

Foreword

The year 2012 ends with great progresses at IMP. We celebrated the 55th anniversary of the foundation of the Institute of Modern Physics. In the 55-year developments, the research fields have been extended from the nuclear reactions at the beginning to multidisciplinary fields including nuclear physics, atomic physics, nuclear astrophysics, heavy ion irradiation applications in material sciences, biophysics, space science, and tumor therapy, etc. Now, IMP foresees her bright future with the ambitious proposals for HIAF and ADS projects.

With the invention of new conceptual designs of ADS transmutation system, ADS project has made substantial progresses in every aspect. The prototypes of subsystems of superconducting linac were finished and tested. The 2.45 GHz ECR ion source of intense proton beams is commissioning. The first superconducting HWR was manufactured and tested vertically. Its performance meets the requirements. The solid-state amplifier of 20 kW was tested with superconducting coupler in full power range. All specifications meet the design values. The first version of digital low level RF system has been tested with room temperature cavity, and the phase loop and amplitude loop are less than 0.1 degree and 0.1%, respectively. Superconducting solenoids were tested and the central magnetic field went up to 8.2 T for the current at 202 A. Furthermore, the prototype of cold BPM, tuning system, stripline BPM, power supply have all been tested and proved.

The new accelerator project HIAF is on its right track, and the general designs of accelerators have been optimized according to physics programs and experimental arrangements. Key technical R&D programs such as SRF cryo-modules and high intensity beam compression are in progress with international collaborations. The proposals for ADS and HIAF projects are ready to be submitted to the National Development and Reform Commission (NDRC) for review and evaluation.

In 2012, HIRFL provided 21 different ion beams, and the on-target beam time reached 4342 hours, among which about 46% was devoted to nuclear and atomic physics, 29% to material science, 11% to radiobiology and cancer therapy, and 13% to machine study. In the mean time, the 320 kV platform for multi-discipline research with highly charged ions delivered in total about 6010 hours of low-energy ion beams of 17 elements with 73 charge states for 37 experimental studies. HIRFL, for the first time, provided ^{112}Sn beams. The superconductive ECR source showed its excellent performance of providing $^{112}\text{Sn}^{26+}$ beams in 60 days without break.

A series of experiments have been performed using primary beams of ^9Be , ^{12}C , ^{20}Ne , ^{40}Ca , ^{58}Ni , ^{86}Kr , ^{209}Bi , and ^{112}Sn , etc. These experiments covered the CSRe-based precision mass measurements of short-lived nuclides, dielectronic recombination measurements at electron cooler of CSRm, nuclear structure and reaction studies using stable and unstable beams at RIBLL1, and some test measurements in CSR concerning laser cooling and stochastic cooling of ion beams. The experimental study of the elastic scattering of the proton drip-line nucleus ^8B on Pb target reveals an important contribution to the process of unraveling the enigma that is ^8B . The mechanism study of the projectile fragmentation reaction and reexamining the beta decay of neutron-deficient nuclei $^{53,54}\text{Ni}$, $^{52,53}\text{Co}$, ^{51}Fe and ^{50}Mn have collected data at RIBLL1. The study of high-spin level structures with both near-spherical and well-deformed shapes gave a better understanding of single-particle and collective excitations in nuclei. Rotational bands in the well-deformed nuclei ^{173}W and ^{174}Re were extended significantly, and this leads to a systematic study of signature splitting and inversion in the mass 170 region.

Of particular importance comes from the precision mass measurements of neutron-deficient $T_z=-3/2$ nuclides in the fp-shell. The breakdown of the quadratic form of isobaric multiplet mass equation (IMME) associated with isospin symmetry for the $A=53$, ($T=3/2$) quartet cannot be explained by either the existing or the new theoretical calculations of isospin mixing. Possible reasons, such as enhanced effects of

isospin mixing and/or charge-dependent nuclear forces in the fp-shell, are suggested.

In atomic physics, a test run of dielectronic recombination experiment with $3.7 \text{ MeV/u Sn}^{35+}$ was performed at CSRm and resonant structure was obtained. The longitudinal dynamics of RF-bunched and electron cooled ion beams have been studied at CSRe, and the longitudinal momentum spread and the bunch length of the $^{22}\text{Ne}^{10+}$ ion beam with an energy of 70 MeV/u were measured by the new resonant Schottky pick-up and the capacitive pick-up, respectively. Ionization processes involving two-electrons at intermediate impact energy have been studied using reaction microscope. Dissociative and non-dissociative ionization process of molecules and argon clusters were studied by electron impact. By observing nano etching effect of highly charged ions guided by nano-capillary, it was firstly showed that, nano-capillaries can focus an ion beam into nano-meter scale, and the etching effects can be accumulated so that the nano-structures created by this method were two orders larger than those created by a single highly charged ion.

