

**Programme Title**

New Trends and Applications of the Casimir Effect

**Programme Acronyme**

CASIMIR

**Acronyme of the Standing Committee**

PESC

**Name and full coordinates of principal applicants**

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**Keywords**

Casimir effect, Micro- and Nanotechnology, Yukawa-type forces, Quantum vacuum

**Abstract**

The availability of experimental set-ups that allow accurate measurements of surface forces between macroscopic objects at submicron separations has recently stimulated a renewed interest in the Casimir effect and in its possible applications to micro- and nanotechnology. In the last few years, a large number of European groups belonging to very different areas of expertise has provided relevant theoretical and experimental contributions to this highly interdisciplinary topic. Collaborations between European theorists and experimentalists, often belonging to different countries, have also given rise to the design of new experiments that, relying on forefront technology, will soon address several open issues of the theory. Some of these experiments have already received economical support and are now under development. This scenario represents a unique scientific opportunity that calls for the development of a European network dedicated to the Casimir effect, which is the subject of this proposal. The CASIMIR network represents an invaluable tool that will allow scientists to discuss long standing problems and analyze new trends in Casimir force experiments, applications, and theory. The network will outline the research required, coordinate its implementation, promote the transfer of skills and knowledge, foster the collaboration of European research community, and forge links with non-European communities. From an educational point of view, young European scientists belonging to the participating groups will benefit from the opportunity to interact with international, highly qualified scientists, an experience that will enrich their professional skills and their personality.

**Previous or other applications**

A.L. and M.B. submitted a proposal for a Casimir network to ESF in 2005.

A.L. has organized the EuroConference Quantum Optics 2003 "From Quantum Fluctuations to Nanotechnology", September 27-October 2, 2003, Contract No. HPCFCT-2001-00037 and is part of the ESF contract NANOCASE, September 2005, Contract No. STRP 12142 (coordinator Chris Binns).

M.B. is part of the ESF contract PARNASS, September 2005, Contract No. STRP 017071 (coordinator Ulrich Schmucker)

## Status of the relevant research, scientific context, objectives and envisaged achievements

According to quantum electrodynamics, the energy density associated to an electromagnetic mode is given by  $E = \hbar\omega(n + \frac{1}{2})$ , where  $\hbar$  is the reduced Planck constant,  $\omega$  is the angular frequency, and  $n$  is the number of real photons at that frequency. As a consequence, vacuum is not empty. Even in the absence of real photons ( $n=0$  at all frequencies), there still exists an infinite amount of energy associated with half a quantum of all possible photon modes. At first, one might think that this energy is only a constant background to every experimental situation, and that, as such, it has no observable consequences. On the contrary, the vacuum energy is an undeniably real part of the makeup of the Universe and it has direct measurable consequences, among which the Casimir effect is the most prominent one.

In 1948 H. B. G. Casimir showed that two electrically neutral, perfectly conducting plates, placed parallel in vacuum, modify the vacuum energy density with respect to the unperturbed vacuum. The energy density varies with the separation between the mirrors and thus constitutes a force between them, which scales with the inverse of the fourth power of the mirrors separation. E. M. Lifshitz, I. E. Dzyaloshinskii, and L. P. Pitaevskii later generalized Casimir theory to dielectrics. The finite reflectivity of real materials gives rise to a decrease of the force with respect to the case of ideal metals.

The Casimir force is a small but well measurable quantity. It is a remarkable macroscopic manifestation of a quantum effect and it gives the main contribution to the forces between macroscopic bodies for distances beyond  $\sim 100\text{nm}$ . It had been measured over the decades for various configurations with increasing precision (Derjaguin, Tabor-Winterton-Israelachvili, van Blokland-Overbeek).

