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OPERATIONAL RESULTS AND DEVELOPMENT OF THE E.C.R. SOURCES AND THE INJECTOR INTO CYCLONE*

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Abstract: A large superconducting ECR-source (ECREVIS) has been producing high charge state ions up to Xe^{27+} for injection into CYCLONE and as a stand alone source for atomic physics for over two years now. An improved analysing system has been installed increasing greatly the acceptance without harming the resolution. Operational results of transmission and realistic charge state distributions are reported. The design of a more compact ECR-source, to be called OCTOPUS and using water cooled copper solenoids, an open permanent magnet octupole structure and an iron yoke is presented. This source will replace ECREVIS and it is expected to have better performance and to be more reliable and economical to operate.

1. A new analysing system for ECREVIS

The ECREVIS source has been described extensively elsewhere [1], [2]. The initial analysing system for the ECREVIS source had been designed to be essentially achromatic. This was done because, at the time of the design (1977), the energy dispersion of E.C.R. sources was assumed to be quite large.

However, some measurements made on the bunching of the ECREVIS beam have indicated that the actual energy dispersion of the beam is less than 5 eV * Q.

It was therefore possible to redesign a new, non achromatic, charge selection system. The requirements of the new analysis system were :

- a high dispersion, to get a good separation of neighbour beams
- an acceptance of 200 π x mm x mrad in each plane, matching the emittance of the source.

The characteristics of the new charge selection magnet are summarized in table 1.

Table 1 : Charge selection magnet data

angle of deviation	60.	deg
bending radius	35.	cm
gap	8.	cm
angle of faces (symmetrical)	11.3	deg
horizontal focal length	90.0	cm
max field	0.3	T
max mass to charge ratio for V_{source} = 10 kV	50.	
dispersion	104.	cm/(Δp/p)

The new beam layout is presented in Fig. 1 and Fig. 2.

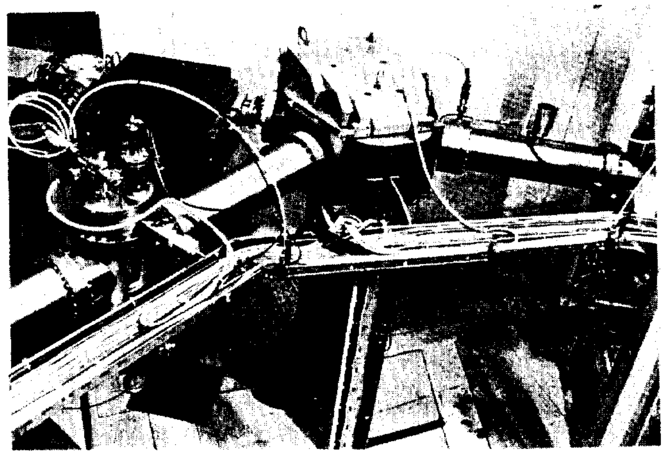

Figure 1

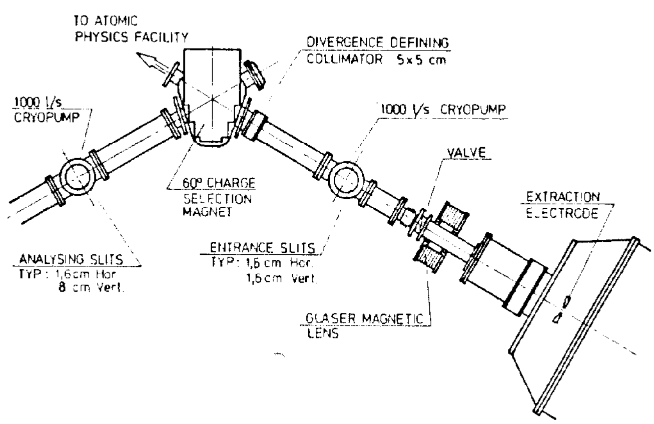

Figure 2

The beam transport was calculated using the well-known "TRANSPORT" computer code, including second order effects. It is worth nothing that, on such large size beams, second order effects can be sometimes larger than first order contributions.

The calculated beam envelopes are illustrated in Fig. 3.

