

# Workshop Quo Vadis BEC?

## 1. Summary

As the end of the funding period of the DFG Priority Program SPP 1116: *Interactions in Ultra-Cold Atomic and Molecular Gases* is approaching in summer 2007, we thought it to be appropriate to reflect upon the major results achieved so far, to integrate the research conducted previously on a national level into the European BEC networks, and to identify, discuss, and evaluate possible future lines of development. Therefore, with major financial support of the ESF activity *Quantum Degenerate Dilute Systems*, we organized the special workshop **Quo Vadis BEC?** at the Department of Physics of the Free University of Berlin, Germany, from October 27 until October 29, 2006:

[http://www.theo-phys.uni-essen.de/tp/ags/pelster\\_dir/BEC/bec.html](http://www.theo-phys.uni-essen.de/tp/ags/pelster_dir/BEC/bec.html)

Our schedule was the following: Friday, October 27, 2006: arrival until 15.00, opening talk within the Physics Colloquium of the Free University at 15.15; Saturday, October 28, 2006: talks and discussions, poster session with pizzas and beverages from 12.00 until 16.00; Sunday, October 29, 2006: departure after 12.00.

At this workshop, the present status of the research field and its future trends were presented and discussed. The workshop brought together experimental and theoretical scientists, who investigate the properties of ultracold gases from their respective points of view. The aim was to exchange opinions, discuss problems, and disseminate new ideas. During the three-day workshop **Quo Vadis BEC?** we had 12 invited talks with a duration of 45 minutes, including discussions which introduced the state of the art of the most promising current research trends within the field of ultracold gases. Leading European experts covered individual topics: Immanuel Bloch (University of Mainz), Jean Dalibard (Ecole Normale Supérieure, Paris), Jozef Devreese (University Antwerpen), Robert Graham (University of Duisburg-Essen), Massimo Inguscio (University of Florence), Maciej Lewenstein (Institute of Photonic Sciences, Barcelona), Alejandro Muramatsu (University of Stuttgart), Markus Oberthaler (University of Heidelberg), Tilman Pfau (University of Stuttgart), Jörg Schmiedmayer (Technical University Vienna), Klaus Sengstock (University of Hamburg), Henk Stoof (Utrecht University).

Further participants from the DFG Priority Program SPP 1116 made sure that the broad scope of its activity was represented at the workshop. A poster presentation, at which pizzas and beverages were offered, took place at lunch time of Saturday, October 28, 2006. Participants were accommodated in the Harnack-Haus of the Max-Planck Society, located near-by.

In total the workshop had 64 participants. Although the majority came from Germany, we also had participants from 7 other European countries: Austria, Belgium, France, Italy, Netherlands, Spain, and United Kingdom.

Axel Pelster (University of Duisburg-Essen)  
Martin Holthaus (University of Oldenburg)

## 2. Scientific Content and Discussion at the Event

The 12 invited talks of our workshop were selected in such a way that major breakthroughs in the BEC research field were explored from both an experimental and a theoretical point of view:

- New pathways in low-dimensional BECs were highlighted by Jean Dalibard who reported about recent experimental observations of the Berezinskii-Kosterlitz-Thouless crossover in a trapped atomic gas. This opening lecture of our workshop took place within the Physics Colloquium of the Free University of Berlin and, thus, attracted further scientists from the Physics Department to the event. Afterwards, Maciej Lewenstein outlined the vision that ultracold atoms in artificial non-abelian magnetic fields could be used for simulating lattice gauge theories. Complementary to that Tilman Pfau demonstrated that today it becomes possible to realize not only short-range but also long-range interactions in quantum gases in an experimentally controllable way.
- Another focus of the workshop concerned the impact of an additional frozen random potential on a dilute Bose gas. Whereas Massimo Inguscio explored an artificial realization of dirty bosons with the help of laser speckles or non-commensurable optical lattices, Jörg Schmiedmayer reported about their natural occurrence in wire traps. The corresponding theoretical discussion of the present status of the dirty boson problem was delivered by one of the organisers, Axel Pelster, as Robert Graham (who had originally agreed to give this talk) could not attend the workshop.
- The subsequent three talks outlined the diverse connections between ultracold quantum gases and condensed matter physics which emerged from optical lattice systems. Immanuel Bloch presented new pathways how to probe strong correlations experimentally. The first realization of a Bose-Fermi mixture in a three-dimensional optical lattice, which led to puzzling results, was reported by Klaus Sengstock. Alejandro Muramatsu presented Monte-Carlo simulations for supersolids with fermions confined in optical lattices.
- The seminal BEC/BCS crossover in dilute atomic gases was analyzed in two theoretical talks by Jozef Devreese and Henk Stoof, where the latter was focused on the recently discovered unbalanced Fermi mixtures. Furthermore, Markus Oberthaler reported how a weakly coupling between two condensates can be used to develop a thermometer.

The abstracts of these 12 invited talks together with the titles of the 32 contributions to the poster session are available on the workshop homepage

[http://www.theo-phys.uni-essen.de/tp/ags/pelster\\_dir/BEC/bec.html](http://www.theo-phys.uni-essen.de/tp/ags/pelster_dir/BEC/bec.html)

They represent a realistic cross-section of the many research directions in the BEC field.

