the extent it is lawfully able to do so, prior to any such disclosure
    - notify the disclosing party, and
    - comply with the disclosing party's reasonable instructions to protect the confidentiality of the information.

Article 14 – Intellectual Property

Definitions

- "Proprietary Results":

Results, including software and databases, which may or may not be protected by intellectual property rights and belonging to one of the Parties, obtained by the LIA Members prior to joining the present Agreement or simultaneous to and independent of the scope of LIA activities;

- "Joint Results":

Results, including software and databases, which may or may not be protected by intellectual property rights to which two or more Parties jointly contributed in a substantial or inventive manner and which are a direct or indirect result of the LIA activities.

- "Qualified Know-How":

All practical results unprotected by intellectual property rights which are: (a) confidential, (b) substantial, i.e. significant and useful for the manufacture of particular products and (c) identified, i.e. described in such a way as to be understandable and adequate to confirm the elements of (a) and (b).

14.1. – Ownership of Results

Proprietary Results remain the property of the owning Party.
Proprietary Results or Qualified Know-how that are not free of access for the purposes of LIA are set out in Annex 5, which shall be regularly updated by the Parties. All Proprietary Results, which are not listed in Annex 5, are free of access for the purposes of LIA

By virtue of a power of attorney by UM2, subject to the French decree n°2009-645, CNRS shall be the sole French administrator of the intellectual property rights related to LIA Results, that it jointly owns with the abovementioned overseeing authority of the joint research unit, pursuant to their mutual agreements, unless this authority or employers explicitly waive its rights.

The LIA Joint Results are the joint property of the entitled Parties (hereinafter referred to as "Joint Owners"), which shall hold such rights in equal proportions.

The above allocation shall be the default in case for LIA Joint Results, but the Parties may negotiate, however, from case to case, a more appropriate allocation of share according to the inventive contributions, if such contributions are substantially not comparable.
In case of disagreement between the Parties regarding to such contributions, the share should be discussed in an amicable way in the framework of the Steering Committee. In case of persisting disagreement such share shall be determined by an external independent patent attorney.

Any transfer of ownership, grant of license or similar right over the LIA Joint Results shall require the prior written consent of the other Joint Owners.

The Joint Owners agree to negotiate in good faith an Inter-Institutional-Agreement ("IIA") settling their rights and duties with regard to any LIA Joint Result, to be concluded before any industrial and commercial use of such Joint Result.

To the extent possible, such IIA shall be based on the terms and conditions with regard to the regulation, the administration and the commercial exploitation of the LIA Joint Result agreed by the Joint Owners and specified in this section.

A LIA Result, which is not a Joint Result, shall be solely owned by the Party who obtained it, and shall not be subject to the provisions regarding the Joint Results.

14.2. – Patent protection of LIA Results

Inventors of a LIA Result shall inform the Co-directors and the Steering Committee and declare their invention to each of the entitled Parties, which shall evaluate any interest in protecting said invention.

Joint Owners shall jointly decide whether or not to patent any LIA Joint Result. In the event a patent is filed, they shall jointly decide on the countries or regions to be covered by the registration. Patent applications shall be filed in the names and for the joint benefit of the Joint Owners; the name(s) of the inventor(s) shall be mentioned pursuant to his/her/their rights.

One or more Joint Owner(s) have the right to file a patent in its (their) name and at its (their) expense, if one or more Joint Owners expressly waive and assign their rights to do so. The Joint Owner who waived and assigned his right should take all steps and/or execute all documents necessary in order to give full force and effect to any such assignment. Such Joint Owner shall be entitled however, to assign its rights in the LIA Joint Result to its inventor/s without obtaining the other Party's approval, provided that the inventor/s has/have undertaken in writing to the other Party to be bound by the provisions of this Agreement.

The remaining Joint Owners has the right to recover the patent rights in their name(s) if, during the term of protection, one of the Joint Owners decides to withdraw its involvement from the patent. Such Joint Owner shall be entitled however, to assign its rights in the LIA Joint Result to its inventor/s without obtaining the other Party's approval, provided that the Inventor/s has/have undertaken in writing to the other Party to be bound by the provisions of this Agreement.

A Joint Owner who does not join in protecting a LIA Joint Result or who withdraws its involvement in the patent protection, shall lose its rights (including the right to remuneration or compensation in respect of such patent rights or such assignment), save for the right (a) to use the LIA Joint Results for internal research purposes; and (b) to be reimbursed together with any other Joint Owner from any income received from such patents for all out-of-pocket costs and expenses incurred by such Joint Owner during the period it participated in protecting a LIA Joint Results and the course of such patent protection.

The Joint Owners involved in such protection shall be the sole beneficiaries of the income generated from commercial exploitation of the patent in the corresponding countries.

Each Joint Owner involved in the protection of an LIA Joint Result is solely liable for ensuring compliance with duties relative to its employees' rights over the invention.

14.3. – Appointment of an Administrator

The Joint Owner most able to valorize or exploit one or more Joint Results of the LIA, identified by mutual agreement between the Parties upon recommendation by the Steering Committee and subject to the French decree n°2009-645, shall administer the protection and exploitation of the(se) LIA Results (hereinafter the "Administrator").

14.4. – Patent infringement actions

In the event that one of the Joint Owners learns of an alleged infringement of a patent owned jointly by the Parties, or of an application pending or a patent belonging to a third party and interfering with the patent held jointly the Parties, the information shall be immediately communicated between the Joint Owners.

