European Cooperation
in Science and Technology
- COST -

Secretariat

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COST 4126/10

MEMORANDUM OF UNDERSTANDING

Subject : Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action MP1001: Ion Traps for Tomorrow's Applications

Delegations will find attached the Memorandum of Understanding for COST Action MP1001 as approved by the COST Committee of Senior Officials (CSO) at its 178th meeting on 25 May 2010.

MEMORANDUM OF UNDERSTANDING

For the implementation of a European Concerted Research Action designated as

COST Action MP1001

ION TRAPS FOR TOMORROW'S APPLICATIONS

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4159/10 “Rules and Procedures for Implementing COST Actions”, or in any new document amending or replacing it, the contents of which the Parties are fully aware of.

2. The aim of the Action is to create scientific added value by organizing a Europe-wide joint effort to develop new basic experimental set-ups and theoretical methods for the trapping and control of cold ions creating the necessary baseline to allow emergence of novel technologies and applications.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 52 million in 2010 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the MC, unless the duration of the Action is modified according to the provisions of Chapter V of the document referred to in Point 1 above.

A. ABSTRACT AND KEYWORDS

In the last two decades our ability to study individual quantum systems (or controlled ensembles of them), virtually free from outside perturbations, has been transformed from a dream to a reality. Trapped atomic and molecular ions have been at the heart of this revolution, providing the key to a deeper understanding of many of the underlying principles of Physics and Chemistry. Physicists can now trap single atoms or photons, prepare these particles in well-defined states and follow their evolution in real time. Deeper insight into the fundamental scientific principles leads to the emergence of innovative applications and stimulates technical evolution. Scientific and technological applications include frequency metrology for the precise determination of fundamental constants; frequency standards (for e.g. global positioning); the determination of atomic ground state properties (mass, life-time, spin, etc.); quantum information and cavity quantum electrodynamics. Notably, the production of cold molecules and the study of chemical dynamics at ultralow temperatures are areas of remarkable current growth within the field. This Action represents an effort by more than thirty experimental and theoretical groups from thirteen European countries covering all of these topics to further strengthen their scientific and technological interactions and to tackle common questions by encouraging substantial Europe-wide collaboration. This Action will advance the frontier of knowledge regarding basic questions in order to foster the emergence of novel applications.

Keywords: Ion trap, quantum information, metrology of frequencies and fundamental constants, ion-neutral interactions, cold molecules, ultra-high resolution spectroscopy

B. BACKGROUND

B.1 General background

Trapped atomic or molecular ions allow the study of individual quantum systems (or controlled ensembles of them) in a quasi-perturbation-free environment. These highly controlled samples constitute the quantum sensors which are at the **basis of tomorrow's most advanced technology**. Applications with enormous impact include frequency metrology, the development of new frequency and time standards, high-accuracy measurements of fundamental constants, quantum information, atomic and molecular spectroscopy, high-precision determination of atomic ground state properties (mass, life-time, spin, etc.), study of non-neutral plasma, cavity QED experiments as well as the production and reaction dynamics of cold molecules.

The goal of this Action is to strengthen existing collaborations and generate new ones between researchers from various fields, who are united by their common usage of the interaction between light and ions stored in Paul or Penning traps. As a consequence of the rapid growth of the European ion trapping community and the remarkable increase in the number of new scientific topics addressed in the field over the past few years, a considerable amount of disjoint expertise has accumulated within the various research groups. A **concerted Action** in the form of a European research network **targeted at promoting scientific exchange** has clearly become **necessary in order to realise the considerable potential for synergies to develop new methodologies for cooling, storing and manipulating ions.** At this stage, COST is the most well-adapted tool for this Action, as the main objective is to profit from the added value generated by the interaction of different approaches to tackle common questions.

High-precision measurements and quantum state engineering only become possible in perfectly controlled experiments; the exploitation of quantum sensors requires a full understanding of underlying interaction processes. By focusing on common challenges, the proposed network will enable the development of innovative approaches to the improved control and optimisation of the systems. Specific problems concern trapped ion dynamics, device geometry and fabrication, nonlinearities, trap anharmonicities as well as cooling and state-preparation techniques.

Although the scientific goals of the groups within the proposed network are distinct they all rely on improvements in the underlying techniques, technologies and methodologies. These topics will be addressed by theoretical, numerical and experimental approaches, profiting from the wide variety of groups included. The proposers are convinced that providing a forum for interactions between workers in the field and opportunities for discussions of wide-spread experimental approaches is indispensable if rapid progress is to be continued and if **Europe's leading role in this field is to be strengthened**.

