High-Power Setup Procedure

Revision: 1.0, 13 July, 1998
Keeper: D. Douglas, x7512

A. Prerequisites/Philosophy

1) Select wavelength/electron beam energy for run
2) Hardware/software punch list complete
3) CW lasing to 2G00 dump with 60 pC/bunch with ½% extraction efficiency
4) Baseline emittance measurement at 2G00 (and in 2F03 region) without lasing
5) Increase power by frequency doubling to 37.4 MHz, pushing extraction efficiency and then pushing charge/bunch as last resort
   a) Reduces load on gun power supply
   b) Stays out of high space charge regime; avoids rematch problems
   c) Puts stress on momentum acceptance of recirculator system

B. Overview

1) Initial beam thread to backleg dump
   a) Set magnets
   b) Thread first arc
   c) Thread backleg
   d) Orbit optimization
   e) Difference orbits/test lasing
2) CSR checkup
   a) rematch
3) Initial thread to reinjection dump
   a) Thread second arc
   b) Orbit optimization
   c) Difference Orbits/test lasing
4) Reinjection thread
   a) Set magnets
   b) Beam to 1G00
5) Longitudinal matching/RF checkout
   a) Adjust path length to set energy
   b) Turn on sextupoles to reduce momentum spread
   c) Adjust momentum compaction to reduce momentum spread
6) Orbit optimization/rematch
7) Pulsed lasing with energy recovery

8) CW Setup/RF checkout
9) CW Lasing/RF checkout
   a) Hold 60 pC/bunch
   b) Push freqency to 37.4 MHz
   c) Push extraction efficiency to 1%
   d) Push charge/bunch beyond 60 pC insofar as system is tolerant.

C. Initial Beam Thread to Backleg Dump

1) Turn off beam, go to 2 Hz pulse mode
2) Fire up arc dipole string
   a) Turn off MDX2G01 trim winding (on MDX3F01)
   b) Verify DY shunts are at 0 excitation
   c) Download buss settings and cycle string
   d) Download and set DY shunt settings
   e) Download and set using Karn protocol DQ trim winding settings
3) Download downstream telescope quad settings (Prerequisite 2) assumes you are centered in these quads so no resteering will be needed and the injection into the arc will be essentially straight with the pre-existing corrector settings)
4) Download backleg quad settings
5) Insert backleg dump IDC4F12
6) Thread 3F arc and 4F backleg. Turn on beam in 2 Hz pulsed mode with FEL laser shutter closed (no lasing)

   a) *Arc Thread*
      i) Using MD(B/H)2F08(H/V), acquire/center beam on IPM3F02
      ii) Using MD(F/C)3F0(1/2)(H/V) acquire/center beam on ITV3F02
      iii) Center beam in QH3F01 and 2 using MD(B/H)2F08(H/V) (this is overconstrained, and if the initial straight-through setup is right and the elements all well aligned, should happen automatically)
      iv) Recenter beam on ITV3F02 using MD(F/C)3F0(1/2)(H/V)
      v) Using MD(F/C)3F0(1/2)(H/V) acquire/center beam on IPM3F02B
      vi) Using MD(F/C)3F0(4/3)(H/V) acquire/center beam on IPM4F01

   b) *Backleg Thread*
      i) Using corrector on each quad, acquire/center beam on next 2 diagnostics (note polarity on quads and FODO lattice indicates this overconstraint should not be troublesome) until beam is at backleg insertable dump

   c) *Arc/Backleg Orbit Smoothing*

i) Using viewers ITV4F0(6-8) center beam in MQH3F03 using MD(F/C)3F0(1/2)(H/V); verify beam remains centered on ITV3F02. Inability to meet all these constraints suggests orbit is not properly aligned on entrance to MDY3F03 or that MDY3F03 excitation is mismatched. Call magnet performance integrator for support.
ii) Using viewers ITV4F0(6-8) center beam in MQH3F04 using MD(F/C)3F0(4/3)(H/V).
iii) Using viewers ITV4F0(6-8) center beam in MQG4F01 using MD(F/C)3F0(4/3)(H/V). Beam should remain centered in MQH3F04 during this process. Failure to achieve simultaneous centers implies alignment problem or mis-excitation in dipole string. Call magnet performance integrator for support.
iv) Using viewers ITV4F0(6-8) center in upstream backleg quads using previous correctors. Note horizontal centering is most effective at quads with positive polarity, vertical centering is most effective at quads with negative polarity, so don't fuss too much over centering in the conjugate case – for example, don't knock yourself out centering vertically in MQG4F02, or horizontally in MQG4F03.
v) Continue centering in quads down to MQG4F09, using ITV4F10. Center, as best you can, in MQG4F10 and 11 using IPM4F12. This should put you into IDC4F12, the insertable dump.

