STOCHASTIC COOLING PROJECT AT THE EXPERIMENTAL STORAGE RING, CSRE AT IMP *

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Abstract

Stochastic cooling at the experimental Cooler Storage Ring, CSRe [1] at the Institute of Modern Physics (IMP) in China, will be used mainly for the experiments with radioactive fragment beams. RI beams arrive from the fragment separator with emittance of 20-50 π mm. mrad and momentum spread *δp/p* of ± 0.5~1.0 %. The electron cooler, which is running now at the CSRe, is not able to cool down this hot beam rapidly enough. Stochastic cooling is effective for these RI beams to reduce the emittance to less than 5 π mm.mrad and of *δp/p* = 5e-4 within 2-20 sec. After stochastic pre-cooling, electron cooling will further cool down the emittance and momentum spread within several seconds. The paper gives the design of the stochastic cooling system and the simulation results. A recently developed forward traveling wave structure is presented as well as the measured results of a test model.

INTRODUCTION

CSRe ring has the circumference of 128.801 m with the layout in Fig.1. A combination of stochastic precooling and subsequent electron cooling is needed to get overall cooling times of the order of 10 seconds for injected secondary heavy ion beams and beams cooled by electron cooling to equilibrium phase space density. The development of a stochastic cooling system is very useful for performing competitive experiments with secondary rare isotope beams. Example of the setup of the stochastic cooling system is illustrated in the figure. It is planned to cool RI beam energies between 300 MeV/u and 400 MeV/u. As no straight section is available for the installation of pickups and kickers for the stochastic cooling and they have to be installed in the C type bending magnet chambers. The aperture of the bending vacuum tube is 236 mm *74 mm thus the useful aperture is 220 mm * 70 mm. The space at two sides in vertical direction can be increased to 4-5 mm if the electrodes are not placed in the middle. So the space is very limited inside it, especially in vertical direction, and the feedthrough is an issue. Thus the size and the number of pickups/kickers are severely limited.

For present operation mode which stochastic cooling will be used, internal-target mode with γ_{tr} = 2.457 and normal mode with γ_{tr} = 2.629, the frequency will be very low with large momentum dispersion of +/- 0.5~1.0 % which causes the slow cooling. A new optical mode at γ_t = 1.86 is developed which allows for an upper limit of the usable stochastic cooling bandwidth at about 1 GHz (of course the high frequency requires the microwave propagation attenuation in CSRe). At this optical mode the stochastic cooling system can be arranged in figure 1, sharing one pickup tank for the whole cooling system. The twiss parameters and the phase advance are shown in table 1. As this optical mode is never operated, the systematic simulation and experimental studies, such as optical optimization and beam acceptance measurement, will be performed in future.

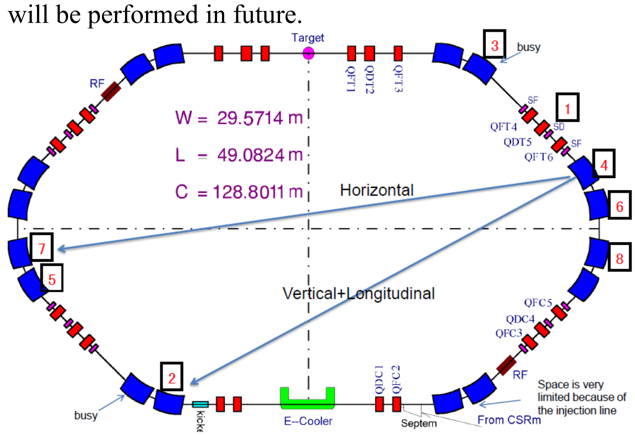

Figure 1 Typical layout of stochastic cooling pickup and kicker system

Table 1 Twiss parameters at pick-up/kicker position

	Horizontal		Vertical+Momentum	
	Pickup	Kicker	Pickup	Kicker
β_x (m)	19.9-14.3	6.6-7.6	19.9-14.3	16.8-11.9
β_y (m)	12.9-13.7	6.7-9.4	12.9-13.7	10.6-9.6
D_x (m)	9.3-7.5	6.0-6.1	9.3-7.5	0-0.4
θ	76^0		78^0	
L(m)	67		49	

PICK-UP/KICKER STRUCTURE

A novel type of perforated travelling wave pick-up/kicker structure is developed which was originally proposed by F.Caspers at CERN in 1998 [2], shown in Fig.2. The unit cell length is 12 mm and the thickness of the electrode metal foil amounts to 0.4 mm. The electrode which is following the bending vacuum chamber inside the dipole magnet is 87 mm wide and 1 m long. The distance between the electrode and the ground is 3 mm. The characteristic impedance is 17 ohm and it can be raised if the distance between the electrode to ground is increased, but in our case it is limited. A large number