The Joint Owners involved in the protection of a LIA Joint Result shall mutually agree on measures to be taken in the event of infringement. The Administrator, who shall be vested with all specific powers in relation thereto, is responsible for such measures; he shall take all necessary steps in order to take cognizance of and put a stop to the infringing action.

The legal fees, costs, damages and interest shall be shared between/among the Joint Owners acting jointly according to their share in the ownership. Joint Owners who do not participate in the action shall not collect any sums resulting from legal recourse.

14.5. – Rights of access

Each Party shall hold, subject to third-party rights, a non-exclusive, non-transferable right to use the LIA Results – including those that are not Joint Results - and the Proprietary Results except for those listed in Annex 5, free of charge for the purposes of the LIA research. For the avoidance of doubt the LIA research does not include any activity of an industrial or commercial nature.

Each Joint Owner shall hold a non-exclusive, non-transferable right to use the LIA Joint Results – including the structure and content of Joint software and databases - free of charge for their own internal research needs, with the exception of any activity which is of an industrial or commercial nature and necessitates execution of an agreement defining the scope, terms and conditions of licensing.

Third-party access to LIA Joint Results including software and databases is subject to the prior consent of the Joint Owners and subject to a written agreement.

14.6. – Commercial exploitation of LIA Joint Results

The consent of all Joint Owners is required to grant third-party rights, as licenses to use and exploit any LIA Joint Result.

The Joint Owners shall agree, with regard to each commercial negotiation with a third party, on the principal financial terms, which shall form part of the commercial agreement with such third party in advance (hereinafter "the Term Sheet").

Express powers are granted to the Administrator by other Joint Owners to act and undertake all activities to commercially exploit the LIA Joint Results.

The Administrator shall regularly inform the Joint Owners of the progress and conclusion of negotiations.

The Joint Owners agree that, after the Term Sheet shall be agreed upon by them, the Administrator shall be entitled to negotiate license and other commercialization agreements on the Joint Owners' behalf in respect of the LIA Joint Results, based on the terms of the Term Sheet and the provisions set out below ("Additional Terms"). The Joint Owners shall jointly execute any such agreements, and shall not be entitled to withhold their signature thereon provided the Administrator has complied with the terms hereof.

In addition to the specific terms of the Term Sheet that shall be agreed by the Joint Owners as aforesaid, an Agreement for any license granted in respect of the LIA Joint Results shall include, *inter alia:*

- a definition of the products for which the LIA Joint Results may be used for their development, manufacture and sale;
- terms securing full indemnification, without exception, and holding harmless of the Parties, and those employed by them, against and from any claim, damage or expense of any kind resulting from any use the Licensee or those authorized by the Licensee may make of the LIA Joint Results or other licensed information;
- a disclaimer as to any representations and/or warranties in respect of the LIA Joint Results, their potential, use, exploitability and/or that it does not infringe third party's rights;
- the license agreement may not be sublicensed, transferred or assigned without the prior written consent of the Joint Owners;
- financial terms: in return for the license agreement the Joint Owners shall get financial return, as royalties (in the form of percentage from sales), part of any consideration other than from sales received in connection with a grant of sub-license, an annual license fee and an equity (in start-up companies). The exact mixture of the above and the terms securing it will be negotiated.
- specific undertakings of commercialization of the licensee (such as, but not limited to achieving milestones for developing and sale of the products (to avoid "shelving" of the technology), receiving prior approval before the grant of any sub-license etc.) ;
- limitation on the use of the names of the Inventors, CNRS, UM2, UPD, IHPP PAS, PAS, IPM, ISP and RFBR and their employees;
- payment/reimbursement of past and future patent expenses by the licensee;
- patent prosecution and maintenance shall be done by the Administrator;

Notwithstanding anything to the contrary herein, in the event that a potential licensee rejects any of the above terms, the Joint owners shall in good faith seek solutions that will be subject to all Joint Owners' written approval, to be advised timeously, and not to be unreasonably withheld.

Licensing agreements shall require signature of all Joint Owners.

The Administrator shall transfer to the Joint Owners their share of the royalties from the license granted over the LIA Joint Result(s) according to their share in the LIA Joint Result(s), after having deducted the Administrator's commercial development fees, capped at 10% of said royalties. For the avoidance of doubt, research funding received from a licensee by either Party shall not be regarded as payment from commercialization of the Invention and/or the Patents.

TITLE V – MISCELLANEOUS PROVISIONS

Article 15 – Renewal

This Agreement may be renewed once for the same term by Amendment executed by the Parties, following a decision by the Parties on advice from the Steering Committee, the relevant evaluating bodies of the Parties and the LIA Co-directors.

Article 16 – Modification – Membership

All modifications to the present Agreement require the mutual consent of all Parties by Amendment.

All additions of members to the LIA, including that of a new laboratory of one of the Parties, require the unanimous consent of the Steering Committee.

Any admission of a new laboratory under the authority of a Party requires the update of Annexes, to be provided by the Co-directors to all Parties.

The addition of new parties to the LIA shall require an amendment to this Agreement.
All admission amendments to this Agreement shall be signed by the new parties and CNRS, authorized by this Agreement to so act on behalf of the other Parties.
The sole purpose of an admission amendment is to join new partners to the LIA. It in no way modifies the scope of the present Agreement.

