Foreword

The present Scientific Report covers the activities connected with research at GSI for calendar year 2003. The primary focus is on new experiments and theoretical studies performed during the past year; but also analyses of previous experiments and important developments and milestones of longer-term projects are reported. As in previous reports, the focus is on brief summaries; for more detailed information references to published work are given. The Report is not intended as an institutional overview, but rather to provide the interested research communities with a reasonably comprehensive picture of the spectrum of science activities carried out at GSI.

Two events – of rather different nature - stand out in 2003. The first is the announcement of the German government in February 2003 to support (with the constraint of 25 % contribution from international sources) the construction of the future international facility for beams of ions and antiprotons at GSI. The project was planned in close collaboration with the universities and the international science community and has been named 'FAIR: Facility for Antiproton and Ion Research'. The enthusiasm triggered by the forward-looking decision of the German ministry has been followed by intense activities and successful developments towards the future facility on several fronts. Clearly this is now a key activity at GSI.

The second event that stands out is the naming of element 110 in November 2003 as 'Darmstadtium'. The name recognizes the innovative and successful work of the heavy-element group over nearly two decades of research. It also reflects on the facilities and technical infra-structures of the institute that are prerequisites for these difficult measurements.

As in the past, the Scientific Report 2003 contains a number of exciting current research highlights. They extend over all science areas pursued at GSI: hadron and nuclear physics, atomic physics, plasma physics, biological and biomedical research, materials science, instrument development, and the intersections between these.

In the study of nuclei, the quest into the unknown regions of neutron-rich nuclei continues: examples are the dipole strength measurements at and near ^{132}Sn, or the shell-structure studies of the near-drip line nucleus ^{23}O. A major addition to the program has been the construction and implementation of the RISING detector. The international collaboration has successfully performed first experiments in high-resolution gamma-ray spectroscopy involving radioactive beams.

In the investigations of nuclear matter, new and interesting results have emerged from low to high energy, and low to high density. Precision measurements on collective flow show good agreement between FOPI and INDRA-ALADIN data. One of the issues addressed, in-medium properties and cross sections, was also pursued for kaons in measurements of azimuthal emission pattern with the KaoS spectrometer. At SPS energies, the NA49 experiment observes unexpected strangeness enhancement in the energy regime between AGS and SPS. A high statistics production run on di-electrons from a heavy-ion collision was completed with the HADES detector and level-2 trigger, leading to a first di-electron mass spectrum.

New results have been obtained in precision QED studies of highly stripped atoms, both at high velocities in the ESR storage ring and at rest in ion traps. They include the g-factor measurement of hydrogen-like oxygen and ground state Lamb shift in hydrogen-like uranium. High-resolution micro-calorimeters and a crystal spectrometer have been successfully tested and are expected to push the limits of precision even further. Isotope shifts of radioactive $^{8,9}Li$ have been measured for the first time. Uranium and lead ions, highly stripped at relativistic energies, have been successfully decelerated and cooled at the ESR, and extracted at energies well below 20 MeV/u for first experiments. Molecular studies have been performed through fragmentation patterns in (atto-second) collision processes with highly charged ions. SHIPTRAP, the ion trap after the SHIP heavy-element separator has been commissioned. A transient collisionally pumped X-ray laser driven by infrared pulses from the PHELIX preamplifier has been put into operation. Strong lasing was observed at 22 nm in nickel-like zirkonium.

The last item indicates the major progress made with the PHELIX petawatt project. In February of 2003 the NOVA laser components from Livermore had arrived. Subsequently a range of important technical installations and developments were performed. It is expected that by the end of 2004 the kilo-Joule operation of PHELIX will be available for the experimental plasma physics program. In the meantime, plasma physics studies of near-critical high-energy-density states of lead generated by intense uranium beams, and enhanced energy losses in shock-wave driven, non-ideal plasmas were carried out.

In biology and in biomedical research emphasis is on microscopic studies in radiation biology on the one hand, and on the technical realization of the Heidelberg clinical facility for ion therapy on the other. A broad range of studies has been performed, from molecular and DNA responses to chromosome aberrations and cellular responses, including the issues of bystander effects. The unique properties of the ion micro probe at the UNILAC has allowed to target pre-selected living cells with a predetermined number of energetic ions.

In materials science, ion track technology allowed the production of unique nanostructures. With membranes containing only one nanochannel it was possible, for example, to detect single DNA molecules, suggesting a promising approach to biomolecular sensing. Further, thermally induced decay of Cu nanowires into pearl strings (Rayleigh instability) was demonstrated, and Co/Cu multilayer nanowires, suitable as self-contacting magnetic field sensors, were realized. Improvements at the ion microprobe provided the fast and efficient production of ordered microscopic track patterns, with every track positioned at will.

The broad range of experimental studies at the GSI facilities is complemented by intense theoretical studies and modelling in essentially all areas of research. Also in theory the broad involvement from university groups is key to the success of these programs.

Finally, an essential feature to keep the research program at the forefronts of the various sciences, is the continuous and innovative development of first-rate und unique instrumentation and methods, at the accelerators, the experimental stations, and in the data handling and analysis softwares. An important milestone was reached with the near completion of the ALICE readout chambers built by the GSI detector laboratory.

Of course, the major activity in development and technical R&D is turning towards FAIR, the future facility. The present Report provides room only for brief summaries on the range of activities underway. It is a broadly based community effort and more detailed information may be obtained from the FAIR Project Office.