

Electron cyclotron resonance ion source

- An electron cyclotron resonance ion source (ECRIS) utilizes magnetic fields to produce high-energy ions for use in particle accelerators and nuclear physics research
- The process involves electron cyclotron resonance, where electrons absorb microwave radiation, creating high-energy collisions that ionize gas within the magnetic chamber
- This method is efficient for generating ion beams of various elements, offering precision in controlling the ion's charge and energy
- ECRIS is crucial for advancements in medical imaging, cancer treatment, and materials science

Practical example: Particle accelerators

- Electron cyclotron resonance ion sources (ECRIS) are a crucial technology in particle accelerators, such as those used in physics research and medical applications
- They generate high-charged ions by using microwaves to heat electrons in a magnetic field, causing ionization of gases like argon or helium
- This process creates a plasma where ions can be extracted and accelerated to high speeds
- These accelerated ions are then used for experiments in nuclear physics or for cancer treatment in radiation therapy

Electron Cyclotron Resonance Ion Sources

Matthaeus Leitner

A decorative graphic consisting of a red circular shape with a white center, partially obscured by a white horizontal bar that extends from the left edge of the slide.

Electron Cyclotron Resonance Ion Sources:

Electron Cyclotron Resonance Ion Sources and ECR Plasmas R Geller, 2018-12-13 Acknowledged as the founding father of and world renowned expert on electron cyclotron resonance sources Richard Geller has produced a unique book devoted to the physics and technicalities of electron cyclotron resonance sources **Electron Cyclotron Resonance Ion Sources and ECR Plasmas** provides a primer on electron cyclotron phenomena in ion sour **Perturbative Measurements of Electron Cyclotron Resonance Ion Source Plasmas** Derek Elwin Neben, 2019 Heavy ion accelerators are a valuable resource for the nuclear science community to study atomic physics One such heavy ion accelerator is the Coupled Cyclotron Facility CCF at the National Superconducting Cyclotron Laboratory NSCL which relies on Electron Cyclotron Resonance ECR ion sources to provide the primary beam to the target ECR ion sources are essential for the efficient operation of research accelerators such as the CCF providing high currents of highly charged ions Highly charged ion beams increase the efficiency of the accelerators but require longer confinement times and higher temperature plasmas in the ion sources than is necessary to produce singly charged beams The need to use high temperature and low density plasmas creates challenges including those relating to plasma stability ECR ion sources provide a good platform to accept metallic vapor ovens and sputtering probes allowing the CCF to accelerate up to 30 types of beams ranging from oxygen to uranium Furthermore ECR ion sources use no filaments or cathodes providing a high degree of reliability for the accelerator facility As the intensity frontier demands ever rarer isotopes from accelerator facilities the heavy ion beam intensity must increase 70 which creates new demands from the ion sources The work presented within this dissertation set out to better understand the mechanism that confines highly charged ions in the ECR plasma Specifically it was explored if hot electrons energy larger than 50 keV contribute to ion confinement by generating an electrostatic well in the plasma potential 68 Perturbative measurements of ECR ion sources are presented with the aim to explore ion confinement times pulsed sputtering Chapter 4 and amplitude modulation Chapter 5 Chapter 3 explores the geometry of the sputtering probe with respect to the magnetic field which was crucial to produce reliable pulsed sputtering results on the ECR ion source Axial pulsed sputtering which could be conveniently implemented on fully superconducting sources incorporated a bias disc effect that highly perturbed the plasma Radial sputtering was emulated by placing a semi shielded probe along the plasma chamber wall in between the electron loss surfaces Ion confinement time was characterized through the decay time of the beam current which is proportional to ion confinement time Ion beam decay times were measured for different charge states of gold in an oxygen plasma in Chapter 4 Decay time always increased with increasing charge state Decay time also increased with hot electron temperature for lower frequency operation 13 GHz but reached an optimized value for higher frequency operation 18 GHz due to plasma instabilities Electrostatic confinement of ions appeared to be the most plausible mechanism to explain the observed decay time behaviors A novel perturbative measurement technique was developed for ECR ion sources using Amplitude Modulation

AM of microwave power The AM measurement was originally motivated by whether or not 50 kHz modulation in microwave power from the microwave source would be observable in the beam current A systematic study was organized on the University of Jyväskylä Physics Department JYFL normal conducting ECR ion source in Jyväskylä Finland Chapter 5 presents the beam current response to AM on the 14 GHz ECR ion source for different weights of noble gases magnetic fields and vacuum pressures The beam current amplitude generally decayed exponentially for frequencies higher than around 400 Hz with the modulation highly suppressed at 10 kHz

Electron Cyclotron Resonance Ion Sources Matthaeus Leitner, 2005-03-23 Berkeley California 26 30 September 2004

