NEW LAYOUT OF THE RINGS FOR THE 0.5 MW / 10 HZ / 50 HZ AUSTRON SPALLATION SOURCE

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Abstract

In 1993-94 a feasibility study for AUSTRON, a neutron spallation source, was made. At that time the machine was a synchrotron cycling at 50 Hz and delivering an average beam power of 410 kW at 1.6 GeV. In 1998, the Austrian Government decided to contribute one third of the total cost of the facility and invited international partners to participate. In 1999, a more ambitious upgrading of the original concept was proposed aiming at 0.5 MW, pulsed at either 50 Hz or 10 Hz. The slower repetition rate is achieved by the addition of a storage ring holding four consecutive (single bunch) pulses from the 50 Hz synchrotron until a fifth pulse is accelerated and transferred to the target with the four stored ones, hereby increasing the intensity per pulse by a factor 5. The resulting 5-bunch pulse duration is 1 µs. The choice of the geometry is discussed, and the lattice design for the storage ring and the transfer line from the synchrotron presented. Also addressed are the critical longitudinal aspects resulting from the mandatory use of harmonic number one.

1 GEOMETRY OF THE COMPLEX

Figure 1 shows the rapid cycling synchrotron (RCS) nested inside the dc storage ring (SR). The beam height is equal for the two rings. The inner ring is slightly off-centred to provide extra space for the linking transfer line (TL). Separating the two rings completely would double the tunnel and shielding costs. Stacking the rings in the vertical plane would make it difficult to access the upper ring, which is a serious consideration in regions where the activity of the components is likely to be high.

In the chosen planar configuration, the circumferences of the two rings are in the ratio 13 to 16. This is used for a coarse synchronisation between the rings when transferring a bunch into one of the four rf buckets in the SR. If at time zero, the chosen empty bucket is not in the correct quadrant of the SR, a delay of four turns in the RCS will cause a slippage between the rings that rotates the pattern of the buckets in the beam direction by three quadrants. Thus a delay of four, eight or twelve turns provides a coarse synchronisation with any bucket. The fine synchronisation is taken from a pickup signal.

The design has been rationalised to have the same dipoles and quadrupoles throughout the linking transfer line, the SR and the extraction. The RCS is unchanged from the original design [1].

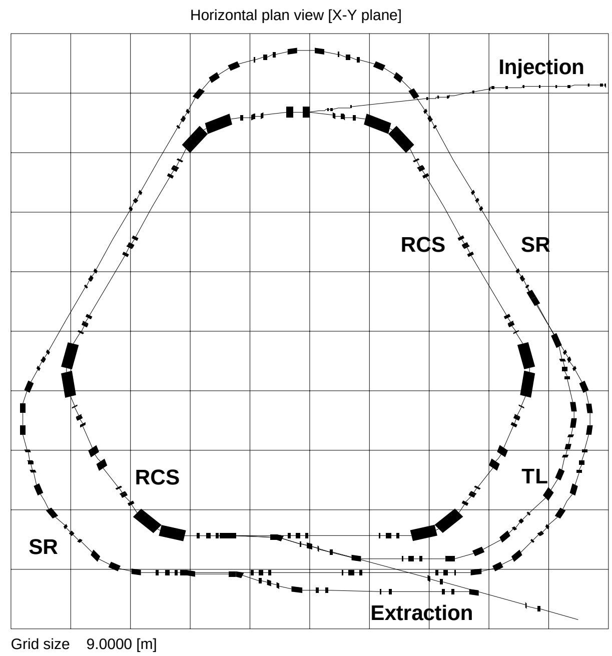

Figure 1 Layout of the Austron accelerator complex

2 LATTICE DESIGN

Figures 2, 3 and 4 show the lattice functions through the accelerator complex.