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of small slots (5 slots in a row and 80 cells along the beam path) in this electrode provides distributed inductive loading, slowing down the phase velocity of the travelling wave structure. The reduction in phase velocity is a function of slot length, slot width, electrode thickness, and the spacing between the electrodes to ground. In contrast to other similar looking electrodes (Faltin type pick-up [3], McGinnis type slotted waveguide structure [4] for β=1) this device is very broadband and operating from low frequencies onwards as a forward coupler. Also advantages of the proposed structure are the simple and cheap construction as well as low mechanical height. This low height permits installation in a bending magnet where in our case vertical aperture is a big issue. This kind of inductive loading, using a large number of rather small slots is applicable for a β range from about 0.5 to 0.95. Due to the small size of the slots the frequency dependency of the inductance of these slots is very low and thus leading to a small dispersion over a large frequency range.

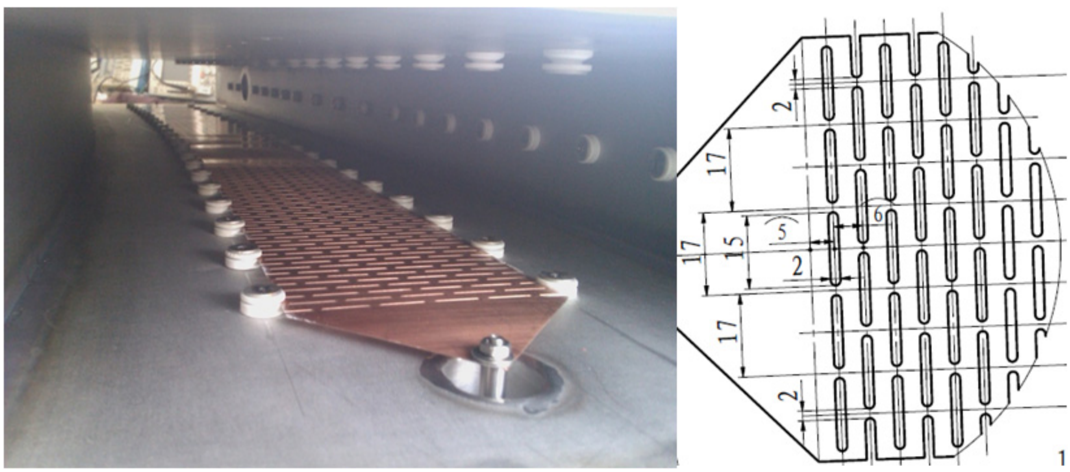

Figure 2: The slotted structure of travelling wave mode, number of cells = 80 and the length L is about 1 meter.

The measured transmission of the electrode is shown in Fig.3. Below 3 GHz the amplitude of the transmission is nearly flat. The phase difference from the linear phase (subtracted=delay term) is not more than 45 degree at 1.5 GHz for the nearly 1 m long electrode. Thus in a frequency range from a few MHz to 1.5 GHz this structure has a phase dispersion acceptable for CSRe stochastic cooling. As this structure has a good phase response, the length of the structure can further be increased, for example 2 m long and then one whole electrode inside the bending vacuum tube will overcome the problems of the signal feedthrough. Also the beam coupling impedance scales with the square of the electrode length.

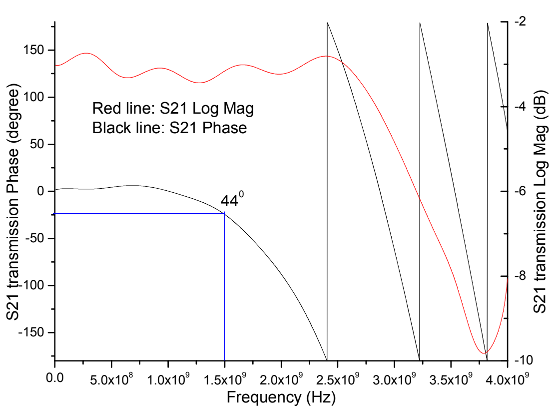

Figure 3: S_{21} transmission for 80 cells

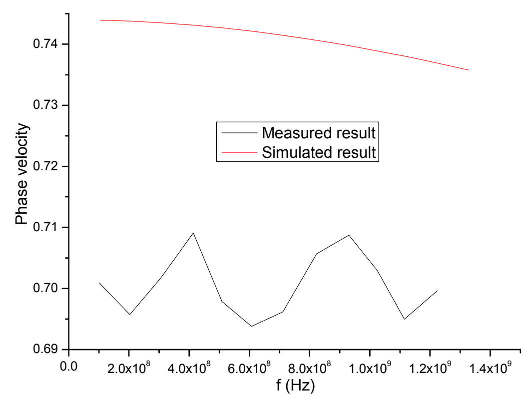

Figure 4: Phase velocity of 87 mm wide electrode

The measurement (resonant method [5]) and simulation results of the phase velocity are shown in Fig.4. The measurement result is roughly about 0.7 which is correspond to the beam energy of 380 MeV/u. The simulation result is a little bit larger than the measurement because in the simulation the attenuation of the electrode cannot be considered very well. For resonant method, of course the resonance frequencies can be very well defined but defining the correct effective length of the electrode is not straightforward. The geometrical length between the ends amounts to 106 cm, including triangular transition sections. Distributing the capacitance of these transition regions from a triangle to a strip with the full width of the electrode returns an effective length of 103 cm. The relatively strong variations for the indicated phase velocity vs frequency are raw data and have not a physical meaning. The variations from the resonator method are very likely due to the fact that the electrode is not completely parallel to ground (slight mechanical undulations that we can see from Fig.2).

The attenuation of the electrode is shown in Fig.5. It will be better if the stainless steel of the vacuum chamber and copper electrode is coated with 10 micron silver and a flash of gold which will be done in the following manufacturing. But for stainless steel this process requires a thin nickel layer on it and there is interaction with bending magnetic field. The analysis will be done further.

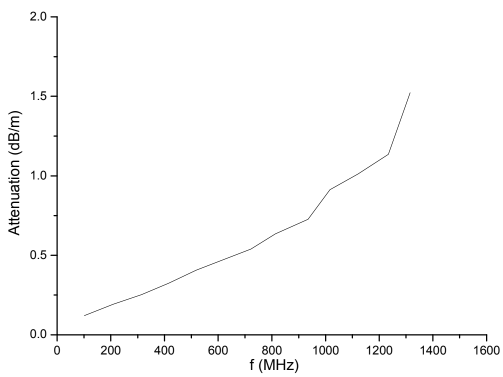

Figure 5: Attenuation values of the electrode

About the pick-up/kicker structure the detailed measurement, simulation and the analysis will be found in this committee presented by Y.Zhang [6].

COOLING SIMULATIONS

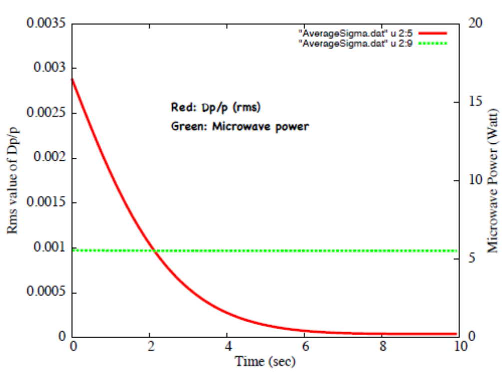

Figure 6: Evolution of rms Δ p/p & RF power

The upstream end of the pick-up will be connected to the input of a low noise pre-amplifier to get low noise temperature around 70^0 [7]. Then for the above pick-up/kicker structure if the bandwidth is 0.5-1 GHz, noise temperature is 80 K and gain is 130 dB, for beam $^{132}Sn^{50+}$ with particle number of 5e3 and beam energy of 380 MeV/u, the simulated result for the longitudinal cooling and the needed RF power is shown in Fig.6. We can get that in 3 s the rms momentum width can be reduced from 3e-3 to 5e-4. Since the pick-up/kicker structure has broad bandwidth more than one octaves we can even increase the bandwidth and get even faster cooling. Also the low RF power means less money to build the system.

CONCLUSION

The perforated travelling wave structure seems to fit best the requirement of the CSRe stochastic cooling system. It features a sufficiently broad bandwidth (amplitude flatness and phase linearity inside the required cooling band), good beam coupling impedance which scales with the square of the length of the device, low losses (low effective noise temperature at ambient physical temperature when operated as a pick-up) and a comparatively easy mechanical construction and installation into the CSRe dipole chamber. As a kicker structure the same design would lead to uncritical thermal cooling requirements in vacuum.

The low gamma transition lattice is preferable to get the effective cooling so as to extend the band width up to 0.5 GHz or more. From the simulation, as a pre-cooling of RI beams stochastic cooling is very effective and useful. Also the RF power is much small. Hopefully next step we can get the IMP support to precede the investigation and build the whole stochastic cooling.

The authors express their sincere thanks to Lars Thohndahl (CERN) for his analysis and advice of the perforated travelling wave structure.

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