Betatron Cooling for the Recycler

John Marriner
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INTRODUCTION

The design of the transverse stochastic cooling system for the Recycler appears to be straight-forward. The strong intrabeam scattering in the longitudinal phase space makes it difficult to achieve adequate momentum cooling rates with stochastic cooling system bandwidths of 4 GHz[1]. The transverse growth rates are expected to be smaller, resulting in lower demands on the cooling system.

The heating rate from intrabeam scattering is calculated to be nearly 0 (growth times greater than 20 hours) for the expected momentum spread of 0.02 to 0.03%. The growth time becomes as short as 20 hours only for an emittance[2] of 0.5π mm-mrad. This small an emittance would probably be avoided in practice because of the increased momentum heating rate from intrabeam scattering. Coulomb scattering from the residual gas would result in an emittance growth rate[3] of about 0.2π mm-mrad/hr for a partial pressure of 10^{-10} Torr of CO. The momentum cooling system will also heat the transverse planes. The heating rate primarily on the construction of the kicker, but one might expect a heating rate[4] of 0.1π mm-mrad/hr.

SYSTEM PERFORMANCE

The cooling system performance has been simulated by assuming an stack size of $5\infty10^{12}$, a parabolic momentum spread half-width of 5 MeV, and an initial emittance of 1.5π mm-mrad. The initial distribution of particle betatron amplitudes and that obtained after 1 hour of cooling are shown separately in Fig. 1 for a 2-4 GHz and a 4-8 GHz bandwidth cooling system. The distributions shown are for particles with $\Delta p/p=0$, and the simulation includes a transverse growth rate of 0.2π mm-mrad/hr.

[1] John Marriner, MI Note #0167.
[2] Unless otherwise stated, all emittances in this note are *unnormalized*. The *normalized* emittances may be obtained for the unnormalized one by multiplying by 9.5.
[3] Fermilab Recycler Ring Technical Design Report (Feb. 1996 draft version).
[4] This is a very crude estimate and a better job should probably be done. I assume that the momentum systems run at 10 times the power of the transverse cooling systems and have 20 dB common-mode rejection in the kicker. If the transverse system heats at 1π mm-mrad/hr (about the cooling rate), then the momentum system will be 10 times less. Betatron heating also results from a non-zero dispersion at the kicker.

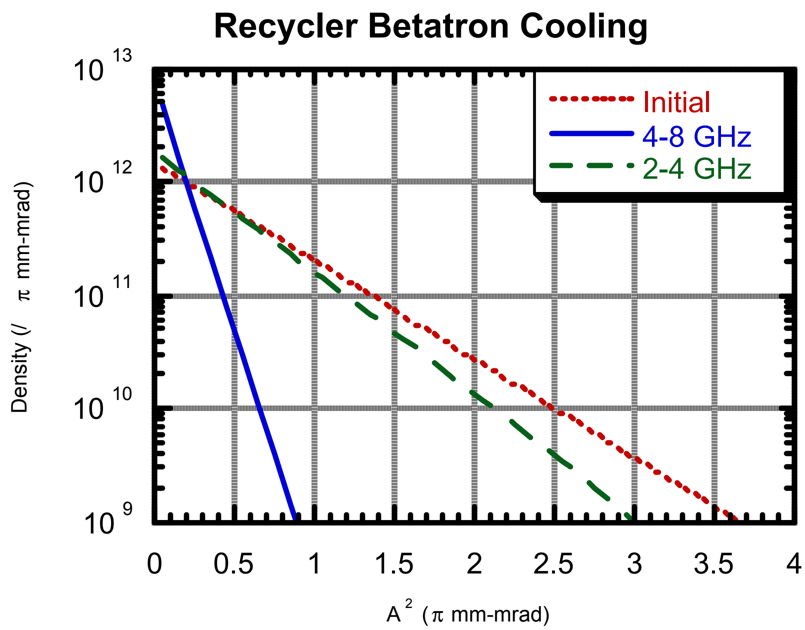

Fig. 1. Transverse emittance distribution cooling simulation for 2-4 GHz and 4-8 GHz cooling systems.