In 1997 Lamoreaux performed the first modern, high precision measurement of the Casimir force. Since then, the number of measurements and important theoretical contributions has been increasing rapidly and continuously. The first series of experiments was situated in the US (Lamoreaux at Washington, Mohideen at Riverside, Capasso-Chan-Iannuzzi at Lucent Technologies and Harvard, Roukes at Caltech, Fischbach at Purdue). European researchers have however caught up quickly with a new generation of Casimir force measurements and by now the number of European based experiments has overturned the US leadership (Ruoso-Carugno in Padova, Chevrier in Grenoble, Iannuzzi in Amsterdam, Speake in Birmingham, Binns in Leicester, Nesvizhevsky in Grenoble). Together with numerous theory groups, most of which are working closely together with experimentalists, Europe has now a strong and still growing community doing research on the Casimir effect.

The Casimir force is highly versatile and changing materials and shape of the boundaries modifies its strength and even its sign. For example the role of surface plasmons to tailor the Casimir force (Lambrecht in Paris, Henkel in Potsdam, Bordag in Leipzig, Barton in Sussex) and the possible interest of metamaterials (Henkel in Potsdam) in order to produce repulsive forces have been studied during the last years. Modifying strength and even sign of the Casimir force has great potential in providing a means for indirect force transmission in nanoscale machines, which is at present not achievable without damaging the components. A contactless method would represent a breakthrough in the future development of nanomachines. More generally, a deeper knowledge of the Casimir force and Casimir torque could provide new insights and design alternatives in the fabrications of micro- and nanoelectromechanical-systems (MEMS and NEMS). Another strong motivation comes from the need to make advantage of the unique properties of Carbon Nanotubes (CNT) in nanotechnology. Here the quest is for a detailed investigation of Casimir forces acting between a CNT and a flat or structured substrate. Measuring the Casimir force is also important from a fundamental standpoint as it probes the most fundamental physical system, that is, the

quantum vacuum. Furthermore, it is a powerful experimental method for providing constraints on the parameters of a Yukawa-type modification to the gravitational interaction or on forces predicted by supergravity and string theory. On the theoretical front, accurate results based on realistic models are sorely needed in order to match the desired levels of accuracy. Four important effects provide the main corrections to the ideal configuration considered by Casimir: non-zero temperature, material properties, a non planar geometry and the mirrors surface state.

Temperature corrections are important for mirror separations above  $1\mu\text{m}$ , whereas material properties and roughness provide the major corrections for short distances, below a few hundred nanometers. The only experiment that has investigated the Casimir force at distances up to  $6\mu\text{m}$ , has surprisingly shown no evidence of thermal contributions. This unexpected result is important and currently investigated. The groups by Bordag in Leipzig, Brevik in Trondheim, Fischbach-Decca in West Lafayette, Martin in Lausanne, Mostepanenko-Klimchitskaya in Russia, Sernelius in Linköping and Svetovoy in Twente are on the forefront of this research. At the same time several European based experiments are being developed to investigate this question, namely Speake in Birmingham, Nesvizhevsky in Grenoble and Carugno-Ruoso in Padova. The Padova group has already explored the Casimir force at distances larger than  $1\mu\text{m}$ , but in their first experiment the accuracy was not sufficient to measure thermal corrections. Another complementary approach comes from the group of Pitaevskii and Stringari in Trento, who are studying the influence of temperature on the Casimir effect out of thermal equilibrium. Within this context a further actual and yet unresolved problem is about the need and the way to include spatial dispersion on metal surfaces in Casimir force calculation.

The investigation of the geometry dependence of the Casimir and van der Waals forces is a topic of high actual interest which is triggered by increasing precision of measurements. A direct calculation in geometries which do not allow for a separation of variables, i.e., beyond parallel planes, is practically impossible. Several approximate methods are known. Most of them, like pairwise summation, perturbation theory in deviation of geometry from plane one, multiple reflection expansion, optical path approximation and world line methods are of restricted applicability and are not able to satisfy the needs of current precision experiments. The most frequently used method is the proximity force approximation (PFA) invented by Derjaguin as early as 1935. It delivers the first curvature contribution. Detailed studies have been performed by Duplantier and Balian in Saclay, while interesting attempts to go beyond PFA have been done by Emig in Cologne, Gies in Heidelberg, Jaffe at MIT and Lambrecht-Maia Neto in Paris. These promising approaches have now been generalized to arbitrary situations. Only this year for the first time a correction beyond PFA could be calculated using a new method by Bordag in Leipzig. A complete development of this method will be the foundation for the description of all future experiments involving nanostructures and nanospheres/particles. Concerning the effect of surface structures such as corrugations, Emig in Orsay and Lambrecht-Reynaud in Paris have studied the lateral Casimir force, while in a recent letter by Lambrecht et al. the Casimir torque due to corrugations is calculated and found to be experimentally accessible.