Due to its special format, the workshop **Quo Vadis BEC?** offered several possibilities for personal and scientific discussions among the participants:

- On the first evening of Friday, October 27, 2006 a workshop dinner was organized at a restaurant near-by the workshop site. This event allowed to establish new and reactivate already existing contacts between the participants.

- It turned out to be advantageous that all scientists, which travelled to Berlin, could be accommodated in the Harnack-Haus of the Max-Planck Society, located near-by the Free University of Berlin. The common breakfast, which was also frequented by some scientists from Berlin, as well as the common walks to and from the workshop site initiated many exchanges of ideas on an informal level.
- An integral part of the workshop program were the 15 minutes coffee breaks between the respective invited talks. On the one hand, they stimulated further discussions with the invited speakers and among the participants. On the other hand, these numerous small coffee breaks allowed everybody to relax and sharpen the absorbing capacity for the next presentation.
- The poster session took place during lunch time of Saturday, October 28, 2006, where pizzas and beverages were offered. We allocated 4 hours for this poster sessions in order to have enough time for intensive scientific discussions.
- During the second evening on Saturday, October 28, 2006 no official program was organized. Afterwards, we were told from many participants that they used this unique opportunity to explore together the touristic highlights of Berlin.

According to our impression, all the participants appreciated these different discussion opportunities.

### 3. Assessment of the Results of the Event

All the invited speakers tried to answer the major underlying question of the workshop **Quo Vadis BEC?** from their own perspective. However, quite soon it became obvious that no simple answer is possible. At present, the research field of ultracold quantum gases is extremely active and expanding in so many different directions, that no unique trend is clearly identifiable. Since the first realization of a Bose-Einstein condensate in 1995, nearly each year of fundamental research led to a major experimental or theoretical breakthrough. In addition, new connections are explored to well-established physical disciplines as, for instance, quantum optics, atomic and molecular physics or condensed matter physics. Thus, fruitful synergies emerge which contribute to the present attractiveness of the BEC research field. Therefore, our workshop was invaluable insofar as we represented a realistic cross-section of these different directions in the invited talks and the poster contributions. With this, we intended to offer a most promising platform for a mutual exchange of ideas upon the most urgent and demanding present-day developments. We are confident that our workshop has an impact upon the future research of each participants.

In addition, the workshop has impressively underlined the fact that the mutual cross-fertilization of experiment and theory is functioning quite well in this immensely active field of physics. With the many existing links between the leading European groups, a good forum is opening up for the training of young scientists who are about to enter this field. As an overall conclusion to be drawn from the workshop, it may be stated that even more than ten years after the realization of the first Bose-Einstein condensates, the number of promising research directions in the field of ultracold atomic gases is still growing. Thus, it seems clear that this particular field of physics will attract highly motivated individuals for years to come. On the other hand, in view of the many diverse directions, some co-ordinating efforts, or activities which offer a somewhat unifying view on the field, will be becoming increasingly important. We hope that our workshop **Quo vadis BEC?** has made a distinct contribution to this need.

## 4. Final Program

### Friday, October 27, 2006:

- until 15.00** arrival at Department of Physics, Free University of Berlin
- 15.15–16.30** opening lecture within the Physics Colloquium  
Jean Dalibard (Paris): *Cold Atoms in Flatland*
- 16.30–17.30** coffee break
- 17.30–18.15** Maciej Lewenstein (Barcelona): *Ultracold Atoms in Artificial Non-Abelian Magnetic Fields: From Hofstadter Moth to Non-Abelian Quantum Hall Effect and Lattice Gauge Theories*
- 18.15–18.30** coffee break
- 18.30–19.15** Tilman Pfau (Stuttgart): *Novel Interactions in Quantum Gases*
- 20.00** dinner

### Saturday, October 28, 2006:

- 09.00–09.45** Massimo Inguscio (Florence): *BEC and Disorder*
- 09.45–10.00** coffee break
- 10.00–10.45** Robert Graham (Duisburg): *The Dirty Boson Problem*
- 10.45–11.00** coffee break
- 11.00–11.45** Jörg Schmiedmayer (Vienna): *Micro Manipulation of Low Dimensional (Mesoscopic) Quantum Gases*
- 11.45–16.00** poster session
- 16.00–16.45** Immanuel Bloch (Mainz): *Probing Strongly Correlated Quantum Systems in Optical Lattices*
- 16.45–17.00** coffee break
- 17.00–17.45** Alejandro Muramatsu (Stuttgart): *Supersolids With Fermions Confined on Optical Lattices*
- 17.45–18.00** coffee break
- 18.00–18.45** Klaus Sengstock (Hamburg): *Fermi-Bose Mixtures in Three-Dimensional Optical Lattices*

### Sunday, October 29, 2006:

- 09.00–09.45** Markus Oberthaler (Heidelberg): *Weakly Coupled Condensates*
- 09.45–10.00** coffee break
- 10.00–10.45** Jozef Devreese (Antwerpen): *The BEC/BCS Crossover in Dilute Atomic Gases*
- 10.45–11.00** coffee break
- 11.00–11.45** Henk Stoof (Utrecht): *Unbalanced Fermi Mixtures*
- 11.45–12.00** coffee break
- after 12.00** departure