Article 17 – Cancellation

In the event of an unresolved dispute, the Parties may mutually consent to canceling the present Agreement before the expiration of its term, upon six (6) months' notice. In such a case, the Parties shall conclude joint actions undertaken prior to notice given.

The decision to cancel shall be taken by the Parties following consultation with the Steering Committee and the LIA Co-directors.

The withdrawal of a Party prior to term, notified to the other Parties with six months' notice shall terminate the present Agreement.

Non-disclosure, publication, intellectual property and exploitation provisions shall continue to apply for their respective terms.

Article 18 – Internal communication between Parties

Internal communication between Parties shall be done in writing (registered letter with acknowledgement of receipt, sent via postal or electronic means, facsimile, etc.).

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Article 19 – Liability

Each Party remains liable, without right of action against the other Parties, except in case of gross or intentional negligence, for repairing damage to its own property during and owing to the implementation of this Agreement.
Should damage be caused to physical assets acquired by the Parties under this Agreement, the latter shall pay repair or replacement charges for said assets on a pro rata basis of their respective financial contributions to the acquisition thereof.
According to the rules of ordinary law, each Party is liable for damage / loss of any nature caused to third parties during the implementation of this Agreement.

Article 20 – Final provisions

The Parties undertake to settle their disputes out of court. Failing that, disputes arising out of or in connection with this Agreement, which cannot be solved amicably, shall be finally settled under the Rules of Arbitration of the International Chamber of Commerce by one arbitrator appointed in accordance with the said Rules.
The place of arbitration shall be Paris, Warsaw or Moscow at the defendant's total discretion.

Done in English, in 6 (six) original copies.

At Paris, on the 14th of October 2014

CNRS Alain Fuchs President By delegation, **Fabrice Vallée** **Acting Director of the Institute of Physics**	**IHHP of the PAS** **Izabella Grzegory** **Director**
UPD **Christine Clerici** **President**	**IPM RAS** **Zakhary Krasilnik** **Director**
ISP SB RAS Alexander Latyshev Director By delegation, **Nikolay Mikhailov**	**The RFBR** **Vladislav Ya. Panchenko** **President**

ANNEX 1

RESEARCH PROGRAM AND INDIVIDUAL PROJECTS

The project is composed of two parts, A and B, described below. Narrow gap HgTe based quantum wells (QW) are relatively new subject in semiconductor physics. Therefore in part C we present more in detail scientific background and challenges related to these new nanostructures. Except collective phenomena that are the main scientific subject of the present project, studying narrow gap HgTe based QWs may lead to widening the scientific research to very "up today", important subjects like topological insulators and/ or spin Hall effect studies.

PART A) "Plasma wave instabilities in GaN and Graphene like HgTe based nanostructures for terahertz (THz) generation and detection"

PARTNERS INVOLVED: L2C (Leader), IHPPPAS, IPM, ISP

OTHER EXPECTED PARTICIPANTS:
- A.F. Ioffe Institute, groups of Dr Alexander A. Lebedev and of Prof. Valentine Kachrovsky & Nikita S. Averkiev,
- Moscow State Pedagogical University, Radio-Physics Research Educational Center, Department of Physics, Moscow, directed by Prof. Gregory N. Goltsman
- Institute of semiconductors physics, Polish Academy of Sciences, group directed by Prof. T. Dietl, J. Wrobel, G. Grabecki.

At the beginning of 90-ties Dyakonov and Shur proposed model of plasma excitations in nanometer field effect transistors for THz detection and emission [1]. They have shown that the channel of a field effect transistor (FET) can act as a resonator for plasma waves with a typical wave velocity s $\sim 10^8$ cm/s. The fundamental frequency f of this resonator depends on its dimensions and for gate length L of a micron or less, f can reach the terahertz (THz) range, since $f \sim s/L$. Dyakonov and Shur predicted also that a steady current flow in an asymmetric FET channel can lead to instability against the spontaneous generation of plasma waves [1]. In the beginning of years 2000 theoretical predictions have been confirmed by experiments on THz emission and detection from nanotransistors. However all observed resonant phenomena were much broader than theoretically predicted. Also in many cases the observed emission was not resonant and not gate voltage tuneable. The basic physics questions rose about completeness of theoretical model of Dyakonov-Shur and possibility of other instabilities.

Basic Physics Problems. Main scientific problems aimed to be solved by the proposed project are: first i) is to understand/explain the physical reasons of unusual plasma wave resonance broadening (or complete lack of resonances) observed in nanometer sized nanostructures emitting or detecting THz radiation [2] and second ii) make experimental verification of existence of new type of plasma instability – so called "edge instability" or "white water instability" [3].These two problems are related because the edge instability, that maybe responsible for observed broad THz emission, is due to oblique plasma modes that at the same time may lead to the plasma resonance broadening in the THz detection. Until now both problems are considered only theoretically [2-3].

Methodology The essence of the project is experimental study of high quality nanotransistors of different geometry. The project aims to i) produce by MBE high mobility two dimensional electron gas (2DEG) based on GaN and HgTe heterostructures, ii) process nanometer size transistor structures of different architectures and ii) to study systematically how THz detection and emission from these structures depend on their specific architecture. Study as a function of the channel length, gate length and width should provide a proof of validity/existence of three recently predicted [2],[3] physical phenomena: ***i) oblique modes broadening ii) plasmon leakage broadening iii) plasma edge instability.***

Timeliness and novelty of the proposed research comes from combination of recently developed fields of research: *Terahertz related science*, *Science of nanostructures*, *Nitrides and graphene like materials science* and most important new theoretical developments concerning *Plasma instabilities* in low dimensional systems. Approach proposed in this project is pioneering because it will combine for the first time very strong technology (growth and processing at the main partner side – Poland,Russia) with modeling and high level and very precise characterization of THz detection and emission (at Montpellier TERALAB - France).

