MEGAWATT UPGRADES FOR THE ISIS FACILITY

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Abstract

ISIS is the spallation neutron source at the Rutherford Appleton Laboratory in the UK. Presently, it runs at beam powers of 0.2 MW, with upgrades in place to supply increased powers for the new Second Target Station due to start operation in Autumn 2008. This paper outlines possible schemes for major upgrades to the facility in the megawatt regime, with options for 1, 2 and 5 MW. The favoured ideas centre around new ~3 GeV rapid cycling synchrotron (RCS) designs that can be employed to increase the energy of the existing ISIS beam to provide powers of ~1 MW or, possibly as a second upgrade stage, accumulate and accelerate beam from a new 0.4 – 0.8 GeV linac for 2 – 5 MW beams. Key features for a new ring design are presented, along with a brief summary of the main aspects of a future design study.

INTRODUCTION

The Rutherford Appleton Laboratory (RAL) is home to ISIS, the world's leading operational spallation neutron source. ISIS has two neutron producing target stations (TS-1 and TS-2), driven at 40 Hz and 10 Hz respectively by a 50 Hz, 800 MeV proton beam from a rapid cycling synchrotron, which is fed by a 70 MeV H^- drift tube linac [1]. Recent accelerator upgrades should allow beam powers of up to 0.24 MW in the near future [2]. This 0.24 MW version of ISIS is the assumed starting point for any upgrade, and is shown in green in figure 1.

MAIN UPGRADE OPTIONS

Upgrade routes for ISIS are summarised in table 1. All designs are to be developed primarily for an optimised neutron facility, and should include the provision of an appropriate proton beam to the newly built ISIS TS-2 [3]. The list here is not exhaustive, but presents the main, reasonable routes that would provide a major boost in beam power. Primary considerations are the cost relative to a new facility and the impact on ISIS operations. Some less optimal ideas are included to put the favoured options into context, and to show some alternatives in case financial and operational priorities change.

Option 1: Add a new 180 MeV Linac and/or 800 MeV Synchrotron

These are major upgrades which increase power by increasing beam current. Beam powers of 0.4 – 0.9 MW may be possible. There are two main options: (a) replace the existing 70 MeV linac with a higher energy ~180 MeV linac, and (b) add a second, nominally identical, 800 MeV synchrotron in the existing hall.

The first option simultaneously replaces one of the oldest parts of ISIS, and with reduced space charge and optimised injection, potentially increases intensity in the ring (~0.4 MW). It is possible that the new linac could be constructed and commissioned in an existing neighbouring hall, with minimal interruption to ISIS operations. However, there are some important reservations: the precise increase in intensity is difficult to predict (perhaps a factor of 1.8), and a practical design for injection at this energy has yet to be established.

The second option is in principle a simple and predictable doubling of beam intensity (~0.5 MW), as long as the linac can provide longer pulse lengths to supply two rings operating in parallel (although this would at very least require a completely new linac RF system). Unfortunately, the practicalities of installing another ring in the existing hall, without a major impact on ISIS operations, make this option look very difficult to implement.

Combined (c), these two upgrades have the potential

Table1: Possible ISIS upgrade options. *Neutron yield is compared with 0.24 MW ISIS – $E^{0.8}$ scaling used may be pessimistic, but should give good allowance for engineering penalties.

Option		Comments	Beam Power (MW)	Neutron Yield*
1(a)	Add 180 MeV Linac	Technical Issues	~ 0.4	1.7
1(b)	Add 800 MeV RCS	Operational Issues	~ 0.5	2.0
1(c)	Upgrades 1(a) + 1(b)	Technical/Operational Issues	~ 0.9	3.8
2	Add ~ 3 GeV RCS	Recommended 1st Upgrade	1	3.2
3	Add ~ 6 GeV RCS	Technical/Cost Issues	2	5.6
4	Upgrades 1 + 2 or 1 + 3	Technical/Operational Issues	~ 2 – 6	~ 6.4 – 16.8
5	400 – 800 MeV Linac + 3 GeV RCS	Recommended 2nd Upgrade	2 – 5	6.4 – 16.0
6	1.3 GeV Linac + Accumulator Ring	Good “Green Field” Option	5	18.8

