Procedure Number: SLAC-I-030-302-059-00-R005

MFX Be Lens/FEL Energy Interlock Certification Procedure

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Summary

This document specifies the process for certifying the MFX Be Lens/FEL Energy Interlock with lenses at MFX (Transfocator in Hutch 4.5) and in XRT on the MFX beam line.

Rev. Number	Description	Date/Author
00	Original Version	September 14, 2016, T. Rendahl
01	Editorial Changes, some rearrangement	September 15, 2016, J. Bauer
02	Simplification to match new code	June 21, 2017, J. Bauer
03	New attachment with trip limits, small edits	June 23, 2017, J. Bauer
04	Adjustment to different way of blocking beam; trip limit modifications based on analysis for new undulator	June 18, 2021, J. Bauer
05	Changing table in 4.3	March 25, 2022, J. Bauer

MFX Be Lens/FEL Energy Interlock Certification Procedure

1 Procedure Overview

1.1 Purpose

This procedure is designed to certify the Be Lens/FEL Energy Interlock for the MFX Instrument, hereafter called *Be Lens Interlock*. This procedure can be used for the initial setup of the system, and for verification of the system, *e.g.*, after Be lens changes or changes to the code.

1.2 Required Personnel

This procedure may be executed by a member of the PCDS group, who is knowledgeable about the system, by the MFX area manager, or by an MFX Instrument Scientist.

1.3 Safety

The procedure requires the MFX stopper S4.5 or any stopper upstream of S4.5 to be in for most of the test. This mitigates the safety hazards from the FEL beam. The final test will be performed with stoppers out, but attenuators and YAG screen in.

1.4 Applicability

This procedure is applicable to the following:

- MFX Be Lens Interlock for the Be lenses in XRT on MFX beamline
- MFX Be Lens Interlock for the Be transfocator in MFX (H4.5)

This certification procedure applies to the following situations:

- Initial and annual certifications and regular checks required by the BLA
- Be lens change (sections as required by RSWCF)
- Change of code on IOC of the Be lens Interlock (sections as required by RSWCF)
- Change of code on PLC of the Be Lens Interlock (sections as required by RSWCF)

1.5 Components used in Configuration

This procedure will use or test the following components:

- Actuators for XRT Be lenses and MFX Transfocator
- IOC “ioc-mfx-tfs-lens” for the MFX transfocator and the XRT Be lenses
- IOC “ioc-mfx-lusiAtt” for the MFX attenuators
- MFX Be Lens Interlock PLC
- Attenuator 11 (the 0.5-cm thick Si plus 0.5-cm thick stainless steel attenuator that stops beam on trip of interlock)

1.6 Outline of Procedure

1. Verify proper setup of code
2. With stopper closed, run script on mfx-control to verify for various FEL energy and Be lens input combinations that the logic correctly decides whether or not the interlock should trip.
3. With stopper open, verify for one FEL energy and few Be lens input combinations that the Be lens interlock indeed trips actual beam and that attenuator cannot be removed while trip condition exists.

2 Preparation

2.1 Participants

Date: 2022-11-09

Name	Signature	Initials
Ken Lauer		KL

2.2 Personnel with Write Access

List below the personnel that has access to the IOC "ioc-mfx-tfs-lens" and PLC of the Be Lens/FEL Energy Interlock.

User Name	Full Name	Position or Group
klauer	Ken Lauer	PCDS/ECS Controls Engineer

2.3 Verify Lens Information

Obtain correct XRT Be lens and Transfocator lens information from MFX staff, then verify via EPICS that the PLC has the correct lens information. Enter information in table below.

