High-Power Setup Procedure

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A. Prerequisites/Philosophy

1) Select wavelength/electron beam energy for run
2) Gun at 60 pC/bunch and 350 KeV
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
   b) Stays out of high space charge regime; avoids rematch problems
   c) Puts stress on momentum acceptance of recirculator system
6) Read and understand following procedure, particularly the part about messing with 200 kW of beam and RF power, so you know you can REALLY screw the hardware up if you are not careful!

B. Overview

1) Initial beam restore/thread to 5F (reinjection) dump
   a) Restore recirculator magnets
   b) Thread recirculator
   c) Orbit optimization
   d) Check/correct dispersions, rough rematch
   e) Difference orbits/test lasing
2) CSR checkup
   a) Careful rematch
3) Reinjection thread
   a) Pull 5F dump
   b) Steer down linac using GASK info; set energy with path length
   c) Beam to 1G00
   d) Aperture check, orbit optimization
   e) Transverse rematch using 5F telescope
4) Longitudinal matching/RF checkout
   a) Adjust momentum compaction to reduce momentum spread
   b) Turn on sextupoles to reduce momentum spread

    c) Vary path length to reduce momentum spread
    d) Track final beam energy with FELEXT
5) Pulsed lasing with energy recovery
6) CW Setup/RF checkout
7) CW Lasing/RF checkout
    a) Hold 60 pC/bunch
    b) Push frequency 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 Reinjection Dump

1) With beam on 2G00 dump, verify 2F08/2G00 correctors are properly set
    a) Set 2G00H,V to zero
    b) Beam should be centered on ITV2G00. If not, put it on center (center raster pattern) using 2F08H and V.
        i) Note that 2G00H,V are set to center in the aperture upstream of the dump, not to steer to ITV2G00.
    c) Record 2F08H,V values for use below
    d) Verify beam is centered in 2F04 – 9 quad telescope. If not, center in all quads and repeat Steps C. 1) a) – c) before proceeding.

2) Insert 5F dump

3) Turn off beam, go to 2 Hz/200 microsecond/60 pC/18.7 MHz BPM capable beam.

4) Fire up recirculator magnets
    a) Zero MDG3F02H string and standardize
    b) Download recirculator restore file settings and cycle dipole strings and quads. This file should contain all quad matches required for initial recirculation setup and assumes the beam was centered in the downstream (2F04 – 9) telescope while in transport to the 2G00 dump.
    c) Verify that
        i) DX3F01 trim is off (0 A). This should have occurred automatically as the dipole string turned on. If it has not, inform the magnet system owner and set manually as follows:
            (1) Turn off the dipole buss
            (2) Set the DX trim coil DX2G01 to 0 A
            (3) Cycle hysteresis on the trim coil
            (4) Turn on the dipole buss and standardize

ii) DQ surface coils are on to -1 A. This should have occurred automatically as the dipole string turned on. If it has not, inform the magnet system owner and set manually as follows:
(1) Turn off the dipole buss
(2) Set the DQ trim coil to –1 A
(3) Cycle hysteresis on the trim coil (–1 A to 0 A to –1 A twice)
(4) Turn on the dipole buss and standardize
iii) DY shunts have restored the .BDL to the requested value

5) Reset 2F08H, V to values established in (final iteration of) Step C. 1) c).

6) Zero excitations of all QH and SC magnets and standardize.

7) Verify beam is threaded through 3F arc, 4F backleg, and 5F arc to ITV5F04 and IPM5F05: turn on beam in 2 Hz pulsed mode with FEL laser shutter closed (no lasing). If beam orbit is not restored through 4F to at least the few mm level, inform FEL commissioning coordinator, magnet system owner and magnet performance integrator and proceed with the following 3 steps. Perform this thread ONLY on their instruction.