### **Facilities and expertise accessible to the Programme**

The European research on Casimir forces is in direct competition with the excellent research performed in the US. During the last years a great number of important experimental and theoretical contributions have been achieved, and European researchers have played a key role in these achievements. The most important of these involve

1. Measurement of the Casimir force using MEMS and study of the influence of the dispersion forces in microtechnology (Iannuzzi-Capasso)

2. Measurement of the Casimir force in the plane-plane geometry (Ruoso-Carugno)
3. Influence of non zero temperature on Casimir forces in and out of thermal equilibrium (Bordag, Brevik-Hoye, Martin, Svetovoy, Sernelius, Stringari-Pitaevskii)
4. Casimir effect in different geometries, influence of surface structures, edge effects (Bordag, Duplantier, Emig, Gies, Lambrecht-Reynaud)
5. Influence of material properties (Bordag, Iannuzzi-Capasso, Lambrecht-Reynaud, Svetovoy)
6. Influence of the mirrors surface states and surface potentials (Bordag, Emig, Lambrecht-Reynaud, Palasantzas, Speake)
7. Importance of surface plasmons for the Casimir force (Barton, Henkel, Noguez-Villareal, Lambrecht-Reynaud)
8. The role of vacuum energy in cosmological models (Brevik-Hoye, Elizalde)
9. Casimir effect with superconducting mirrors (Bimonte-Calloni)
10. Casimir effect with metamaterials (Henkel)

The CASIMIR network proposes to bring together these groups with the following high level research groups that are implementing new experiments and studies on the Casimir effect :

1. Philippe Andreucci, Laboratoire d'électronique et de technologie de l'information, Commissariat à l'énergie atomique, Grenoble (Casimir effect in NEMS)
2. Chris Binns, Head of the Condensed Matter Physics group, Leicester Univ. (experiments with Magnetic Nanoparticles and Nanoclusters, now Casimir force measurement using nanospheres, violation of PFA and Casimir effect in MEMS/NEMS)
3. Enrico Calloni, University of Naples (gravitational effects on the Casimir force, now ALADIN experiment to measure Casimir force between superconducting mirrors)
4. Joël Chevrier, Head of the picoNewton group, Univ. of Grenoble (experiments in surface science, AFM nonlinear force measurements, since 2004 Casimir force measurements, now between corrugated surfaces, violation of PFA, search for repulsive Casimir forces)
5. Valery Nesvizhevsky, Permanent staff scientist, ILL Grenoble (experiments on quantum states of neutrons in gravity and weak forces measurements, now Casimir force measurement to investigate the temperature dependence and improve limits on Yukawa forces)
6. Clive Speake, Head of the Gravitational Group, Birmingham Univ. (Tests of the Equivalence principle, High precision measurements of G, now high precision Casimir force measurement to study the temperature dependence)

The CASIMIR network will profit from all experimental facilities already present in these research groups.