Europe has a long-standing tradition in ion-trapping. On the international scene, European ion trapping groups represent more than 60% of all ion trappers, the rest of the groups being dispersed through the USA, Japan and Australia. Europe stands on the fore-front of this field concentrating in its countries a large number of the key players, and an increasing number of applications and new developments. However, in particular the USA home a few of the first groups in ion trapping. Only a common effort assures the competitiveness of European groups in this ever-developing context. The present Action unites the European ion trapping community by including 38 experimental and theoretical groups from 13 European countries with a global research equipment budget provided by the national funding agencies of approximately 19 million € per year. The ion trapping groups see this Action as an ideal way of co-ordinating their efforts to enhance progress on common scientific and technological topics. A tight collaborative network will **encourage scientific exchange and the mobility of European scientists**, and be the basis for the emergency of novel and innovative technologies.

Difficulties in recruiting motivated and skilled students and researchers in this highly specialized domain, with its clear potential for shaping some of the key technologies of tomorrow, can be overcome by co-ordinating a strong and dynamic network. Emphasis will be put on encouraging and strengthening education, teaching and exchange of young researchers, allowing them to specialize in a high-technology domain, fundamental for state-of-the art science and technology.

B.2 Current state of knowledge

Europe has a strong background in ion trapping dating back to the seminal work of Wolfgang Paul, which led to the award of the Nobel Prize in 1989. The **European community** of researchers using ion traps has grown and diversified enormously in recent years. At present, **more than thirty research groups** are studying emerging applications and fundamental interactions of stored particles experimentally or theoretically. The research is spread over a **large range of topics throughout atomic and molecular physics, nuclear physics, plasma physics, and chemistry for various applications including ultrahigh-resolution spectroscopy**. Laser-cooled ions in Paul traps form the basis of one of the most promising and advanced experimental realisations of a quantum information processor. The possibility to trap single ions under controlled conditions for extended periods of time has recently enabled extremely precise spectroscopic studies of a possible time variation of fundamental physical constants and the most accurate comparison of optical frequencies performed to date. These promising experiments pave the way for critical tests of fundamental physical theories and the next generation of time and frequency standards. Similarly, advances in the technology for trapping and manipulating ions in Penning traps have enabled the most precise determinations of particle masses existent to date. Most recently, progress in the cooling and trapping of molecular ions has added a new dimension to the field and opened up perspectives for novel areas of study such as the ultralow-temperature reaction dynamics of trapped ions with neutral molecules and ultrahigh-resolution spectroscopic measurements on trapped molecular species.

These experiments require a technology which is on the fore-front of current knowledge to realise original protocols based on innovative approaches. An active dialogue between experiment and theory allows to deepen the understanding of the underlying mechanisms and to extend the frontiers of knowledge in these domains.

By strengthening the networking activities maximum benefit can be gained from the existing resources and the proposers are convinced that a **COST Action provides an ideal framework** for these activities, as it **facilitates and increases the interaction and cooperation between scientists**, which is exactly the parameter needed to provide scientific and societal added value to the existing research. In the last three years members of the ion trapping community have spontaneously organised two highly successful meetings, each with more than a hundred participants. In 2006 there was a satellite meeting immediately after the International Conference on Atomic Physics (ICAP) in Innsbruck entitled ‘Atomic Physics with Trapped Ions’ (http://heart-c704.uibk.ac.at/icap2006/program_sm.html). The spring of 2008 saw a meeting held at Les Houches entitled ‘Modern Applications of Trapped Ions’ (http://www.spectro.jussieu.fr/Mappi08/) which broadened the scope to include molecular ions and low-temperature chemical dynamics. Despite the limited availability of external funding for these meetings workers in the field ‘voted with their feet’ and made attendance a high priority. The participants of MAPPI08 were unanimous in their view that the scope of the meeting successfully identified an emerging community which would benefit greatly from enhanced links and further meetings of this type and the next meeting is scheduled to be in the UK in 2010. The activities of our proposed network will be coordinated with worldwide research in our field, by including interested groups, working on various themes with trapped ions. About twenty other groups exist worldwide, most of them in the USA and Japan. A number of these groups were already represented at the MAPPI08 meeting.

B.3 Reasons for the Action

Ion trapping finds an increasing number of applications throughout physics and its related disciplines. The most important established application of ion traps is in mass spectrometry instruments, serving diverse fields such as pharmaceutical development or the detection of toxic gases. The development of the **technologies targeted in the Action** potentially has **considerable economic value in the long term**, in particular in the domains of quantum computation, quantum simulation, mass spectrometry and frequency metrology. It is widely accepted that ion traps have a vast potential for the implementation of new quantum technologies. However, due to the many challenges in implementing such technologies, a **coordinated European approach** such as proposed in this Action is required. The relative small size of most of the groups (with a mean value of about 7 members including PhD students), makes cooperation **vital in order to foster rapid progress**. In a strong and dynamic network the emergence of novel technologies and applications creates a long-term economic impact.

