HEAVY ION FACILITY IN ATOMKI

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ABSTRACT

A plan of a heavy ion facility based on ECR ion source, compact cyclotron and electrostatic acceleretor is presented. The project is partly funded and the development of the ECR ion source is in progress.

1. INTRODUCTION

Experimental atomic and nuclear physics research in ATOMKI are based on the particle accelerators of the institute. During the 38-years history of the institute the beam power of the accelerators was increased continuously: 0.8 MV Cockroft-Walton generator (1962), 1 MV Van de Graaff generator (1969), 5 MV Van de Graaff generator (1971), K=20 variable energy cyclotron (1985).

The latest trend of accelerator based atomic and nuclear physics research is undoubtedly heavy ion collision physics. Our participation in front line research programmes requires the extension of our atomic and nuclear physics studies into this direction.

To facilitate heavy ion collision research in atomic and nuclear physics a decision has been made to establish a heavy ion physics facility, based on an electron cyclotron resonance (ECR) ion source .

Beside an ECR ion source, which can be used alone (low energies up to 10 keV/amu), or can be coupled to an electrostatic accelerator (medium energies) or to the cyclotron (higher energies), one gets a special heavy ion facility not available in Central- and East-European countries, and it makes possible a variety of research programs. The scheme of the planned facility can be seen in Fig.1.

2. THE ECR ION SOURCE

The basic element of the proposed facility is an ECR-type ion source. Although ECR ion sources are commercially available, because of the limited financial support we plan to manufacture it in ATOMKI, buying only the main units and using the experiences of other laboratories.

After making a detailed survey on working and planned sources,[1] we restricted our interest to room-temperature ECR-s. Examining the cost/power ratio, knowing the $A/Q \leq 4$ condition for the cyclotron and studying the world-wide trends in ECR developments, a 14 GHz ECR source seems to be the optimum choice for us.

For these type of ion sources one of the most critical point is the structure of the magnetic field. In order to prepare the design, the measurement and the final formation of the magnetic field of the ECR source, preliminary model computations and instrumental developments were carried out.

1. Using a simple interactive PC computer code the axial magnetic field and the parameters of the coils, creating this field, can be determined. In Fig.2 the result of such a calculation is given for a 2-stages, 14 GHz source. The calculation of the total magnetic field, which is a superposition of the magnetic field of a hexapole (radial) and the coils (axial), is also possible.

2. To measure the magnetic field inside the coils and/or the hexapole, a PC-controlled Gauss-meter was developed.[2] With a small modification it can be used for measuring the magnetic field in the hole of the cyclotron yoke, as well.

3. The results of magnetic field measurements can be transformed to any required text or graphics form, and axial, radial or azimuthal magnetic fields and two-dimensional field maps can be obtained. A Fourier-analyzis of the B_r(phi) or B_{phi}(phi) field components is also possible (Fig.3).

3. THE ELECTROSTATIC ACCELERATOR

To cover the energy gap between extraction energy (5-10 keV/amu) of the ECR source and energies after the acceleration by cyclotron (MeV/amu), a 500 kV electrostatic accelerator was proposed (Fig.1). Technical details are being continuously worked out. According to our present concept the accelerator will be similar to the 350 kV PIIECR facility of the Argonne National Laboratory .[3] During the operation of the ECR source at the cyclotron, a hollow-cathode type ion source will be used[4] to produce single charged ions for the users.

4. THE CYCLOTRON

The existing MGC-20 cyclotron was designed to accelerate protons, deuterons, $^3He^{2+}$ ions and alpha particles in an energy range determined by the K value of 5-20.[5] Mainly the first harmonic mode of operation is used, but low energy alpha particle and deuterons beams are accelerated on the third harmonics of the revolution frequency.

