LOW FREQUENCY FERRITE CAVITIES

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Introduction

Cooling rings for accumulation and acceleration/deceleration of anti-protons and heavy ions require RF cavities for beam handling purposes. The operating frequency is, generally, of the order of a few MHz; it is almost constant in the accumulation rings [1] [2], whereas, in the others, it slowly varies (order of seconds) through a range of say one to ten [3] [4] [5] [6], or even more [7]. The gap voltage lies between several kV and a few volts, which, in turn creates severe beam loading effects if the cavity impedance is higher than some 50 Ω. In all rings, space in the straight sections is at a premium and, therefore, the physical length of the RF equipment should be as short as possible. The low operating frequency requires ferrite loaded cavities. As gap voltage is proportional to the ferrite volume, the optimal solution is a compromise between available space and accelerating voltage. Solutions will be presented in the paper which have been adopted at CERN for the AA (Antiproton Accumulator), LEAR (Low Energy Accumulator Ring) and AC (Antiproton Collector) rings. The cavity of the latter served as a prototype for other rings such as CELSIUS (Uppsala), COSY (Jülich) and ASTRID (Aarhus).

AA Ring

Requirements and constraints: almost constant 1.8 MHz operating frequency, 14 kV voltage gain, heavy radiation environment, no space restriction. A spare 26 GeV Proton Synchrotron accelerating cavity [8] was available which required only mechanical modifications to be equipped with a bakeable vacuum chamber. The RF generator had to be replaced to meet the 50 Ω gap impedance requirement. The cavity consists of two λ/4 ferrite loaded sections, push-push connected by a ~1 metre long copper bar, carrying at the same time the RF power, by direct connection to the anode of the power tube, and the polarizing current. Thanks to this arrangement, the RF voltage is just half of the needed voltage gain. The anode d.c. voltage has to be 8 kV or slightly more.

A spare power amplifier from the ISR (Intersecting Storage Ring) was used [9] [10], which consists of an Eimac 4CW10000C power tetrode, cathode driven by 8 Eimac 4CX350A tetrodes in parallel. The cascode arrangement, due to the ~30 Ω cathode impedance and despite the considerable stray and electrode capacitances, allows the amplifier bandpass to extend to 10 MHz, thus making the cavity and amplifier complex inherently stable when gap feedback is applied. To reduce the number of vacuum tubes, the original preamplifier was modified and now consists of two E55L tetrodes, one as an inverting amplifier, the other as a cathode follower for the cascode stage. A simple stabilizing filter at the anode of the first E55L was necessary to cut out some high frequency oscillations due to the gap connecting bar which, evidently, was not foreseen for feedback operation. The system has worked correctly for 10 years. Tube replacement has occurred once and the fact that the anode d.c. voltage of the power tube is above its maximum rating, does not seem to have had an influence on its performance.

LEAR Ring

For the LEAR cavities, two 1.6 metre long spaces were available in straight sections. The operating frequency should vary between 0.4 and 4 MHz in a time interval of a couple of seconds with an accelerating voltage as high as technically feasible. Negligible radiation damage was expected. The λ/4 solution, as shown in Fig. 1 was adopted. Tuning to

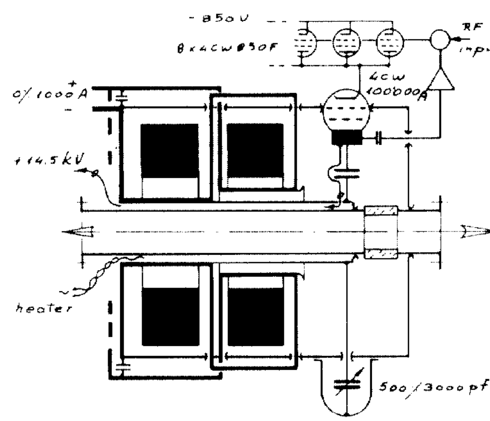

Fig. 1 The LEAR Cavity schematic diagram.

