PULSED-RF TO START THE CYCLOTRON CAVITIES IN A SHORT TIME

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The start-up of a high Q cavity is normally troublesome, because multipacting discharges prevent reaching the operating cavity voltage. A time-consuming conditioning of the RF surfaces can be avoided by pulsing the RF power. In this case the cavity voltage rises so fast that the build up of multipacting is suppressed.

INTRODUCTION

Multipacting is a very disturbing phenomenon appearing in high-Q RF cavities. Electrons are pulled out from the walls of resonators by the RF voltage. By hitting other metallic surfaces new electrons are produced. This kind of discharge will limit the power level until the surfaces will be cleaned through the conditioning. But this process is very time-consuming. A fast enough rise time of the RF voltage would avoid any multipacting and thereby increase the availability of the cyclotrons.

This fast turn-on system was presented at the Third Workshop of the RF System Users Group [1].

PHILOSOPHY OF THE RF TURN-ON

The resonance of the cavity is searched at a very low level of RF power (typical 1 W), below the first multipacting region. A fast rising pulse of typically 200 kW pushes the RF voltage through all critical regions so fast that the conditions for multipacting do not arise. At the end of the pulse the power is reduced to a level, above the multipacting region, to allow the power supplies to recover. A slow ramping up of the RF power is now started. All these conditions are realised with a control loop for the incident power.

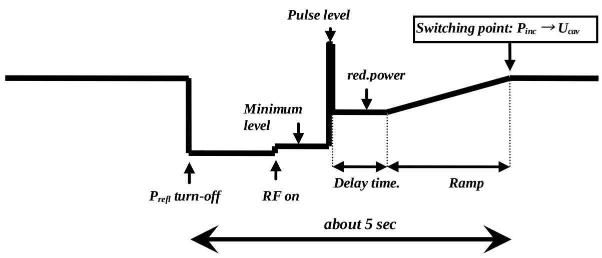

Fig. 1 Time dependent incident power at start.

As the voltage attains the nominal value, the incident power loop is switching off and the amplitude control loop is switching on.

CRITERION FOR RESONANCE

The cavity resonance will be found at very low power level by comparing the phase of the incident power to the phase of the cavity voltage.

A look at the shape of voltage and power during the high pulse is very instructive. If the system is out of resonance, only very little voltage is building up in the cavity and most of the power is reflected.

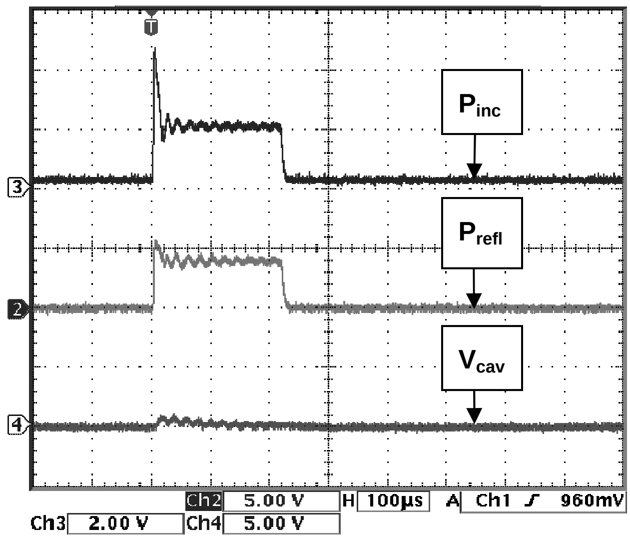

Fig. 2: Measurement with a detuned cavity.

If the tuning system is locked on the resonance frequency, the RF voltage is increasing exponentially. The reflected power is decreasing to almost zero if the impedance of the coupling loop is 50 Ohm. After the pulse the cavity voltage will again decrease, because the incident power is returning to the low level; this is also visible on the short peak of reflected power appearing behind the pulse.

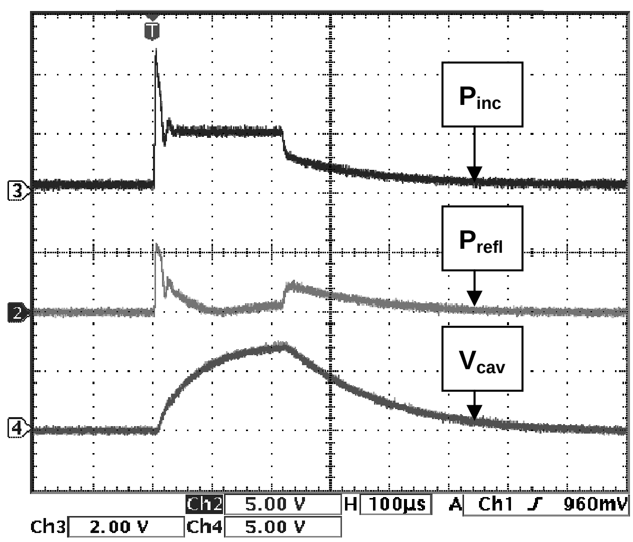

Fig. 3: Same measurement as before, but with the tuning system locked on resonance.

The value of the reflected power at the end of the pulse is measured.