Because of the increasing interest in the heavy ion beams, which have a higher mass to charge ratio and they should be accelerated in the third harmonic mode of operation, an extensive study of that mode was carried out.[6] At first the formation of the isochronous field, the radial stability of the beam and the orbit centring in the central region were investigated using the measured value of the magnetic field of the cyclotron, then with runs of $^3He^+$ and $^4He^+$ ions the results of the calculations were experimentally tested. The conclusions of these study are the followings: the MGC-20 cyclotron is capable of accelerating heavier ions with a mass to charge ratio up to 4; the magnet yokes have suitable axial holes for injection of a low energy beam from an external ion source; there is a serious beam loss during the acceleration at pressures of $(0.8\text{-}1.2)10^{-3}$ Pa due to the stripping on the residual gas atoms.

To couple the ECR ion source to the cyclotron studies begin in the near future to work out the method of injection, the beam transport system and to improve the vacuum system of the cyclotron. The external ion sources (ECR and duoplasmatron for protons and deuterons) could be roomed on the underground floor near to the cyclotron.

5. PLANNED RESEARCH

The research activity at the proposed heavy ion facility will include investigations with a variety of ion beams at low and medium energies in atomic physics, solid state and plasma physics, while in the high energy range atomic physics, nuclear spectroscopy and applications will be the main topics.

Atomic physics. Atomic physics investigations with multiple charged heavy ions are performed with beams of high-power ion sources (ECR, IBIS) or with high-energy heavy ion accelerators; the range between them has not been covered. If after the ECR source an electrostatic or linear accelerator would be applied, a new experimental area would be opened, covering partly the gap between the energy of the ECR's (<10 keV/amu) and high energy ion accelerators (>500 keV/amu). The most interesting fields to study are: charge exchange processes, molecular mechanism, direct ionization, ion-solid state interaction, quantum electrodynamical effects.

Nuclear physics, nuclear spectroscopy. One of the most important direction of progress in nuclear physics is heavy ion physics. In large nuclear physics research centres heavy ion physics is the main field of research, and smaller laboratories in the neighbouring countries (Krakow, Warsaw, Prague, Bucharest, Kiev etc.) do significant efforts to establish heavy ion accelerators. Some proposed experiments with heavy ions are: determine new level parameters by (heavy ion,xn) reactions, study of the structure of high-spin levels (rotational bands, back-bending, yrast-levels), proton-neutron multiple high-spin states of the odd-odd nucleus, Coulomb excitation.

Applications. Among the many industrial, medical etc. applications we plan to deal with production of nuclear filters, investigation of the radiation damage in various materials, materials sciences.

6. REALIZATION IN THE ATOMKI

A design study has been made to reveal the possibilities of establishing the proposed facility in ATOMKI.[7] In this study we worked out the specifications of the units (ECR source, injection into the cyclotron, electrostatic accelerator), finance, the necessary manpower, time schedule.

The realization of the facility is suggested in two steps. First the ion source and the electrostatic accelerator will be built in the rooms used formerly by the Cockroft-Walton generator and they will be applied for atomic physics investigations. In the second step the ECR source will be coupled to the cyclotron, and further on, it will be used alternately in the low and high energy ranges.

At present the financial resources seem to cover only the development costs of the ECR ion source. This work starts in the very near future, and we continue our efforts to get the necessary funds for the injection system and the electrostatic accelerator, as well.

7. REFERENCES

1) Proc. 10th workshop on ECR sources, Knoxville, USA, 1990. Proc. 4th Int. Conf. on Ion Sources, Bensheim, Germany, 1991. Rev.Sci.Instr. **63**, Number 4, Part II, (1992).
2) Biri, S., Efremov, A.A., Behterev, V.V. and Molnár, J., presented at XII. All-Union Conf. Charged Part. Accel., Moscow, USSR, 1990. (in Russian)
3) Pardo, R., Nucl.Instr.Meth. **B40/41**, 1014 (1989).
4) Biri, S., Pálinkás, J. and Báder A., ATOMKI Ann. Rep. 143 (1991).
5) Galchuk, A.V., Koroljev, L.E., Stepanov, A.V., Kormány, Z. and Valek, A., in **Proc. IX. All-Union Conf. Charged Part. Accel.** (JINR,Dubna, USSR, 1984) p.40. (in Russian)
6) Kormány, Z., Szucs, I., Valek, A. and Vámosi, J., Acta Phys. Hung. **65**, 359 (1989).
7) The heavy ion physics program of the ATOMKI. Non- published. ATOMKI, Debrecen, Hungary, 1991. (in Hungarian)