Why Nitrides? - Because they guarantee high mobility and high carrier density at the same time. Transistors based on Nitrides can handle high power so they are the best candidate for THz emitters. We have already observed THz emission from single transistors. Making high mobility and specially structured (grating gate) emitters can lead to resonant high power THz emission. Common studies on high mobility quantum wells have been already initiated - see Ref.[4].

Why HgTe? Because HgTe based quantum well structures – with proper choice of HgTe quantum well thickness (around 7nm) one gets grapheme like structure with very high carrier mobility. Contrary to nitrides these structures cannot handle very high power and cannot be efficient emitters. However their extremely high mobility make them ideal structures for voltage tuned, resonant THz detectors. Their advantage with respect to Graphene is that they preserve their mobility even after the processing – whereas Graphene on SiC or Si substrates looses its high mobility properties. Common studies on HgTe quantum wells have been already initiated by PhD (cotutelle) M.Zoludiev, first author of Ref. [5]. More details can be found in part C.

Impact We expect that the project will have very high impact on the research field on plasma instabilities in nanostructures because it will answer the main question: Can one reach high quality factor plasma resonances in the nanometer semiconductor structures and what physical conditions (border conditions, material properties etc.) are necessary to observe them.

Applications We expect also important outcome from the point of view of applications. Understanding of the mechanism of broadening should allow finding nanotransistor structures with narrowband gate tunable THz emission and detection. *Such transistors can be extremely useful for THz spectroscopy and imaging* in security, quality control or medical applications.

This project can be done only in collaboration because the French partners has necessary experience, skills and equipment to model and characterize the nanostructures for terahertz and Mid –Infrared (TERAMIR) generation and detection. The Polish and Russian partners have experience, skills and equipment in fabrication (growth and processing) of the high quality GaN and HgTe based nanostructures. ***The partners are complementary and they are leaders in their research domain granting this way the new scientific insight in "THz Plasma Instabilities in Nanostructures" and the success of the project*.**

References:

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[5] M. Zholudev, F. Teppe, M. Orlita, C. Consejo, J. Torres, N. Dyakonova, M. Czapkiewicz, J. Wróbel, G. Grabecki, N. Mikhailov, S. Dvoretskii, A. Ikonnikov, K. Spirin, V. Aleshkin, V. Gavrilenko, and W. Knap ***Magnetospectroscopy of two-dimensional HgTe-based topological insulators around the critical thickness*** Phys. Rev. B 86, 205420 – Published 16 November 2012

PART B) TERA-MIR Collective excitations in wide Quantum Wells

PARTNERS INVOLVED: MPQ (Leader), L2C, IHPPPAS, ISP, IPM,

OTHER EXPECTED PARTICIPANTS:

- Lebedev Physical Institute, Laboratory "Nonlinear and nonequilibrium phenomena in solids", Russian Academy of Sciences Moscow, directed by Prof. Yury Mityagin
- Kotelnikov Institute of Radio Engineering and Electronics, Saratov Branch, Photonics Laboratory, Russian Academy of Sciences, Saratov, directed by Prof. V.V. Popov

Recently we have investigated collective excitations in highly doped two-dimensional structures. We have measured strong resonances in absorption and emission at energies independent of the electronic spectrum imposed by the size quantization of the quantum well [1]. The nature of this excitation is an admixture between single particle electronic transitions and plasma collective effects issued from Coulomb dipole-dipole interaction [2]. In a quantum well where the Fermi energy is such that several electronic levels are occupied, each transition is coupled to the others and produces a single bright collective excitation that contains the whole oscillator strength of the system [1]. The narrow linewidth of these plasmonic resonances (<5% of the transition energy) makes them attractive for optoelectronic applications.

All our studies have been performed on GaAs and InP related materials where the doping and the other physical parameters (effective mass, dielectric constant) has limited our investigation to resonances up to l = 10mm. We are therefore very interested in developing collaborations to explore extremely doped materials such as GaN where the collective excitations can reach shorter wavelength down to the near infrared.

Another strong interest that we have in this collaboration is to extend the studies on light-matter strong interaction of these collective excitations in zero-gap materials like in Grapheme or HgTe based QW or HgCdTe heterostructures. In this case very strong plasmonic effects are expected due to the vanishing effective mass. Furthermore light-matter interaction in these materials would be profoundly modified and is expected to give rise to superradiant quantum phase transitions. Electroluminescent devices with high quantum efficiency are expected to be realized in the THz thanks to these effects [3]. More details concerning HgCdTe heterostructures can be found in part C.

References:

[1] A. Delteil, A. Vasanelli, Y. Todorov, C. Feuillet Palma, M. Renaudat St-Jean, G. Beaudoin, I. Sagnes, and C. Sirtori, ***Charge-Induced Coherence between Intersubband Plasmons in a Quantum Structure,*** Phys. Rev. Lett., **109**, 246808 (2012).

[2] Yanko Todorov and Carlo Sirtori, ***Intersubband Polaritons in the Electrical Dipole Gauge,*** Phys. Rev. B **85**, 045304 (2012).