The 2-4 GHz cooling system demonstrates a much slower cooling time than the 4-8 GHz cooling system. This difference in cooling time results from the fact that the 4-8 GHz system has nearly 4 times the cooling rate (2 times for the bandwidth, 2 times for the mixing factor) and the fact that the assumed emittance growth rate of 0.2π mm-mrad/hr is a more substantial subtraction to the cooling rate of the 2-4 GHz system. Based on this type of reasoning, a 4-8 GHz cooling system is the preferred transverse cooling system. However, a 2-4 GHz system is probably sufficient with the assumptions that have been made — it just takes longer for the cooling process. The 4-8 GHz system also has a weakness that it can cool particles only over a ±10 MeV momentum range. If it should be necessary to cool particles in a larger momentum spread, the 2-4 GHz option would be preferred.

SYSTEM DESIGN PARAMETERS

The system parameters of the 4-8 GHz cooling system are given below. The 2-4 GHz cooling system parameters would be similar. It is assumed that there are 2 separate systems: one for horizontal and one for vertical.

Table I. Betatron Stochastic Cooling System Parameters

No. of Pickups	32	
Pickup Impedance	50	Ω
Pickup Sensitivity	0.8	
Dispersion at PU	0	m
Pickup Gap	10	π-mm-mrad
Noise figure	1	dB

PU to Kicker Mixing	0.2	
Minimum frequency	4	GHz
Maximum frequency	8	GHz
Maximum Beam	$5\infty10^{12}$	
Electronic Gain	112	dB
No. of Kickers	32	
Kicker Impedance	50	Ω
Kicker Sensitivity	0.8	
Dispersion at Kicker	0	m
Schottky Power	9	W
Amplifier Power	3	W
Total Power	12	W

LATTICE REQUIREMENTS

The lattice requirements for the betatron cooling systems are:

1. Pickups and Kickers are in regions of zero dispersion
2. $\beta_H \geq \beta_V$ at the horizontal pickup and kicker (vice versa for the vertical system).
3. Pickup to kicker phase advance an odd multiple of 90°.
3. Fractional tune near 1/4 in both planes.

CONCLUSION

A design of a betatron cooling system for the Recycler is presented. A 4-8 GHz system is the preferred solution, but a 2-4 GHz system would be considered if it appeared that there might be some difficulty confining the stored beam to the ±10 MeV momentum range of the 4-8 GHz system.

Appendix on Intrabeam Scattering

In order to make this document self contained, I have included the intrabeam scattering growth rate calculations performed by Pat Colestock. The horizontal heating rate is shown in Figure A1.

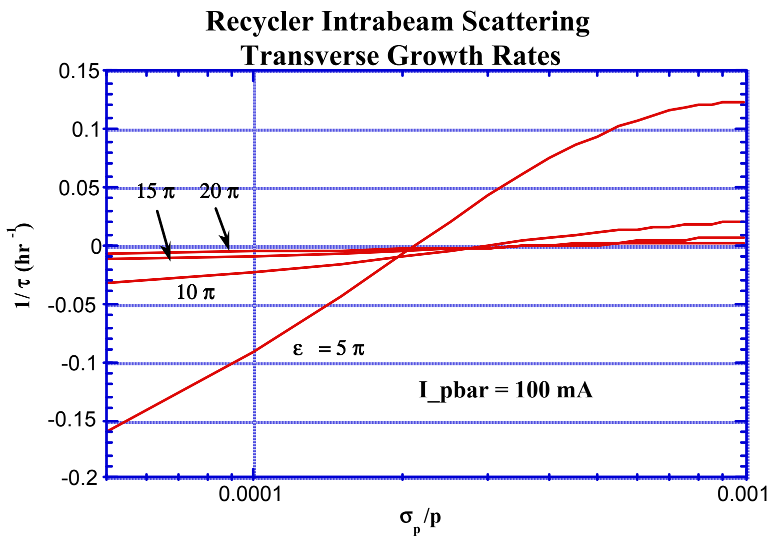

Fig. A1. Predicted transverse (horizontal) growth rates from intrabeam scattering.