FEL TEST PLAN WORKSHEET

PROGRAM DEPUTY APPROVAL	COMPLETION INFORMATION
FEL Exp Coordinator Signoff: ________________ Date: _______	Completion Date: _____________
PI Reviewer Signoff: __________________ Date: ___________	Crew Chief/PI Signoff: ____________________________
Expiration Date (max. 90 days from approval): _____________	Comments (partial completion, etc.):
Presentation Required? ❑ yes ❑ no	☐

NOTE: Information addressing the appropriate content of each of the following sections can be found in Section 2.0 of the Test Plan Instructions.

Test Plan Title: **Injector Setup**

Author(s): R. Legg, D. Douglas, D. Kehne, P. Piot, C. Bohn (Rev. 4)

Date Submitted: Aug. 4, 1997

Revision Number: Rev. 4, 3 April, 1998

Brief Purpose of Test

To set the injector orbit and beam parameters to the nominal values described in the modeling for the machine.

Anticipated Benefits

Beam Conditions Required

Complete all of the following tables, entering a value or an **X** in the appropriate spaces:

Beam Type/Current (enter value)

Beam Type	Beam Current
Beam Off	
Pulsed (std. current = 1 µA)[a]	X
CW	

a. The standard current for pulsed beam operation is 1 µA. If your test requires pulsed beam current >1 µA, then specify the required current and provide a brief explanation next to the specified current.

Beam Energy (select one)

Beam Off	350 keV	10 MeV	42 MeV	Energy Recovery dump
		X		

Beam Termination Point (select one)

Inj Dump	ER Dump	Straight Ahead Dump	Other (specify)
X			

Type of Test (select one)

Invasive (disrupts beam delivery)	Non-invasive (does not disrupt beam delivery)
X	

Time Required

16 hours (2 shifts)

Preferred Time of Test

swing and owl shift

Staff Required to Execute the Test (including contact info)

R. Legg, (w,p) 7592

(h) 877-1028

Controlled Access Requirements

none planned.

Hardware and/or Software Changes Required

NOTE: If software changes are part of the test plan, include the name of the application, the old revision level, the new revision level, and if applicable, whether or not it is possible to roll back to the old revision level (are there hardware limitations, etc.).

Setup Procedure

1. PSS setup
2. FSD clear
3. Magnets at nominal
4. Beam parameters setup mode.
   a. 10 usec pulse width
   b. Micropulse Frequency 2.339 MHz
   c. 60 Hz D. < 1 pC/bunch
   d. Viewer limited beam mode
5. “Turn-On Checklist”

Test Procedure

COARSE INJECTOR SETUP

1. With the buncher rf off, steer the beam onto the viewer ITV0F02.

2. Center low current beam in solenoid, MFF0F01, using the Picomotors.

3. Turn the buncher rf “ON”. Center the beam in the buncher by varying the buncher phase between +/-30 degrees while watching the beam motion on the viewer, ITV0F02. Steer the beam entering the buncher using correctors MBH0F01H and V until the beam on the downstream viewer doesn’t move as the phase is changed.

4. At this point, beam should be low and to the right on viewer ITV0F02 (Figure 1). If not, put it there using MBH0F01H and V.

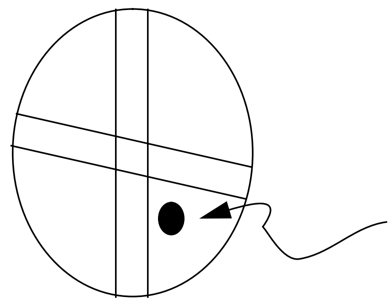

Figure 1: “Sweet spot” on ITV0F02

5. Turn off the beam. Turn the cryounit on and tune it using “AUTOTUNE”. Set the gradient in the first cavity to 11 MV/m and the second cavity to 9 MV/m.

6. Turn On the beam. Retract the viewer, ITV0F02, set the field in the quads MQJ0F03 and MQJ0F04 to 0 G-cm, increase the laser pulse width to 100 usec and transient phase the buncher according to the Transient phasing procedure.