### **Proposed activities, key targets and milestones**

The topic of Casimir forces has become highly competitive with the arrival of micro- and nanostructures such as MEMS, NEMS, Carbon Nanotubes, nanospheres,... The Casimir interaction has revealed itself an important feature in micro- and nano-mechanical systems that necessarily have components separated by distances at which this force becomes significant. Understanding the Casimir force in a whole variety of real and flexibly shaped boundaries would potentially open novel techniques in the engineering of nano-mechanical systems. There are also aspects of the Casimir interaction that have never been experimentally verified, such as a repulsive force between certain combinations of materials. The main lines of this research involve:

1. Casimir force in complex geometries and novel topologies such as pattered or corrugated surfaces, nanospheres or small spheroidal shaped bodies (Barton, Binns, Bordag, Brevik-Hoye, Chevrier, Duplantier, Lambrecht-Reynaud)

2. "Vacuum torques" acting on irregular bodies (Iannuzzi, Lambrecht- Reynaud, Svetovoy)

3. Studying the Casimir force using new materials such as superconductors, magnetic materials, meta-materials or Carbon nanotubes (Binns, Bordag, Bimonte-Calloni, Lambrecht, Henkel)

4. Dispersion forces and NEMS Devices (Andreucci, Iannuzzi, Palasantzas, Svetovoy)

5. Nanoscale surface/interface roughness influence on functional properties of MEMS, NEMS (Andreucci, Emig, Lambrecht, Palasantzas)

6. Development of new instrumentation for surface force measurements in liquids, also at cryogenic temperatures (Iannuzzi)

The fundamental questions, such as Yukawa-type modification to the gravitational force, the influence of temperature and the relation between Casimir interactions and quantum chaos and cosmology, will be addressed along the following research lines:

1. Studying the temperature dependence of the Casimir effect in thermal equilibrium (Bordag, Brevik, Martin, Nesvizhevsky, Speake, Sernelius, Stringari-Pitaevskii, Svetovoy)

2. High precision determination of the Casimir force and search of Yukawa-type interactions (Lambrecht-Reynaud, Nesvizhevsky, Speake)

3. Casimir forces out of thermodynamic equilibrium (Barton, Brevik, Stringari-Pitaevskii, Svetovoy)

4. Cross-links between Casimir interaction and quantum scattering in chaotic configurations (Emig)

5. Violation of the Proximity Force Approximation and interplay between geometry and temperature effects (Binns, Bordag, Gies, Iannuzzi, Lambrecht)

6. Casimir effect and cosmology (Brevik, Elizalde, Reynaud)

### **Expected benefit from European collaboration**

All above projects are common between experimental and theory groups. Furthermore, an important number of European groups have overlapping research projects. The proposed network will provide the forum for a quick and frictionless exchange of techniques and methods as well as the close collaboration between experiment and theory.

The Casimir effect has seen a very rapid development in recent years, due to its importance for fundamental physical questions and at the same time for technological applications. It has relevant overlaps with other important areas of physics, such as condensed matter (material properties), nanophysics (key role for micro- and nanodevices), cosmology and gravitation (exclusion domains for new hypothetical forces) and statistical physics (surface roughness and disorder). Currently, the number of physicists with permanent positions and of PhD students working in this area in Europe is rapidly increasing. The fast dissemination of the latest results, the smooth exchange of new ideas and the interdisciplinary training and collaboration are necessary to uphold the current lead in the theoretical investigations and the experimental engagement on a competitive level. The European progress in fundamental research and the development of new technologies will receive a significant impact from the CASIMIR network.

### **European context**

The CASIMIR network can build on the synergy already achieved by the community thanks to many international workshops and conferences organized these last years. One of the most successful instruments of integration and dissemination is the series of Conferences "Quantum Field Theory under External Conditions", initiated by Michael Bordag, which started in Leipzig in 1989 and was continued there in 1992, 1995, 1998 and 2001 (Chairman: Michael Bordag), in 2003 in Oklahoma (Chairman: Kimball Milton) and 2005 in Barcelona (Chairman: Emilio Elizalde), while the next QFEXT conference is to be held in 2007 in Leipzig (Chairman: Michael Bordag). CASIMIR plans to further support and sponsor this conference series, which brings together leading research groups in the field and is now recognized to be the most important bi-annual event in the field.

The next important instrument, which also addresses the training of young researchers, are the QED workshops, already held in 1998, 2000 and 2005, respectively in Bulgaria, Trieste and Les Houches. CASIMIR plans to continue the stimulation and support of such small or medium sized pan-European events.