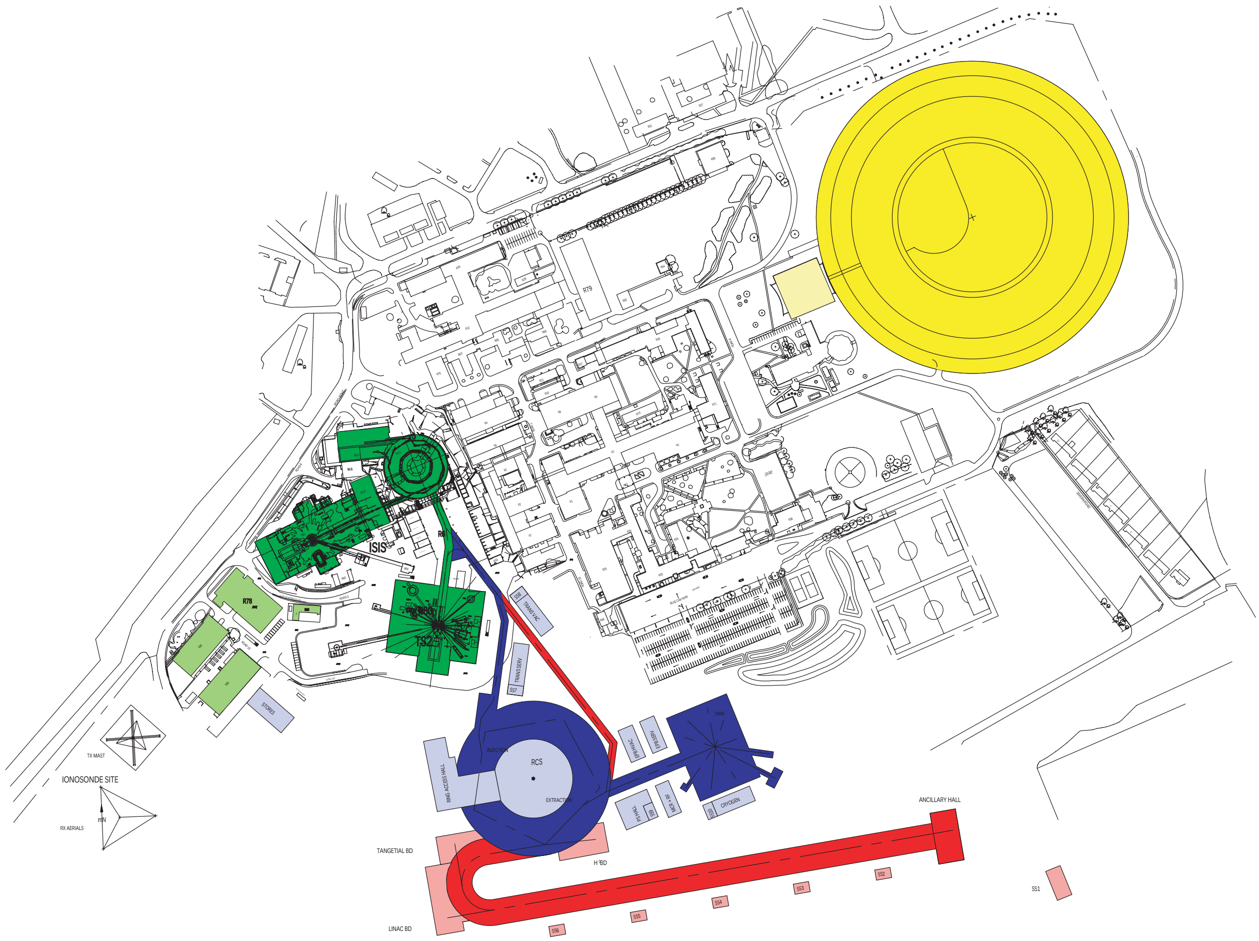

Figure 1: Schematic showing the RAL site with ISIS (green), the recently built Diamond light source (yellow), upgrade Option 2 (blue) and upgrade Option 5 (red).

for ~0.9 MW, but with the associated problems already noted. In addition the capability of TS-1 above 0.5 MW would need to be carefully considered, with the probability that a third target station (TS-3) would then be required. There are more practical and predictable options, assuming appropriate funding is available, and therefore these routes are not recommended. However, these ideas could well become more important if obsolescence of the linac becomes an issue in the future, or if funding priorities or assumptions change.

Option 2: Add a new ~3 GeV Synchrotron

This upgrade increases beam power to ~1 MW by taking the output of the existing facility and increasing beam energy by adding a ~3 GeV RCS. This new ring would require a new building, along with a new 1 MW target station. This could be built with minimal interruptions to ISIS operations, gives predictable increases in power at reasonable estimated costs, has well defined upgrade routes, and is the favoured upgrade path.

A number of candidates exist for the ~3 GeV, 50 Hz ring, but it is most likely to be based on a design with five superperiods outlined in [4] and shown in figure 2. This design includes features required for fast injection directly from ISIS, plus the option for optimised multi-turn injection from a new 400 – 800 MeV linac, which would allow for upgrades to the 5 MW regime (see Option 5 below). A key feature of the ring is the ~100 m set aside for RF acceleration systems, which are needed to achieve the required energy at 50 Hz (twice the frequency of the roughly comparable J-PARC ring [5]). A more detailed layout for this option, including a possible location and supplementary buildings is shown in blue in figure 1.