7. Transient Phase the cryounit using the transient phasing procedure to put it on crest. If no beam response is seen on the GASK signal, steer the beam around through the unit using the corrector pair, MBH0F01BH and V until a response is seen or beam is seen on viewer ITV0F04. If no response is seen after finding the beam on the viewer so the beam is going <u>through</u> the unit, slowly adjust the drive laser attenuator to increase the peak current until a response is seen on the GASK or until the average beam current exceeds 1 microamps (use the lightbox harp as the diagnostic, the amplitude of the beam will be about 450 pA). Repeat for the second cavity in the cryounit.

8. Once the cavities are rough phased, reset the drive laser attenuator to its original value.

9. Steer the beam to the viewer ITV0F04 using the corrector pair MBH0F01BH and V.

10. Center the beam in the cryounit using the corrector pair MBH0F01BH and V.

To determine if the beam is centered, adjust the PSET by +/-30 degrees while watching the beam on viewer ITV0F04. If the beam is centered, it will only focus and de-focus on the viewer. If the beam is steered so strongly that it moves off the viewer, use corrector pair MBH0F04H and V to bring it back on viewer ITV0F04.

11. Re-energize the quads MQJ0F03 and MQJ0F04 to their original settings and put them back on their hysteresis loop. Subtract 27.5 degrees from the phase of the second cavity in the cryounit.

12. Thread the beam to the 10 MeV dump using steps 4.0 and 5.0 of the “IR FEL Injection Line Setup Procedure”.

13. Set the pulse control to 1 kHz, 4.68 MHz, 50 microseconds. Cycle light box harp and record the amplitude and sigma of the pulse. Adjust the drive laser attenuator until the amplitude is about 6300 picoAmps with a sigma of about 0.128 inches, see Fig. 2. This sets the charge per bunch to 60 pC and the average current to 14 uA. Cross calibrate the measurement with the intercepted current in the injector dump.

14. After checking the charge per bunch, reset the pulse rep rate to 60 Hz.

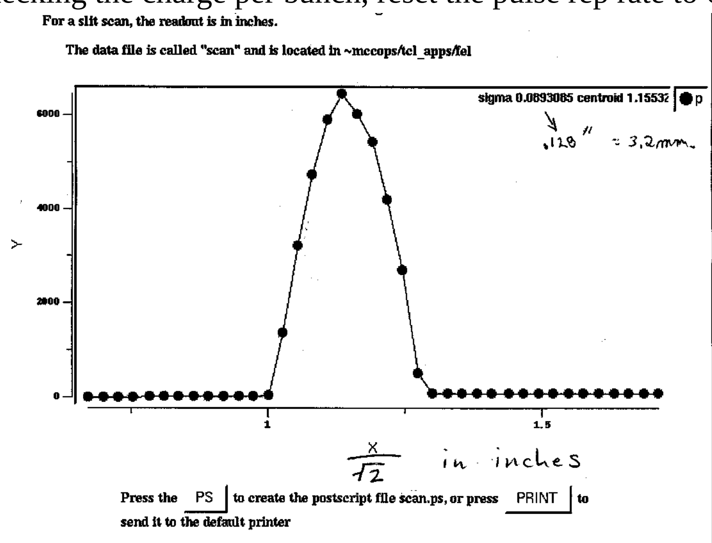

Figure 2

CORRECTION OF SKEW COUPLING

1. Check all viewscreens (ITV0F02, 4 and 6, ITV0G01, and, if at all possible, change injection dipole string to look at ITV0F01). A nastily coupled beam looks like Figure 3, where the beam spot is a diagonal stripe.

2. Set the gradiant integral of MSQ0F03 (downstream of the unit) to the nominal value required to correct the HOM coupler-driven skew quad of the second cavity of the unit. This is nominally ~8.6 gauss, but may vary slightly depending on energy gain (assumed to be 5 MeV) and phase (assumed to be on crest).

