# A NOVEL TYPE OF FORWARD COUPLER SLOTTED STRIPLINE PICKUP ELECTRODE FOR CSRE STOCHASTIC COOLING*

J. X. Wu#, Y. Zhang, G. Y. Zhu, M. Li, X. J. Hu, J. X. Xia, J. C. Yang, IMP, China
F. Caspers, CERN, Geneva, Switzerand

*Abstract*

A novel type of 2.76 m long slotted, or perforated, strip-line pick-up, or kicker electrode structure, for CSRe stochastic cooling of medium energy heavy ion beams with $\beta \sim 0.7$ is presented. It is installed inside a bending magnet vacuum chamber with the output signal taken from the downstream end. This slotted structure features a sufficiently broad bandwidth, good beam coupling impedance, low losses and a comparatively easy mechanical construction and installation into the CSRe dipole chamber. In this paper the electrode structure and pickup tank, as well as the beam test results will be presented.

## INTRODUCTION

A combination of stochastic precooling[1] and subsequent electron cooling is needed on CSRe[2] to get overall cooling times of the order of 10 seconds for injected secondary heavy ion beams with large momentum dispersion and transverse emittance, which the existing electron cooling can hardly achieve in a sufficiently short period. The development of a stochastic cooling system is very useful for performing competitive experiments with secondary rare isotope beams. As no straight section is available for the installation of pickups and kickers for the stochastic cooling on CSRe, they have to be installed in the C type bending magnet chambers. The aperture of the bending vacuum tube is 236 mm by 74 mm, thus the useful aperture is 220 mm by 70 mm. The space at the sides in the vertical direction can be increased by 4-5 mm if the electrodes are not placed in the middle. The space is extremely limited, especially in vertical direction. Also, the feed-through of the signal is problematic for the ultra-high vacuum system with a pressure of less than $3.5\times10^{-9}$ Pa. Therefore, the size and the number of pickups/kickers is severely limited.

A novel type of perforated travelling wave pick-up/kicker structure [3] has been developed and a pickup tank inside of the bending magnet was constructed and installed as well, see Fig. 1. Four electrodes are installed inside the beam tube to give the beam positions or provide the excitations. The electrode, which is following the bending vacuum chamber inside the dipole magnet, is 87 mm wide and 2.76 m long. It is supported and fixed by ceramic cylinders inside the beam tube. Two feed-throughs, one for signal output and one for the load resistor, are located outside of the magnet, which solved the feed-through problem very well. The thickness of the electrode metal foil amounts to 0.4 mm and the distance between the electrode and the ground is 3 mm. A detailed description of the slotted structure can be found in reference 3.

Figure 1: The slotted stripline electrode inside the bending vacuum tube (top) and the pickup tank installed on CSRe.

## MEASUREMENT RESULTS

### *Dispersion and Phase Velocity Measurement*

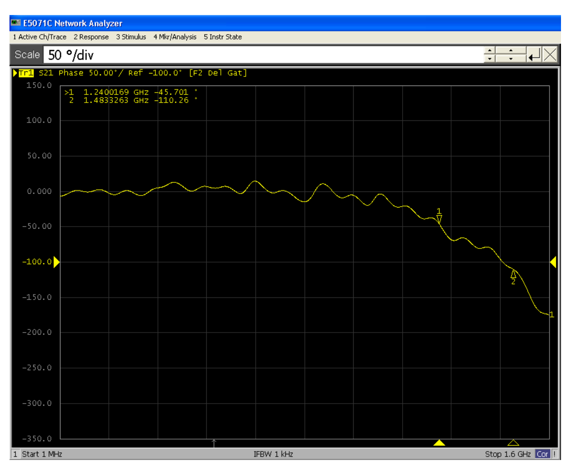


Figure 2: Phase dispersion measurement on a test bench.

*Work supported by NSFC (10705039) , HIRFL-CSR
#wujx@impcas.ac.cn


ISBN 978-3-95450-122-9

The phase response measurement of the 2.76 m long electrode is shown in Fig. 2. Below 1.2 GHz the difference from linear phase is never more than 45 degrees. Thus, in a frequency range from a few MHz to 1.2 GHz, this structure has a phase dispersion acceptable for CSRe stochastic cooling. Because of its rather good phase response, this slotted structure can be made very long to overcome the problems of intermediate signal feed-throughs in our case.

The phase velocity is measured using the resonant method [4]. It is close to 0.73c, see Fig. 3. The phase velocity variations are very likely due to the fact that the electrode is not flat after installation, also the gap between the electrode and the ground is not exactly the same for each electrode. After all it is difficult to install such a long, thin, bending-shaped electrode with many slots inside the bending magnet vacuum tube.