Option 3: Add a new ~6 GeV Synchrotron

This option is the same principle as Option 2, but taking the energy higher gives the possibility of a single step upgrade to ~2 MW. Unfortunately, an appropriate ~6 GeV, 50 Hz ring is technically challenging, potentially expensive, and not thought a practical proposition when compared with other options. The main difficulties centre on achieving the required acceleration in the space available, with additional concerns over longitudinal stability at the higher energy. Further upgrade routes are also uncertain, with optimised multi-turn injection lattices being more difficult in a higher energy ring.

It is unlikely that this upgrade will represent good value when compared with 2 or 5 MW via Options 2 and 5. This is also at an energy significantly higher than the preferred ~3 GeV for neutron production.

Option 4: Upgrades to the 800 MeV Machine plus a 3 or 6 GeV Ring

This upgrade combines the ideas of Options 1 and 2 or Options 1 and 3. Implementing both upgrades in Option 1 results in powers of ~0.9 MW. Adding the 3 GeV synchrotron of Option 2 leads to powers of 3 MW. Similar calculations for the 6 GeV ring suggest powers of 6 MW.

Whilst the ideas are interesting in that they apparently offer high beam powers, they include all the problems and uncertainties of Option 1. In addition, it is not clear that the higher energy rings could operate with acceptable loss levels whilst at these higher intensities. The combination of uncertainty and impracticality makes these options hard to recommend compared to Options 2 and 5. As in Option 1, there may be reason to pursue these ideas with some detailed studies if funding and operational priorities change.

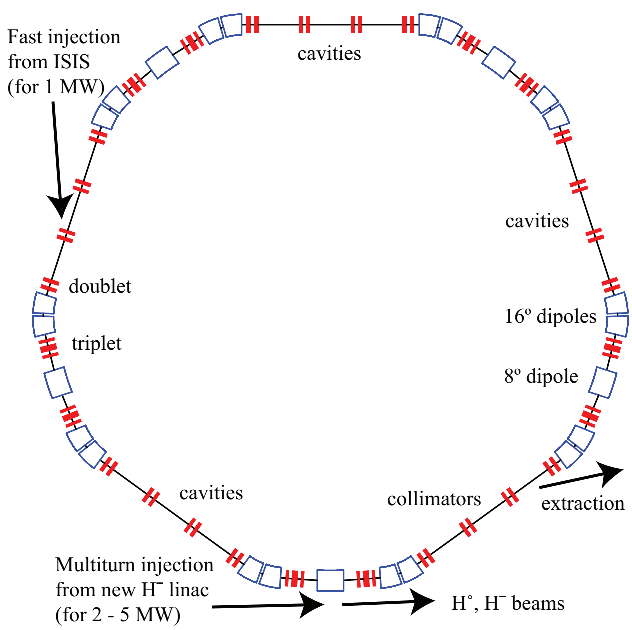

Figure 2: Schematic layout for the 0.8 – 3.2 GeV, five superperiod, doublet-triplet, RCS.

Option 5: A 400 – 800 MeV Linac Plus a 3 GeV Synchrotron

This option uses a 3 GeV, 50 Hz ring injecting directly from a 400 MeV linac, providing 2 MW. Increasing linac energy (~800 MeV) provides upgrade options to 5 MW. This option could either be a second upgrade from Option 2, or a new green field option. As a second stage upgrade to ISIS, the machine given by Option 2 could continue to operate whilst the new linac was constructed. Some interruption would be required while the new injection line and system for the 3 GeV ring were constructed and commissioned. It should be noted that a significant collimation section or "achromat" would be required after the linac, to provide a suitably stable beam for injection. The overall accelerator configuration is similar to the JPARC machine [5], but the synchrotron is slightly larger and runs at twice the repetition rate. This is a predictable option with reasonable estimated cost, based on well established design ideas, and is the recommended upgrade route to 2 and 5 MW.

A more detailed layout for this option as a second upgrade from Option 2, including a possible location, and supplementary buildings is shown in red in figure 1.

Option 6: A 1.3 GeV Linac plus an Accumulator Ring

This is a new machine based on the favoured ESS design. This consists of a 1.3 GeV linac and an accumulator ring (circumference ~220 m), giving a beam power of 2.5 MW. The addition of a second ring gives the 5 MW proposed for the ESS 50 Hz target [6]. This is a well studied design that provides a useful reference point for ISIS upgrades.

SUMMARY AND FUTURE WORK

The favoured routes for major upgrades to ISIS have been identified as Options 2 and 5. As more detailed design studies begin, the relative merits of these options compared with existing designs and machines (e.g. ESS, Option 6) will be considered in more depth.

Work is now underway to study the key issues for the ring and linac designs. For the rings the main topics are space charge, injection, provision for RF, beam stability and loss control. Many of these topics are already the subjects of detailed studies applied to the ISIS ring [7, 8, 9]. A suitable linac for Option 5 is being designed by the ASTeC Intense Beams Group at RAL.

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