

Workshop on ,Physics of Spinor-Bose-Einstein-Condensates' **Barcelona, September 8th -9th , 2005**

Organizers:

Dr. Montserrat Guilleumas, University Barcelona, Spain.

Prof. Dr. Maciej Lewenstein, Institut Ciències Fotòniques, Barcelona, Spain.

Prof. Dr. Anna Sanpera, University Autònoma Barcelona, Spain.

Prof. Dr. Klaus Sengstock, University Hamburg, Germany.

1. Summary

The physics of spinor and multi-component Bose Einstein condensates has attracted a lot of attention since the first theoretical discussions by T.L. Ho and T.Ohmi and K. Machida as well as the first experimental realization by MIT group in 1998. In the last years further groups have actively joined this new research area and we observe currently an increasing interest by the scientific community in the physics of multi-component- and spinor-BEC.

For that reason, we proposed to bring together the leading scientists on the field to discuss in a rather informal style the recent development on the field as well as to openly discuss and signal the most significant unresolved open questions in this area. Before initiating any action, we asked the opinion of the main researchers involved in this area and all of them reacted very positively to this initiative. We then organise a two days satellite meeting in connection to the followler ESF - BEC 2005 conference in Sant Feliu de Guixols in September 2005. Taking advantage of the fact that many of the speakers we invited were also attending the ESF-BEC2005 meeting afterwards, to attend the satellite meeting supposed almost not additional cost in terms of time and/or money. For such reason we were able to bring with a relative small budget, the world- leading figures on the field including a Nobel Laureate.

The meeting was organised in a 2 days sessions, with introductory tutorial talks followed by detailed researched oriented talks. Both experimental and theoretical aspects of the physics of spinor condensates were treated on equal footing. Finally there was an plenary talk given by the Nobel Laureate E. Cornell summarizing the-state-of-the-art on the field.

The meeting was hold at the University of Barcelona and we provided accommodation for all participants and invited speakers in one of the residences belonging to the University. In this way we could one one hand cover most of the expenses of the participants who wished to stay in the residence, and on the other we offered an appropriate atmosphere to discuss physics allowing the contact between the participants and speakers. We also put an special emphasis in a balanced contribution between experimental and theoretical research. In this way the communication between both communities becomes highly efficient and stimulating.

Finally, as discussion leaders we invited well known figures on the field of Bose Einstein Condensation from both areas experiments and theory. They were able to engage participants to participate in the open discussions after each talk and provide a lively atmosphere for research interchange. The number of participants was higher than expected, and eventually in the peak sessions, e.g. Eric Cornell (Nobel Laureate) talk's more than 90 people were attending the meeting. The number of registered participants was 66, but on average the talks were attended by 75-80 people because also Ph.D students and professors from the different local Universities were attending some of the lectures.

As organisers we were very satisfied by the response of the scientific community to such a small meeting. we believe that these satellites workshops organised around a big eve provide a unique possibility to discuss quite focussed topics bringing world leading figures of the field.

2. Description of the scientific content of and discussion at the event

Spinors condensates have additional freedom degrees that do not appear in the description of scalar condensates. The field operator in the former case is not longer an scalar but a vector and depending on the various parameters the system can condense in different spin components and present a richer dynamics and excitation spectrum. From skyrmions to topological defects, exotic quantum phase transitions, complex thermal excitations, non-degenerate Landau Levels, the complexity of such systems manifest fully in the limit of strongly correlated systems.

The workshop was open for all people interested, preferentially working in the field of cold quantum gases, as intensive discussions on new theoretical, experimental and cross-linked ideas and projects on spinor-Bose Einstein condensates were in the focus of the workshop. People from condensed matter physics were very welcome since there is a clear connection between spin-physics in quantum gases and magnetism in condensed matter physics.

To discuss about the physics of spinor condensates, which is a relative young and very promising field on the area of cold gases we 11 speakers most of them being the leading researchers on the field of spinor condensates were invited to participate. Although we thought first on restricting the total number of participants, the number of registration was higher than we expected and we finally decided to open the meeting to anybody interested without any registration fee.