Characterization of Electron Cyclotron Resonance Ion Source Instabilities by Charged Particle Diagnostics Bryan Isherwood, 2020 Ion sources are invaluable tools for producing charge particles for scientific industrial and medical applications In particular Electron Cyclotron Resonance ECR ion sources ECRIS are high power sources capable of producing high intensity high charge state beams of heavy ions The system uses microwaves to resonantly heat of electrons within an inhomogeneous magnetic trap However the internal dynamics of the resulting plasma are complex and poorly understood In particular the excitation of kinetic instabilities within the plasma can make operating these ion sources difficult and unpredictable This thesis focuses on studying these instabilities to determine ways to optimize ECRIS performance by minimizing their impact on the extracted beam current This study focuses on two measurements that look at the steady state and time resolved measurements of charged particle currents escaping the ion source during stable and unstable operations The first measurement is a novel diagnostic of electrons escaping confinement from the plasma chamber The second was a measurement of high charge state ions Ar⁸⁺ extracted from the plasma chamber over a broad set of parameter spaces These measurements provide insight into the ideal operating conditions for an ECR ion source and the dynamics of the ion and electron populations within its plasma

ECR (electron Cyclotron Resonance) Ion Sources and Applications with Heavy-ion Linacs, 1990 The electron cyclotron resonance ECR ion source has been developed in the last few years into a reliable source of high charge state heavy ions The availability of heavy ions with relatively large charge to mass ratios 0.1-0.5 has made it possible to contemplate essentially new classes of heavy ion linear accelerators In this talk I shall review the state of the art in ECR source performance and describe some of the implications this performance level has for heavy ion linear accelerator design The present linear accelerator projects using ECR ion sources will be noted and the performance requirements of the ECR source for these projects will be reviewed

30 refs 3 figs

ECR (Electron Cyclotron Resonance) Ion Sources for Cyclotrons, 1986 In the last decade ECR Electron Cyclotron Resonance ion sources have evolved from a single large power consuming complex prototype into a variety of compact simple reliable efficient high performance sources of high charge state ions for accelerators and atomic physics The coupling of ECR sources to cyclotrons has resulted in significant performance gains in energy intensity reliability and variety of ion species Seven ECR sources are in regular operation with cyclotrons and numerous other projects are under

development or in the planning stage. At least four laboratories have ECR sources dedicated for atomic physics research and other atomic physics programs share ECR sources with cyclotrons. An ECR source is now installed on the injector for the CERN SPS synchrotron to accelerate O^{8+} to relativistic energies. A project is underway at Argonne to couple an ECR source to a superconducting heavy ion linac. Although tremendous progress has been made, the field of ECR sources is still a relatively young technology and there is still the potential for further advances both in source development and understanding of the plasma physics. The development of ECR sources is reviewed. The important physics mechanisms which come into play in the operation of ECR sources are discussed along with various models for charge state distributions. CSD. The design and performance of several ECR sources are compared. The 88 Inch Cyclotron and the LBL ECR is used as an example of cyclotron ECR operation. The future of ECR sources is considered.

ECR (electron Cyclotron Resonance) Ion Source Beams for Accelerator Applications, 1987. Reliable easily operated ion sources are always in demand for accelerator applications. This paper reports on a systematic study of ion beam characteristics and optimization of beam quality for production of light ion beams in an ECR ion source. Of particular interest is the optimization of beam brightness defined as ion current divided by the square of the emittance which is typically used as a figure of merit for accelerator quality beams. Other areas to be discussed include the measurement of beam emittance values, the effects of various source parameters on emittances and scaling effects from operating the same ECR source at different frequencies. 4 refs, 4 figs.

Electron Cyclotron Resonance (ECR) Ion Sources, 1984. Starting with the pioneering work of R. Geller and his group in Grenoble, France, at least 14 ECR sources have been built and tested during the last five years. Most of those sources have been extremely successful, providing intense, stable and reliable beams of highly charged ions for cyclotron injection or atomic physics research. However, some of the operational features of those sources disagreed with commonly accepted theories on ECR source operation. To explain the observed behavior of actual sources, it was found necessary to refine some of the crude ideas we had about ECR sources. Some of those new propositions are explained and used to make some extrapolations on the possible future developments in ECR sources.

Ion Beam Extraction from Electron Cyclotron Resonance Ion Sources and the Subsequent Low Energy Beam Transport Daniel Winklehner, 2013. **An Ultra Compact 10 GHz Electron-cyclotron-resonance Ion Source (ECRIS) for the Production of Multiply Charged Ions**

, 1996. There is a growing interest in the use of beams of multiply charged ions produced in special environments like high voltage platforms, dynamitrons, Van de Graaff accelerators or on-line production systems for radioactive beam facilities. A compact 10 GHz ECR ion source, 200 mm long, 170 mm diameter, has been developed and tested. The complete magnetic structure made from permanent magnet material is comprised of four ring magnets producing an asymmetric axial magnetic field with a mirror ratio of 2.5 and a 24-piece hexapole magnet with a maximum radial field of 0.94 T inside the plasma chamber of 25 mm inner diameter. The coupling of the microwave to the plasma using a resonant transition line from

rectangular to circular waveguide shows efficient ECR plasma heating at microwave power levels around 10 watts Charge state distributions for various elements with intensities up to 320 e mu A and their dependence on operation parameters will be presented as well as VUV spectra in the wavelength region down to 15 nm

