Foreword

The photo on the cover page of this report shows the nucleus of a human cell that was irradiated with helium ions and then stained to reveal a repair protein assembling at the location of the ion track damages. The pattern inscribed by the individual ions traces the GSI acronym. It illustrates the precision and control achieved in ion irradiation – and it is an example of the fruitful interplay between research disciplines. Control of the ion irradiation down to individual ions and with high spatial precision was achieved by perfecting the ion-beam microprobe in the materials research group. Application in radio-biology extends these studies to the microscopic level.

This example is one of a number of developments in the different research areas pursued at GSI, some others are mentioned below. In addition, substantial effort was directed towards a range of developments for the FAIR project (Facility for Antiproton and Ion Research). Directly or indirectly, these dual tasks have required a special commitment from the staff, as well as from our guests and the many external collaborators involved in the present and/or future activities of the institute. This report reflects on their work. And this Foreword provides me with an opportunity to express my personal thanks and those of GSI to everybody involved.

In nuclear structure research, studies far from stability have continued with relativistic radioactive beams. New results were obtained, for example, in relativistic Coulomb excitation of the giant dipole resonance in heavy nuclei with up to eight neutrons (^{132}Sn) beyond the last stable isotope. They establish the low-energy excitation mode predicted for neutron-rich nuclei with excess neutrons at the nuclear surface oscillating against the core. The measurement also illustrates the sensitivity that can be achieved for selected reactions when carried out at relativistic energies. Orders of magnitude in event rate are gained from higher target thickness, favourable kinematics and resulting solid angle, as well as from substantially higher reaction cross section. Good-quality measurements are thus possible, as with the present example, for secondary beams with a few tens of ions per second.

Expected yields of radioactive beams follow from a comprehensive study carried out at GSI over several years, and recently completed, of cross sections and kinetic energies in the spallation of 1 AGeV ^{238}U with protons, measured in inverse kinematics with a uranium beam. Analysis of the masses of neutron-rich nuclei, previously measured in the ESR storage and cooler ring with isochronous mass spectroscopy, is nearing completion and will provide information on r-process components that would occur in a stellar environment of relativeley low neutron flux.

Proton elastic scattering of neutron-rich ^{6}He and ^{8}He in new detector geometry and now extending beyond the first diffraction minimum, provides new information on the respective nuclear matter distributions and facilitates a test of theoretical predictions within the Fermionic Molecular Dynamics model recently developed by the GSI theory group.

In the study of nucleus-nucleus collisions, new results are obtained at SIS energies on azimuthal angular emission patterns of kaons, providing important input to the understanding of the repulsive K^+N versus the attractive K^-N potential in the nuclear medium. At SPS energies, the analysis of pion to kaon yields reveals intriguing dependences on strangeness production in dense nuclear matter. Tantalizing evidence is also possibly seen in experiments at the FOPI detector for a deeply bound kaonic cluster state. A broad program to search for bound meson-nucleus states, both kaonic and with eta-mesons, is in preparation.

The study of di-lepton production in nucleus-nucleus collisions at SIS energies is entering an exciting phase with production runs and first results from proton-proton and heavy ion collisions from the HADES detector.

In addition to the experimental achievements in nuclear matter research, in hadron properties in nuclear matter, and in the dynamics of nucleus-nucleus collisions major progress has been made in the complementary theory work described in this report.

In atomic physics, advances in precision spectroscopy of highly charged ions are opening new opportunities. High-resolution dielectric recombination in few-electron heavy atoms promises excellent sensitivity to changes in nuclear charge radius between isotopes. A major step forward has been achieved experimentally by decoupling the dual functions of the ESR electron cooler namely, at the same time, beam cooling and electron target. By using stochastic cooling instead, one achieves a larger dynamic range and increased precision from dielectric-recombination transitions.

Proof of principle was made for laser cooling of beams of highly stripped atoms. Using the Lamb-shift transition in lithium-like carbon, a carbon beam in the 3^+ charge state was cooled in the ESR to a relative momentum spread of a few times 10^{-7}. Applying this to lithium-like heavy ions, laser cooling of highly relativistic beams in the future at FAIR, e. g. at energies of about 30 GeV per nucleon, might become reality.

Much of the effort in the area of plasma physics was directed towards the construction of the PHELIX petawatt laser. A major technological challenge is the damage threshold of various components, in particular of the compression gratings. Using a pulse from the PHELIX fs-frontend and compressing it in the existing terawatt compressor and down to a 300 micrometer spot size, a unique test bed for 500 femto-second laser-induced damage threshold measurements under vacuum was set up. This allowed extensive tests of gratings, in particular the ones of the emerging technology of multi-layer dielectric (MDL) gratings, from producers worldwide.

In the area of radiation biology, the research efforts were split again between an extensive program in microscopic studies of various aspects of cell responses to radiation on the one hand, and the efforts towards ion therapy on the other. The first involves the new development of live cell imaging at the beam target station of the UNILAC accelerator. The second involves the continued irradiation of patients at the GSI pilot facility, the construction of the dedicated clinical facility at Heidelberg, as well as technical developments such as the irradiation of moving organs.

Material science has continued its studies with the ion-microprobe and sample irradiation with high-energy ion beams in a pressure cell. Interesting ion-induced high-pressure phase transitions are observed. A major activity is directed towards investigations of the properties of nano-structures such as nano-wires of poly- and single-crystalline character, down to 20 nanometer diameter, and grown by electrochemical deposition in the nano-pores of etched ion-track polymer membranes.

For advancing the FAIR project, an International Steering Committee (ISC) was founded with representatives from 10 member countries that have signed on MoU for the preparatory and pre-contact phase, and also several observers. The Steering Committee has formed two major working groups, again with representatives from the partner states, one on scientific and technical issues (STI) and a second on administrative and financial issues (AFI), each with sub-working groups, in particular technical and scientific program advisory committees to evaluate and advise on accelerator issues and the scientific program. For the latter, letters-of-intent were solicited for June 2004 and, based on their evaluation, technical proposals (for the experiments) and technical reports (on accelerator sub-projects) were called for and collected at the beginning of 2005. These reports are the basis for establishing baseline cost and final project definition by the Steering Committee during 2005.

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