With its natural emphasis on the interdisciplinary character, which now includes – besides the quantum field theory and quantum optics communities – the communities of surface science, nanophysics, condensed matter, gravitational physics and statistical physics, the CASIMIR network plans to establish links to the corresponding ESF programmes and to synchronize its activities with the FP6 contracts of the European Union. Currently there exist several European contracts:

- the STRP Contract No. 012142 (NEST) NANOCASE, which is devoted to the subject of Casimir forces in NEMS (coordinator Chris Binns, Leicester Univ.).
- the STRP Contract No. 017071 (IST) PARNASS, which investigates novel technologies incorporating Carbon Nanotubes utilizing van der Waals and Casimir forces (coordinator Ulrich Schmucker, Fraunhofer Gesellschaft zur Förderung angewandter Forschung).
- the STRP Contract No. NMP4-CT-2003-505634 X-TIP, which studies STM/AFM tip-surface interaction, nanoscale mapping and surface structure modification (coordinator Fabio Comin, European Synchrotron Radiation Facility Grenoble).

The NANOCASE coordinator, Chris Binns, and two project partners, Astrid Lambrecht and Bo Sernelius, as well as the PARNASS project partner Michael Bordag, are part of

the CASIMIR steering committee. Joel Chevrier is partner of the X-TIP programme and part of the CASIMIR collaboration.

The CASIMIR network will also synchronise its activities with national research programmes on Casimir forces. At the time of writing this proposal, members of the CASIMIR Steering Committee are actively involved in the following national research programmes

- France: Institut Carnot contract “Nanostructures for MEMS in IC” (Andreucci, Chevrier, Lambrecht)
- Germany: Eastern Europe programme offering grants for East-European visiting scientists and the Heisenberg-Landau programme which supports German-JINR Dubna collaborations (Bordag)
- Netherlands: “Casimir force under suitably engineered conditions: fundamental problems and applications to micro- and nano-machinery”, NWO (Netherlands Org. for Scientific Research) programme (Iannuzzi)
- Spain: “Cosmology, Gravitation and Zeta Functions” Ref. BFM2003-00620 (Elizalde)  
“Quantum Field Theory under the Influence of External Conditions” Ref. FIS2004-21161-E (Elizalde)

#### **Duration**

60 months

#### **Programme Work Plan**

The following operational activities are envisaged:

1. Application for and co-sponsoring of an ESF Research Conference Series bringing together the main European actors as well as American colleagues every two years. Such a bi-annual series will follow the tradition of the Euresco conference series and allow for high level scientific meetings inside Europe. The CASIMIR network foresees two conferences from the series “Quantum Field Theory under the influence of external conditions” to be held in fall 2009 in Paris and in fall 2011.
2. Co-sponsoring or application, and organizing of small workshops, study centers and conferences, in particular in the years between the ESF conferences, that is in 2008, 2010 and 2012. Study centers should gather up to 30 participants for about 6 weeks and would have similar format as the Les Houches Summer Schools. The accompanying workshops will gather up to 70 participants for 3-4 days. The other workshops which may be sponsored will have a format similar to the workshop “QED2005” (Les Houches, 2005).
3. Short term research visits between collaborating institutions on a trans-national basis with particular attention to a “Theory visits Experiment” and “Experiment visits Experiment” exchange. Applications will be reviewed by the Chairman of the CASIMIR network who will forward his recommendations to the ESF office.
4. Fellowship program for young researchers, namely PhD. By default, support is on a 50 percent pitch-in basis for up to 6 month, yet full support may be granted in exceptional circumstances. The scheme is competitive. The program and a “Call for applications” will be announced. The applications

will be reviewed by the CASIMIR Steering Committee. Decisions of the Committee are forwarded to the ESF via the Chairman of the CASIMIR network.