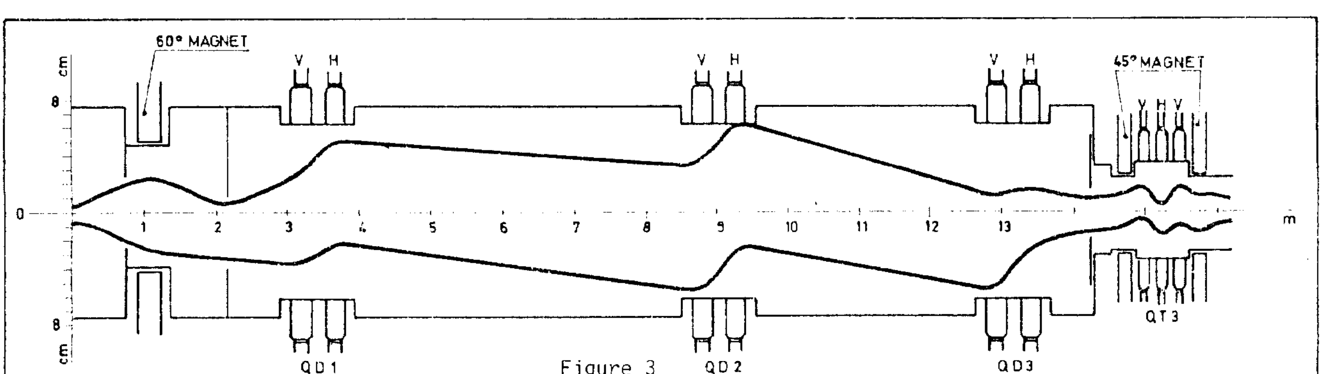

Figure 3

*This work is supported by I.I.S.N., Brussels, Belgium.

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The new system was installed in January 85 and tested in February. Table 2 summarizes beam intensities at the exit of the new analysing system. Table 3 illustrates some recent beams of ECREVIS accelerated by CYCLONE.

Table 2 : ECREVIS source, analysed currents (in electrical micro-amps).

Charge state	Oxygen	Neon	Sulphur	Argon
6^+	75	57	*	21
7^+	8.5	31	42	40
8^+		10	*	105
9^+		0.53	25	80
10^+			*	*
11^+			0.44	23
12^+			*	8.3
13^+			0.016	3
14^+				0.7
16^+				0.040

* mixed beam

2. OCTOPUS design

In October 84, it was decided to replace ECREVIS by a new source of conventional design. The expected characteristics for this new source are

- improved reliability, to eliminate the long down times associated with cryogenic problems
- smaller plasma volume, to have a higher E.C.R. heating power density with the same microwave generator
- "shorter" aspect ratio
- open octupole, allowing a radial access to the plasma, for diagnostic purposes or for the introduction of metal elements
- iron yoke, reducing the power needed and the stray field ; reduces also the sensitivity of the source to external magnetic perturbation.

The source uses low current density water cooled copper solenoids. The power needed to generate the nominal field is only 48 kW. The parameters of the new source are summarized in Table 4.

The source is now under construction and will be installed in September 85 to replace ECREVIS.

Table 3 : Recent beams obtained with the ECREVIS-CYCLONE combination.

Particle	Charge State	E fin max MeV	Beam currents (in electrical micro-amps) analysed after source	injected beam yoke	Internal beam R = 20 cm	Internal beam R = 92 cm**	Final target
Oxygen	6^+	270	61	42	10	8.8	5.4
Neon	7^+	294	28	18	4.6	3.9	3
Sulphur	7^+	184	42	30	8.3	5.2	2.5
	9^+	304	22	15	4.3	3.0	2.0
Argon	9^+	243	31	19	5.2	3.7	2.6
	11^+	363	23	16	5.2	3.5	2.4
	12^+	432	8.3	6	1.7	1.4	0.9
	13^+	507	3	2	0.55	0.4	0.28
	14^+	588	0.9	0.53	0.15	0.1	0.065
	15^+	675	*	*	*	*	0.008
	16^+	768	*	*	-	-	0.004
Krypton 84	17^+	413	*	*	0.5	0.25	0.16
86	17^+	403	*	*	0.15	0.07	0.051
Xenon 132	23^+	480	*	*	*	0.04	0.02
	24^+	523	*	*	*	0.004	0.002
	25^+	568	*	*	*	0.003	0.001
	26^+	615	*	*	*	0.002	0.001
	27^+	663	*	*	*	-	0.0002

* mixed beam
\- non available
** extraction radius

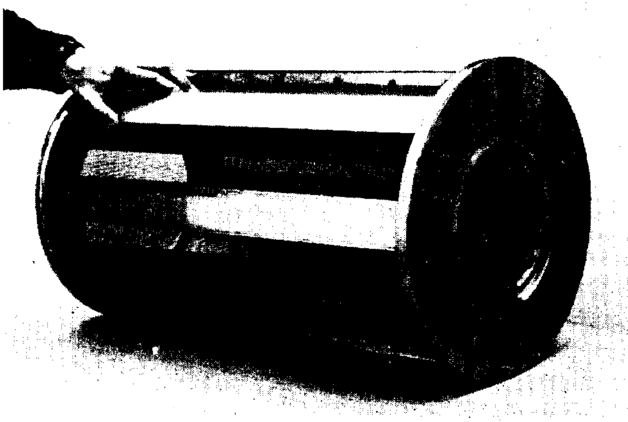

Figure 4 : Octupole support structure.

