A new 15 MHz-4 MV/m RF-Deflector for the Munich Heavy Ion Recoil Spectrometer (MRS)

K. Rudolph and P. Jaenker
Sektion Physik, University of Munich
Am Coulombwall 1, 8046 Garching, W-Germany

abstract

A new 15 MHz resonant deflection system has been developed. It reaches 4 MV/m with an input power of 20 kW. It opens new possibilities to study strongly inverse reactions with the Munich Recoil Spectrometer.

1. INTRODUCTION

A new rf system has been designed and constructed for the Munich Heavy Ion Recoil Separator [1], [2]. This system generates a strong electrical field between two deflector plates. It has an operation frequency of 15 MHz and reaches an electrical field strength of 4 MV/m . This limit is only given by the available generator power of 20 kW. Since insulator materials have been avoided, the maximum field strength is not restricted by electric breakdown in insulators.

A sophisticated regulation system provides field amplitude stabilisation and resonance tuning. An electronically regulated mechanic damping system prevents the excitement of mechanic oscillation caused by electromagnetic-mechanic feedback (ponderomotive oscillations[3]). Also external mechanic disturbances as caused by floor vibration are compensated.

2. DESIGN OF THE DEFLECTION SYSTEM

2.1 Choice of the deflector type

At frequencies as low as 15 MHz the construction of a discrete resonance circuit is an adequate choice. Quarterwave resonators have more or less the same power consumption but are very inconvenient due to their length ($\lambda/4$ =5 m). Therefore the deflection unit consists of a pair of deflector plates through which the heavy ion beam passes and a discrete coil completing the resonance circuit.

2.2 Mechanical construction

The whole deflection system is mounted on the top flange of a vacuum box making assembly and maintenance very easy. The resonance circuit is a self supporting structure made out of copper tubes (diam. 28 mm) with 10 mm thick stainless steel deflection plates brazed to the ends of the copper tubes. The structure is stiff enough to dispense with positioning insulators. Hence, the performance of the structure is not limited by electrical breakdown in insulator material.

The coil was constructed with straight pieces of tubes and commercially available 90 degree tube fittings. This way the coil resulted with a rounded square profile. The parts were brazed together using silver solder. This manufacturing method allows the inductance of the coil to be tuned to the desired value by changing the coil length or by adding or subtracting windings. After final tuning the brazed construction was electro-plated with copper achieving a shiny surface with an excellent RF-conductivity. This construction method is very versatile and can generally be recommended for building high power coils.

To carry away the dissipated power we installed an inner flexible stainless steel hose. For both halves of the coil, cooling water enters at ground potential into the coil centre, flows through the flexible tube to the coil end where the deflection plates are attached, and returns in the outer tube to the middle of the coil. RF power is inductively fed to the resonant circuit by a coupling loop diving into the middle of the coil. The vacuum flange carrying the loop can be rotated for impedance matching.

The relevant mechanical dimensions of the deflection system are summarised in table 1.

Table 1
Mechanical characteristics of the deflection system

coil diameter	200 mm
tube diameter	28 mm
no. of windings	8
winding distance	35 mm
coupling loop diameter	50 mm
deflection plate length	250 mm
deflection plate width	120 mm
defl. plate separation	70 mm
vacuum box dimensions	1000*800*400 mm^3

0-7803-1203-1/93$03.00 © 1993 IEEE

Power dissipated in the coupling loop is carried away by flowing compressed air through the hollow loop tubing. Macor ceramics are used for vacuum sealing and insulating the inner conductor .

The magnetic flux induces eddy currents in the coil housing. To keep power losses in the walls of the stainless steel vacuum vessel as low as possible we surrounded the deflection system by a screening shield made of a coaxially welded copper sheet.

2.3 RF characteristics

The tube diameter of 28 mm selected for mechanical rigidity is also near the optimum value for maximum shunt impedance of the resonator at the given vacuum chamber dimensions. Thus the values given in table 2 could be measured. Maximum reachable RF-voltage was only limited by the available power.

Table 2

RF performance of the resonator

resonance frequency	15 MHz
shunt impedance	2 MOhm
quality number Q	3000
RF-voltage	270 kV at
RF-power	20 kW

2.4 The power source

An air-cooled tetrode push-pull class C amplifier supplies up to 20 kW c.w. to the resonator by a 8/13-Flexwell coax cable.. The power flow from the source to the load and the reflected wave is observed with a standing wave meter. Amplitude and phase of the deflection field are measured with a small pickup-loop.

3. TUNING AND AMPLITUDE CONTROL

Due to the high electrical quality of the circuit a precise resonance tuning is necessary. The deflector circuit is easily put out of tune by small mechanic deformations as:

- field strength dependence: the deflector plates are attracted by the radiation pressure
- thermal expansion caused by the dissipated power

We use adjustable capacitors to tune the resonance frequency of the deflector circuit: Two electrically grounded spherical bodies are excentrically mounted near both ends of the coil. Their capacity can be changed by turning them towards or away from the coil.

3.1 Slow tuning

A regulation circuit drives one of these capacitors by a gear-motor and tunes automatically the deflector circuit measuring the relative phase between pickup signal and power source with an rf mixer unit.

3.2 Fast damping system

In spite of all efforts to get the resonator as stiff as possible, the avoidance of any stabilising insulators leads to a somewhat shaky construction that tends to mechanical oscillations. This fact not only leads to an extreme susceptibility to external vibrations but especially to heavy ponderomotive oscillations. We suppress these oscillations with a fast tuning loop that keeps the resonator always on top of resonance regardless of the actual mechanical state. To be able to control the mechanic oscillation the cut-off-frequency of the tuning system must be higher than the frequency of the mechanic mode of the coil (3 Hz). Therefore we gyrate the second variable capacitor with a galvanometer motor originally constructed to drive the pen of an electrocardiograph recorder. The movement is transmitted into vacuum by a low friction rotational feedthrough with ferrofluidic vacuum isolation. The arrangement acts like a gyrating pendulum with a resonance frequency mainly determined by the momentum of inertia of the capacitor body that must be kept as low as possible. A light-weighted hollow ball (diameter 10 cm) was manufactured of copper by a galvano-plastic method. A weight of 39 g and a cut-off frequency of 7.5 Hz was obtained.

To drive the fast tuner the same signal as for the slow tuning is used as the input. The driving amplifier for the galvanometer coil uses current feedback in order to avoid additional phase shifts due to the inductance of the coil.

3.3 amplitude stabilisation loop

A feedback loop between pickup loop and power source regulates the amplitude of the electrical field to the desired value within 0.5 %.

References

[1] K.Rudolph et al.Nucl. Instr. and Meth. 204 (1983) 407

[2] S.J. Skorka et al. Il Nuovo Cimento 81A (1984) 331

[3] V. E. Shapiro Soviet Physics JETP 28 (1969) 301