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) Roughly center beam in QH3F01 and 2 using MD(B/H)2F08(H/V) (this is over-constrained, and if the initial straight-through setup is right and the elements all well aligned, should happen automatically)
   iv) Re-center 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 over-constraint should not be troublesome) until beam is at backleg insertable dump

8) *3F Arc Orbit Optimization*
   a) Record values of, then zero, all DF and DC correctors (3F01,2,3,4; 5F01,2,3,4) and standardize.
   b) Record value of MD(B/H2F08(H/V) (twiddle save)
   c) With 2F08H and V at value from Step C. 1) c), adjust recirculator buss until beam is centered in QH3F01:

i) Activate relative BPM screens and zero offsets
ii) Take QH3F01 off loop and change gradient integral by 140 g
iii) Observe beam motion through 4F region. Maximum amplitude of beam motion is roughly amplitude of offset in QH3F01. Record value and positions of maxima.
iv) Reset QH3F01 to zero. Change dipole buss by 100 g-cm and repeat Steps C. 8) b) i) – iii). Take differences in values of maxima and establish correct dipole buss setting by computing slope and extrapolating to dipole buss setting required to give zero maximum offset.z
v) Set dipole buss to value established in the previous step and repeat Steps C. 8) b) i) – iii) to verify beam is centered in quad to ~ 1 mm level.
vi) If needed, repeat C. 8)-b) i) – v) to center beam vertically in QH3F01 using 2F08V corrector.
vii)Update "Step C 1) c) saved value" value for 2F08H and V for use in all subsequent steps

d) Repeat the procedure of Step C. 8) c) to center in QH3F02 using 2F08H, V.
e) Iterate Steps 8 b) and d) until beam is centered in both 3F01 and 3F02 quads.
f) Verify that beam is in center of field of view at 3F02 viewer. If not, log discrepancy and inform commissioning coordinator, magnet system owner, and magnet performance integrator before proceeding.
g) Using procedure of Step C. 8) c), center beam in QH3F03 using shunt (in BDL mode) on DY3F03. If vertical centering is needed, use DC3F02V.
h) Using procedure of Step C. 8) c), center beam in QH3F04 using DF3F01H (NOT DF3F04H!); use DC3F02V to fine-tune vertical centering.
i) Iterate Steps C. 8) g) and h) until beam is centered in both 3F03 and 3F04 quads.
j) Using procedure of Step C. 8) c), center vertically in QG4F01 using DC3F03V; similarly center horizontally in QG4F02 using DF3F04H.
k) Iterate Steps 8 g) through j) until beam is simultaneously centered in all 4 quads to the 1 mm level (maximum 4F orbit response to 140 g change in gradient integral) and in the center of the field of view of the DY dipole. If this cannot be achieved without undue effort and without corrector settings in excess of ~ 100 g-cm or so, inform the commissioning coordinator, magnet system owner, and magnet performance integrator to get instructions before proceeding further.

9) *4F Backleg Orbit Optimization*

a) Using 4F01V, center vertically in QG4F03.

b) Repeat with 4F02H to center horizontally in QG4F04,
c) Repeat with 4F03V to center vertically in QG4F05,
d) Etc, through to QG4F13.

At this point, beam should be through 5F to ITV5F04, IPM5F05, and, if the 5F dump is pulled, to IPM5F08. If it is, proceed. If it is not, insert the 5F dump and call the commissioning coordinator, magnet system owner, and magnet performance integrator to get further instructions before proceeding.

10) *5F Orbit Optimization* – in the following, beam will be steered around with the 5F dump out, so use as low a rep rate as possible while still allowing BPM operation.
   a) Using 4F13H and V, center in QH5F02 using procedure of Step 8) c). Verify this also has beam centered in QH5F01 (which should by default occur because the dipole buss was set in Step 8) c)). If this does not occur, log the event and call the usual cast of characters.
   b) Verify beam is at or near center of field of view of ITV5F01 (at DQ5F02) and ITV5F02 before proceeding; if not, log the discrepancies and call the usual suspects for instructions.
   c) Using the shunt on DY5F03 and DC5F02V, center beam in QH5F03.
   d) Using DF5F01H and DC5F02, center beam in QH5F04.
   e) Iterate Steps 10) c) and d) until beam is at center in both quads.
   f) Verify beam is at center of field of view on ITV5F04 (next to DX5F05).
   g) With 5F5 – 8 telescope quads unexcited, center beam in QB5F05 using DF5F04 and DC5F03.
   h) Iterate Steps 10) c) – g) until beam is centered in all of QH5F03, QH5F04 and QB5F05. If this is not possible without undue hardship or correctors in excess of the ~100 g-cm level, inform the commissioning coordinator, magnet system owner, and magnet performance integrator and get further instructions before proceeding.
   i) With 5F05 – 8 reinjection telescope quads at nominal settings, center beam in QB5F07/8 using 5F05H and V by looking at ITV1F01. You will be spraying beam *everywhere* while doing this, so turn down the charge per bunch and thumb-wheel setting to the lowest values you can stand while executing this procedure.