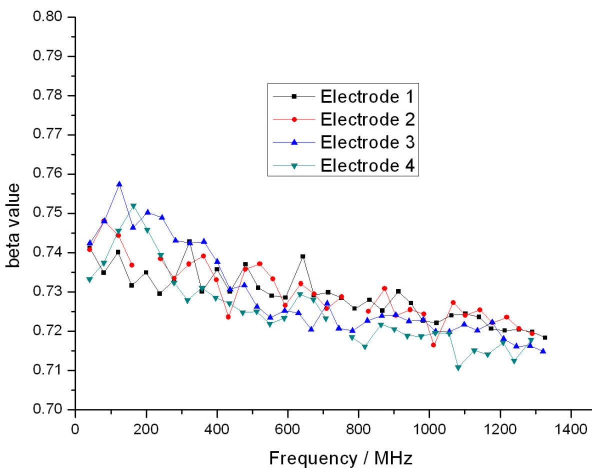


Figure 3: Phase velocity measurement.

### *Attenuation Measurement*

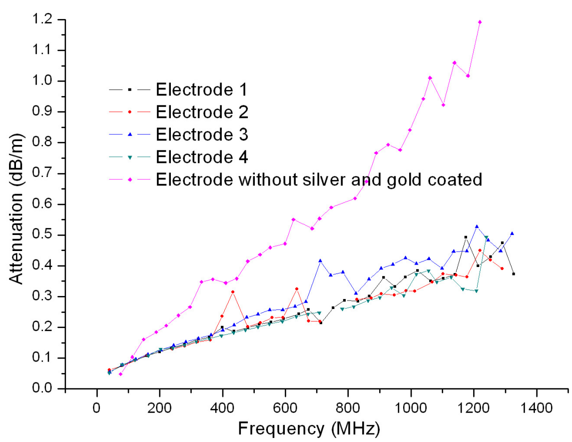


Figure 4: Attenuation measurement on a test bench.

After manufacturing the perforated copper electrode, about a 20 micron silver layer with a flash of gold was coated on it to improve the attenuation. We compared the attenuation with and without silver and gold coated for the same electrode, as shown in Fig. 4. It is clear that the electrode attenuation is decreased by half with silver and gold plated.

### *Characteristic Impedance Measurement*

Figure 5 shows the step response in real time obtained with a sampling scope. The characteristic impedance came out as about 16 Ω. The impedance can be increased by increasing the spacing between the electrode and ground, but in our case it is restricted. The variation of the characteristic impedance versus the spacing s between electrode and ground is also depicted in Fig 5. The difference of the electrical length between the electrodes is mainly caused by the phase velocity dispersion. From the result the electrical length is about 25.37 ns for the 2.76 m long electrode, so the phase velocity turns out to be roughly $\beta = 2L/ct = 0.725$, in good agreement with the resonant method.

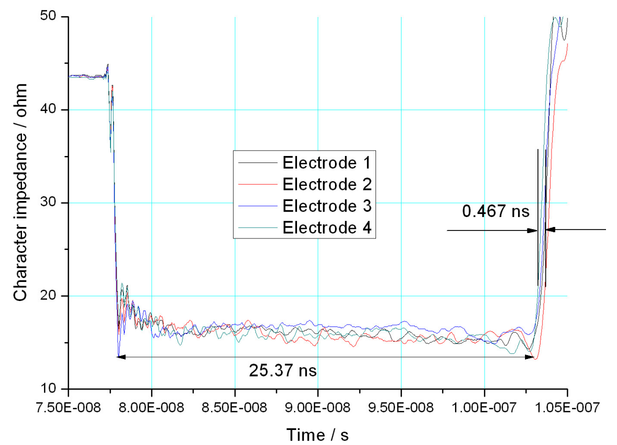


Figure 5: Impedance measurement results using the TDR (Time Domain Reflection) method.

### *Impedance Mismatch Effects*

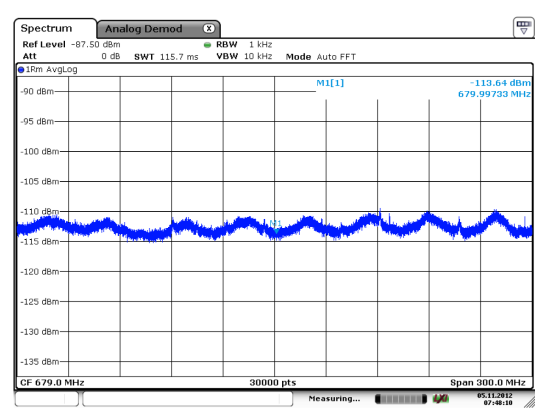


Figure 6: Noise measurement of the electrode.

From the above impedance measurement we can clearly see that there is an impedance mismatch between the electrode, the feed-through and the output signal transmission. This was also verified by the noise measurement after the pickup tank was installed on CSRe, shown in Fig. 6. There are undulations caused by the impedance mismatch and the undulated frequency is roughly about 37.5 MHz. From that we can get the length of the impedance discontinuity L= λ /2= β c/2f=2.92 m which is roughly the sum value of the electrode length and the feed-throughs.