5. Establish and maintain a Web-server which presents the European activities and possibly a database useful for Casimir effect theory, force measurements and calculations (optical and surface state data, validity or violation of PFA, temperature dependence...). This server is meant to become the standard resource on the Casimir effect. The bibliography on the Casimir effect (<http://cfa-www.harvard.edu/~babb/casimir-bib.html>) maintained by J. Babb at ITAMP can be considered as a precursor. Furthermore, our server should become an efficient link between the various theory and experimental groups with all groups participating to provide data for the update. The Web-server will be installed by a professional web administrator, but will be maintained by the chairman of the CASIMIR network.
  
6. An annual committee meeting in conjunction with an ESF conference or workshop. Activities of the committee include program organization of subsequent workshops and conferences, management of grants in the framework of the fellowship program for young researchers, and the review and preparation of an annual report to the PESC and ESF, respectively.

### **Budget estimate**

The program duration is planned to be 5 years from January 2008 to December 2012. The program budget derives from the envisaged operational activities as described above (all figures in kEuros)

Activity	2008	2009	2010	2011	2012
Workshop	20	-	20	-	20
Conference	-	60	-	60	-
Fellowship	30	30	30	30	30
Short term	20	20	20	20	20
Coordinator	5	3	3	3	3
Website	5	2	2	2	2
Total	80	115	75	115	75



# Appendices

## Short CV's

1. **Michael Bordag**, 54 years, Male, German Citizenship, Married, two children

### Academic Record

State University of Leningrad (St.Petersburg), Russia, Diploma with distinction, 1977

University of Leipzig, PhD (Dr. rer.nat.) in Physics with magna cum laude, 1980

University of Leipzig, Dr. sc. nat. in Physics, 1986 (transformed into Habilitation, 1991)

### Appointments

1977- present                      Staff at University of Leipzig, Physics department

1983-1987                         Researcher at Joint Institute of Nuclear Research, Dubna, Russia

1996- present                     'Privatdozent' at University of Leipzig, Physics department

### Publications

83 journal publications, 1 review paper, 2 books edited

#### 5 recent publications related to the current project

1. M. Bordag, „Casimir effect for a sphere and a cylinder in front of a plane and corrections to the proximity force theorem“, Phys.Rev. D 73, 125018 (2006).

2. M. Bordag, "Special issue - Proceedings of the Fifth Workshop on Quantum Field Theory under the Influence of External Conditions - University of Leipzig, Germany - Preface." International Journal of Modern Physics A **17**, lii-iv. (2002).

3. M. Bordag, U. Mohideen, et al. "New developments in the Casimir effect", Physics Reports-Review Section of Physics Letters **353**, 1-205 (2001).

4. M. Bordag, B. Geyer, et al., "Casimir force at both nonzero temperature and finite conductivity", Physical Review Letters **85**, 503-506 (2000).

5. M. Bordag et al. "New constraints for non-Newtonian gravity in the nanometer range from the improved precision measurement of the Casimir force, Phys. Rev. D **62**, 011701 (2000)

### Projects, grants and conferences

- "Casimir Forces as a Test for Long Range Hypothetical Interactions", Nato Linkage Grant (1993-95)
- "Ground State Energy", German-Spanish grant "Acciones Integradas" (1995-97)
- Grant "Research in Pairs" (RiP) of the Volkswagen foundation for the implementation of the meeting "Calculation of Special Heat Kernel Coefficients" in Oberwolfach (Germany), 19.-23.8.1996
- Grants from the DFG and the local government for the implementation of the "Workshop on Quantum Field Theory under the Influence of External Conditions" in Leipzig (1995, 1998, 2001)
- "Ground State Energy in General Background Fields" DFG Grant Bo 1112/2 (1995/97)
- "Ground State Energy and Higher Loops" DFG Grant Bo 1112/4-1 and -2 (1997-99)
- "Vacuum polarization in spherically symmetric background fields" DFG Grant Bo 1112/11 (1999-2001)
- "Local methods for the calculation of vacuum polarization", DFG Gr Bo 1112/12 (2002-2005)
- "Vakuumpolarization – mathematische Methoden und physikalische Anwendungen", DFG Gr Bo 1112/13 (2006-2007)
- Organizer of the "Workshop on Quantum Field Theory under The Influence Of External Conditions", Leipzig, (1995, 1998, 2001)
- Chair of the international organization committee in Oklahoma and Barcelona (2003, 2005)