XRT Actuator Position	Effective radius (µm)
Top	750.0 (DIA:01)
Middle	428.6
Bottom	333.3

Transfocator Position	Effective radius (µm)	Transfocator Position	Effective radius (µm)
1	n/a	6	125.0
2	500.0	7	62.5
3	300.0	8	50.0
4	250.0	9	50.0
5	200.0	10	50.0

	Initial
MFX Transfocator lens information is correct in the PLC	KL

2.4 Check for Open RSWCFs

	Initial
Verify there is no open RSWCF that could void the certification	KL

2.5 Close FEL Stopper

	Initial
The following stopper is in ☒ Stopper S4.5 OR ☐ Any stopper upstream of Stopper S4.5 (Stopper _____)	KL

3 Tests Without Beam To Be Lenses

Execute the script that tests the phase space of photon energy vs. effective lens radii for the four cases with pre-focusing lenses: One of the three prefocusing lenses inserted and no focusing lens inserted. Attach the output to the procedure.

	Initial
Verify from the output of the test script that the phase space was sufficiently covered, with points both above, below, and within the excluded region.	KL
Verify from the output of the test script that a trip occurs if and only if the points are inside the excluded area (red area in figures shown in appendix).	KL
Test report generated and attached to the procedure.	KL
Verify on *MFX Be Lens Interlocks* EPICS Screen that the FEL Energy PV is no longer bypassed.	KL

4 Test With Beam Through Be Lenses:

4.1 Setup

Prepare for the test in the following way:

		Initial
Energy of FEL Beam	keV	
Remove all lenses from beam		
Insert sufficient attenuators such that YAG screens do not get damaged. (Do not use Attenuator 11.)		
Insert YAG screen DG1 (located d/s of S4.5, inside MFX)		
Open S4.5 and/or other stoppers and verify beam is visible on YAG screen.		

4.2 Test with PLC Turned Off

Open EPICS MFX Transfocator Panel and MFX Attenuator Panel.
Turn off Be Lens PLC (by removing power or by remotely rebooting it) and verify that MFX Be Lens Interlocks EPICS Screen labels have red or yellow borders (alarm indicators).

	Initial
MFX Be Lens Interlocks EPICS Screen labels have red or yellow borders when Be Lens PLC is off.	
The beam disappears from the YAG screen at the same time.	

Turn IOC back on and verify that Be Lens Interlock is again o.k. and the beam reappears on the YAG screen.

4.3 Inserting Lenses For Trip With Beam Through Be Lenses

The following test verifies that the interlock trips the beam when a lens is in motion and when a lens combination is in that should trip the beam. For this, the beam is observed to disappear from the YAG screen, and the Be Lens Interlock is observed to trip according to the EPICS MFX Transfocator Panel. It also checks for cross-talk between the XRT Lens interlock and the MFX Transfocator interlock.

For this select one transfocator lens set that should trip the Be Lens Interlock, one that should not, and one XRT lens that should trip the Be Lens Interlock, and one that should not. While the system is in a tripped state, make sure that one cannot remove Attenuator 11 by pressing the relevant button on EPICS MFX Attenuator Panel.

	Energy (keV)	**XRT lens Stack**	**Transfocator lens combination**	**Expected Behavior on YAG Screen**	**Initial**	**Expected Behavior on EPICS Display**	**Initial**	**Initial if attenuator cannot be removed**
Tripping Transfocator Lenses alone				No trip when lenses out		No trip when lenses out		n/a
				Trip when lenses in motion		Trip when lenses in motion		n/a
				Trip when lenses in		Trip when lenses in		
Tripping XRT Lens alone				No trip when lenses out		No trip when lenses out		n/a
				Trip when lenses in motion		Trip when lenses in motion		n/a
				Trip when lenses in		Trip when lenses in		
Tripping Transfocator Lenses plus tripping XRT lens				Trip when lenses in		Trip when lenses in		
Tripping Transfocator Lenses plus non-tripping XRT lens				Trip when lenses in		Trip when lenses in		
Non-tripping Transfocator Lenses plus tripping XRT lens				Trip when lenses in		Trip when lenses in		
Non-tripping Transfocator Lenses plus non-tripping XRT lens				No trip when lenses in		No trip when lenses in		n/a

5 Close-out

Note: Certification of this interlock is only complete after successful close-out with LCLS Safety Office and Radiation Physics.