A deeper understanding of basic processes, like the interaction of ions with electromagnetic radiation or interaction of atomic or molecular ions with neutrals, is essential for the development of new research protocols extending the frontiers of knowledge in these domains and opening up new fields of research with relevance to physics, chemistry and spectroscopy.

Various applications could be adopted more widely through the development of improved and refined implementation techniques. The Action is therefore also aimed at **scientific and technological advances of benefit to the wider scientific community** beyond the perimeter of the involved research groups. The Action will facilitate and develop novel approaches for the implementation and use of ion traps in quantum-information processing, ultrahigh-resolution spectroscopy of trapped atomic and molecular species, frequency metrology, high-precision mass spectrometry and ultralow-energy chemical dynamics.

A considerable societal impact will be the encouragement of mobility and **education of early-stage researchers**. They will be able to profit from this network by acquiring an excellent specialisation in parallel with a polyvalent approach to various disciplines. The Action will therefore enable researchers to establish scientific contacts early in their career and thus foster the integration of the European research community.

B.4 Complementarity with other research programmes

Various aspects of ion trapping benefit from current EU support. Two European Integrated Projects ("Qubit Applications" and "SCALA") focus on quantum information processing and involve some of the European ion trapping groups, while the 'QUELE'-collaboration focuses on quantum computing with electrons. The STREP MICROTRAP is concentrating on the development of miniaturized segmented linear ion traps for their application in quantum computing. An EU RTD network, HITRAP, ran from 2001-2005 and underpinned a current collaborative research programme based at GSI in Darmstadt on physics with trapped, highly charged ions. Despite all of this support no Action bringing together the study of fundamental topics in ion trapping and the interaction of stored ions, comparable with the network we propose here, currently exists.

C. OBJECTIVES AND BENEFITS

C.1 Main/primary objectives

To create scientific added value by organising a Europe-wide joint effort to develop new basic experimental set-ups and theoretical methods for the trapping and control of cold ions creating the necessary baseline to allow emergence of novel technologies and applications.

C.2 Secondary objectives

The Action is designed to **integrate experimental and theoretical approaches** in order to gain **insight into the fundamental interaction processes of trapped ions**, **promoting their use for various applications** in quantum information, frequency metrology and the determination of fundamental constants, ion-ion or ion-neutral interactions at ultralow energies, cavity QED or the production of cold molecules.

The global aim of the cooperation project is the development of innovative experimental approaches based on optimized experimental conditions. The operational objectives are:

a) Coordination of ion trapping research within Europe.
b) Providing a conduit for efficient interaction, networking and education of younger researchers.
c) Development of robust and easy to implement ion trapping technologies for a wide variety of applications.
d) Addressing fundamental problems in ion trapping that are applicable to the wider community.
e) Developing approaches for the scaling of ion traps for different applications.
f) Developing novel protocols for the interaction between ions and laser light.
g) Developing novel cooling and state-preparation schemes for atomic and molecular ions as a basis for their application in molecular physics, chemistry and frequency metrology.
h) Promoting new applications of trapped ions in physics, chemistry, bio- and nanosciences.

This Action aims at producing several concrete outcomes which will serve the ion trapping community as well as neighbouring disciplines. These concrete deliverables are in particular important for small groups, as they concern common basic features, and therefore allow the users to concentrate on their scientific focus and pursue advances in their research.

The proposed **deliverables** are

1 - The production of **“universal” optimized ion trap recipes**: for example, one allowing the estimation of trap dimensions and trapping parameters depending on the mass and number of ions to be trapped.

2 - **Universal computer codes**, applicable to a wide range of applications that calculate basic features regarding laser-atom interaction processes and/or laser cooling. This tool is important in particular to take into account the real experimental parameters (natural and laser linewidths, local magnetic field, laser intensities and detunings, velocity distribution of the ions..) in order to perfectly control experiments.

3 - A **tool and component catalogue for “standard” ion trapping set-ups**, discussing experimental constraints and solutions, addressed in particular to newcomers in the field, acting as a detailed guide to the realisation of an ion trapping set-up

4 -The **development** and sharing of various **electronic devices and components** necessary for ion trapping and specific guides how to build them (i.e. rf confinement drive, or specialized pulse-probe excitation). Several necessary devices are too specialized to be commercially available. At present, each group develops part of its electronics. A common effort leading to an accessible database gathering plans of the most frequent devices will lead to an important gain of time for all groups.

