

ELECTRODE DESIGN IMPROVEMENT IN THE SPIRAL2 SINGLE BUNCH SELECTOR

P. Balleyguier, CEA/DAM/DIF, F-91297, Arpajon, France
M. Di Giacomo, M. Michel, G. Fremont, P. Bertrand, GANIL/Spiral2, Caen, France

Abstract

The high current driver accelerator of the SPIRAL 2 project uses a single-bunch selector to reduce the bunch repetition rate at the experimental target. The device works at almost 1 MHz and handles fast RF pulses of 18 ns with transient times shorter than 6 ns.

The first electrode prototype, built in the framework of the Eurisol DS project, was used for thermal and RF tests and didn't show correct delay and matching. The paper describes the studies to improve these two important issues and the results of thermal tests.

INTRODUCTION

Within the context of the design of the heavy-ion post-accelerator for EURISOL (Task 6), the potential user community [1] considered that the frequency of 88 MHz ($\Delta t \approx 11,4$ nsec) currently adopted for the operation of the linac was too high for experiments based on time-of-flight measurements and required separation between beam pulses of 100-200 nsec (~ 5 -10 MHz). The development of a travelling wave single bunch selector working at 1 MHz, with voltages of several kilovolts was begun [2] as a first step to the final goal of 10 MHz repetition rate. To reduce the required power, the device was based on a steerer continuously deflecting the beam on a beam dump, and a short pulse travelling along two, high characteristic impedance, 100 Ohm, meander electrodes.

This work led to the design and manufacture of prototypes of the main RF components: positive and negative pulsers, electrode plates (Fig. 1) and one matching resistor. Measurements on these devices have shown good performances for the pulsers but significant differences with respect to simulated values appeared on the delay and the impedance of the meander line.



Figure 1: Electrode prototype on its support.

This preliminary work is being continued now in the context of the Spiral 2 driver project [3], where the Neutron for Science experiments [4] ask for a single bunch selector with similar requirements, the European

project SPIRAL2 PP founding one year of complementary R&D.

All along the article, the expressions *single bunch selector* and *fast chopper* are used indifferently. Nevertheless the first expression underlines the typical requirement in ion accelerator which is different from that of proton linac used as injectors for higher energy boosters or storage rings.

MEASUREMENTS

Several measurements [5] have been performed on the prototype to quantify the cooling possibilities and to check the RF design. For that purpose the cooled support of Fig. 1 was built.

Cooling

Previous CERN studies [6] had already shown that the cooling of a ceramic plate just clamped on the cooling support is limited by the very low heat conductivity of the metal-ceramic interface under vacuum. In their case, 100 W were dissipated on a 400 mm plate, which operating temperature was around 100° C.

Brazing such large ceramic plates on a metallic support is considered very risky and probably not efficient from the RF point of view. This process requires a metallization of the plate bottom side that can't be thick enough with respect to the skin depth. The brazing alloy would then necessarily be crossed by the pulse current, inducing frequency dependent losses. The same considerations apply in case of any other interface material that should be compatible with both RF and vacuum constraints.

It was then proposed to cool the ceramic by the sides, as in this direction, stronger pressure can be applied to ensure good thermal contact. For this same purpose, an Indium strip was also inserted in order to increase the surface contact. The principle is shown on Fig. 2.

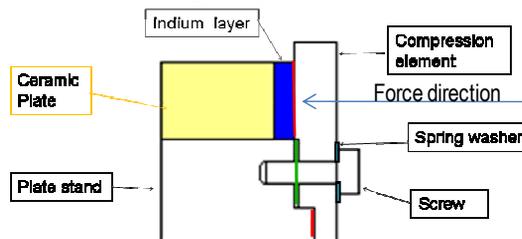


Figure 2: Assembling principle for side cooling.

Thermal simulation had shown that losses of 100 W/10 cm can be cooled quite efficiently as shown in Fig. 3. Thermal measurements were performed both at air pressure and under vacuum, using a DC generator to drive

the meander resistance and measuring the temperature of the Cu-plated side of the Alumina.

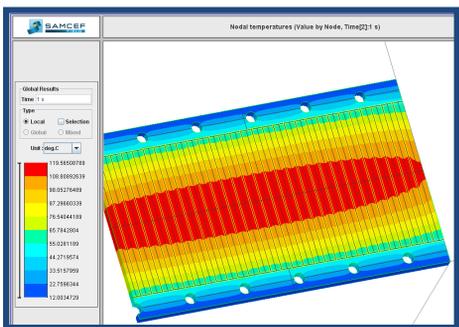


Figure 3: Thermal simulations.