In theoretical nuclear physics, a correlation among the symmetry energy, the slope parameter, and the curvature parameter at saturation density have been established. The in-medium effect on the dynamics of heavy ion collisions has been explored, and it is shown that the in-medium cross sections play a significant role in isospin emission. The rapidity distribution of the difference between neutron and proton transverse flows turns out to be a promising probe to the stiffness of symmetry energy. In the aspect of theoretical hadron physics, the decay widths and the line shapes of the open-charm radiative and pionic decays of $\Upsilon(4274)$ have been investigated, and further experiments for searching the open-charm radiative and pionic decays of $\Upsilon(4274)$ have been suggested. The role played by the nucleon resonances in the $\Lambda(1520)$ photo-production off a proton target is investigated. Inspired by the observed $\Upsilon(2175)$ state, its nonstrange partner $\Upsilon(1915)$ has been predicted. Experimental search for $\Upsilon(1915)$ is proposed.

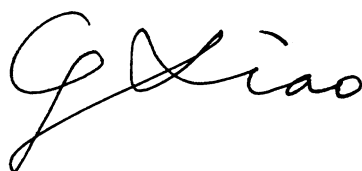
In materials sciences, a new beam-line has been established which is designed to fabricate nuclear-track membrane in air with several tens of MeV/u heavy ions. InSb nanowire back-gate field-effect transistors have been synthesized and characterized. It is concluded that bulk transport dominates InSb nanowires. The accumulation of radiation damage in materials (ferritic steels including ferritic ODS steels, silicon carbide) candidate to future fusion reactors was studied. The results of evolution of microstructures and its effects on mechanical properties of materials provide useful information for understanding of defect production and for further upgrade of the candidate materials. Single ion hit system was built at the high energy heavy ion microbeam facility, which is able to do material irradiation with single ion hit, pattern irradiation, raster scanning mode etc.

The research and development of experimental instrumentation made new progresses. New large area particle track detectors based MWPC and MWDC were developed. The TPC prototype with GEM readout was developed with a resolution of 700 mm at longitudinal and $250 \sim 450 \text{ mm}$ at transverse directions. A prototype of front-end electronics for a plastic scintillator array detector was developed for space dark matter exploration. A FEE and data acquisition system (1024 channels) for γ array detector of CSR External Target Facility (ETF) was developed and tested. High sensitive low current measurement circuit, beam diagnostic system of heavy ion cancer therapy facility, beam monitoring system of ADS, and many prototype modules were developed. The improvement of growth condition for scintillation crystal ensures the CsI(Tl) crystal quality. The critical problem has been solved for the array crystal detector of small pixel.

Clinical trial of deep-seated tumor therapy, in collaboration with local hospitals, was continued, and 35 patents with varieties of tumors were treated by carbon ions. A treatment nozzle compatible for passive and active beam delivery in heavy ion therapy was designed and two types of mini ridge filter and tilting mini ridge filter could be adopted so as to reduce the distal dose falloff for a resulting spread-out Bragg peak. The studies on the functions of radiation-related microRNAs revealed the regulatory function of miR-3928 on the expression of Dicer, a key factor of microRNA biogenesis, and that of miR-185 on the expression of ATR, a sensor and transducer of cellular signaling pathway responding to ionizing radiation. Ionizing radiation-induced energy metabolic alterations related to mitochondria damage and free radical

mechanisms of central nervous system injury and repair have been observed. Meanwhile, cell autophagy was found to influence the cellular radiosensitivity at high-LET radiations significantly. In microorganism studies, the hyper-productive strain of *Aspergillus Nigers* train H4002 was obtained using heavy ion induced mutation breeding technique. IMP/CAS signed a contract of achievement transformation with a commercial Group about the hyper-productive technique of citric acid and the total amount is over 2 million RMB. Response surface methodology optimization and use of effective C^{6+} -ion irradiation methods can considerably enhance ability to degradation of microbial. Two commercial contracts to build dedicated machines for cancer therapy have been signed, and the construction is under its way.

Finally, I would like to take this chance to thank all the staffs at IMP and NLHIAL as well as colleagues from collaborating institutes and universities for their dedication and creative contributions for the achievements obtained in the year of 2012.

A handwritten signature in black ink, appearing to read 'G. Xiao', with a stylized, cursive script.

Director of IMP

Vice Director of NLHIAL