C.3 How will the objectives be achieved?

The 38 groups proposing this Action represent all facets of experimental and theoretical approaches and applications in ion trapping. Joining forces will allow us to attain a critical mass in manpower and to distribute effort efficiently among the participants. Complementary challenges can be confronted in parallel leading to a goal-oriented result-finding process. The Action will draw on existing resources in manpower and equipment which are already available at the partner groups or being funded by complementary sources (universities, national research councils, European Union) in order to fulfil its objectives. The Action will facilitate and accelerate the flow of information, by encouraging mobility of junior and senior researchers, through the organisation of thematic workgroup meetings, and by setting up a common interaction platform and database in electronic form accessible by all participants. The steering committee and the work group committees will monitor the achievement of the objectives and adherence to the work plan.

C.4 Benefits of the Action

The **primary benefit is joining the wider ion trapping community in order to reach the critical mass required for the efficient tackling of different topics**. The expected scientific benefits will be found on fundamental, technological and methodological aspects. The study of ion dynamics, heating processes, trapping constraints (especially for non-standard trap dimensions), novel trapping geometries and large ion clouds are all crucial for the optimisation of trap operation and act as precursors for the wide variety of innovative experimental avenues described above. **Scientific benefits** are:

- Gaining fundamental understanding of ion dynamics on different scales from the synthesis of existing experimental approaches.
- Development of fundamental trapping, cooling and state-preparation technologies applicable to a variety of ion trapping applications.
- Making advances in basic ion trapping technology available to a wider community
- Collaboration in developing basic technology required by a multiplicity of users.

- Proposal of novel interrogation protocols; development of optimised cooling and diagnostic methods based on the study of the fundamental interaction of ions with electromagnetic fields, other ions and neutral species.
- The control of light-mediated interactions between ions, either in the same or two remote trapping locations.
- The development of novel applications of trapped ions in ultralow-temperature ion-neutral chemical reaction dynamics, in the preparation of cold molecules and in molecular frequency metrology
- Allowing for efficient use of funding by using a collaborative approach in solving problems shared by a number of different groups.

The synergy of a variety state-of-the-art experiments will be exploited to accelerate progress and generate various benefits in the field of **innovative technology**:

- The optimization of ion trap geometries, with an emphasis on microtraps and their fabrication.
- The evaluation of different ion species with respect to the implementation of experiments in quantum control and spectroscopy of trapped ions.
- The development and production of specialized electronics for ion trapping.
- The development of advanced lasers for ion trapping.
- The development of cooling, interrogation and preparation methods for molecular species.

The Action will also benefit to the **general public**. We will make every effort to disseminate our results as widely as possible including a strong commitment to public engagement, with the goal of improving the understanding of quantum devices by society at large. This key technology of the next few decades will profit from publicity beyond the limits of the academic research community.

The **integration, mobility and training of young researchers**, in particular PhD students and post-docs, in a dynamic network, collectively constitute a second benefit to European society in general.

C.5 Target groups/end users

Different target groups can be identified depending on our various objectives. The above cited **long-term economic impact** will clearly profit to **society**. The **European scientific community** will undoubtedly benefit from the proposed Action. The strong networking aspect strengthens the ability of the **participating groups** to pursue their research goals. A particular effort will be made towards **early stage researchers**, focusing on their training and encouraging their mobility. With an increased control of ion trapping technology and a deeper understanding of interactions of ions with electromagnetic radiation, novel experimental approaches can be imagined in atomic and molecular physics. **Neighbouring scientific domains** (chemistry, aeronomy, biology, nanoscience) rely on ion trapping development and techniques and improved performance of these approaches will have a positive impact on these applications.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

Ion trapping is the basic tool employed for different applications by the participating groups. Samples ranging from a single ion up to 10^7 particles can be confined for several hours or even months in a vacuum chamber with essentially no interactions with either the walls or other particles. The main goal of this Action is to consider, from different points of view, the basic problems encountered in ion trapping and control, and to promote a Europe-wide collaborative effort in tackling these problems. The insight gained into ion trapping devices and interactions on different size scales will enable the pursuit of, for instance, a scalable approach to quantum information processing. Investigations can be divided into four major topics:

1. **Developing technology for ion trapping experiments**. While the research goals are various for different ion trapping groups, many of the technological challenges are the same. Examples include the development of complex computer controlled frequency and pulse sources, the development of microfabricated ion traps, the implementation of novel cooling methods for species which cannot be laser cooled (including molecular ions), and the quantum-state preparation of trapped ions.