The temperature was measured in two different conditions: the plate being clamped to the dissipater (side + bottom effects) and the plate being raised of 0.5 mm (side effect only) in order to quantify the small contribution of the bottom surface.

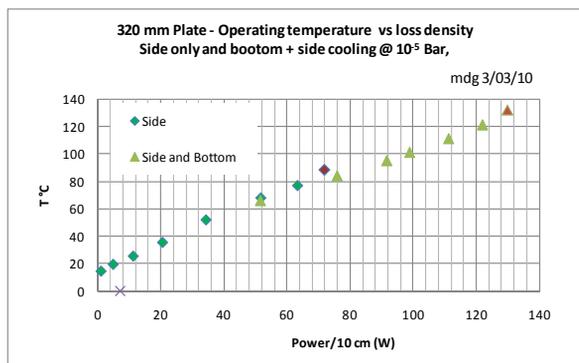


Figure 4: Measurement of operating temperature vs linear loss level.

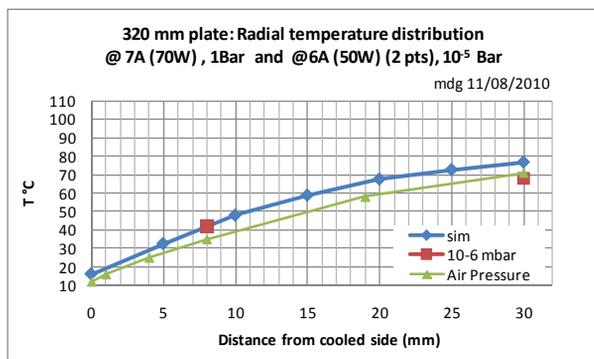


Figure 5: Operating temperature vs distance from cold point. Simulated and measured values.

Results [Fig. 4 and 5] show that the cooling principle works like expected but the high power operation of the meander is limited by other factors. In fact, an important number of U-bends, which are located very near to the cold point, were damaged even if the Alumina

temperature was rather low. All measured plots stop because of this problem (red dots in Fig. 4).

The phenomenon was attributed to a smaller width of the meander strip at corners, which is visible in Fig. 6, and led to a modification of the U-bend shape, which will be more rounded in the next version.



Figure 6: strip width reductions at corners.

RF Measurements

The 45-meander-period electrode prototype was dimensioned from a 2D strip-line model to fill the following requirements: $Z_c=100 \Omega$, delay such that $\beta=0.040$. Its dimensions are: track width= 0.45 mm, thickness= 30 μm ; meander period= 7 mm, width= 43 mm; alumina thickness= 3 mm.

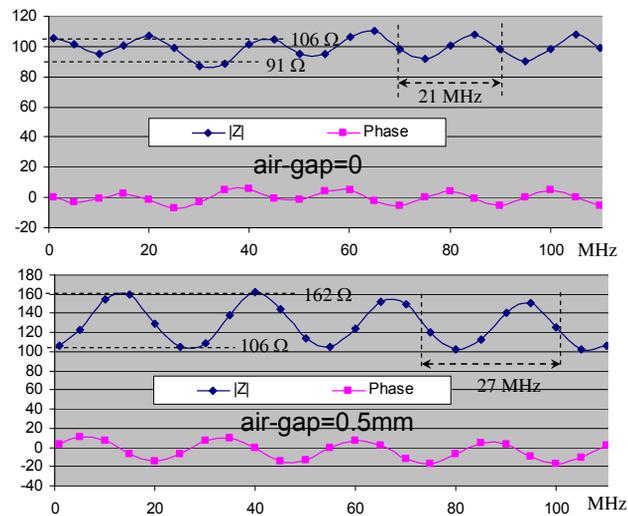


Figure 7: Impedance measurements on prototype electrode.

We measured the prototype characteristics, with an impedance-meter (Fig.7) and an oscilloscope: $Z_c=94 \Omega$, $\beta=0.044$. We also moved the alumina 0.5 mm apart from the copper ground, and we measured then: $Z_c=127 \Omega$, $\beta=0.057$. It came out that the discrepancy (with respect to expected values) was due to coupling between adjacent tracks of the meander.