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Part C) HgTe based quantum wells – scientific background and objectives related to LIA

PARTNERS INVOLVED: L2C (Leader), IPM, ISP, IHPPPAS, PAS

Because HgTe has an inverted band structure (the conduction band is formed by the wave functions of Γ8 symmetry, and the valence band wave functions have Γ6 symmetry see, e.g., [1,3] and references therein) $Hg_{1-x}Cd_xTe$ band gap becomes zero for x ~ 0.16. In the recent years there has been an appreciable progress in the MBE growth of such structures, which has revived interest to this compound as a promising material for Terahertz (THz) detectors and emitters. But HgTe based QWs exhibit a number of other remarkable properties. First of all, at the critical HgTe QW thickness (6.3 to 7 nm depending on Cd content in the barrier), the forbidden gap is absent and both electrons and holes are characterized by the linear energy-momentum law of massless Dirac fermions [1,2]. When HgTe QW width exceeds this critical value, the energy band structure is inverted. In the inverted band structure regime, HgTe QWs are shown to be two-dimensional topological insulators that have attracted a great fundamental interest [1,2,4,5]. It was demonstrated [4] that a quantum spin Hall insulator state exists in such systems that can be destroyed by magnetic field [6]. Actually, these two levels have recently shown to display the effect of the avoided crossing [7,8]. Furthermore, hole-like symmetry of conduction-band Bloch functions enhances spin-dependent effects like the Rashba splitting that has been shown to achieve 30 meV [3,9] in these structures. The very strong spin-orbit coupling in these materials also make them good candidates for experimental observation of the Spin Hall Effect predicted more than 40 years ago [10, 11]. Moreover, wide HgTe/CdTe QWs (above 12.5 nm) have an indirect band structure [12] and the side maxima of the valence band can overlap with the conduction band. Then, the Fermi level can cross both valence and conduction bands and a semimetallic state can be implemented [13,14].

Another very important property of wide HgCdTe QWs is their very high electron mobility which makes them highly interesting for the study of different physical phenomena as Fractional Quantum Hall Effect and THz plasma wave resonances in Field Effect Transistors (FETs). Indeed, when electron mobility is high enough, FETs can efficiently detect and generate THz radiations via resonant plasma excitation in the transistors channel [15-17]. Furthermore, a spectacular analogy between ultra-relativistic particles in quantum electrodynamic and electrons in some solid-state systems has been demonstrated both in one dimension (carbon nanotubes [18]) and in two dimensions (graphene [19, 20]). However, a three-dimensional (3D) solid-state system whose electrons would mimic massless particles (in which such an analogy would be even closer) appeared to be missing up to now. Very recently, a group from LNCMI Laboratory in Grenoble (M. Orlita) in collaboration with L2C laboratory and Nizhny Novgorod have characterized a bulk HgCdTe, at the point of a topological transition. The presence of 3D massless electrons with the velocity about 10^6 m.s^{-1} in this material is clearly manifested (i) by infrared absorption which increases strictly linearly with the photon frequency, and (ii) in a magnetic field B, by a B dependence of inter-Landau-level resonances. This very significant experimental work opens a new field of investigation regarding the massless Dirac Fermions in these materials.

Another important project is related to light-matter strong interaction of the collective excitations in zero-gap materials like Grapheme or HgTe/CdTe heterojunctions. In this case very strong plasmonic effects are expected due to the vanishing effective mass. Furthermore light-matter interaction in these materials would be profoundly modified and is expected to give rise to superradiant quantum phase transitions. Electroluminescent devices with high quantum efficiency are expected to be realized in the THz thanks to these effects

Our goal in LIA "Terahertz and Mid-Infrared Collective Phenomena in Semiconductor Nanostructures (TERAMIR)" will be to study by THz spectroscopy and photoconductivity, as well as by magnetotransport and photoluminescence measurements, the new physical phenomena that make take place in HgCdTe heterostructures. Although the plasma oscillations in nanostructures is the main well identified project we would like to mention also other important solid state physics projects that can be initiated by creation of the LIA.

1) Topological Insulators

Surface states in semiconducting and insulating materials are usually fragile with respect to disorder and perturbations such as impurity scattering, many-body interactions, and geometrical effects. However, there are systems in which surface states are robust due to the topology of the band structure in the material volume. A well-known example is the integer quantum Hall effect in two-dimensional systems. More recently, another type of topological invariance was predicted in materials with band inversion (semiconductor with a gap between the upper p-type and lower s-type energy bands) due to strong spin-orbit coupling [21]. In this case, one speaks of topological insulators [22].