At this point, the beam is centered up throughout the recirculator and has a "best effort" straight line at the reinjection point. Save settings now!

11) *Dispersion correction, rough rematch.*
   a) Using guidance from JLAB-TN-98-035, correct remnant dispersion in backleg (insert 4F, 5F dumps) and in reinjection telescope (4F, 5F dumps pulled). Following the 5F dispersion check, reinsert the dump!
      i) To correct dispersion offset at 4F01 (5F06) use QH3(5)F01/2.

ii) To correct dispersive angle at 4F01 (5F06) use QH3(5)F01/4. *A trim quad gradient integral in excess of a few tens of g should be suspect and reviewed by the commissioning coordinator before proceeding.*

b) Verify beam is well matched into backleg by certifying spots all look the same at ITV4F05, 7 and 9 and all the same at ITV4F06, 8 and 10. At the odd viewers, the beam should be upright and 2-3 times higher than wide; at the even viewers the beam should be flat and 2-3 times wider than high. If this is not the case, call commissioning coordinator for instruction on rematching with 2F04 – 9 telescope.

c) Check aspect ratio of beam in ITV5F04; it should be upright and 2-3 times higher than wide. This information can be used as a starting point, with instruction from the commissioning coordinator, for matching into the reinjection region using the 5F05 – 8 telescope.

12) When beam spots are good through the system:

a) *check momentum / betatron aperture with difference orbits*
   i) Adjustment/correction of transfer matrices may be required based on the outcome of these measurements.
   ii) Measurements of difference orbits while running off-momentum will be needed to characterize possible variations of betatron functions with momentum.

b) *Lase 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 needed to verify).
   i) Shift in beam energy centroid due to lasing may necessitate shift in dipole excitation to avoid scraping. This may be done ONLY with the permission of the commissioning coordinator, ONLY as a diagnostic measure, and should be done using the following sub-procedure

(1) Verify DY shunts are in percentage mode (2) Decrease dipole string strength to center beam with lasing on ITV3F02, ITV5F02 (dispersion comparable to optical cavity chicanes) and ITV5F01 (~2 m of dispersion).

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

D. CSR Checkout/Rematch

1) Deactivate FEL and restore pulsed beam conditions present prior to lasing test. If dipole buss has been shifted to accommodate enlarged momentum spread, reset buss.

2) Check emittance and beam envelopes at start of backleg using quad/monitor or multi-monitor techniques.

3) If significant mismatch or emittance growth is found, develop rematch under direction of commissioning coordinator.
   a) Use of injector telescope has not yet been needed; avoid this and instead review injector phase/gradient settings
   b) Use 1F03 – 2F03 telescope for spot size control at wiggler only. This has not been needed to date; poor performance at this location is indicative of either injector phase drifts or a need to standardize 1F/2F matching quads
   c) Use 2F04 – 2F09 telescope to match to backleg only. Do not attempt to improve transmission to 1G dump using these quads
   d) Use 5F05 – 5F08 telescope for spot size control from reinjection to 1G only.

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LET THE WILD RUMPUS BEGIN!!!!!

Assumptions:

1) Machine is in energy recovery mode but not lasing

2) Recirculator dipole string is matched to full accelerated beam energy, not central energy after lasing (restore any setting altered during lasing tests in Section C.)

3) Module gang phase is at value required for lasing

4) Beam is centered in the 5F telescope, as in Step C. 10)

5) All trim quads are unexcited (save those needed for dispersion correction) and all sextupoles are unexcited

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E. Reinjection/Energy Recovery Thread and Orbit Optimization

1) Pull the 5F dump IDC5F06.