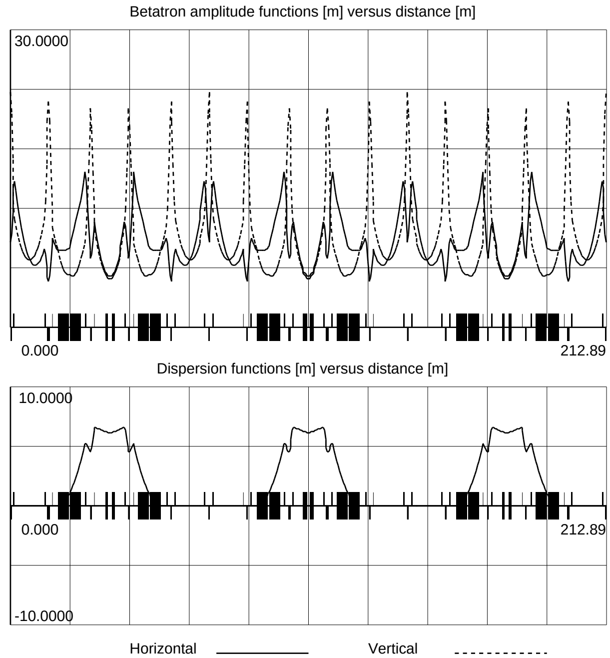

Figure 2 Lattice functions of the RCS

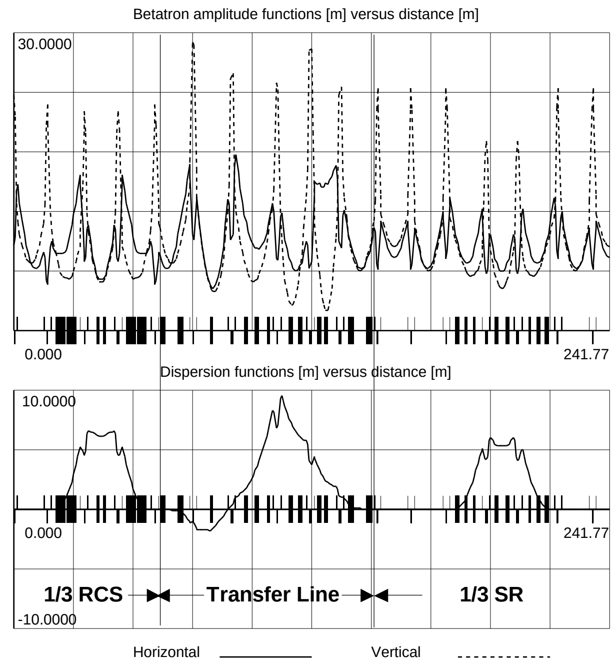

Figure 3 Lattice functions of one third of the RCS with the linking transfer line and one third of the SR

It should be noted that in Figure 3 the plots start and end at symmetry planes with zero dispersion in the RCS and SR respectively.

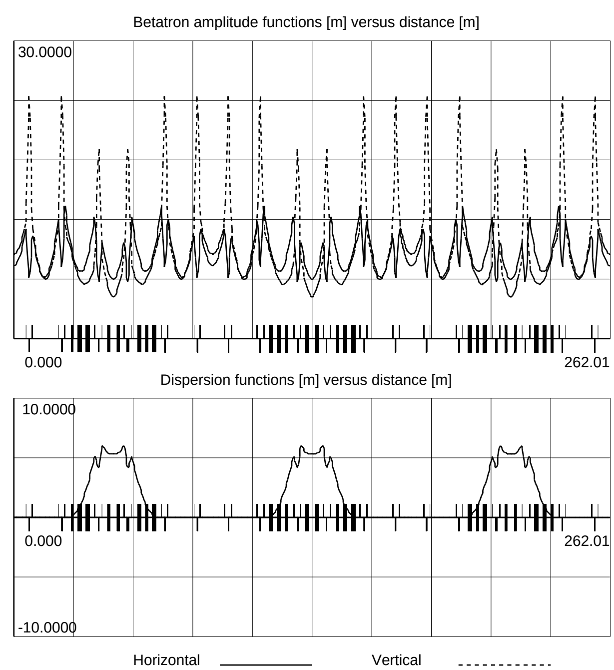

Figure 4 Lattice functions of the SR

In both rings, the quadrupole triplets are arranged with the larger betatron amplitude in the vertical plane, and values such that the horizontal betatron amplitude function with the dispersion function give equal beam sizes in the two planes. The dipoles benefit from small vertical beam sizes in both rings and the long straight sections have zero dispersion. The same kicker and septum units are used in both rings. The storage ring could be run with one dipole supply and one quadrupole supply powering two quadrupole families that differ only in length. The RCS tune values are $Q_h = 4.20$ and $Q_v = 4.33$, the SR tune values $Q_h = 5.17$ and $Q_v = 5.29$.