A New Miniature Electron Cyclotron Resonance Ion Source Caesar Romero Jackson,1992 **Physics of Multiply Charged Ions and Physics of Electron Cyclotron Resonance Ion Sources** S. L. Bilman,Commission of the European Communities. JET Joint Undertaking,1988

ECR [ELECTRON CYCLOTRON RESONANCE] ION SOURCES AND APPLICATIONS WITH HEAVY-ION LINACS. R.C. PARDO,1990 Electron Cyclotron Resonance Microwave Ion Sources for Thin Film Processing ,1990 Plasmas created by microwave absorption at the electron cyclotron resonance ECR are increasingly used for a variety of plasma processes including both etching and deposition ECR sources efficiently couple energy to electrons and use magnetic confinement to maximize the probability of an electron creating an ion or free radical in pressure regimes where the mean free path for ionization is comparable to the ECR source dimensions The general operating principles of ECR sources are discussed with special emphasis on their use for thin film etching Data on source performance during Cl base etching of Si using an ECR system are presented 32 refs 5 figs Status of ECR (Electron Cyclotron Resonance) Source Technology ,1987 ECR Electron Cyclotron Resonance ion sources are now in widespread use for the production of high quality multiply charged ion beams for accelerators and atomic physics experiments and industrial applications are being explored Several general characteristics of ECR sources explain their widespread acceptance For use with cyclotrons which require CW multiply charged ion beams the ECR source has many advantages over heavy ion PIG sources Most important is the ability to produce higher charge states at useful intensities for nuclear physics experiments Since the maximum energy set by the bending limit of a cyclotron scales with the square of the charge state the installation of ECR sources on cyclotrons has provided an economical path to raise the energy Another characteristic of ECR sources is that the discharge is produced without cathodes so that only the source material injected into an ECR source is consumed As a result ECR sources can be operated continuously for periods of weeks without interruption Techniques have been developed in the last few years which allow these sources to produce beams from solid materials The beam emittance from ECR sources is in the range of 50 to 200 pi mm mrad at 10 kV The principles of ECR ion sources are discussed and present and future ECR sources are reviewed

ECR (Electron Cyclotron Resonance) Source for the HHIRF (Holifield Heavy Ion Research Facility) Tandem Accelerator ,1990 Electron Cyclotron Resonance ECR ion source technology has developed rapidly since the original pioneering work of R Geller and his group at Grenoble in the early 1970s These ion sources are capable of producing intense beams of highly charged positive ions and are used extensively for cyclotron injection linac injection and atomic physics research In this paper the advantages of using an ECR heavy ion source in the terminal of the Holifield Heavy Ion Research Facility HHIRF 25 MV tandem accelerator is discussed A possible ECR system for installation in the HHIRF tandem terminal

is described **Properties of Electron Cyclotron Resonance Plasma Sources** Aseem Kumar Srivastava, 1995

Electron Impact Ion Sources for Charged Heavy Ions Grigory D. Shirkov, Günter Zschornack, 2013-06-29 Presently many different types of ion sources exist worldwide for producing highly charged ions The object of the present book is the treatment of electron impact ion sources like ECR Electron Cyclotron Resonance ion sources EBIS Electron Beam Ion Sources EBIT Electron Beam Ion Trap and ERIS Electron Ring Ion Sources which altogether are able to produce ions of high charge states This criterion delimits the book according to classic ion sources which as a rule can deliver high currents of low charged ions In the last decades there has been an intense development and building up of sources of highly charged ions The first impetus to the building of such sources came from heavy ion accelerator centers since the effectiveness of a heavy ion accelerator is predominantly determined by the available ion sources Thereby the critical criteria for the operation of an ion source are the charge state distribution of the ions produced and the intensity of the extracted ion currents Besides the employment of sources of highly charged ions in accelerator centers such sources increasingly are inserted separately from accelerators for basic investigations in atomic physics surface physics and related areas *19th International Workshop on Electron Cyclotron Resonance Ion Sources (ECRIS 2010)*, 2014 **A New 14 GHz**

Electron-Cyclotron-Resonance Ion Source (ECRIS) for the Heavy Ion Accelerator Facility ATLAS., 2001 A 14 GHz Electron Cyclotron Resonance Ion Source ECRIS has been designed and built at Argonne National Laboratory The source is a modification of the AECR at Berkeley and incorporates the latest results from ECR developments to produce intense beams of highly charged ions including an improved magnetic confinement of the plasma electrons with an axial mirror ratio of 3.5 The aluminum plasma chamber and extraction electrode as well as a biased disk on axis at the microwave injection side donates additional electrons to the plasma making use of the large secondary electron yield from aluminum oxide The source is capable of ECR plasma heating using two different frequencies simultaneously to increase the electron energy gain for the production of high charge states The main design goal is to produce several μA of at least U^{38+} in order to accelerate the beam to coulomb barrier energies without further stripping First charge state distributions for gaseous elements have been measured and $210\text{e} \mu\text{A}^{16+}$ O^{7+} has been achieved A normalized 90% emittance from 0.1 to 0.2 $\pi\text{ mm mrad}$ for krypton and oxygen beam has been found

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