2. **Storage and cooling at different trap size scales**. Increase of ion numbers to large cloud sizes and, at the other extreme, reduction of trap dimensions for use with individually resolved ions, pave the way for an extension of a number of applications beyond the frontiers of existing knowledge. Measurement of heating rates in a variety of ion trap structures with different ion species may shed more light on this phenomenon. Collating an inventory of existing experimental devices in a 'data base' and the development of new devices will allow the development of a scalable approach to ion trapping devices.
3. **Interaction of ions with electromagnetic radiation**. Light, and in particular laser light, allows the state preparation, cooling and manipulation of the stored ions, as well as measurements of metrological interest. Novel experimental protocols can be theoretically developed and validated in a wide variety of experiments.
4. **Investigation of atomic-molecular ion and ion-neutral interactions** to elucidate the scattering and chemical dynamics at ultralow collision energies. Such studies are of considerable interest for the development of novel sympathetic cooling schemes and for the characterisation of quantum-mechanical effects that influence chemical reactivity at very low temperatures.

These topics are of interest to all of the participants in the network and allow the integration of new participants at different stages in the course of the Action.

This Action **unites almost forty groups** with a human potential of nearly **300 scientists, with more than 50% of PhD students**. There is an overriding emphasis on experiment although we do include a number of theoretical groups and most of the experimentalists perform simulations relevant to their approaches.

The Action will rely on the technical infrastructure already existing in the various research groups and will focus on the exchange of knowledge and expertise between senior researchers, postdocs and PhD students largely funded by other European and national schemes.

D.2 Scientific work plan methods and means

The scientific work plan is guided by the principle of finding the most efficient way of tackling the four scientific topics described in section D.1. **Four Working Groups** (WG) will be set-up corresponding to these four general areas. These four WG are not completely disjoint as a single experimental or theoretical approach often depends on at least two of the major scientific topics. There is thematic overlap and effective interaction between all of the workgroups; i.e. the thematic of *fabrication methods* depends on the WG "technology" and "various scales", whereas the topic of *light activated chemistry* concerns the WGs "interactions of ions with electro-magnetic radiation" and "cold molecular ions", just to cite two examples. Almost every item has a direct influence on the others, sustainable progress is made by organizing an efficient interplay between all of the WGs.

WG1 "Technology" will start by compiling an inventory of technological issues and open questions, sufficiently important to concern a considerable number of involved groups. Information will then be gathered on the various items, building a common knowledge basis. During the annual work group meeting best practice will be exchanged and a common operational task will be discussed for the following year. This WG has two **tasks**: tackling cutting edge technological obstacles in a joint manner to guarantee progress through common means and simplifying the access to key technologies and experiments in order to promote the use of ion trapping in a large number of domains. The **milestones** of this WG are a common development protocol for the fabrication of microtraps, a standardisation of certain first-order experimental components (for example the rf drive for trapping which is commercially not available), and the compilation of the technical requirement specifications for a "standard" ion-trapping set-up.

Heating rates in radiofrequency traps are a major issue for all applications. Likewise the questions regarding ion density, maximum ion numbers, the use of multipole traps etc cannot be generalized for different trap sizes in a direct way. The main **task** of **WG2 "Various scales"** is to open the way for a scalable approach concerning ion numbers as well as trap dimensions and fabrication methods. The first **milestone** of this WG is the set-up of a data-base of all experimental, theoretical and simulation results concerning this question. Further **milestones** are the proposal, development and realisation of experimental and/or numerical solutions for missing items in the database, and finally the deduction of a "universal" solution with respect to geometric dimensions, ion numbers, ion density, and heating rates.

The annual WG assembly will discuss the proposals of new devices and eventually coordinate efforts to develop these.

A third workgroup **WG3 "Interactions of ions with electro-magnetic radiation"** will focus on the **task** of proposing novel interrogation protocols. The state preparation, entanglement, cooling, probing and detection of trapped ions are all achieved using electromagnetic radiation over a wide frequency span up to the deep ultraviolet. Theoretical and experimental insight into this fundamental tool forms a sound basis for the emergence of novel approaches and protocols. Answering these questions requires a permanent dialogue between theory, simulation and experiment to propose original and innovating solutions. **Milestones** of this WG concern the development of a common numerical code to simulate ion response as a function of electro-magnetic interrogation, its application to different ions with various energy level schemes, as well as the study of dynamics and thermodynamic effects (i.e. cooling and crystallisation).