7) If beam spots are good through the system:
   a) *check momentum/betatron aperture with difference orbits*
   b) *lase in pulsed mode into IDC4F12* to check momentum apertures and limit scraping. Push extraction efficiency to 1% to ascertain limits to momentum acceptance (use BLMs as needed to verify).
      i) Shift in beam energy centroid due to lasing may necessitate shift in dipole excitation to avoid scraping:
         (1) Verify DY shunts are in percentage mode
         (2) Decrease dipole string strength to center beam with lasing on ITV3F02 (dispersion comparable to optical cavity chicanes)

      Be prepared to back this shift out (and cycle dipole buss) when proceeding with thread through 5F arc

   If beam spots are not good through the system, proceed with following CSR check and then rematch.

D. CSR Checkout/Rematch

1) Detune FEL and restore pulsed beam conditions present prior to lasing test. If dipole buss has been shifted to accommodate enlarged momentum spread, reset buss using procedure of Step C 2).
2) Check emittance and beam envelopes at start of backleg using quad/monitor or multi-monitor techniques. This is to be compared to result of measurement specified in Prerequisite A 3).
3) If modest mismatch is detected or measurement cannot be performed, adjust downstream matching telescope to meat-ball beam through and get a measurement that can be used as a basis for a rematch.
   a) If CSR is a very dramatic effect, the downstream telescope match that will allow us to proceed loss-free through the first arc and into the backleg may be “phenominological” and require some searching to find. In this event, the backleg will probably have to be used to match into the second arc to overcome the impact of CSR therein as well. In this case be sure especially to retain the ½ betatron wavelength C-bend to C-bend separation needed to suppress CSR effects at the reinjection point.

E. Initial Thread to Reinjection Dump

1) Turn off beam, retract backleg dump IDC4F12 and insert reinjection dump IDC5F06.
2) If buss excitation has been shifted to accommodate pulsed lasing tests, verify nominal excitations have been restored using procedure of step C 2) above.
3) Thread beam through to IPM5F05 using procedure analogous to the arc thread of step C 6) a).
4) Optimize orbit through second arc using process analogous to the orbit optimization of step C 6) c).
5) Check beamline momentum and betatron performance with difference orbits.
6) Rematching is not possible as no diagnostics on beam profile are available other than ITV5F02. If beam appears good and transport is apparently loss-free, attempt lasing in pulsed mode into IDC5F06 to check momentum apertures and limit scraping. Push extraction efficiency to 1% to ascertain limits to momentum acceptance (use BLMs). As in step C 7) b) i), it may be necessary to shift dipole buss excitation to limit scraping.

F. Reinjection Thread

1) Turn off beam and retract dump IDC5F06.

2) If buss excitation has been shifted to accommodate pulsed lasing tests, restore nominal excitations using procedure of step C 2 above.
3) Download reinjection matching telescope quad strengths. Verify MQI1G01-3 are set to values minimizing betatron size on the dump and putting dispersion at ~ ½ m.
4) Turn on pulsed beam with sufficient power to allow BPM use. Verify beam is in and centered on IPM5F05. Using MD(B/H)5F05(H/V), acquire and center beam on IPM5F06. Verify centering in first (QB) doublet using IPM5F06.
5) Insert ITV1G01.
   a) Begin to monitor module cavity GASK signals.
   b) Using MD(B/H)5F07(H/V), steer beam to acquire evidence of beam loading on cavity GASKs and to acquire beam at OTR.
   c) Bring up BPM relative spikes and zero them. You will need to resteer following rephasing, as the DG string may cause some changes in the orbit. Vary DG trim string to zero cavity GASKs; this indicates the recirculated beam is 180^{o} out of phase with the accelerated beam. When all GASKs are essentially zero, beam should be on 1TV1G01. If it is not, systematically search for beam using the following options:
      i) Persist in steering with MD(B/H)5F07(H/V),
      ii) Vary DG string excitation to vary output energy, resteering as necessary to remove residuals on BPM relative spikes.
      iii) Vary FELEXT string strength

      It may prove useful (though not definative) to
      i) insert ITV1F01/2 and try to see 2 beams,
      ii) look at IPM1F01/2 analog signals to search for evidence of 2 beams, or
      iii) look for beam using BLM analog signals

F. Longitudinal Matching/RF Checkout

When beam is acquired on ITV1G01, it is likely to be diffuse and horizontally distended due to large momentum spread. Note that this will be even more of a problem in Step H, below, when we start lasing, so the following will serve as conceptual practice for later work. To reduce momentum spread

1) Turn on sextupoles MSC3F02/3 and MSC5F02/3 to (4/m^3 *** need field integral value) to cancel T_{566} contribution to bunch length
2) Turn on trim quads MQH3F02/3 and MQH5F02/3 to (-0.16/ m^2 *** need field integral value) to adjust M_{56} to value giving desired momentum compression from recirculation/energy recovery transport.