This kind of topologically protected surface states was first demonstrated to exist in two-dimensional HgTe based QWs [1,4]. In QWs wider than a critical thickness $d_c = 6.3$ nm ($d > d_c$), the electronic structure in the well remains inverted. However, for narrow wells ($d < d_c$), it is possible to obtain a conventional alignment of the quantum well states. So, a topological quantum phase transition occurs at the critical thickness d_c, where the system is described by a massless Dirac theory. Unlike graphene [23], where two valleys of Dirac fermions exist, in this new material Dirac fermions appear only at a single point in the Brillouin zone. In QWs of critical thickness, the electron energy depends linearly on its momentum and under applied magnetic field the Dirac energy spectrum evolves into Landau levels with energies having a square root dependence on magnetic field (B). The presence of a band inversion in the HgTe quantum well leads to the existence of topologically protected edge states in which propagation with given k is linked to the spin orientation [21]. As a result, these states are robust with respect to time-reversal symmetry invariant scattering processes. Under applied magnetic field, a particular pair (zero-mode) of Landau levels (LLs) splits from the upper and lower energy bands. In the case of inverted band structure these LLs cross at certain field B_c, above which the topologically insulating phase is transformed into the conventional quantum Hall insulator phase [4]. So far, there have been no systematic magnetospectroscopy studies of HgTe/CdTe QW heterostructures versus QW width. In [24], the spectra in two [013]-oriented HgTe samples with a QW width of 7 and 8 nm for different levels of electron concentration were investigated. In [25], two different samples, each containing a 8-nm-wide, [001]-oriented HgTe quantum well were studied. The field evolution of the particular pair of Landau levels was studied by magnetospectroscopy. It was shown that these zero-mode Landau levels in HgTe quantum wells with the inverted band structure do not cross, but instead display the effect of the avoided crossing. In our recent study we have experimentally studied far infrared Landau level transitions spectra under magnetic field in a series of HgTe/$Cd_xHg_{1-x}Te$ (0 1 3) QW heterostructures around the critical thickness. The measurements performed in four HgTe QWs with different thicknesses around the critical value, allowed us to track the evolution of the magneto-optical response from a narrow-gap semiconductor with very light but still massive carriers, to a Dirac-type

system with massless fermions. We have confirmed the observation of the crossing of the zero-mode Landau levels caused by the breaking of time-reversal symmetry, expected in two dimensional topological insulators. We have shown a very good agreement between the experimental data and the Landau levels transition energies calculated using the 8 × 8 Kane model. However, some lines are still not well explained and obviously the above approach to interpret the data does not take into account all possible effects that may influence the measured spectra. A full quantitative interpretation of the results requires more complete theoretical and experimental developments.
Precise knowledge of the HgTe and CdTe parameters is particularly crucial for the band structure calculations, while many previously published data exhibit lack of precision. Therefore, a research into the band spectrum of HgTe/CdTe QW heterostructures should involve a variety of techniques, one of the most informative being the THz transmission spectroscopy under tilted magnetic field. Indeed, there is still a limited number of experimental data available on the Quantum Spin Hall phase, and therefore more experimental data will be relevant to the scientific community. One of the tasks of the project will be to measure the magnetotransmission of samples having QWs close to and above the critical thickness and with semi-transparent gates, in order to follow the Landau level transitions by varying the position of the Fermi level. This will allow us to extract the band structure parameters, such as the Dirac velocity, effective masses and anisotropic g-factors. The gap will be measured by photoconductivity and photoluminescence experiments. Theoretical developments taking into account the effect of impurities will evidently be important at this stage of this project.

2) Spin Hall Effect

It was predicted a long time ago [10, 11] that because of spin-orbit interaction an electrical current produces a transverse spin current. More recently it was shown theoretically [26] that this spin current results in a spin accumulation near the sample edges causing a small decrease of the sample resistance. Because of the combined effects of spin-orbit coupling and of Hanle effect, a magnetic field applied in the current plane should destroy the edge spin polarization, leading to a positive magnetoresistance. This so called Spin Hall Effect (SHE) could then be measured electrically in 2D and 3D semiconductors with strong spin-orbit coupling.
Preliminary experiments have already been performed in Montpellier in the 2D and 3D cases. For 2D samples, a processed InGaAs/AlGaAs QW was first used in magnetotransport experiments at liquid Helium temperatures. In this case, a special processing geometry was needed in order to study the effect of the 2D channels thickness on the positive magnetoresistance induced by the SHE. However, the InGaAs spin-orbit interaction is not very strong and the expected normalized change of resistance is on the order of 10^{-5}. Therefore, at low temperatures the magnetoresistance is dominated by quantum effects such as weak localization and anti-localization and no positive change of resistance could be attributed to the SHE. For this reason and because spin accumulation should be temperature resistant, other experiments were done at higher temperatures, but also at different width of the conducting wires. Indeed, because for narrow samples the spin polarization is destroyed by diffusion faster than by spin relaxation, the magnetic field dependence becomes weaker as the width of the conducting wires decreases. Up to now, the experimental results obtained on InGaAs QWs do not clearly show the expected effect of spin accumulation. Nevertheless, it was possible in these structures to follow the effect of temperature on weak localization up to 100 K [27].

The third step of this study is then to use materials with greater spin-orbit interaction as HgCdTe heterostructures. For the 3D case, the magnetoresistance of HgCdTe heterostructures (bulk like) have already been measured at low current by using gold vapor deposition small circles as contacts. However, this geometrical configuration is very close to the Corbino geometry and the first results in both materials are showing a strong linear Hall effect which is much larger than the expected change of magnetoresistance due to the SHE.

The aim of this part of the project is therefore to measure the in plane magnetoresistance of narrow conducting wires etched in a HgCdTe based QW and the magnetoresistance of a HgCdTe heterostructures material. To date, the first processing parts for 2D and 3D cases are already done.