3. Verify improvement in coupling on all viewers - diagonal stripes should be more upright.

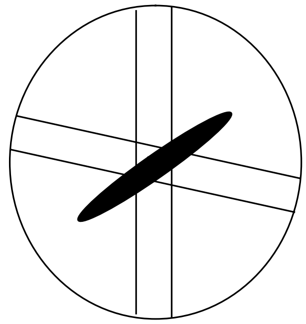

Figure 3: Skew-coupled beam spot

4. Set skew quad MSQ0F02 (upstream of the unit) to remove HOM coupler driven coupling of first cavity of unit and to correct for error coupling from MFF0F02. Nominally, the cavity “should” give small effects, but the solenoid can be nasty and the effect depends on where the beam goes through the lens and what the lens is set to. As a best bet, pick a viewer showing residual coupling (not removed by Step 2), and try to dial it out.

5. Verify all signs of coupling are gone on all viewers.

6. If remnant coupling remains, iterate as follows:

- **a.** minimize coupling effects with MSQ0F03
- **b.** minimize coupling effects with MSQ0F02
- **c.** iterate Steps 6a and 6b to convergence, frustration, or exhaustion (pick one).

NOTE: this procedure should be repeated after each resteering upstream of/through the unit, each change of MFF0F02, and/or and each change of unit RF parameters (*e.g.* energy/phase).

FINE INJECTOR SETUP

1. Make a multislit measurement of the beam emittance after the unit. Make a hardcopy of the measurement. This is the baseline measurement.

2. Make a bunchlength measurement using the Happek device, if available. Record the measurement.

3. Set the field in quads MQG0G01 and MQG0G02 to 0 G. Make a measurement of the beam width (sigma X) at the dump viewer ITV0G01. The dispersion is 1.6 m at this location. The momentum spread of the beam is sigma X in meters divided by 1.6 meters.

SETTING THE PHASE AND GRADIENT OF THE BUNCHER

1. The phase is set by measuring the eccentricity of the beam shape versus buncher phase.

a. To measure the beam's eccentricity, insert the viewer ITV0F04.

b. Bring up the emittance measurement program from the FELMAIN screen. Take an average of 6 images and record sigma X and sigma Y as the buncher phase is adjusted.

c. Fill in the table below:

Table 1:

Degrees from Nominal phase		Initial Phase =			
	-5	-2	0	2	5
sigma X					
sigma Y					

2. Set the buncher phase to a value which corresponds to an eccentricity of 1. The simulations show alpha changing from 1 to -2.5 for -/+5 degrees, so if the change is small call in the PI listed in the call in section, because something is wrong.

3. The buncher gradient is set by minimizing the momentum spread at the viewer ITV0G01. The sensitivity at this viewer from simulations is roughly a 3 mm increase in momentum spread for a 10% change in buncher gradient. The overall beam width on the viewer should be about 1 cm if the cryounit is close to nominal settings. Using the beam sigma function from the frame grabber, set the buncher gradient to minimize the beam sigma.

4. As a final test of the buncher phase, insert viewer ITV0G01 and record the beam centroid. Turn the buncher rf OFF and take a second beam centroid reading off the viewer. If the beam centroid moves on the viewer by more than 1 mm, then the beam properties don't match the beam momentum and the cryounit is off the nominal setup. Set the buncher phase to a value which doesn't move the beam on the viewer when the buncher is turned on and off, and then proceed to set up the cryounit.

CRESTING THE CRYOUNIT

1. The first cavity of the cryounit operates on crest at 11 MV/m nominal gradient. The phase is set by measuring and plotting alpha X (alpha is measure of how much the beam is diverging or converging) versus cavity phase.

a. To measure alpha X at the multislit, insert the multislit and the viewer.

b. Bring up the emittance measurement program (?).

c. Fill in the table below:

Table 2:

Degrees from Nominal phase		Initial Phase =			
	-5	-2	0	2	5
Alpha X					

2. Set the cavity phase to a value for alpha of 0.3. This sets the cavity to the phase with the proper beam properties.

3. Record the phase of the second cavity in the cryounit. Zero Pos On the BPMs in the line into the dump to keep track of the launch angles.

