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FOREWORD

A historical achievement in experimental atomic physics took place in 1995: the creation of Bose-Einstein condensates (BECs) in ultracold bosonic gases by the groups of Eric Cornell and Carl Wieman at the University of Colorado in Boulder, who used the gas of ^{87}Rb, and of Wolfgang Ketterle at the Massachusetts Institute of Technology, which worked with ^{23}Na. As a recognition of the scientific impact of their work, Eric Cornell, Carl Wieman, and Wolfgang Ketterle were awarded the 2001 Nobel Prize in Physics "for the achievement of Bose-Einstein condensation in dilute gases of alkali atoms, and for early fundamental studies of the properties of the condensates." Simultaneously to the above 1995 developments, BEC in ^{7}Li was also created by the group of Randall Hulet at Rice University in Houston. These milestone results represent the pinnacle of seven decades of forefront scientific research in cold- and ultra-cold bosonic gases. Predicted theoretically in 1924-1925 in two classical papers by Satyendra Nath Bose and Albert Einstein, the direct realization of the first BEC became possible after many years of ongoing experimental research in laser and atomic physics, especially on cooling and trapping of atoms, which engrossed leading research centers world-wide. The 1997 Nobel Prize in Physics was awarded to Steven Chu, Claude Cohen-Tannoudji, and William D. Phillips "for development of methods to cool and trap atoms with laser light" that were instrumental in the first experimental creation of an atomic Bose-Einstein condensate. The workhorse in atom cooling experiments was the invention of the magneto-optical trap in 1987, which is still used in most studies of BEC. Indirect realizations of BEC were well known long before 1995, such as the low-temperature superconductivity, which is BEC of electron pairs with opposite spins, bound together by the Cooper mechanism. However, in that case, the metal as a whole only hosts the BEC, but itself remains in a usual crystalline state. It should also be noted that the Nobel Prize in Physics in 2003, awarded jointly to Alexei A. Abrikosov, Vitaly L. Ginzburg, and Anthony J. Leggett "for pioneering contributions to the theory of superconductors and superfluids," was also closely related to these developments: in fact, many of the predictions of the theory of superconductivity and superfluidity (including the formation of Abrikosov's vortex lattices) received their most convincing demonstrations in the context of atomic BECs.

Over the past two decades, the study of ultra-cold quantum gases has turned into an extremely active research area, which has been drawing hundreds of experimental and theoretical research groups, and a great number of individual researchers. Following a series of major experimental breakthroughs, the work has partly shifted the principal focus from bosonic species with contact interaction to molecular gases and atomic species with dipolar and three-body interactions (dipolar BECs have been created in gases of chromium and dysprosium atoms), spin-orbit-coupled systems, multi-component and spinor BECs, the role of thermal and quantum fluctuations, and has also extended to fermionic and hybrid systems, as well as to the BEC-BCS crossover in fermion gases and the condensation of quasi-particles in solid-state settings (exciton-polaritons, magnons, and cavity photons). Being sensitive to various external fields, BECs have became an ideal test bed for numerous challenging problems, which include atom lasers and atom interferometry, quantum computation and teleportation, slow-light propagation, emulation of black holes, emulation of phenomena occurring in condensed-matter, solid-state and even high-energy physics and astrophysics, nonlinear waveforms such as solitons and vortices, quantum turbulence and far-from-equilibrium phenomena, as well as quantum phase transitions, among many others. It is thus not surprising that the research on BECs has had a tremendous impact on many branches of physics in the course of these last 20 years.

To celebrate the twentieth anniversary of the realization of the atomic BEC, the current Special Issue of *Romanian Reports in Physics* gathers a series of articles, which address recent developments in the field of ultra-cold quantum gases, with emphasis on nonlinear-science aspects of these extremely diverse studies. The Special Issue opens with an introductory overview of the whole area. Thanks to a happy coincidence, or perhaps due to a felicitous though somewhat veiled correlation of meanings, 2015 was declared the International Year of Light and Light-based Technologies, which lends additional essential overtones to this Special Issue. We are grateful to all authors and referees for their efforts, which have made the compilation of this Special Issue possible. We are particularly thankful to Margareta Oancea and Alexandru Grecu, from the Editorial Office of *Romanian Reports in Physics*, for their technical support.

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