COLUMBUS - A SMALL CYCLOTRON FOR SCHOOL AND TEACHING PURPOSES

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Abstract

A small cyclotron has been constructed for school- and teaching purposes. The cyclotron uses a water-cooled magnet with adjustable pole-pieces. The magnet provides a field up to 0.7 T.

The vacuum chamber is positioned between the two poles. The vacuum chamber provides ports for different subsystems, measuring tools and some viewports.

A turbo molecular pump backed up by a dry compressor vacuum pump is used to evacuate the chamber to a pressure of 10^{-5} mbar.

The ions are accelerated between two brass RF electrodes, called dee and dummy-dee.

In the center of the chamber there is a thermionic ion source. A mass flow controller fills it with hydrogen gas ionized by electrons from a cathode.

The required 5.63 MHz RF power is supplied by a RF transceiver. A matching box adjusts the output impedance of the transceiver to the input impedance of the cyclotron.

The expected final energies of the protons are 24 - 48 keV after 6 - 8 revolutions. These energies don't produce any radiation outside the chamber.

The purpose of this project is to realize a low-cost cyclotron using standard devices as far as possible.

INTRODUCTION

In principle a cyclotron is an easily understandable accelerator. It is found in every textbook descriptions and tasks on the cyclotron, but in contrast a real cyclotron is a very complex device so that most of the students have never seen a working cyclotron in reality.

The project COLUMBUS intends to change this situation by providing a minicyclotron for school and teaching purposes.

TECHNICAL DATA

In order to build such a small cyclotron one has to meet two conditions:

- Vacuum, magnetic field, frequency etc. must be so low that one can use standard components as far as possible, otherwise the costs will go to infinity
- The final energy of the cyclotron must be small enough so that no harmful radiation can arise, so that the students can do experiments with the cyclotron.

Table 1 shows the technical data of COLUMBUS. One can easily recognize that COLUMBUS meets all the conditions mentioned above.

In addition no beam will be extracted to make sure that no harmful radiation can escape during the experiments.

Table 1: Technical Data

Diameter of the Dees	140 mm (5.5 in)
Flux-density of the magnetic field	0.38 T
Vacuum in the chamber	10^{-5} mbar
dto with H_2	10^{-4} mbar
Cyclotron frequency	5.63 MHz
Number of revolutions	6 - 8
Voltage between the dees	2.0 -3.0 kV
Final energy	24 - 48 keV

MAGNET AND VACUUM-CHAMBER

At the very beginning there were two big problems:

- How to get a magnet for the homogenous field and
- How to get a suitable vacuum-chamber.

The first problem was solved by the Research Institute of Jülich. Prof. Dr. Maier and his team donated a Bruker BE-15. This is a laboratory magnet with two water-cooled coils. The pole-diameter is 150 mm (~ 6 in). The pole pitch is adjustable from 50 - 120 mm (~ 2 - 5 in). The flux-density is up to 2 Tesla depending on the spacing of the poles. At a distance of 100 mm the flux-density is up to 0.7 Tesla.

The second problem was solved by VACOM, a company specialized in vacuum-components. VACOM built the vacuum-chamber, i.e. Fig. 1, for us free of charge.

It has got ten ports, as shown in Fig. 2, the pumping-port, a port for instruments, another one for the RF, some view-ports, two ports for the filament-heating. Between these ports there is the gas-inlet for the ion source.

Figure 1: The vacuum chamber.

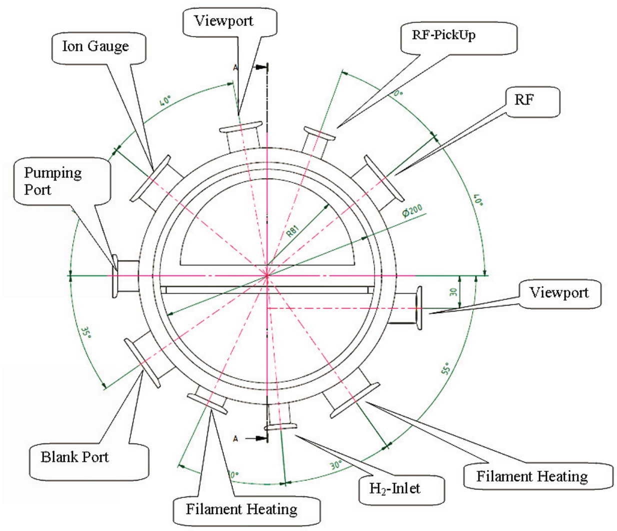

Figure 2: Layout of the vacuum chamber.