   a) Optimization of final energy spread may be performed using DG trim string (path length) and QH trims (momentum compaction). Sextupoles probably will not matter or help beyond the initial improvement available from roughly correct excitation.
3) If well-defined spot cannot be produced at 1G01, call accelerator performance integrator for support.
4) If well-defined spot can be produced, perform RF system tests with pulsed beam

G. Orbit Optimization/Rematch

1) When best effort spot is achieved, optimize orbit to dump
   a) Recheck steering on relative spikes (zeroed in Step F 5) c)) through arc to verify use of DG string has not significantly altered steering.
   b) Using ITV1G01, center in MQG5F08/9 by steering with MD(B/H)5F05(H/V).
   c) Verify centering in module by dithering module gang phase (or phase of 1st and last cavity pair) and looking for steering
   d) Search dump beam line aperture using BLMs and varying FELEXT string and MD(B/H)5F07(H/V).
2) Improve spot at ITV1G01 insofar as possible or needed using reinjection telescope rematch.
3) Perform difference orbit checkout of momentum and betatron aperture.

H. Lasing with Energy Recovery in Pulsed Mode

If beam appears good and transport is apparently loss-free, attempt lasing in pulsed mode into 1G00 dump, to check momentum apertures and limit scraping. Basically, repeat Steps F and G while lasing in pulsed mode. Track changes in dipole buss, DG trims, FELEXT excitation, and QH trims while turning laser on and optimizing performance of energy recovery.

1) Push extraction efficiency to 1% to ascertain limits to momentum acceptance.
2) As in step C 7 b) i), it may be necessary to shift dipole buss excitation to limit scraping.
3) If dipole buss is changed, DG trim string will need to be changed to restore RF phases – a 1% change in recirculator buss will lead to about 2 mm change in the path length; this is offset by about ½ mrad change in the DGs, or about 70 g-cm at 42 MeV
4) Vary QH trim family to manage momentum compaction/momentum spread

5) REMINDER: The available parameters for optimizing energy and momentum spread in the dump line are:
   a) FELEXT excitation
      i) within limits – the recirculated beam has to fit through the chicane!
   b) Path length, as set by DG trim string
      i) this may cause some residual steering
   c) momentum compaction as set by the QH trim family

   Thus for example you could play the phase of the energy recovered beam off against the momentum compaction to get better momentum compression at the expense of final energy, and use the FELEXT knob to get the beam into the dump at the “wrong” energy. The recirculator buss is used to center the beam in the recirculator aperture – it is set once and left thereafter

I. CW Setup

1) Shut off pulsed beam and test all BLMs
2) With FEL off and nonlasing beam conditions (nominal dipole buss excitations, FELEXT and DG/QH trim excitations) restored, verify/generate loss-less transport through system by monitoring BLM response. Steer away from scraping.
3) Monitor appropriate dump current, water temperature, and vacuum signals.
4) Unmask BLMs
5) Fire up CW operation. Test frequency doubling from 18.7 to 37.4 MHz at high power (1.25 to 2.5 mA jump while energy recovering); compare to ramped charge/bunch operation at 37.4 MHz.

J. CW Lasing

1) Restore lasing with pulsed tuneup beam as in Step H.
2) With pulsed lasing beam, verify/generate loss-free conditions through system by monitoring BLM responses.
   a) Operate FEL at extraction efficiencies consistent with momentum limitations derived during previous tests of lasing with pulsed beam
   b) Shift recirculator dipole buss excitation as described above to maximize free aperture around spent beam during lasing
      i) Make appropriate path length adjustments with DG trim string as needed when recirculator buss is changed
   c) Steer away from scraping.

3) Monitor appropriate dump current, water temperature, and vacuum signals.
4) Unmask BLMs
5) Fire up CW operation according to path dictated by results of tests without lasing. Sample scenarios follow. All scenarios juggle some pushes of charge/bunch, frequency, and extraction efficiency to get to 1 kW with available current from gun power supply (4 mA).
   a) Scenario I
      i) Initiate CW lasing with 1 mA, 60 pC/bunch
      ii) Frequency double to 2 mA, 60 pC/bunch
      iii) Push extraction efficiency to 1% to get ~1 kW
   b) Scenario II
      i) Initiate CW lasing at 37.4 MHz, low charge per bunch (30 pC?)
      ii) Increase charge/bunch to 60 pC/current to 2 mA
      iii) Push extraction efficiency.
6) As during pulsed mode lasing, can play with

   a) FELEXT
   b) Path length
   c) Momentum compaction

   to improve momentum spread at dump

What do we still need?

1) Choice of energy/charge/frequency scenario
    a) Power ramping scenario during energy recovery
2) Choice – first energy recovery/cw run with wiggler in or wiggler out?
    a) Above scheme assumes wiggler in
3) Completed hardware punchlist
4) RF checkout testplan/procedure
5) More systematic/detailed High Power Setup Sub-procedures
6) BLM setup and procedure