2) *Check recirculated spot* on ITV1F01; if needed, conjure up some 5F05 – 8 match based on CSR measurement and viewer image at 5F04. It would be a good idea to include the commissioning coordinator in this activity.

3) Verify MQI1G01-3 are set to values believed to
   a) minimize betatron size on the dump and
   b) Make dispersion at dump ~ ½ m.

4) Turn on pulsed beam with sufficient power to allow BPM use. Bring up and zero relative BPM spikes.

5) *Steer into module*:
   a) First rough steering and phasing
      i) Steer with 5F08H and V to reduce GASKs
      ii) Adjust DG3F02H string to zero GASKs
      iii) Iterate a) and b) until all GASK values are zeroed
   b) *Re-steer recirculator* to remove DF3F02H string-induced orbit errors:
      i) When best effort GASK results are achieved, steer with 3F04H and 4F01H to zero backleg relative BPMs, and use 5F04H and 5F05H to zero 5F relative BPMs.
   c) *Iterate* Steps F. 5) a) and b) to produce 0 GASK signals and zero relative BPMs in backleg and 5F regions. This sets best phasing and best injected orbit.

6) *Improve orbit in module*:
   a) Aperture scan the module using (***5F08H,V***) for injection angle and (***5F04H, 5F03V***) for injected position [*must rederive for each 5F match using machine model – call commissioning coordinator for latest protocol*].
   b) Verify that the beam is well-defined (GASKs jump sharply from zero as steering is done)
   c) Verify that aperture is larger than beam (steering required to go from side to side (GASK jump to GASK jump) is much larger than steering required to get GASKs to jump from zero to full value)
   d) Center beam in aperture using (***5F08H,V; 5F04H, 5F03V***) correctors

   If any of Steps E. 6) a) – d) are difficult to accomplish, you may need to revisit the 5F quadrupole match. Call Court.

7) *Rephase*: You now have good orbit in the recirculator and the module, but may have degraded the phasing somewhat due to steering in the 5F arc region. We will now fix this.
   a) Rezero BPM relative spikes
   b) Adjust DG3F02H string to zero GASK values
   c) Resteer with 3F04H and 4F01H to zero backleg relative BPMs, and use 5F04H and 5F05H to zero 5F relative BPMs.
   d) Iterate steps a) – c) to get 0 GASK and relative BPM spikes to zero

Sanity Check: Through the process of steps 4) – 7) the machine should now exhibit the following properties:
   a) Spots are good on ITV1F01
   b) GASK information implies beam is centered and well-defined in a large available aperture in the module and is energy recovering 180 degrees away from the module gang phase set point (no power into cavities)
   c) Beam is well steered – zero relative BPMs from 4F01 to 5F08; absolute BPMs should show about zero from 4F01 through 5F02B, with the absolute orbit residual on IPM5F06 and IPM5F08 being due to the reinjection orbit offset needed to center the energy recovered beam in the module aperture during deceleration.

At this point, the beam will hopefully appear on ITV1F02!

8) Adjust FELEXT to find beam on 1G viewer
   a) Verify that this does not steer the recirculated beam; if it does, inform the commissioning coordinator, magnet system owner, and magnet performance integrator and seek guidance before proceeding.
      i) Steer with 1F02 and 2F00 correctors to hold the high energy beam stationary (keep zero relative BPMs) through the recirculator while you whang the FELEXT buss around.
      ii) Or, you can go downstairs, do a stray field survey, and magnetically shield everything…

9) *Verify that the betatron match is "okay"* by observing spot on ITV1G01.
   a) If spot is bad, seek guidance from commissioning coordinator, particularly before attempting to adjust by altering the 5F match.