4. Add 27.5 degrees to the phase of the second cavity in the unit. Set the gradient in the second cavity of the unit to 8 MV/m. This should put the cavity on crest and at the right momentum for the transport to the viewer.

a. If the beam is on viewer ITV0G01, crest the cavity using the viewer. Higher energy is to the right (?) on the viewer and the sensitivity on the viewer is about 7 mm per degree. Zero Pos On the BPMs in the line into the dump to keep track of the launch angles.

b. If the beam is NOT on the viewer, insert the viewer ITV0F05, and look for the beam there. The dispersion there is only 0.5 m (2mm/degree), so this checks for a course error in momentum. Check that the second cavity in the cryounit is close to crest on this viewer, and has not been inadvertently set to -55 degrees. Once the cavity is within 1 degree of crest, adjust the GSET on the second cavity to bring the beam to the center of the viewer. Once beam is centered at ITV0F05, retract the viewer and check for the beam on ITV0G01. Fine tune the launch to the dump viewer by adjusting the GSET of the second cavity while watching the Relative BPM spikes for the BPMs in the line into the dump. Once the beam is on viewer ITV0G01, go to step a. above.

5. Record the PSET and PMES of the second cavity in the cryounit when it is on crest.

6. Before subtracting 27.5 degrees to the second cavity in the unit to return its phase to the original value, crest the first cavity in the quarter cryounit using the dump viewer. Maximum energy corresponds to crest for the cavity.

7. Record the PSET and PMES of the first cavity in the cryounit when it is on crest. Call the on-call PI listed in this testplan if this value does not agree with the value in Table 1 within +/-1 degree.

CALIBRATE THE GSETS OF THE CRYOUNIT CAVITIES

1. With the cryounit cavities still on crest, fill in the table below to obtain calibration data on the cryounit GSET's (couplers). The idea behind this technique is that the couplers have a linear error and an offset. By taking a sufficent number of measurements, the linear equations can be solved for the coefficients.

2. Record the setting of the rotational polarizer, then use it to attenuate the drive laser and reduce the charge per bunch until a the peak intercepted current on the lightbox harp is less than 80 pA. Increase the pulse width to 250 usec.

3. To fill out the table,

Table 3:

p, MeV/c	MDU0F01, Bdl, G-cm	Cavity 1			Cavity 2			ITV0F06, centroid pos.
		GSET, nom.	GSET, actual	GMES	GSET, nom.	GSET, actual	GMES	
7	8.103E3	7			7			
7	8.103E3	9			5			
8	9.260E3	7			9			
8	9.260E3	11			5			
9	1.042E4	9			9			
9	1.042E4	11			7			

a. set the dipole to the indicated Bdl and cycle it through hysteresis twice.

b. set the GSET's for the cavities to the indicated values. If changing the GSET of cavity 1, re-crest cavity 2 after the gradients are changed.

c. If the beam appears on the viewer, great, record the GSET's and GMES's and the beam centroid position on the viewer. If not (more likely), adjust the GSET for the second cavity until the beam appears on the viewer and record the actual GSET used and GMES and the beam centroid position.

4. Reset the dipole to its initial Bdl setting and cycle it through the hysteresis loop twice.

5. Set the phase of cavity 2 to -27.5 degrees off crest.

6. Set the GSET of cavity 1 to 11 MV/m and adjust the GSET of cavity 2 to bring the beam to the center of the BPM IPM0G01.

7. Reduce the pulse width to 50 usec and reset the rotational polarizer to its original value.

Backout Procedure

1. Check the phase setting on the buncher again by re-measuring the alpha X of the beam at the multislit. It should be about 0.3.

a. Check that the phase of the buncher is close to zero crossing by inserting the viewer, ITV0F06, and turning the rf to the buncher OFF. The beam should get broader on the viewer, but the centroid should not move more than +/- 1mm.

b. If either of these test fails, go back to the section **SETTING THE PHASE AND GRADIENT OF THE BUNCHER** above. The problem probably indicates the unit was not set properly when the buncher setup was done.

2. Make measurements of the beam momentum, dp/p, emittance, alpha and beta.

Test Results

Calculate the coefficients for the cryounit cavites' couplers.

aX1+b+cY1+d = Z1

aX2+b+xY2+d = Z2

:

: