RESULTS FROM FIRST OPERATION OF THE SPALLATION NEUTRON SOURCE PROTON STORAGE RING

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The proton storage ring (PSR) at Los Alamos is an 800 MeV accumulator ring which has recently been constructed at the Clinton P. Anderson Meson Physics facility, LAMPF.[1] The prime use will be for driving a spallation neutron source for materials science applications. The design average current of 100 μA is to be achieved by operating the ring at a pulse rate of 12 Hz with a stored beam of 5.2×10^{13} protons per pulse. The 800 MeV H^- beam from the LAMPF linac is first magnetically stripped to H^o just outside the ring lattice and then is injected into the ring as H^+ by use of a 300 $\mu g/cm^2$ carbon foil stripper. During the injection period of 750-1000 μsec the rf voltage applied to the single 2.8 MHz buncher cavity is ramped up linearly from 3 to 15 kV, in order to counter the longitudinal space charge potential and maintain a 270 nsec bunch length. After accumulation of the linac macropulse is completed, the beam is immediately extracted in a single turn using a combination of two stripline kickers and a dc septum magnet.

PSR project construction was completed in late March, 1985, and a first low-intensity beam was circulated in the ring on April 26. Successful operation of the single-turn extraction system was achieved at the end of May. The concentration of effort during the summer was on understanding PSR operation at low intensities, improving controls software and beam diagnostics, and in wringing out equipment problems.

A major surprise for PSR tuners was the unexpectedly high level of beam losses occuring during the accumulation process, now firmly associated with scattering of the circulating protons in the injection stripper foil. Machine experiments focussed strongly throughout the summer on obtaining a clear picture of this phenomenon.

During a first high-peak current beam test (November 1985) the number of protons accumulated in the ring was raised to 1.6×10^{13} ppp, representing an average current of 30 μA at 12 Hz. PSR was then run at that average current level for several days to provide neutron-scattering users with first access to production. Several experiments were successfully carried out, and the users exhibited strong enthusiasm for the high neutron fluxes available at their spectrometers.

Fast beam loss was initially observed at peak intensities slightly above that of this production run. In later high-current tests, however, it was possible to raise the number of protons accumulated to 2.7×10^{13} ppp (half the design value) by increasing the transverse beam size in the machine and the buncher rf amplitude. At the end of the run cycle, the peak intensity in PSR was limited by the intensity of the presently available H^- beam. Ion source improvements now in progress should raise the H^- intensity high enough to permit machine experiments up to 4×10^{13} ppp during the 1986 run cycle.

During production at 30 μA, the beam losses appeared to be about 5%, which was associated with scattering from multiple passes of the stored protons through the stripper foil (3%) and the single-turn extraction process (2%).

The machine was operated at the tunes $Q_x = 3.2$ and $Q_y = 2.2$. The chromaticities $(dQ/Q)/(dp/p)$ were measured to be $\xi_x = -1.9$ and $\xi_y = -1.1$; predicted values were $\xi_x = -0.8$ and $\xi_y = -1.3$. This observation has suggested the possibility of a significant sextupole error in the ring lattice.

Early data showing the fast beam loss is displayed in Fig. 1, an oscilloscope trace of the circulating beam current vs. time into the injection cycle. The picture shows a linear ramp up to 1.6×10^{13} protons accumulated, followed by rapid loss of more than half the beam within about 100 μsec. The remaining beam is then extracted about 700 μsec after the start of injection. Information obtained from the storage-ring fast-position pickups suggests that the beam begins to execute coherent transverse motion just prior to the fast beam loss. The amplitude of the oscillation, which appears to start first in the vertical plane, grows with an apparent e-folding time of about 20 μsec.

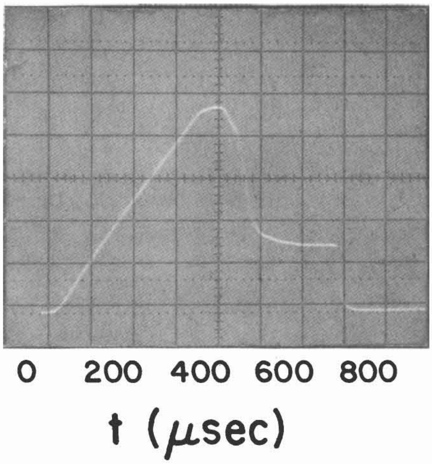

FIGURE 1 Oscilloscope trace of PSR current transformer output (accumulated current vs. time into cycle). Picture shows fast beam loss after reaching 1.6×10^{13} ppp, followed by extraction of remaining beam at 700 μsec.

During the present six-month shutdown, the commissioning team is studying results of the 1985 beam tests and implementing various improvements to PSR. They hope to uncover the source of the larger than predicted horizontal chromaticity and the foil-scattering losses. These phenomena may be related to one another. Detailed particle tracking through a model PSR lattice that includes non-linear effects and foil scattering falls short of predicting the magnitude of the observed beam loss by about a factor of ten. Several practical steps are being taken to reduce overall beam losses from scattering, including using thinner stripper foils, beam collimation in the ring, and opening up restrictive apertures.

Further studies of the possible coherent instability are planned with improved instrumentation for the next run cycle, which begins in July, 1986. The observations made to date are too preliminary to warrant initiating development of a fast transverse damper, a device that may, nevertheless, eventually be required to reach the PSR peak current design goal of 5.2×10^{13} ppp. In the meantime, equipment is being added to improve control over radial and longitudinal space-charge distributions and increase the effective working area in betatron tune space, all of which should aid in pushing the maximum stored charge level beyond what was achieved in 1985.[1] These improvements include the addition of harmonics to the fundamental 2.8 MHz buncher waveform, and installation of non-linear magnetic elements in the lattice.

REFERENCES

1. G. P. Lawrence, R. A. Hardekopf, A. J. Jason, P. N. Clout, and G. A. Sawyer, Los Alamos High Current Proton Storage Ring: A Status Report, IEEE Trans. Nuc. Sci. NS-32, 2662 (1985).