F. Longitudinal Matching/RF Checkout

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

1) *Verify Phasing*: Scan DG3F02H string to vary path length (resteering as needed according to the procedure of Section E. 7) a) – d)), to find the minimum output energy at 1G.
   a) You will probably need to search the trough of the RF waveform for ±1 cm, which corresponds to ±2.5 mrad or ±350 g-cm.
   b) Adjust the path length away from minimum by the length equivalent to the gang phase offset of the module – about 5 mm for 8 degrees. Verify this restores the minimum GASK values established in Section E. 7); if not, contact the commissioning coordinator for further instructions. (Resteering, as in Section E. 7) a) – d) may be needed.)
   c) Tracking beam motion with FELEXT may be required. If so, resteering, as described in Section E. 8) a) i) may be required.

2) *Turn on trim quads* MQH3F02/3 and MQH5F02/3 to (1.5*(-0.167/ m^2) = 48.3 g gradient integral at 38.5 MeV/c) to adjust M_{56} to the 0.3 m value giving desired momentum compression from recirculation/energy recovery transport. This assumes the module gang phase is about 8 degrees off crest – if the value is different, call the commissioning coordinator for appropriate M_{56} and quad numbers. If you are properly centered from the setup of Section C, this will not degrade the orbit significantly.

3) *Turn on sextupoles* MSC3F02/3 and MSC5F02/3 to (0.85*4.2/m^3 = 13.75 g/cm curvature integral at 38.5 MeV/c) to cancel T_{566} contribution to bunch length and offset curvature of RF waveform during energy recovery. If you are properly centered from the setup of Section C, this will not degrade the orbit significantly.

Sanity Check: Steps 1) – 3) should improve (though not minimize!) the spot at 1G. If further improvement is needed, proceed as follows after receiving authorization from the commissioning coordinator

a) Raise recirculator dipole buss to nominal energy PLUS (not minus!) the expected energy shift from lasing (e.g., 38.5 MeV goes to ~39 MeV)
b) Grid-search

        i) path length in 1 mm or smaller increments, (with resteering as in Section E 7) and 8))
        ii) trim quads in 1 g increments, and
        iii) sextupoles in 0.25 g/cm increments

        to find minimum momentum spread at 1G
    c) Adopt "best momentum spread values" of the 3 allowed variables, and restore recirculator buss to nominal.

4) Review orbit using procedure of Section E. 6) and 7), match in 5F with new path length and trim quad values.

5) *Perform difference orbit checkout of momentum and betatron aperture.*

G. 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 the substance of Steps E and F 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) With machine set up as in Step F, bring up and zero relative BPMs; observe and record location of beam spot on all viewers

2) *Initiate lasing in pulsed mode*

3) *Verify that orbit has not changed*
    a) Check relative BPMs to ascertain that they have remained at or near zero at all nondispersed locations (2F04, 2F09, 4F01-13, 5F06, 5F08).
    b) Variations of beam envelopes/phase space distribution with momentum spread may potentially cause centroid shifts, resulting in nonzero relative BPMs. As a crosscheck, verify beam centroid location on all viewers is within 1 mm or so of position observed in Step G. 1).
4) *Verify dispersion suppression/betatron behavior in backleg*
    a) Insert viewers in 4F region; verify spots have approximately the same aspect ratio with lasing as without. If difference is significant (>10%)
        i) Inform commissioning coordinator
        ii) Recheck/correct dispersion
        iii) Log possible problem with momentum dependence of beam envelopes
5) *Verify dispersion suppression/betatron behavior at reinjection*

a) Insert viewers in 5F region; verify spots have approximately the same aspect ratio with lasing as without. If difference is significant (>10%)
   i) Inform commissioning coordinator
   ii) Recheck/correct dispersion
   iii) Log possible problem with momentum dependence of beam envelopes

6) *Verify energy compression / betatron control at dump*
   a) Examine IPM1G01 relative spike and ITV1G01 image. If difference with/without lasing is significant (1 mm spot motion, 10% change in spot size
      i) Call commissioning coordinator
      ii) Proceed to Step G. 7).