3. Aknowledgements

This work is obviously the result of the efforts of a large team. The skill and dedication of the operation and development groups of the cyclotron were the key of success.

4. References

[1] ECR Ion sources : The ECREVIS project
Y. Jongen et al., Proc. Int. ion Engineering, Congress ISIAT '83 8 IPAT '83, Kyoto (1983) p. 199.

[2] ECREVIS-CYCLONE status report
Cyclotron Group, Proc. of 10th Int. Conf. on Cyclotrons, East Lansing (1984) pp. 226-229

Table 4 : OCTOPUS design

Main stage	
diameter	: 25 cm
length between mirrors	: 70 cm
type of multipole	: octupole
pumping	: radial
ECR frequency	: 8.5 GHz
max. RF power	: 5 kW
field at walls	: 4.3 kG
field at mirrors	: 4.1 kG
Injector stage	
ECR frequency	: 14.3 GHz
max. RF power	: 1,5 kW
Magnet power	
typical	: 48 kW
maximum	: 85 kW
Weight	
copper coils	: 1100 kg
Sm-Co for octupole	: 96 kg
yoke	: 2000 kg

OCTOPUS SOURCE.

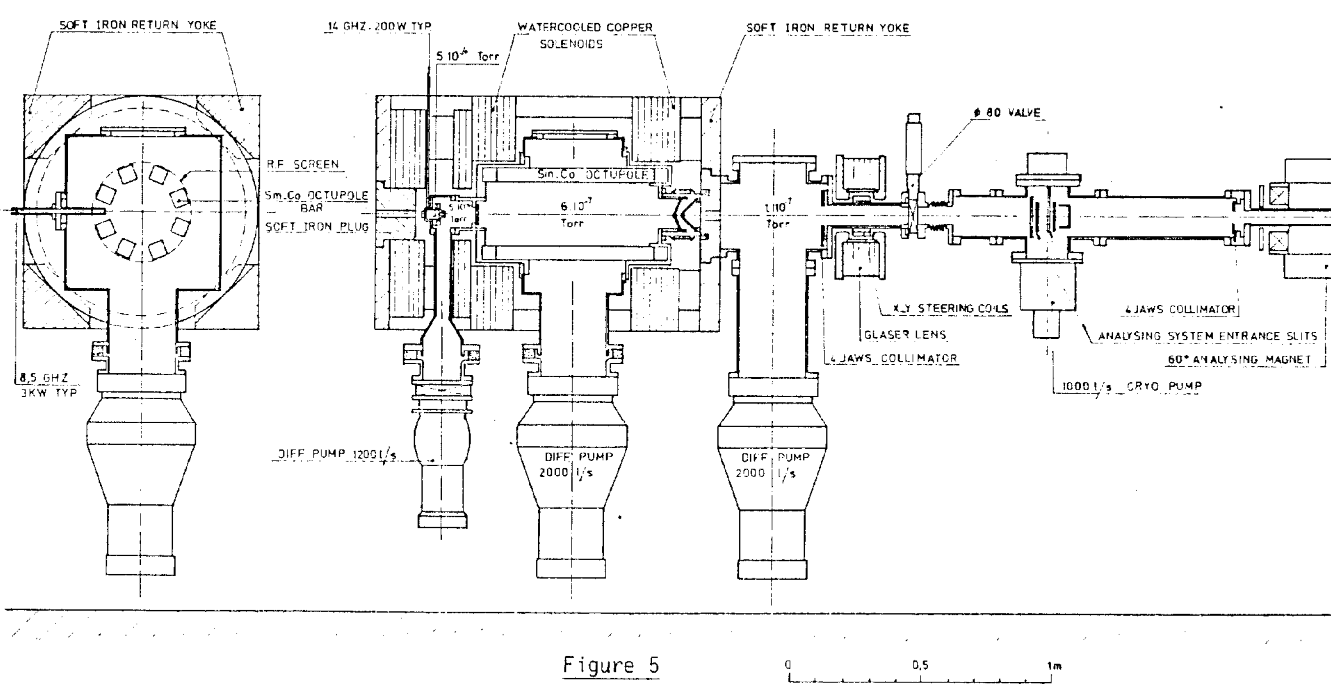

Figure 5