WG4 "Cold Molecular Ions": The recent development of sympathetic cooling of molecular ions by the interaction with laser-cooled atomic ions has, for the first time, enabled the preparation of ensembles of molecular ions at millikelvin temperatures. The unique properties of cold molecular ions in ion traps (very low temperatures, localisation of the ions in ordered structures, minimal interactions with the environment) pave the way for exciting new fields of research in molecular and chemical physics. First promising applications in the domains of mass spectrometry, low-temperature chemical reaction dynamics and high-resolution molecular spectroscopy have recently been demonstrated highlighting the considerable scientific potential of cold molecular ions. The efforts of the workgroup will concentrate on the **task** of advancing the experimental methods to prepare cold molecular ions and address new applications. The **milestones** of this WG include: Development of cooling methods for a variety of molecular species, establishment of new optical protocols for the preparation and interrogation of trapped cold molecular ions and implementation of new experimental approaches to study sympathetic cooling, ion-neutral interactions, collisions and chemical reactions.

E. ORGANISATION

E.1 Coordination and organisation

The main goal of this proposal is the development of a strong, innovating, dynamic European network of researchers who use ion traps for a wide-range of applications. Research topics span a wide spectrum of modern scientific endeavours. Their core funding is assured by different national programs however COST is the ideal framework for the realisation of ‘horizontal cross-links’ as described above that provide added value for each of the subdisciplines. A **steering and Management Committee (MC)** that is responsible for managing the day to day business of the Action will be formed. Members of the committee will be elected during business meetings to be held at the biannual scientific meetings. The MC will include the Action chair, the workgroup leaders (see below) and the representatives of early-stage researchers (see section E.4). The MC will also be in charge of monitoring the scientific progress of the Action (see below). The members of the MC will be in regular contact by e-mail to identify possible problems at an early stage and meet face-to-face annually, usually at the workshops and schools organized by the Action.

The MAPPI08 meeting in May 2008 (Les Houches) has laid the basis for a European network, open to researchers world-wide. A business meeting towards the close of the MAPPI08 meeting gave unanimous support to the initiation of a **bi-annual workshop combined or alternated with a (pre-) doctoral school** to promote the training of students in the key concepts and technologies. The next meeting will be held in 2010 in the UK. These meetings will guarantee closer interactions between all the involved researchers, encouraging scientific discussions over the whole realm of ion trapping applications. Conference chairs for the next meeting will be nominated and elected at the end of each meeting during a specially scheduled business meeting.

To achieve the best coordination of the participating research teams, **exchange** on all levels (**PhD students, postdocs, senior scientists**) will be facilitated between research groups. This will include a biannual workshop meeting for all the participating research groups. In addition to the exchange between research groups, a **summer school** component will contribute to the training of younger researchers. The thus established personal contact and connections will form the basis for successful future collaborations.

As described in section D2, workgroups will be set up, corresponding to the proposed scientific topics. **Workgroup meetings** will be held at least **once per year** for a maximum of three days, and will allow efficient discussions and mini-courses on chosen subtopics. Each work group meeting will be held on the thematics of one of the operational tasks cited in section D.2., certain topics at the intersection of two WGs (see upper viewgraph) will be discussed in joint meetings of 2 WGs. **Workgroup leaders** will be nominated to co-ordinate these activities. Along with face-to-face interaction, email lists will be created that facilitate exchange about the particular workgroup. Mutual visits of (young) researchers for periods between a couple days and a few weeks will allow efficient collaboration on certain subtopics and will strengthen the ties between the member groups.

A **Wiki site/diffusion list** has already been set up (http://groups.google.fr/group/eutin) to guarantee rapid interaction between the groups and the creation of an easily accessible knowledge base. The aim of this Wiki site is manifold: current information ("news" and job offers) are rapidly and easily published, discussion fora allow exchange of information and points of view on concrete points. The setup of a **technology database** is a valuable tool for the experimental groups involved in the Action, allowing the exchange of technical information on the design and implementation of systems. This Wiki site will eventually form part of a dedicated website for the Action which will be used to facilitate the communication between its members, to present its achievements to a wider scientific community and to promote the network vis-à-vis a wider scientific audience and the general public as part of its outreach activities. The implementation and continuous update of this website will be monitored by the MC and its maintenance will be delegated to one of the MC members.

An additional discussion point has been launched on the Wiki site concerning **outreach and dissemination to the public** at large about ion trapping devices and their physical applications. At present, a variety of different activities are being organised individually by the participants in the Action. One of our aims is therefore to coordinate these efforts to propose mobile experimental demonstrations or posters in public events in order make the public aware of these devices.