THE ION SOURCE

The protons are produced in the ion source which was built according to Tim Koeth's pattern [2], which he first used in his cyclotron.

As shown in Fig. 3 it consists of a ceramic block of macor [1] containing a filament of tungsten in an ionisation-room. The macor-block is covered by a copper-plate, which holds the source-head - the so-called "chimney" - and is used as an acceleration-electrode for the electrons emitted from the glowing filament.

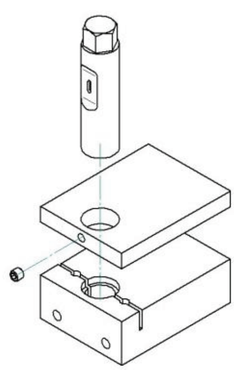

Figure 3: The ion source.

The source is supplied with hydrogen gas close to the filament. The ionisized hydrogen-atoms, i.e. the protons rise into the chimney and exit through a tiny slit into the gap between the dee and the dummy-dee.

The hydrogen gas is stored in a hydro stick, a small tank containing 10 liter of hydrogen under a pressure of 10 bar. This pressure is reduced to 0.3 bar and with this pressure the gas enters a mass flow controller (MFC) which allows a precise dosage of the hydrogen gas.

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THE RF-SYSTEM

The protons are accelerated by the RF-system [1]. It consists of an RF-power-source which is connected to the cyclotron by a matchbox as it is shown in Fig. 4.

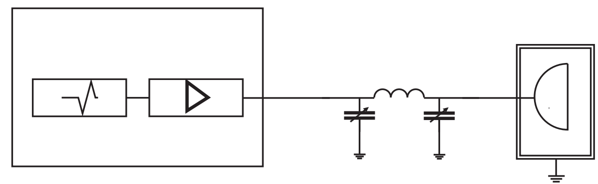

Figure 4: The RF-system

The RF-power-source is a short-wave transceiver for marine radio. It provides an AC voltage of 50-70 V_{eff} at frequencies from 500 kHz to 35 MHz. The available power is 120 W.

The matchbox, i.e. Fig. 5, which connects the power-source to the cyclotron, is designed as a Collins-filter and is used as an impedance-converter to adjust the low output-impedance (50 Ω) of the power-source to the high input-impedance (0.33 MΩ) of the cyclotron .

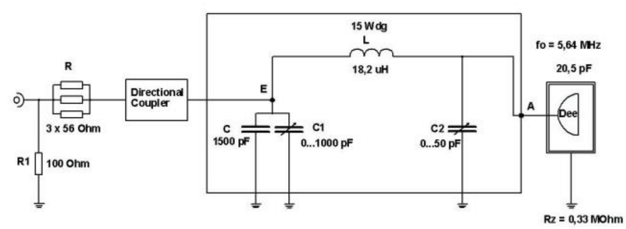

Figure 5: The matchbox.

As well as an impedance converter the matchbox is also an RF-transformer transforming the 50 - 70 V output voltage of the power-source up to 2000-3000 V voltage, which is needed for the acceleration of the protons.

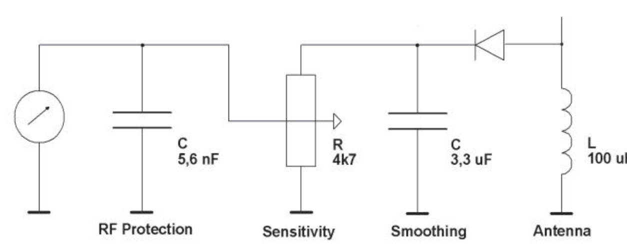

Figure 6: The RF–pickup.

A directional-coupler in the input-circuit of the match-box makes it possible to control and minimize the reflections back into the RF-source and a RF pick-up, i.e. Fig. 6, in the output-circuit allows to check whether the cyclotron is tuned to the cyclotron-frequency of 5.63 MHz .

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