Closeout by LCLS Safety Office and Radiation Physics that certification has been successfully completed.

	Name	Signature	Date / Time
LCLS Safety Office			
Radiation Physics			

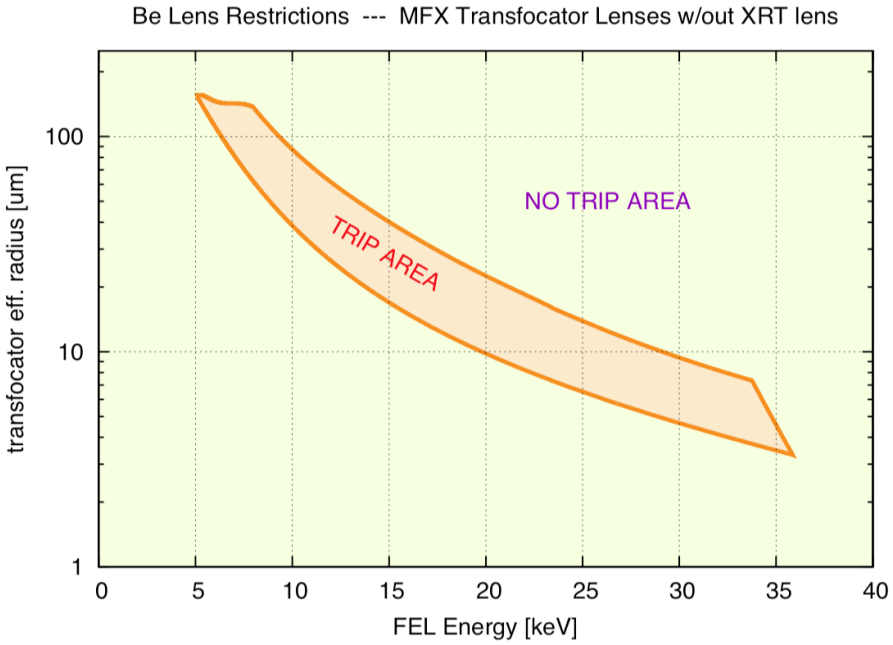
APPENDIX: Trip Limits

As of August 2020, the trip limits enforced by the Be Lens Interlock are based on the analysis described in LCLS Memo "*Estimation of the hutch wall burn-through hazard from Bragg-reflected focused SASE FEL generated by copper-linac beam in the LCLS-II hard x-ray undulator*" by Alyssa Prinz, June 12, 2020.

The data from that analysis were provided via e-mail by Alyssa Prinz on January 5, 2021, "*Fw: MFX Interlock Numbers*". The data sets are shown – for illustration only – in the plots. The interlock program interpolates linearly between adjacent data points.