We have published a special issue "Modern Applications of Trapped Ions" in a widely accessible journal (Journal of Physics B: Atomic, Molecular and Optical Physics) to collect the proceedings of the Mappi08-workshop and to make them available to a large community. This special volume has also been open for the publication to any research articles connected to the thematic area of ion trapping, and has raised great interest. The **publication of a bi-annual volume on advances in ion trapping** will be an important tool for our community. Naturally, the dissemination of concrete research results arising from the collaborative work nurtured through the Action will be assured through **common publications**.

The **MC will be in charge of piloting and evaluating the ongoing Action** by checking against the milestones defined in section D.2. It will also be responsible for the dissemination of results throughout the whole community. Moreover, it will prepare and organise the dissemination of results to a wider scientific community, and in particular to interested new groups. The steering committee will in particular **encourage the emergence of novel scientific topics and applications**.

Evaluation will concern all of the activities cited earlier in this section, in terms of their efficiency and scientific output. This will be **scheduled twice a year**, in order to encourage or eventually re-orientate certain topics and to maintain an overall equilibrium of the research carried out, in view of the defined objectives.

E.2 Working Groups

Four Working Groups (WG) will be set up, each dealing with a different scientific topic (see D.1 and D.2). A **WG leader** will be nominated by the MC to coordinate the WG efforts. Each WG will have an internal email list to simplify discussions. An **annual face-to-face meeting** will be held per WG for a period sufficiently long to allow for discussions but not longer than 3 days. During this meeting dedicated to one pre-defined operational task, recent scientific results will be presented, at least one "brain-storming" discussion will be scheduled to encourage the emergence of novel experiments, protocols or approaches; and a round-table with an evaluation of past activities and steering of future tasks will be organized. In view of the common interest of WGs in certain topics, some WG meetings will be organized to benefit from a spatial and temporal overlap of two groups to allow for joint meetings.

Two common workshops are planned which allow the whole community to gather and discuss. The final workshop will eventually be held jointly with a **larger international conference** to allow substantial dissemination of the Action's results.

E.3 Liaison and interaction with other research programmes

The existing European projects (see B.4) all aim exclusively towards quantum information. Some ion trap groups take part in these projects but they only represent a fraction of our participants. The present Action unites groups from a large variety of scientific applications (including quantum information, but also including frequency metrology, the measurement of fundamental constants, cold chemistry etc.) that use the ion trap as a common tool. The complete understanding and control of this key technology will open the way to new original experiments in a wide range of domains. The ion trapping quantum information groups involved in the existing European projects will also greatly profit from this Action as it will result in an unprecedented concentration of key players in the field that can form a critical mass. This will enable Europe to take a leadership role in the implementation of new quantum technologies.

E.4 Gender balance and involvement of early-stage researchers

This COST Action will respect an appropriate gender balance in all its activities and the MC will place this as a standard item on all its MC agendas. The Action will also be committed to considerably involve early-stage researchers. This item will also be placed as a standard item on all MC agendas.

From the groups involved in the Action, 10% are led by a woman. An effort has been made for the organisation of the Mappi08 Workshop, where 20% of the speakers have been female, as well as 18% of the participants. We are aware of feeble number of female researchers in this Action, reflecting the general underrepresentation of women in physics. However, the community involved in this Action comprises several role-model female senior scientists and the designated coordinator of the Action is also female. A particular effort will be made to **encourage female scientists throughout this Action**, by implying them preferentially in all responsibility tasks.

The Action will promote a strict **equal opportunity policy** and encourage female researchers to apply for positions in the field. We will also particularly insist on attracting women as young researchers, e.g., through **outreach activities** organised by the involved research groups and through a **special section on the Action's website**. One – preferably female - member of the MC will act as a **gender balance representative** in charge of implementing and overseeing the Action's gender balance policy.

A special effort will be made on **capacity building**, encouraging early-stage researchers to use the know-how and skills they have acquired in the field to push further the application and the physics where ion traps are used: research groups in academia, applied research in industry, the creation of new companies, cross-fertilization of science and technology. **Early-stage researchers** (PhDs, Postdocs) form **more than 70% of the scientific personnel involved in this Action** and will hence particularly benefit from its activities. The groups implied consider that capacity building is a long-term, continuing process, which starts within the framework of this Action. It is a first step versus increasing and consolidating European managerial competences and scientific expertise in this domain of physics. Each WG will elect a **"junior" representative** which will be a privileged discussion partner to the WG coordinator concerning any issue specific to early-stage researchers. These four representatives will be part of the MC, they will also be in charge of organizing the **"young ion trapper's" business meeting** which will be held at each workshop and summer school to allow the discussion of specific questions.