By choosing the speakers we also aimed at covering a wide range of aspects concerning the physics of spinor condensates. In particular the following topics were extensively discussed during the meeting:

1. Which effects are intrinsically related to the spinor nature of the condensate in opposition to scalar condensates.
2. What are the fundamental differences between pseudo-spinors (spin $\frac{1}{2}$) multicomponent condensates and spinor condensates?
3. Spin domains.
4. Spin liquids.
5. Spinor condensates in optical lattices.
6. Dynamics and excitations of rotating spinor condensates.
7. Spinor condensates in the strongly correlated limit.
8. Temperature effects in spinor condensates.
9. Spin $F=1$ and Spin $F=2$ condensates in Rb.
10. Observation "in situ" of spinor dynamics.
11. Low dimensional spinor gases.
12. Coherent and Quantum spin dynamics.
13. Open questions.

A general first overview about the subject was provided by Prof. T. L. Ho, which was (together with Prof. Mashida) one of the initiators of the physics of spinor condensates.

This part was covered with a tutorial talk of 45 minutes (+15 minutes discussion) about the state-of-the-art with spinor condensates. Prof. Stamper-Kurn gave then a tutorial talk on experimental physics of spinor condensates, in particular how to image real time dynamics of spinors condensates and their coherence properties.

The meeting focussed then on the theoretical description of spinor condensates: the validity of Single Mode Approximation where all the spin components have the same spatial wavefunction was analysed in different scenarios. Special emphasis was also devoted to the role of uncondensate atoms in the formation of spinor condensates. Numerical approaches as well as analytical ones were presented. Collisional spin dynamics of spinor condensates in optical lattices were also extensively discussed. Transition from the weakly interacting regime to the strongly interacting one as well as the possibilities of crossing a quantum phase

transition and the length of the spin domains in such case was presented by condense matter theorist Prof. E. Demler.

Decoherence effects in spinor samples in both the condense and non-condense cloud was other of the topics that were discussed in detail, both at experimental level as well as theoretically. Descriptions of coupled Bogoiuvov-de Genes equations and Hartree-Fock approach were envisioned as possible methods for their description. The meeting end up with a list of open problems and challenges presented by the Nobel Laureate E. Cornell.

3. Assessment of the results and impact of the event on the future direction of the field

To the best of our knowledge this was the first meeting devoted to this subject, and has been an enriching experience for all participants. This kind of small meeting with a very focused subject allows discussions within a much deeper level between the participants since all of them are in one way or other actively working on the field. The flow of discussions, exchange of ideas, or simply the possibility to ask for expertise in very particular questions is an opportunity that does not happens often. Also, the fact that the meeting was open to everybody who wanted to attend, gives the possibility for young researchers to have access to very experienced world leading people on the field. Something that scarcely happens in a major event, where the contact with well established researchers is often difficult for the new ones. Certainly such a meeting would not be possible without the infrastructure provided by the ESF Conference in BEC which was hold immediately after. Only for that reason we could obtain the best speakers, cover travel expenses for many young participants and organise a first class international conference with a very small budget.

We firmly believe that this kind of small workshops around a big event provide a unique opportunity to discuss at deeper level emerging scientific topics of clear relevance.

4. FINAL PROGRAM

Spinor- and Multi-Component Bose-Einstein Condensates
Barcelona, 8-9 September 2005

Programme:

Thursday, September 8th:

- 15.30 Workshop Opening
Chair: A. Sanpera
- 15.40 T. L. Ho (45 + 15 min)
- 16.40 D. Stamper-Kurn (45 + 15 min)
- 17.40 break
Chair: K. Sengstock
- 18.00 L. You (35 + 10 min)
- 18.45 M. Guilleumas (35 + 10 min)
- 19.30 Discussion and dinner

Friday, September 9th:

- Chair: K. Rzazewski
- 9.0 M. Ueda (35 + 10 min)
- 9.45 K. Bongs (35 + 10 min)
- 10.30 break
Chair: M. Ignuscio
- 11.00 M. Chapman (35 + 10 min)
- 11.45 A. Widera (35 + 10 min)
- 12.30 Lunch and discussions
Chair: M. Lewenstein
- 14.00 E. Demler (45 + 15 min)

15.00 N. Bigelow (35 + 10 min)

break

16.15 E. Cornell (45 + 15 min)

17.15 Final discussions

18.00-20.00 End of workshop (buffet and drinks)