the instantaneous frequency is obtained with a figure-of-eight d.c. current loop (in reality, these are two in parallel, for symmetry), well decoupled by means of RF capacitors and a low impedance filter to avoid RF leakage. Because of danger of spurious resonances, which would have made impossible any feedback arrangement, the figure-of-eight was made single turn. Since the one-to-ten tuning ratio would have required an excessively high biasing current, it was decided to use a mixed ferrite plus variable capacitor tuning arrangement. Ferrite discs, Ø 50 x 30 cm, 2.5 cm thick have been utilized with a μ_i = 800. Forty-six discs, each cooled with a copper water cooled disc 5 mm thick, could be accommodated in each cavity. One cavity uses 8C12 ferrite from Philips, the other PE17 from Toshiba. Both materials show almost similar electrical properties. At 4 MHz, with 1000 A bias, each disc has an impedance of about 45 Ω at 250 V; at ~ 0 V the disc impedance reaches ~ 100 Ω; at 0.4 MHz, only 150 V are available with some 20 Ω impedance. To avoid excessive losses and distortions, the disc requires some 50 A polarisation current which causes the μ to be lowered to 400. In the middle of the frequency range, the ferrite behaves in a slightly more favourable way, so that 12 kV are expected at 1 MHz. The cavity gap being directly connected to the power tube anode, the d.c. supply voltage is 14.5 kV, which obliges over running an Eimac 4CW100'000 A tetrode. The gap capacitances are such that, when polarized with 50 A, the resonant frequency of the cavity is about 1 MHz. To lower it to 0.4 MHz, a variable capacitor of 500-3000 pf, usually employed for broadcasting transmitters and insulated with pressurized SF6 gas, was put in parallel with the gap, Fig. 2. The long connections between power tube, accelerating gap and variable capacitor are such that an anti-resonance is generated close to the operating frequency, thus facilitating the overall stabilization when feedback is applied. Tuning down the cavity over the whole range requires simultaneous action on the condenser setting by means of an appropriate electromechanical device and on the biasing current. The Eimac power tube is cathode driven by means of 8 Eimac 4CW850F tetrodes in a similar way to that of the AA cavity. The higher input capacitance of the cascode stage

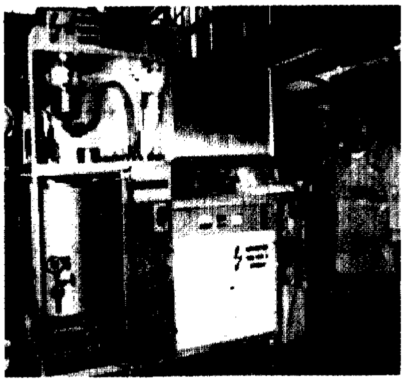

Fig. 2 The LEAR Cavity.

needs a low output impedance solid state amplifier to cope with the feedback stability requirements. This amplifier is an adaptation of an existing one conceived for the same feedback purposes, but for another CERN machine [11].

AC Ring

For the rebunching cavity the prescriptions are: 3.5 kV, 1.85 MHz fixed frequency, low space available, high radiation environment. The cavity (Fig. 3)

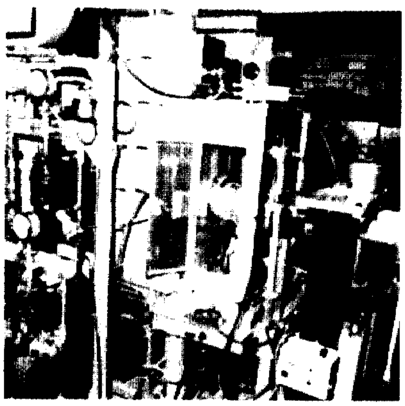

Fig. 3 The ACOL Cavity.

is loaded with 16 rings of the same type as the LEAR cavity plus appropriate fixed gap capacitors and is energized with one of the many ISR power amplifiers which are now available after the machine shut-down. Only minor modifications were necessary, namely at the power tube filament decoupling coil because of the much lower frequency. The figure-of-eight, 1 turn tuning loop, whose hot side is visible in Fig. 3, is energized with a current generator of max. 80 A in order to keep the cavity continuously tuned.

CELSIUS

Only 2 kV are required, but the operating frequency extends over a broader range than LEAR. Stepwise changes can be accepted, which allows the cumbersome variable condenser to be dispensed with. To better utilize the tuning capabilities of the ferrite, 2 turns in a figure-of-eight are employed together with a 5 V, 2 kA d.c generator. No spurious oscillations have yet been detected. The amplifier is an old ISR specimen.

Conclusion

Ferrite cavities are well known to the accelerator community, the ones described are practically of a modular type and can be reproduced with only minor changes. Being of the appropriate frequency range their realisation has been beneficial for other machines such as CELSIUS, COSY and ASTRID.

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Finally, P. Gourcy was responsible for the realization and setting-up of all amplifiers, installations and controls.

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