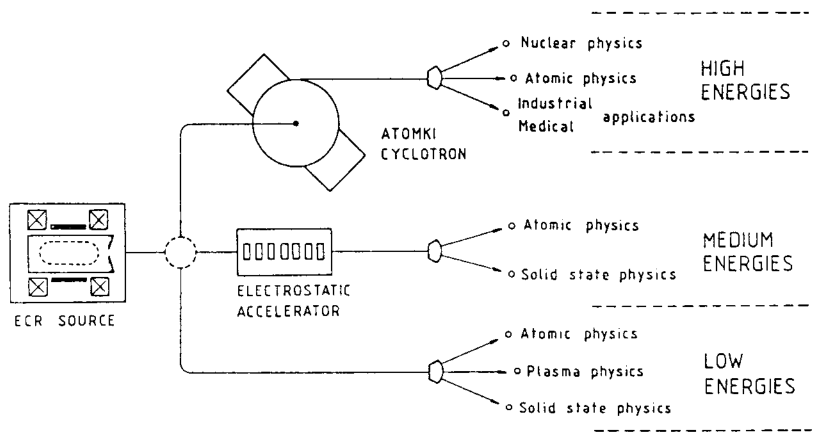
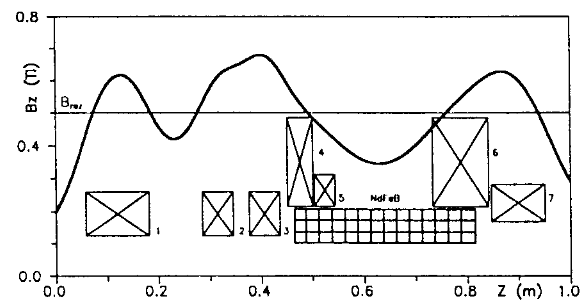


Fig.1. The scheme of the proposed heavy ion facility.



Num	R-in(m)	R-out(m)	Leng(m)	Dist(m)	Turns	Current(A)
1	0.050	0.140	0.124	0.120	120	800
2	0.050	0.140	0.060	0.315	60	800
3	0.050	0.140	0.060	0.406	60	800
4	0.110	0.290	0.050	0.476	60	800
5	0.110	0.175	0.040	0.524	28	900
6	0.110	0.290	0.107	0.787	120	900
7	0.080	0.155	0.104	0.899	80	900

dz(m)=0.001

Fig.2. Axial magnetic field on the axis of the ECR ion source and coil parameters.

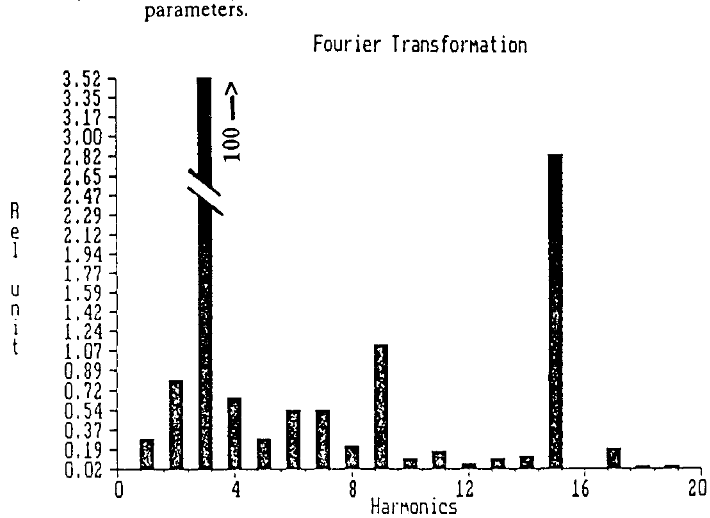


Fig.3. The Fourier-spectra of the radial field component at a given axial position inside a NdFeB hexapole magnet (region: 0-360^{o}, R=33 mm).