Figure 5 shows the horizontal and vertical beam sizes in one third of the RCS followed by the linking transfer line and then one third of the SR (corresponding to the lattice functions of Figure 3). The beam sizes are slightly larger in the linking transfer line, but even if the beam touches the poor field region this is of little importance as it is a single passage. The linking transfer line requires six independently powered quadrupole families to ensure the matching.

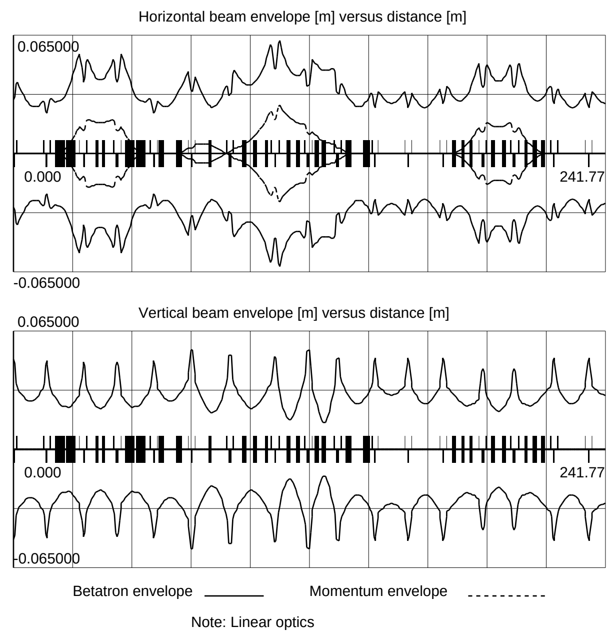

Figure 5 Beam sizes (1/3rd RCS – Transfer – 1/3rd SR)

3 LONGITUDINAL ASPECTS

The one change that is of prime importance in the RCS compared to [1] is the use of an $h = 1$ rf system. The rf capture and early acceleration is far more critical at $h = 1$ than for the previously chosen optimum harmonic number $h = 2$. This is mainly due to the reduced synchrotron frequency, rendering the rapidly changing theoretical bucket essentially non-adiabatic. Tracking studies, performed with the LONG1D code [2] that was already used in the investigation of earlier stages, aimed at the reduction of losses below 1% for an unchopped linac beam. In order to achieve this for the 0.5 MW / 50 Hz version of 1999 at $h = 2$, the acceleration time had to be extended by use of a dual-frequency magnet cycle, plus flat bottom clamping during 0.44 ms [3]. This clamping turned out to be insufficient for $h = 1$, and a loss figure of ~0.5% could only be achieved with an extended flat bottom of 0.65 ms. One would expect further loss reduction by the use of chopping.

