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Bose-Einstein condensation in atomic gases

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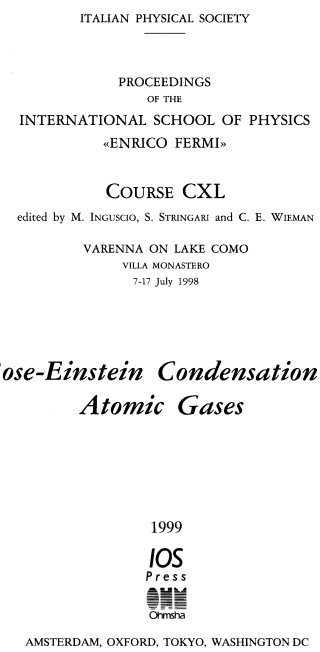

The book edited by M.Inguscio, S.Stringari and C.E.Wieman contains the proceedings of the International School of Physics "Enrico Fermi" (Course CXL) which took place at Varenna on Lake Como, 7–17 July 1998. The problem of discussion – phenomenon of Bose-Einstein Condensation (BEC) in atomic gases – incorporated both the experiments related to BEC and theoretical considerations.

There are 21 articles in the Proceedings presented by lecturers that are highly skilled specialists in this branch of condensed matter physics. In the beginning we can read a profound historical review by A.Griffin that describes the stages of understanding the BEC starting from Bose and Einstein papers in the early 1920-ies up to Beliaev's contribution in the middle of 1960-ies. The author has mentioned the names of F.London, L.Tisza, L.D.Landau, N.N.Bogoliubov, L.Onsager, R.P.Feynman – the cohort of outstanding scientists whose contribution to the understanding of low temperature phenomena in condensed matter physics can be hardly overestimated. At the same time the reader is guided through the main points of the theoretical frameworks elaborated by these physicists: the two-fluid concept, "new" hydrodynamics introduced by L.D.Landau to describe superfluid phenomena, a quasiparticle dispersion relations, the wave-functions formalism for the description of many-particle quantum states and so on.

Another article by E.A.Cornell, J.R.Ensher and C.E.Weiman is a very interesting survey of experiments in dilute atomic BEC. Starting from a basic model of an ideal gas with subsequent sophistication of the picture due to the effects of interactions, the authors described plenty of nontrivial phenomena like laser and evaporative cooling in atomic gases, magnetic trapping of the particles. The concept

of the "phase" of a condensate is introduced and overviewed in connection with the problem of quantum decoherence. A topical problem of the heating of the system from primary and secondary scattering of the particles is discussed in the context of both experimental setup and theoretical consideration.

An article by W.Ketterle, D.S.Durfee and D.M.Stamper-Kurn is a logical continuation of the previous paper enriched by the addition of the sections related to thermodynamics of Bose condensates at non-zero temperatures as well as to hydrodynamics. A good portion of the work to be done in the future is marked in "challenged ahead problems" like studying the transition from discrete modes to continuous sound propagation or possible chaotic propagation of localized excitations.

In the lecture given by D.Kleppner, T.J.Greytak, T.C.Killian, D.G.Fried, L.Willmann, D.Landhuis and S.C.Moss there is a good piece of experimental data on BEC of atomic hydrogen (spectra of trapped hydrogen before and after condensation, time evolution of the condensate) accompanied by basic formulas related to the energy distribution of H atoms in the scattering processes.

Much more detailed explanation of the above mentioned dynamic properties of a dilute low-temperature trapped Bose condensate is presented in theoretical review by A.L.Fetter. The lecture starts with a brief review of scattering theory, proceeds with the Bogoliubov's concept of quasiparticles and basic physics of the Gross-Pitaevskii equation and covers hydrodynamics of a dilute trapped Bose gas in application to vortex prediction in superfluid ^{4}He.

Another viewpoint regarding the excitations for a trapped gas based on the mean-field theory is presented in the lecture by K.Burnett. A step beyond mean-field approximation because of quantum fluctuations in BEC gas has been made in the paper by L.P.Pitaevskii.

Of great interest for both experimentalists and theorists is the subject of collisional dynamics of ultracold atomic gases. The problem could be sophisticated when the investigator locates BEC into electromagnetic fields, where a sample undergoes the influence of radiative forces. Hence, one is able to manipulate BEC with light in various laser induced experiments. The mentioned phenomena have been investigated in the papers by J.Dalibard, D.J.Neinzen and K.Helmerson with co-workers, where a reader could accomplish a transfer from theoretical schemes based on model potentials (Wan der Waals, $1/r^3$-potential, inelastic collisions) to the particular scattering experiments in ultracold rubidium, lithium, sodium or trapping of neutral atoms and BEC by external fields.

More specific types of traps (planar surfaces, quadrupole-Ioffe configuration traps, iron-core electromagnets) are considered in the papers of D.Schneble et al, T.Esslinger et al and A.Aspect et al. The first lecture gives us an example of a low-dimensional gas behaviour in a single potential well of a standing light wave at a distance less than 1 μm from a metallic surface while the processes of magnetic trapping and evaporative cooling of BEC in a high magnetic field are the subjects of investigation in the second and the third articles.

Since its theoretical prediction, the Josephson effect has played a major role in

the physics and technology of superconductors, superfluids and Bose condensed systems. Some aspects of different types of the Josephson effect (external spatial and internal hyperfine) together with quantum self-trapping and macroscopic interference between separate BEC are touched upon in the lecture by F.Sols.

We also need to mention the paper by E.Arimondo, E.Cerboneschi and H.Wu, where very interesting results of Monte Carlo simulation for evaporative cooling in BEC are presented for reader's attention. The effect of the condensate fraction growth after a very fast evaporation has been observed and the rate constant for the condensate formation has been derived during this computer simulation.

We did not mention the remainder of the papers though they undoubtedly deserve a close attention of the reader interested in the theory and experiments of BEC in atomic gases. We believe it is not a complicated task to pick up a specific information from this book of Proceedings or to perform an exciting tour together with authors through the stages of the development of BEC-related experiments or theoretical concepts. Even if someone did not find all the answers to the questions that emerged during studying of this course of lectures, the forthcoming papers announced in this book and the "challenged ahead problems" could shed more light on the understanding of Bose-Einstein condensation in various systems.

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