**2. Giovanni Carugno**, 45 years, Male, Italian Citizenship, Married, two children

### **Academic Record**

University of Roma (Italy), Laurea summa cum laude in Physics, 1986

### **Appointments**

2002 – present	Senior Researcher at INFN, Padova University
1996	Visiting Scientist at CERN (EU contract under Prof. G. Charpak)
1993-1994	Visiting Scientist at Paul Scherrer Institute, Zurich
1993-2002	Junior Researcher at INFN, Padova University
1989-2002	Associate Scientist at Legnaro National Laboratory
1987-1988	CERN Fellow with Prof. C. Rubbia and M. Ferro-Luzzi

### **Publications**

80 publications in peer reviewed journals and proceedings, 1 review paper.

#### **5 recent publications related to the current project**

1. P. Antonini, G. Bressi, G. Carugno, G. Galeazzi, G. Messineo and G. Ruoso  
Casimir effect: a novel experimental approach at large separation, New Journal of Physics, Vol. 8, 239 (2006)
- 2 C. Braggio, G. Bressi, G. Carugno, et al, "A novel experimental approach for the detection of the dynamical Casimir effect", Europhys. Lett. 70, 754 (2005)
- 3 G. Bressi, C. Carugno, G. Ruoso, and R. Onofrio, "Measurements of the Casimir force between parallel metallic surfaces", Phys. Rev. Lett. 88, 499 (2002)
4. G. Bressi, G. Carugno, A. Galvani, R. Onofrio, G. Ruoso, and F. Veronese  
Experimental studies of macroscopic forces in the micrometre range  
Classical and Quantum Gravity, vol. 18, 3943 (2001)
5. C. Braggio, G. Bressi, G. Carugno. A. Lombardi, A. Palmieri, G. Ruoso, D. Zanella  
Semiconductor microwave mirror for a measurement of the dynamical Casimir effect  
Review of Scientific Instruments, Vol. 75, 4967 (2004)

### **Projects, Grants and Scientific coordinations**

- Principal investigator in the five following research project (Fully financed by INFN):
  - o Infrared activity in gaseous and crystal media (2002-2004)
  - o Electron tunneling processes in liquid-gas interface (1998-2000)
  - o Laser resonant ionization in noble gases (2001-2002)
  - o Development of a liquid methane time projection chamber (1992-1994)
  - o Electrons drifting in large volume semiconductors (2004-present)
- Italian patent n. 41150 A/90 on Liquid and Gas purification techniques (1990)
- Member of the INFN Italian Scientific Panel for Research Funding in Instrumental physics (1999 – present)
- Referee in the INFN Italian Scientific Panel for Research Funding in Basic Research (1999-present)
- Co-organizer of the International workshop on the Dynamical Casimir Effect (Padova, June 2004)

**3. Astrid Lambrecht**, 39 years, Female, German Citizenship, Married, four children

### **Academic Record**

Imperial College London and University of Essen, Physics Diploma with Honors, 1992  
University Paris 6/Ecole Normale Supérieure, Paris, Physics PhD with Honours, 1995  
University Paris 6/Ecole Normale Supérieure, Paris, Habilitation in Physics, 2002

### **Appointments**

2000 – present                      Staff Scientist CR1 at CNRS, Laboratoire Kastler Brossel, Paris

1998                      Research fellow at the Institute of Physics, Univ. Rio de Janeiro & Physics Department, Univ. of Pernambuco in Recife, Brazil  
1996 – 2000              Staff Scientist CR2 at CNRS, Laboratoire Kastler Brossel, Paris  
1995 – 1996              Post-doctoral fellow with T.D. Hänsch, Max-Planck Institute for Quantum Optics in Garching

