CLOSING REMARKS FOR ECRIS'10

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Abstract

The scientific topics of the ECRIS10 Workshop are introduced. New results presented by a selection of authors during the sessions are summarized.

INTRODUCTION

ECRIS'10, the 19th ECRIS workshop, was held in Grenoble, France, from the 23rd through the 26th of August 2010 with 100 participants. It is well known that Grenoble is the Mecca for ECRIS, as it has already played host two previous times (1982 and 1988). The programs this year covered the foremost topics related to the design and operation of ECR ion sources, including status reports, new developments, radioactive ion beam production, plasma physics and plasma diagnostics, beam extraction and transport, and applications. In this workshop, we found several clear trends in the development of ECR ion sources: 1) intense beam production for secondary beams (including radioactive beams); 2) pulsed mode operation for beta-beam projects; 3) new applications; and 4) plasma diagnostics, beam extraction, and transportation. Several highlights in these trends are presented in this short report.

TOPICS

Several facilities using ECR ion sources for radioactive beams are currently in operation. Requirements in this field lead us to employ higher magnetic fields and microwave frequencies to increase the beam current of ions in a medium charge state such as U^{33-35+}. H. W. Zhao demonstrated the effect of the microwave frequency (18 and 24 GHz) on the intensity of beams of highly charged heavy ions with SECRAL. D. Leitner presented the excellent results of VENUS after the re-commissioning. The NSCL team reported the excellent results of their 18 GHz ECR ion source (SuSI) and the requirements of the ECR ion source for the FRIB project. The experimental results of these ion sources clearly show that the beam intensity is not saturated at the highest RF power (~0.7 kW/L). This indicates that there is some scope to increase the beam intensity. The NSCL team made systematic bremsstrahlung and ion beam current measurements to examine the production mechanisms of highly charged heavy ions in the ion source. For the first time, they experimentally demonstrated the effect of the field gradient at the resonance zone on the beam intensity and bremsstrahlung X-rays.

For fourth-generation designs, the technical challenges in attaining the optimum magnetic field strength at 56 GHz were independently proposed by D. Leitner and Z. Q. Xie on the basis of their own concepts. Two Korean teams proposed and designed a new 28 GHz SC-ECRIS for the Korean Rare Isotope Beam Accelerator (KoRIA) project and a compact heavy ion linear accelerator facility.

ECR ion sources are used for the production of other secondary beams. A 2.45 GHz ECR ion source is used to produce thermal neutrons for a neutron imaging facility in Peking University. The CEA and CNRS have undertaken a research and development program on very high beam power accelerators, such as the Accelerator Driven Transmutation of Waste, a new generation of exotic ion facilities, and neutrino and muon production. The CEA is also involved in projects such as the European Spallation Source and IFMIF.

Utilizing metallic particles of rubidium, the charge breeder CARIBU (ANL) project has reached an extraction efficiency of 11.9% from an ECR ion source. Multiple-frequency operations also exhibit the potential to increase the beam intensity for the charge breeding system. The TRIUMF team achieved high-efficiency charge breeding for radioactive ions (1.4% efficiency for $^{124}Cs^{20+}$, 1.7% efficiency for $^{76}Rb^{15+}$, and 6.2% for $^{74}Kr^{15+}$). T. Lamy reported that grounded tube removal is very promising for charge breeding. In the SPIRAL project, a new multi-charged ion source, based on an asymmetric magnetic structure, was both proposed, and designed by L. Maunoury.

An intense short-pulse beam plays a crucial role in the Beta-Beam project. For meeting the requirements, the IAP-RAS and LPSC teams both experimentally and theoretically investigated the mechanisms behind the preglow of a multi-charged heavy ion beam from an ECR ion source. They reported that the effective generation in the short preglow peak is possible under powerful heating at a high frequency. In the study of the time evolution of plasma potential, O. Tarvainen concluded that the plasma potential is higher during the plasma build-up and decay compared with that under steady-state conditions; however, the processes explaining the potential fluctuations are different for preglow and afterglow. For realization of the intense short-pulse beam for the Beta-Beam project, a 60 GHz ECR ion source (megawatt-class) was proposed and tested in Grenoble.

ECR ion sources have several advantages as ion sources for trace element analysis (high ionization efficiency, production of stable plasma under the very low gas pressure ($<10^{-6}$ Torr), long plasma confinement for multi-charged ion production, etc.). Recently, the ANSTO ECR ion source was successfully used for measuring the isotopic ratios of elements such as carbon, nitrogen, and oxygen. An ECR ion source was successfully used as an ion source for AMS at Argonne to detect the noble gas elements (^{39}Ar, ^{81}Kr). R. Pardo proposed a new plan for laser ablation of actinides into an ECR ion source for AMS. P. Sortais fabricated a very small ECR ion source

(COMIC) that produces multiple or broad beams for new industrial applications (ion implanter, surface treatment, etc.). The number of facilities for heavy ion therapy is now increasing rapidly. It is clear that the ECR ion source is one of the important devices for this purpose. The status and development of the ECR ion sources at HIMAC, Gunma University, and HIT were reported. A. Villari presented the status of their commercial ECR ion source, which included the new liquid-He-free SC-ECRIS (PK-ISIS).

The basic studies for ECR plasma, beam extraction, and transportation are perennially important to improving ECR ion source performance. C. Lyneis reported on microwave coupling of the plasma chamber, which is interesting not only for the static properties, but also for dynamical processes. A new simulation code (PIC + Monte Carlo simulation) was developed by D. Mascali in order to understand the plasma dynamics, plasma–microwave interaction, and so on. Visible light emitted from a plasma was systematically measured by S. Biri. The X-rays from a plasma were carefully measured by H. Koivisto and T. Ropponen. In order to investigate the heating mechanism of electrons in the ECR plasma, they studied the maximum energy of bremsstrahlung and the relation between the magnetic field gradient and the average kinetic energy of the X-rays. C. Peaucelle presented the status of the heavy ion low energy beam transport line of SPIRAL 2. The Spiral 2 specifications could be met by an increase in RF power (2 kW) and high voltage extraction (60 kV). The intense U ion beam from VENUS was simulated with the WARP code, and the calculated emittance was in reasonable agreement with the measurements. The beam extracted from the ECR ion source was measured by the KVI4D pepper pot emittance meter and it was observed that the dipole magnet induced a second order aberration of the beam. At end of the workshop, it was announced that O. Tarvainen was awarded the Richard Geller Prize for his contributions to "physics experiments on ECR plasmas that resulted in a deeper understanding of the plasma physics of ECR ion sources."

CONCLUSION

The performance of ECR ion sources is rapidly improving. We do not yet know of any performance ceiling for ECR ion sources. Although the ECR plasma is especially complicated, we are able to gradually deepen our understanding. The applications of ECR ion sources continue to expand. It is obvious that the future of the ECR ion source is still open. There is a tremendous amount of work to be done.

ECRIS’10 was an enormous success due to the efforts of both the participants and the contributors. We thank the chairman, T. Thuillier, the local organizing committee, and the international advisory committee. The next workshop is scheduled for 2012 in Sydney, Australia, which is a new world for the ECR ion source community. See you there!