F. TIMETABLE

This Action is supposed to run on the normal four-year term in order to create an efficient interaction between the groups, build lasting links, allow workgroups to work efficiently and schedule training events which profit to early-stage researchers. Frequent monitoring will allow to encourage emergent innovations and to eventually re-orientate certain tasks where it appears to be necessary.

	Technology	Various scales	Interaction of ions with em radiation	Cold molecular ions
Year 1	Scientific kick-off meeting of the MC			
	Set-up of Working Groups			
	WG1 meeting	WG2 meeting	WG3 meeting	WG4 meeting
	Training school for early-stage researchers			
	Progress report			
Year 2	MC meeting: scientific evaluation, orientation and schedule			
	WG1 meeting	WG2 meeting	WG3 meeting	WG4 meeting
	Common workshop with publication of special issue			
	Progress report			
Year 3	MC meeting: scientific evaluation, orientation and schedule			
	WG1 meeting	WG2 meeting	WG3 meeting	WG4 meeting
	Training school for early-stage researchers			
	Progress report			
Year 4	MC meeting: scientific evaluation, orientation and schedule			
	WG1 meeting	WG2 meeting	WG3 meeting	WG4 meeting
	Common workshop with publication of special issue			
	Final report – joint review publication			

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: Austria, Denmark, France, Germany, Israel, Italy, Netherlands, Poland, Portugal, Romania, Spain, Switzerland, United Kingdom. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 52 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

Important beneficiaries of the results will be the participating research groups which will profit from the added value and synergies realised through the collaborative Action. The **wider ion-trapping community and non-participating research groups** in the field will benefit from the results published in the scientific literature, the possibility to take part in the meetings periodically organised as part of the Action and through collaborative projects with member groups. The expected results will also be of considerable value for **neighbouring research communities** such as the analytical sciences, biosciences, nanosciences, ion- and plasma physics which will be targeted through publications in the relevant scientific journals and through presentations at scientific conferences. An important impact on the activities of **national laboratories and standards institutions** is also to be expected. **Master level and PhD students** will directly benefit through the teaching and career development activities organised within the framework of the Action. The **general public** will be addressed through the public website and outreach activities organised by the members. Having a coordinated European approach will allow for effective communication with policy makers both on national and European levels as important issues can be identified by the relevant scientific community as a whole.

H.2 What?

The Action's dissemination strategy rests on several pillars:

1. Periodically organised **workshops and workgroup meetings** will enable the exchange of knowledge and expertise among the participating groups and facilitate the planning of joint projects and publications. Participation in the workshops will also be promoted among non-members of the Action (usually from overseas) thereby establishing and consolidating links with the worldwide ion trapping community.
2. The **results** achieved within the Action's activities will be **published in the scientific literature** and **presented at national, European and international conferences** to make them available to the wider scientific community.

3. The **Action's website** will form an integral part of the dissemination strategy. It will contain a **newsgroup**, a **knowledge database** and a **job market** thereby acting as an information portal for all members. The website will also promote the activities and results generated through the collaborative efforts to the wider scientific community and facilitate the communication with the general public.
4. The **training schools** organised in conjunction with the Action's workshops are aimed at training students and postdoctoral researchers in the basic and advanced techniques used in ion trapping. The new knowledge generated as a result of the collaborative activities will also feed back into the **general teaching of physics** through lectures given by the members of the Action.
5. **Outreach activities** organised by the members of the Action such as public lectures, talks, open days and popular-science publications will be used for disseminating the results to the general public.

H.3 How?

Every effort will be made to make our results amenable to the wider community and to encourage a dialogue with all interested parties.

The proceedings of the MAPPI08 workshop have been published in a special issue, on the theme of trapped ions, of a well-known and high-visibility journal (Journal of Physics B, Vol 42, Nr. 15 (2009)). This special volume has been open to the whole community. Proceedings of the two major workshops planned during the Action will be published in a similar way. Tutorials which will be given during the training schools will be published in a special edition, and will be downloadable on the internal website for all groups participating in the Action.

A first impact of this publication can already be seen from the growing interest of the EBIT-community in our work. In a general way, we will strengthen the interactions with the neighbouring disciplines and topics through talks and conference invitations in order to disseminate results directly to interested colleagues.

The Action will also provide an inventory of individual dissemination tasks organized by the participants which will constitute a database of existing posters, publications and experiments. It will also facilitate the participation of members of the Action in local events (for example the French "Fête de la Science").