Abstract

This report discusses the design and performance of 2 Ramped Quadrupoles (RQ). They are to be used to rapidly move the horizontal tune close to the half integer (7.5) for extraction of the up to 1.0 GeV electron beam stored in the SHR. The design chosen is an 8 conductor array symmetrically placed about the beam axis at ±15° to the 4 axes and connected to produce a quadrupole field. The conductors are half imbedded in a ferrite shield, a boost in the internal field strengths by about a factor of 2 and a significant reduction in external stray fields could be expected. This work is supported in part by the Department of Energy under contract #DE-AC02-ER03069.

I. GENERAL

The SHR design calls for a half integer beam extraction system to smoothly extract the stored electron beam of up to 80 mA average and up to 1.0 GeV energy during periods as short as 1.0 ms during the interpulse periods of the linac (1000 pps maximum and 1.32 microseconds pulse length for 2 turn injection). There are 3 octopoles and 2 ramped quads which make up the resonant extraction beam line components. A review of approaches taken by others in the literature include: current sheets in air[4], current tubes in vacuum, current tubes within flat ferrite plates, and some others with very complex end connections as the number of current elements becomes large. Aircore calculations using MATHCAD determine the resulting field gradients for symmetrically placed current elements about the axis. Calculations were performed for a number of conductors (4,8,12,16,20) at various angles and radii from the beam axis. The selected design was a compromise between a simple configuration and a good field region over a fair fraction of the aperture. By placing the conductors half buried in a ferrite shield, a boost in the internal field strengths by about a factor of 2 and a significant reduction in external stray fields could be expected. This design approach, reduces the required current and power by factors of 2 and 4 respectively, while doubling the inductance.

The horizontal β-function value at the lattice location of the RQs affects the amount of tune shift obtainable.
injector linac. The final circuit design is not yet finalized, but it is expected that we will drive the current into and out of the ramped quadrupoles by using a linear amplifier to gain experience in the extracted beam behavior at various energies from 0.3 to 1.0 GeV.

**IV. TESTING**

The tests performed on the RQs were done with the ferrite shield and DC current on the Harmonic Analyzer\(^\text{[2]}\) to measure the harmonics of the quadrupole fields. Figure 1 shows the relative strengths of the various harmonics as measured at various currents. Measurements of the median plane field and gradient strengths versus radius are shown in Figure 2. Harmonic field ratios for the ramped quadrupole are shown in Figure 3.

**V. ALIGNMENT**

The RQs will be measured to determine their magnetic axes, fiducialized and aligned using MIT-Bates standard methods\(^\text{[4]}\). The RQs can be placed in the SHR lattice to within ± 100 microns horizontally and vertically using these techniques.

**VI. CONCLUSIONS**

The requirements for a relatively fast quadrupole set to rapidly move the horizontal tune from 7.42 to close to the 7.5 half integer value for smooth resonant extraction from the SHR has resulted in the construction, testing and installation of the above described units. The use of ferrite rings to both boost the internal fields and to provide shielding has proved successful. The array of conductors has provided the required field strengths in a relatively simple arrangement. The excitation circuits while not finalized appear to be feasible and will be constructed in the near future. The system to produce a resonantly extracted electron beam is expected to be tried in the 2nd Quarter of this year.

**VII. REFERENCES**


By(x) and dBy(x)/dx versus X for 200 Amps DC for RQ1

Figure 2.

|Bn/B2| versus n for RQ1 at 192.32 Amps at R = 30mm

B0Left/a = 0.078324 Tesla

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Figure 3.