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ANNEX 2

COMPOSITION OF THE LIA TERAMIR AS OF JANUARY 1st 2015

A. LIA Members

COUNTRY	INSTITUTION	LABORATORY/TEAM	PERSONNEL	TITLE
FRANCE	CNRS and UM2	L2C	*Permanent* Wojciech KNAP Michel DYAKONOV Dominique COQUILLAT Frederic TEPPE Nina DIAKONOVA Petre BUZATU Sandra RUFFENACH Christophe Consejo *Temporary* Dmytro BUT Aleksandre KADYKOV Michał MARCINKIEWICZ	 DR Prof.Em. DR CR IR IE UM2 IR IR UM2 PhD stud PhD stud PhD stud
	CNRS and UPD	MPQ	*Permanent* Carlo SIRTORI Yanko TODOROV Angela VASANELLI *Temporary* Baptiste DAILY	 Prof. CR McF PhD stud
	CNRS	LNCMI	*Permanent* Marek POTEMSKI Milan ORLITA Clément FAUGERAS	 DR CR CR
POLAND	IHPP PAS		*Permanent* Czesław SKIERBISZEWSKI Grzegorz CYWIŃSKI Pawel WOLNY Stanisław KRUKOWSKI *Temporary* Krzesimir SZKUDLAREK Ivan YAHNIUK	 CR CR IR Prof. PhD stud. PhD stud.
RUSSIAN FEDERATION	IPM	Laboratory of Physics of semiconductor heterostructures and superlattices	*Permanent* Vladimir GAVRILENKO Vladimir ALESHKIN Sergey MOROZOV Aleksandre ANTONOV Anton IKONNIKOV Kirill MAREMYANIN	 Prof. Prof. Senior .res. Researcher Researcher Researcher

			Maksim ZHOLUDEV Vladimir RUMYANTSEV *Temporary* Aleksandre KADYKOV Leonid BOVKUN	Junior res. Junior res. PhD stud. PhD stud.
	ISP SB	Laboratory of Epitaxial Technology from Molecular Beams of A2B6 compounds	*Permanent* Sergey DVORETSKY Nikolay MIKHAILOV Vasiliy VARAVIN Vladimir REMESNIK Danil IKUSOV Ivan UZHAKOV	 DR DR DR DR IR IR

B. Composition of the Scientific Management Committee

INSTITUTION/LABORATORIES	NAME	CITY, COUNTRY
L2C	Fréderic TEPPE	Montpellier, FRANCE
PMQ	Carlo SIRTORI	Paris, FRANCE
LNCMI	Marek POTEMSKI	Grenoble, FRANCE
IHPP -PAS	Grzegorz CYWIŃSKI	Warsaw, POLAND
IMP	Vladimir ALESHKIN	Nizhny Novgorod, RUSSIAN FEDERATION
ISP-SB RAS	Sergey DVORETSKY	Novosibirsk, RUSSIAN FEDERATION

C. Composition of the LIA TERAMIR Steering Committee

INSTITUTION	TITLE, NAME, FUNCTION	CITY, COUNTRY
CNRS	Dr Fabrice VALLEE, Acting Director of INP*	Paris, FRANCE
UPD	Dr Sylvie Rousset, Vice-President for Research	Paris, FRANCE
PAS	Dr Urszula WAJCEN, Director of the International Relations Office	Warsaw, POLAND
IHPP PAS	Dr Izabella GRZEGORY, Director	Warsaw, POLAND
IPM	Prof. Zakhary KRASILNIK, Director	Nizhny Novgorod, RUSSIAN FEDERATION
RFBR	Dr Alexander SHAROV, Director of the International Relations Office	Moscow, RUSSIAN FEDERATION

* President for the first two-year mandate

ANNEX 3

CONSOLIDATED PROJECTED BUDGET FOR 2015

A. Specific allocations for the LIA TERAMIR

The LIA TERAMIR shall be supported by the allocation of earmarked financial contribution of each Party, mainly devoted to cover mobility expenses (short-term stays and meeting), in addition to other resources to which the relevant research teams have access.

COUNTRY	INSTITUTION	LABORATORY/ TEAM	TYPE OF RESOURCES ALLOCATED TO THE LIA TERAMIR	AMOUNT (€)
FRANCE	CNRS(*)	L2C MPQ LNCMI	Specific funding	Total amount: 15.000 €
	UPD	LMPQ	Specific funding and Fellowships	Additional specific funding for co-supervised PhD fellowships, invited professor positions, Master students grants, subject to annual tenders.
POLAND	IHPP PAS		Specific funding and Fellowships	Total amount: 10.000 €
	PAS		Specific funding under the CNRS/PAS cooperation agreement	Total amount: 8.000 €
RUSSIAN FEDERATION	RFBR	IPM ISP	Specific funding and Fellowships	Projects selected within the framework of the CNRS/RFBR agreement are given a specific allocation to fund visits, missions, seminars and operating costs of the LIA
	IPM		Specific funding and Fellowships	Total amount: 6.000 €
	ISP		Specific funding and Fellowships	Total amount: 6.000 €

(*) CNRS' Specific funding for the LIA TERAMIR started in 2014. Additional 90.000 € were allocated in 2012-2013 for the valorization of joint results obtained in the framework of the previous GDRE-GDRI.