### **Publications**

39 publications in peer reviewed journals, 1 review article

#### **5 recent publications related to the current project**

1. R. Rodriguez, P. Maia Neto, A. Lambrecht, and S. Reynaud, "Vacuum induced torque between corrugated metallic plates", *Europhys. Lett.* to be published (2006)
2. R. Rodriguez, P. Maia Neto, A. Lambrecht, and S. Reynaud, "Lateral Casimir force beyond the proximity force approximation", *Phys. Rev. Lett.* 96, 100402 (2006)
3. A. Lambrecht, P. Maia Neto, and S. Reynaud "The Casimir effect within scattering theory", *New J. Phys.* 8, 243 (2006)
4. F. Intravaia and A. Lambrecht, "Surface plasmon modes and the Casimir energy", *Phys. Rev. Lett.* 94, 110404 (2005)
5. C. Genet, A. Lambrecht and S. Reynaud, "The Casimir force and the quantum theory of lossy optical cavities", *Phys. Rev. A* 67, 043811 (2003)

### **Honors and Awards**

- 2005 "Prix Aimé Cotton" Award of the French Physical Society (SFP) in Atomic, Molecular and Optical Physics  
1996 Senior Fellow of the German National Academic Foundation  
1988 Junior Fellow of the German National Academic Foundation

### **Scientific Coordination**

- Member of the Advisory Board of the int. conf. "QMFBA2006", Bologna (2006)
- Member of the Advisory Board of the int. conf. "TQMFA2005", Palermo (2005)
- Organizer of the international conference "QED 2005", Les Houches (2005)
- Organizer of the international conference "Quantum Optics", Euro Conference on Cavity QED and Quantum Fluctuations : From Fundamental Concepts to NanoTechnology", Granada, Spain (2003)
- Co-organizer of the conference "Gravity and Experiment", Pisa, Italy (2002)
- Co-organizer of the international conference "Quantum Optics, EuroConference on Quantum Atom Optics : From Quantum Science to Technology", San Felio de Guixols, Spain (2002)
- Coordinator of the Franco-Brazilian Collaboration CNRS-CNPq "Cavity QED" (2001-2002) and CAPES-COFECUB "Fundamental Processes in Atom-Light Interaction" (2000-2001)

### **Program Steering Committee**

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**International dimension****NSEC (Nanoscale Science and Engineering Center)**

NSEC is a research network supported by the National Science Foundation (USA) promoting scientific collaborations between groups belonging to Harvard University, the MIT, and the University of California at Santa Barbara. The goal of NSEC is to develop tools for understanding systems that link physics, chemistry, and biology at mesoscopic scales through the design and test of quantum devices and the theoretical understanding of their behaviour. The collaboration between CASIMIR and NSEC will allow the two networks to benefit from the exchange of expertise and know-how developed in several internationally renowned groups that operate in the field of micro- and nanotechnology, a topic intimately intertwined with the Casimir effect. The CASIMIR-NSEC link will also strengthen the collaboration of CASIMIR participants with the group of Federico Capasso (Harvard University), a well established authority in the investigation of the Casimir force with MEMS. It is also important to stress that NSEC has already established collaborations with the Delft University of Technology (The Netherlands), the Basel University (Switzerland), Tokyo University (Japan), Brookhaven Laboratories, Oak Ridge Laboratories, and Sandia National Laboratories. This broad network will increase the opportunity for CASIMIR scientists to come in contact with new potential collaborators.

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**REGINA (REd de Grupos de Investigacion en NANociencias)**

REGINA is a funded Mexican network that promotes the development of collaborative projects in Nanoscience and Nanotechnology within the Universidad Nacional Autonoma de Mexico (UNAM) and abroad. The CASIMIR-REGINA collaboration will encourage bilateral exchanges between European groups involved in the Casimir effect and Mexican groups working in related areas, among which the group of Raul Esquivel Sirvent (theorist working on the surface-impedance approach to Casimir force calculations), the group of Cecilia Noguez (theorist working on the effect of surface-plasmons and geometry of the boundaries in the Casimir effect), and the group of Carlos Villareal (theorist working on the calculation of the Casimir force between structured materials and on the vacuum induced torque between anisotropic surfaces).

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