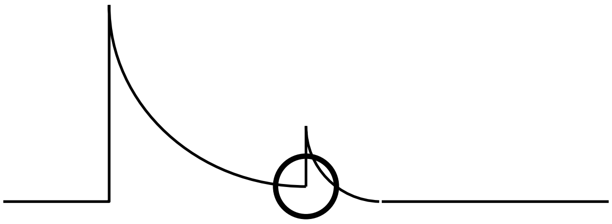

Fig. 4: Shape of the reflected power for a pulse

If this value is lower than a given reference level, the electronics will decide to switch the RF power from the top of the pulse back to a reduced level; higher than the multipacting level, but low enough for the power supplies to stabilize again.

As said before, the search for resonance is done at a very low RF power level. If other cavities are operating at nominal value at the same time, they can induce a disturbance in the starting cavity. This leads to a small phase error for the tuning system and therefore a reflected power at the end of the pulse still higher than the reference value. The starting electronics will stay in the pulsing mode and refuse to go to the next step, the reduced level. To avoid this bad situation, a small sweep signal will be added to the phase detector after a delay of four seconds.

MEASUREMENTS

After an RF interlock, the entire procedure of the restarting cycle has been registered. In the event below, the second pulse of the starting electronics was decisive.

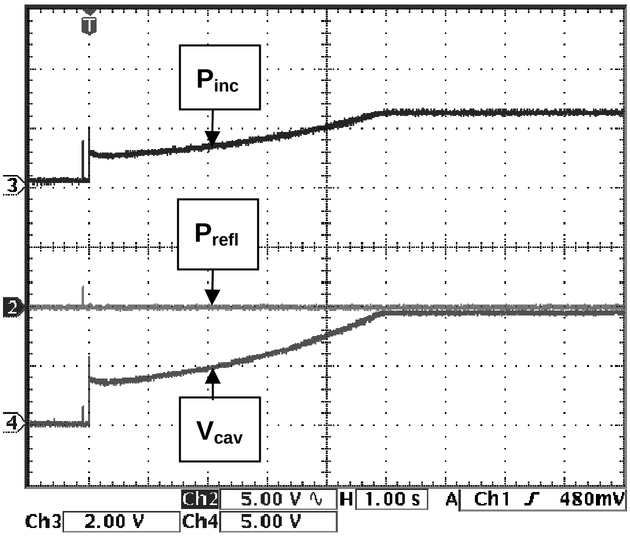

Fig. 5: After the pulse, the power is reduced to a low level and remains there 0.5 second before ramping up to the nominal value.

A RF break-down in a cavity results in interrupt interval of about five seconds.
The measurement of Fig. 5 is very similar to the theoretical curve of Fig. 1.

CONCLUSIONS

In the original version of the tuning system -with a slow increasing level and waiting at every multipacting regions until surfaces will be well conditioned- each RF break-down leads to an interruption of approximately half an hour.

The new pulsing system dramatically increased the availability of the RF cavities. The next pictures show for a 10-day period the break-down record of all cavities without and with the new fast turn-on system.

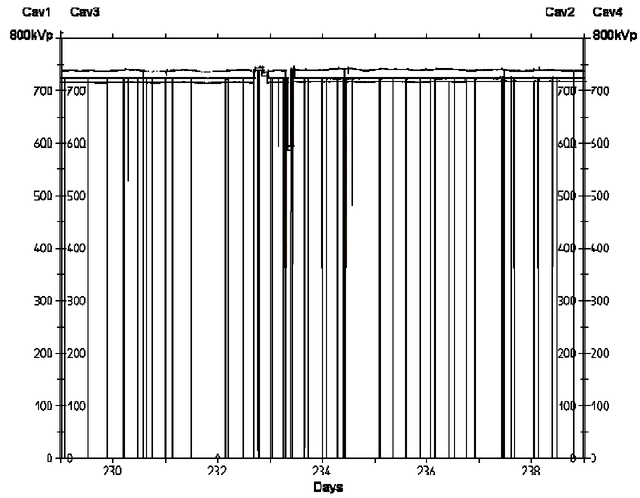

Fig. 6: Voltage of all four cavities during a 10-day interval. Each vertical line is a registered break-down of the RF voltage followed by a beam time lost of approximately half an hour.

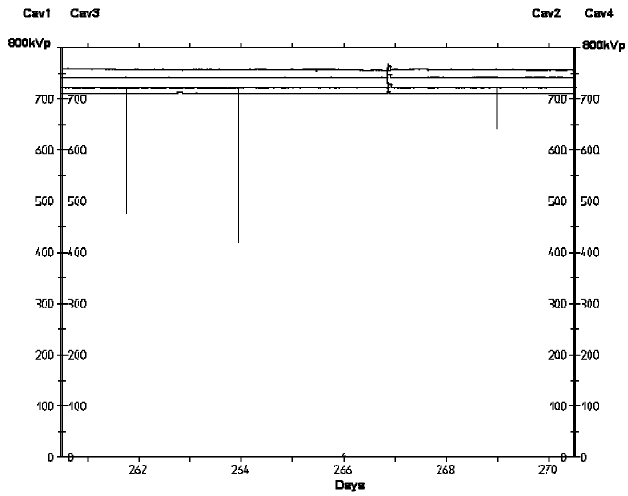

Fig. 7: Voltage of the same four cavities during a similar 10-day interval after the introduction of the new fast turn-on system. The few visible interrupts are only a couple of seconds each.

REFERENCE

[1] 3rd Workshop on CW and High Average Power, RF System Users Group, April 5-7 2004, PSI, Villigen, Switzerland.