      Otherwise, proceed to Step G. 8)

      Use of Step G. 7) will almost certainly be necessary…

7) *Optimization of energy compression while lasing* – proceed in analogy with Step F. 3) b) and c) to manage the beam momentum spread at the dump.
   a) Bring up and zero relative BPM screens
   b) Grid – search parameter space to minimize momentum spread (and thus, spot size) at 1G while lasing. The control parameters to be varied, and their variation tolerance, are:
      i) Momentum compaction – varied by correlated changes of QH3F02/3, QH5F02/3 in gradient integral steps of 1 g. If properly steered, the beam will not move when these alterations are made.
      ii) Nonlinear momentum compaction – varied by correlated changes of SC3F02/3, SC5F02/3 in curvature integral steps of 0.1 g/cm. If properly steered, the beam will not move when these alterations are made.
      iii) Path length – varied in 1 (0.5?) mm steps by changes of the DG3F02H path length string field integral of 30 (15?) g-cm for a beam of ~40 MeV. Note that this manipulation will produce remnant orbits errors. The following procedure should be used for fine-tuning of this parameter.

(1) Bring up and zero relative BPM spikes
(2) Change DG3F02H excitation by 30 g-cm. This corresponds to a ¼ mrad angle at ~40 MeV, leading to ~1 mm path length

variation (positive change implies longer orbit length with resultant later arrival time/RF phase delay of the recirculated bunch)

(3) Use DF3F04, DB4F01 to zero (to ~0.1 mm) relative BPM spikes in the backleg (4F)

(4) Use DF5F04, DB5F06 to zero (to ~0.1 mm) relative BPM spikes in the reinjection telescope (IMP5F06/8).

(5) The steering of Steps (3) and (4) may cause a shift in path length away from the target value set in Step (2). Iteration of this procedure may be needed to achieve a particular result.

c) *Key points* to remember:

i) 1st and 2nd order momentum compactions and path length are the primary knobs for control of the momentum spread, and hence spot size, at 1G during lasing

ii) If the reinjection match is suspect, either it will remain suspect when the lasing is turned off, or we have a significant variation of beam envelopes with momentum. In the first case, Step E. 9) was not properly done; in the second case, the results of Step F. 5) were not properly interpreted and acted on. This latter case is in fact difficult to manage, as it will require creative use of sextupoles and/or a chromatically insensitive rematch to cure. In either case, random twiddling of matching quads will serve only to raise both HE and Preble blood pressures; it is unlikely to improve the spot.

iii) Steering through the recirculator must be reasonably good to allow you to fiddle with the compactions without degrading the orbit

iv) Resteering will probably have to accompany significant adjustments of path length

v) If the recirculated phase (path length) is significantly adjusted, FELEXT may have to be varied to hold the beam on the dump. *Do this only after resteering the recirculator using the procedure outlined in Step G. 7) b) iii) (1)-(5).* Failure to proceed in a controlled fashion will lead to significant self-annoyance as you keep loosing the beam at the dump and have to look for it again, again and again…

vi) For now, I wouldn’t mess with the recirculator buss excitation at any time. The machine hopefully has adequate momentum aperture without this, and using it only increases the dimensionality of the problem. Thus for example, if the recirculator buss is changed, the path length must be shifted, as must the linear portion of the momentum compaction. Shifts in the recirculator buss thus entail significant rework of the above setup and should be left, if possible, as a diagnostic exercise only.

8) Push extraction efficiency to 1% to ascertain limits to momentum acceptance.

H. CW Setup

1) Shut off pulsed beam and test all BLMs
2) With FEL off and nonlasing beam conditions (nominal lasing/energy recovery dipole buss excitations, gang phase, FELEXT and DG/QH/SC trim excitations) activated, 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.

I. CW Lasing

1) Go to pulsed operation and mask BLMs
2) Restore lasing with pulsed tune-up beam as in Step G.
3) 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) Steer away from scraping.
4) Monitor appropriate dump current, water temperature, and vacuum signals.
5) Unmask BLMs
6) Fire up CW operation according to path dictated by results of Step H 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.
7) As during pulsed mode lasing, can play with

a) Path length
b) Momentum compaction (1^{st} and 2^{nd} order)

to improve momentum spread at dump and

c) FELEXT to keep beam on dump as energy is shifted by changes induced in a) and b).

Bear in mind you will be messing with as much as 200 kW of beam and RF power…!!!