It is obvious that the impedance mismatch effects cannot be ignored and we made several attempts to improve that. For the feed-through part, one way is to use 3 or 4 feed-throughs connected in parallel to the electrode to match the 16 Ω inside the vacuum. Outside of the vacuum, after three short 50 Ω cables, the signals would be preamplified first, and then combined. This requires much space for the N-type feed-throughs, which is not available. Another method is to use a modified N-type feed-through with 16 Ω by increasing the diameter of the inner pin and inserting the ceramic dielectric between the inner pin and outer conductor, see Fig. 7. At the outside of the feed-through, a multistage λ /4 transformer or another type of impedance transformer will be used to transfer the impedance from 16 Ω to 50 Ω. This option is preferred at present as it has no space constraints.

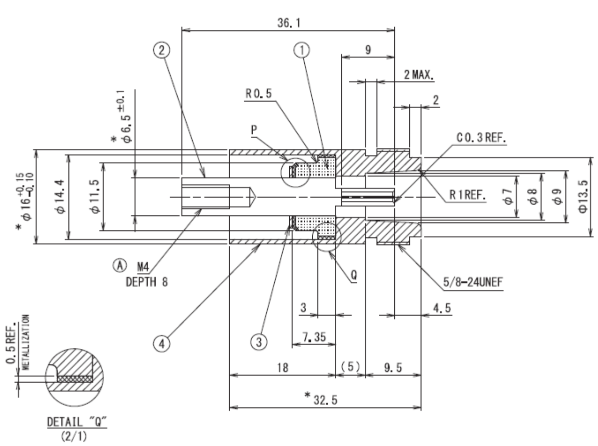

Figure 7: Special modified N type feed-through.

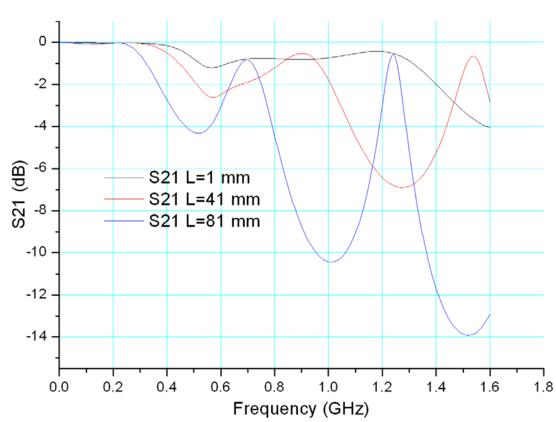


Figure 8: Transmission comparison from simulation for different length of the triangle section.

A triangular shape is used to gradually match the impedance of the feed-through at the end of the electrode. A simulation with CST microwave studio was done to decide whether the triangular section should be kept anymore if the feed-through has a wave impedance of 16 Ω. The result is displayed in Fig. 8, where L is the length of the triangular section. In the simulation it is assumed that both ports (excitation and receiver) have a wave impedance of 16 Ω, too. It is clear that the best solution is to leave the triangular part away.

### *Beam Test Result*

In September of 2012 the pickup tank was installed on CSRe and in November we did an experiment with a $^{117}Sn^{50+}$ beam with an energy of 253 MeV/u. The output signal was first preamplified by 34 dB and then after the transmission along a 10 m coaxial cable, it is further amplified by 40 dB for the weak signal to be sent to the spectrum analyzer. Figure 9 is one of the beam measurement results from one single electrode. The transverse and longitudinal signals can be observed clearly by the pickup.

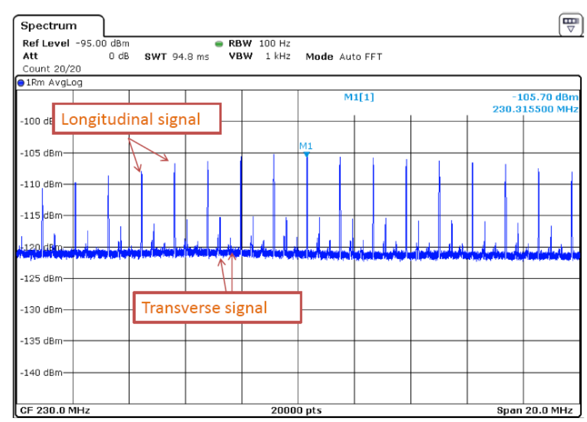


Figure 9: Beam measurement with the slotted pickup.

## CONCLUSION

A novel type of forward coupler slotted strip-line pick-up/kicker to be installed inside a 2.35 m long bending magnet was developed for CSRe stochastic cooling and successfully verified by a beam experiment. It is very well suited to the requirements of CSRe stochastic cooling. The following work will aim at solving the impedance mismatch effects and improve its performance.

## REFERENCES

[1] J.X. Wu et al., Stochastic Cooling Project at the Experimental Storage Ring, CSRe at IMP, Proceedings of COOL11, 2011.
[2] J. W. Xia et al., Nucl. Instrum. Methods, 2002, A488:11.
[3] F. Caspers, A novel type of forward coupler slotted strip-line pickup electrode for non-relativistic particle beams, ATS/Note/2011/075(TECH), 2011-09-09.
[4] T. Kroyer, F. Caspers, E. Gaxiola, Longitudinal and transverse wire measurement for the evaluation of impedance reduction measures on the MKE extraction kickers, AB-Note-2007-028.


ISBN 978-3-95450-122-9