B. Preexisting staff effort devoted to the LIA TERAMIR

COUNTRY	INSTITUTION	LABORATORY/ TEAM	TYPE OF RESOURCES ALLOCATED TO THE LIA TERAMIR	AMOUNT (FTE**)
FRANCE	CNRS	L2C MPQ LNCMI	**Laboratory Staff** *Permanent*	1,2
	UM2	L2C	**Laboratory Staff** *Permanent* *Non-permanent*	0,35 1,3
	UPD	MPQ	**Laboratory Staff** *Permanent* *Non-permanent*	0,25 0,2
POLAND	IHPP PAS		**Laboratory Staff** *Permanent* *Non-permanent*	0,55 1,3
RUSSIAN FEDERATION	IPM		**Laboratory Staff** *Permanent* *Non-permanent*	1,0 0,8
	ISP		**Laboratory Staff** *Permanent*	0,65

*** The staffing needs of the LIA are calculated based on the full time equivalent (FTE) by its members.*

ANNEX 4

FACILITIES AND EQUIPMENTS

France

L2C

- BWO: from 120 GHz to 1.2 THz sources
- Gunn diode 300 GHz
- Sources 220-325 GHz75-110 GHz
- Cyclotron emission THz spectrometer
- THz fast Fourier transform spectrometers.
- These instruments are coupled with high magnetic field facility with 16 T high homogeneity magnet allowing for cyclotron resonance and spin resonance related THz spectroscopy of solids.
- 2 Si-Bolometers
- Calibrated Pyroelectric detector
- Several systems of cryogenic temperature equipment

MPQ

- Two Fourier Transform Infrared spectrometers (one specific for THz, the other for MIR spectral ranges)
- Bolometer for THz detection (300μm-15μm / 1- 20 THz)
- MCT detectors, covering the range 12μm-5μm
- Two Janis cryostats with electrical leads and infrared windows
- Superconducting magnet with far-infrared optical port.
- KBr lenses for Mid-Infrared and Beam condenser setup for Far-Infrared
- Automated reflectivity measurement setup with variable incident angle (5°-80°)
- High frequency oscilloscope and microwave spectrum analyzer
- Low noise current amplifier

LNCMI

- 2, THz fast Fourier transform spectrometers
- Set of sample probes equipped with bolometers (4)
- CO2 pumped gas laser with few THz emission lines
- Sub-THz (0-60GHz) Agilent source, 90 GHz Gunn diode, sample probes equipped with coaxial cables
- the equipment can be coupled to superconducting magnets (12,16T) and/or to high field resistive magnets (upon the proposal evaluation procedure)
- appropriate cryogenic systems

Poland

IHPP PAS

- Clean-room facilities for processing and lab characterizations of nitride based devices
- Two Molecular Beam Epitaxy reactors (VG90 and Gen20A) for growth of advanced devices

- Molybdenum sputtering for GaN substrate preparation (Mo layer on the backside of transparent substrates improving temperature uniformity across substrate)
- Two Atomic Force Microscopes (one at clean-room for substrates and processing characterization, and one for other advanced measurements)
- Two Nomarski contrast optical microscopes for fast surface inspection
- Step profiler, ellipsometer, XRD diffractometer, optical and electrical characterization systems, and other necessary equipments

Russian Federation

IPM

- CW tunable Ti:sapphire laser «Matisse» for photoluminescence excitation ;
- Optical parametric oscillator (OPO) and difference frequency generator (DFG) of company SOLAR (Minsk, Belarus) - pulsed tunable sources of radiation in the range of 0.4 - 17 micron for nanosecond photoconductivity relaxation measurements, photoluminescence excitation and optical pumping of laser structures ;
- Femtosecond laser «Tsunami», regenerative amplifier «Spitfire» and parametric amplifier OPA-800CF-0.3 (1.1-2.8 micron tuning range) for studies of the photoconductivity relaxation and photoluminescence excitation;
- Sets of quantum cascade lasers operating in pulsed regime (3.0 THz , 3.2 THz , 4.3 THz) and tunable with temperature (in the range of 10-38 microns) pulsed diode lasers based on PbSnSe for magnetooptical measurements;
- Optical closed cycle helium cryostats for temperature range 3-350 K for studies of photoconductivity, photoluminescence and stimulated emission;
- Helium cryostats with a superconducting solenoidsup to 12 T;
- Closed cycle helium cryostat with a superconducting solenoid in the field of 12 T with inset module and a sample temperature control in 1.6-300 K range;
- Fourier Transform Infrared Spectrometer Bruker 80v with step-scan mode - for photoluminescence, photoconductivity and magnetoabsorption spectral measurements;
- Tunable monochromatic sources of radiation (120-850 GHz) - backward-wave tubes for the experiments on detection of THz radiation by field-effect transistors ;

s and amplifiers, "Stanford Research Systems" low-noise preamplifier, lock-in amplifiers and boxcars, digital oscilloscopes with bandwidths up to 1 GHz, voltmeters and power supply units "Keithley", pulse generators

ISP

- The molecular beam epitaxy setup with an automated system of growth control and analytical tools of control (RHEED and ellipsometry) for monitoring structural perfection, composition and morphology during growth;
- The Hall measurement system of carrier concentration and mobility T - 77-300 K, B – 0,05 – 2 kGs;
- The contactless microwave photoconductive decay measurement for mapping minority carrier life T - 77-300 K;
- The surface macrodefect mapping analyzer;
- The Fourier Transform Infrared Spectrometer for measurement of transmission spectra λ - 2 – 14 μm;
- The current – voltage (I-V) and capacitance – valtage (C-V) measurements system.

ANNEX 5

PROPRIETARY RESULTS EXCLUDED FROM THE PURPOSES OF LIA TERAMIR

France

None

Poland

None

Russian Federation

None