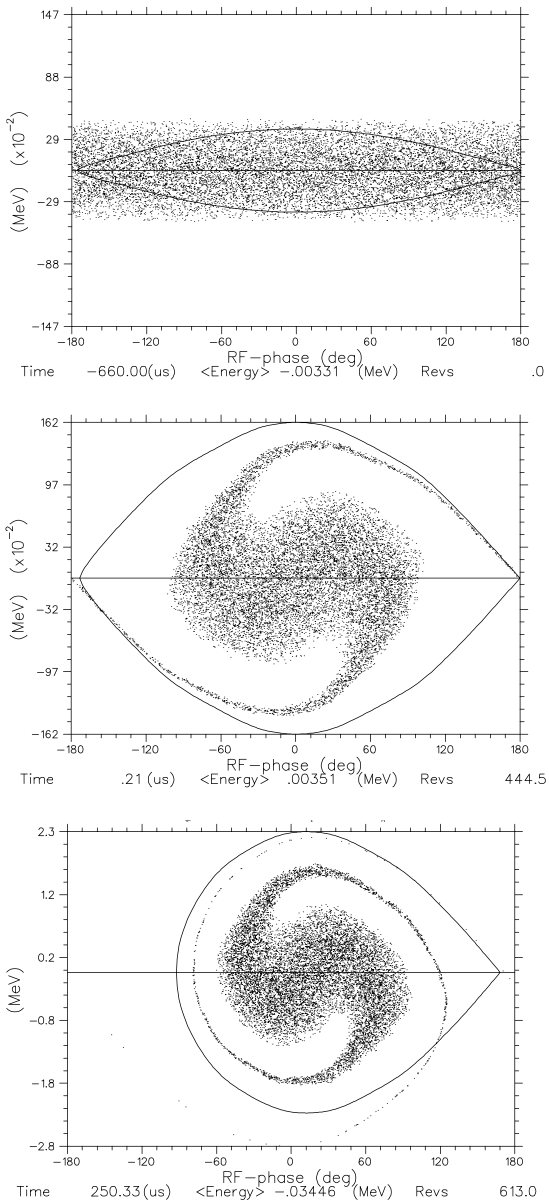

Figure 6 Phase space plots of rf capture in the RCS

Figure 6 shows longitudinal phase space plots of various stages during the capture process in the RCS. The top picture shows the incoming coasting linac beam. The middle picture shows the situation at the end of the clamping time i.e. at the start of the field ramp. Tracking experience suggests that the minimum loss is obtained when the linac beam has rotated by 180 degree at this moment. The bottom picture shows the beam 0.25 ms later during early acceleration. Only the part of the filament outside the separatrix will be lost, the other part is recaptured by the continually rising rf voltage.

The increased clamping time raises some concern as it reduces the already tight magnet fall time of ~5 ms to an extent where the induced voltages become unbearable. This problem could be alleviated by suitably programming the magnet cycle using IGBT power converters. In fact, acceleration could easily be speeded up at high energies, where the rf bucket is very large relative to the beam. This is illustrated in Figure. 7, which shows the RCS bucket, scaled with respect to the bunch, and the bunch transfer into the waiting, matched, $h = 4$ rf buckets of the storage ring. The bunch length at extraction is 76 ns, the corresponding rf voltages are 250 kV in the RCS and 65 kV in the SR.

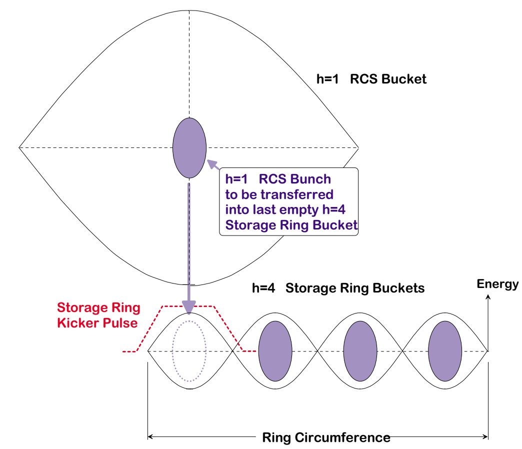

Figure 7 Bunch-to-bucket transfer from RCS to SR

4 CONLUSIONS

The accumulation of beam in a second ring and the subsequent operation at 10 Hz with fivefold intensity increase in the individual pulses is of prime interest to the potential user community of AUSTRON, since it transforms the machine, when compared on a single pulse basis, into a world leader. The feasibility of crafting this upgrade onto the existing machine study has been demonstrated. There are now many engineering details to be studied before an execution design can be completed. In particular, the main power supply of the RCS will require considerable development, since it will be at the forefront of today's technology. Spallation sources in general require an extremely tight loss management system. In the new layout, the additional extraction and injection insertions will be potential points for beam loss and will need to be designed and monitored accordingly.

5 REFERENCES

[1] F. Baumann and 27 co-authors, "The accelerator complex for the AUSTRON neutron spallation source and light-ion cancer therapy facility", CERN/PS 95-48 (DI).

[2] S. Koscielniak, "The LONG1D Simulation Code", EPAC'88, Rome, June 1988.

[3] P. Bryant, E. Griesmayer, E. Jericha, H. Rauch, M. Regler, H. Schönauer, "A 0.5MW / 10Hz Option of the Spallation Source AUSTRON", PAC'99, New York, April 1999.