RF SIMULATIONS

To improve the simulation efficiency, we first observed that wavelengths involved in transient voltages are rather long compared to the structure dimensions. So, both of magnetic and electric fields almost obey to Poisson

equation. They can be computed successively with a static solver (we used MAFIA). Inductance and capacitance values are computed from field integrals, then impedance, propagation delay and coverage factor are derived. We successfully validated this “static” method in the case of a single track with the Bahl&Garg microstrip formulas [7].

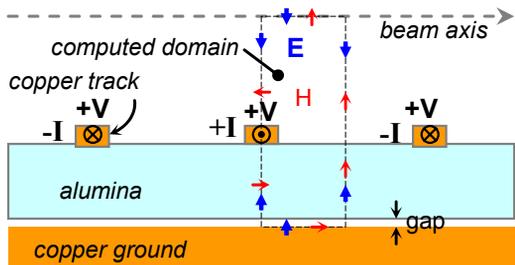


Figure 8: Boundary conditions for static solver.

Back to our geometry, symmetries and adjacent tracks are considered implicitly in boundary conditions (Fig. 8). Thus, the 3D-model is only a quarter of meander period (Fig. 9). Computed characteristics ($Z_c=89 \Omega$, $\beta=0.040$ with gap, $Z_c=129 \Omega$, $\beta=0.057$ without gap,) are now close to measured ones. We also showed [8] that the gap is approximately equivalent to increase the alumina thickness.

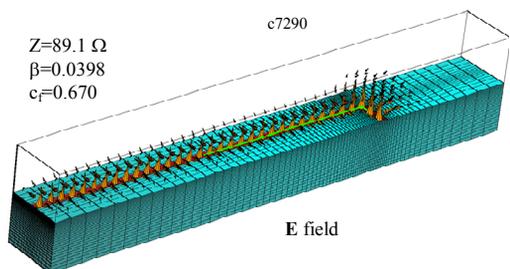


Figure 9: Electric field for “static” simulation.

To confirm our results, we used the MWS time domain solver on a multi meander-period model. We obtained almost the same results than with the static method, but the delay was slightly faster ($\beta=0.042$).

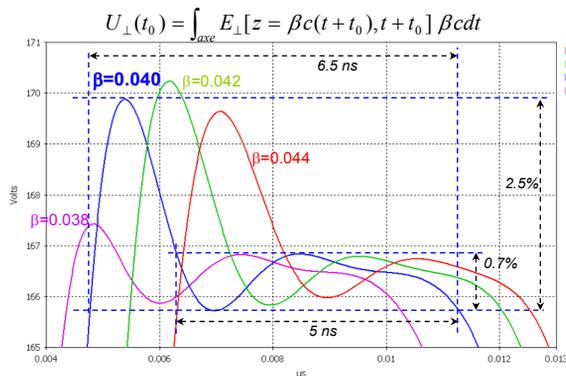


Figure 10: Transverse kick seen by the beam.

This much more time-consuming method (hour instead of seconds of CPU) has the advantage to consider transient effects. We can compute the actual kick

experienced by the beam for a given particle speed. After an initial overshoot due to frequency dispersion in the structure, the kick is rather flat (better than 1% for a 45-period meander). We also checked that the 3% discrepancy in delay estimation has no real consequence as shown in Fig. 10.

CONCLUSION

We eventually re-designed our electrodes (Fig. 11) to fit the specified impedance and delay. U-bends of the meander are now circular instead of rectangular to avoid high current densities in corners. Alumina is now 4.3-mm thick and lies directly on copper ground. Meander width is 50 mm and other dimensions are unchanged.

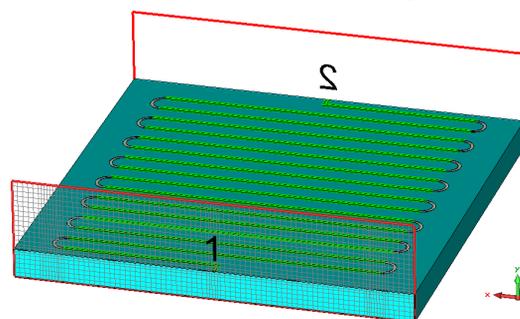


Figure 11: MWS model for new electrode geometry.

ACKNOWLEDGEMENTS

Authors are grateful to F. Caspers (CERN) for hints on lots of subjects, J.F. Leye for RF measurements, F. Consoli (INFN-LNS) for meander width measurements, C. Barthe-Dejean and F. Pellemoine for thermal simulation supervision, P. Toussaint for manufacture suggestions and Ph. Gallardo for providing indium strips.

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