Trip Limits for MFX Transfocator alone

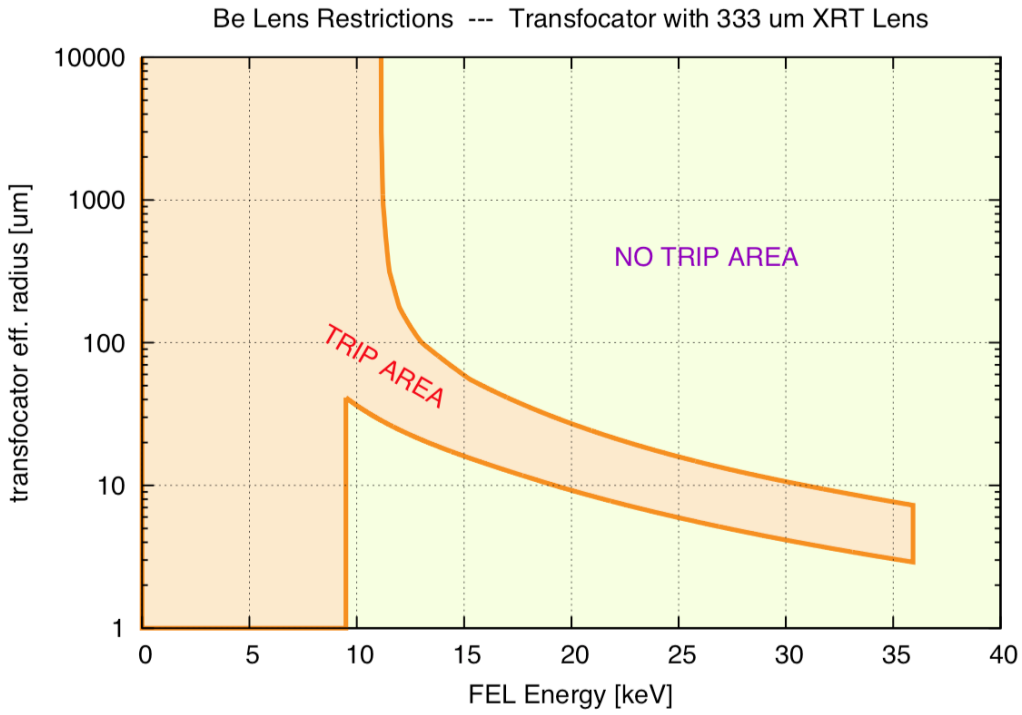
If no pre-focusing lens is inserted, the interlock must trip for any FEL energy/transfocator effective radius combination indicated below in the red area. The table below gives the actual data points. (For E < 5.069 keV, all radii are allowed.)



Trip Limits for MFX Transfocator with 333 µm XRT Lens alone

For energies below **9.50 keV**, the 333-um pre-focusing lens stack is **not allowed**, regardless of transfocator setting. For **9.50 keV to 11.11 keV**, the use of the 333 µm pre-focusing lens stack alone (without a transfocator lens in the beam) is **not allowed**.

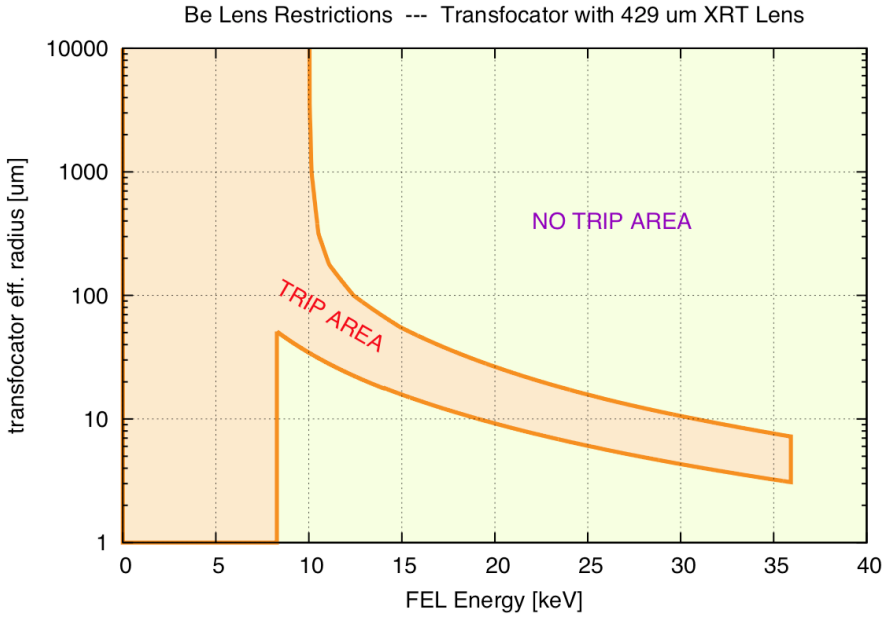
If the 333 µm XRT lens is inserted and any transfocator lens is inserted, the allowed energy depends on the effective radius of the transfocator lens stack that is inserted. The FEL energy/effective radius pair may not be in the red area shown below.



Trip Limits for MFX Transfocator with 429 µm XRT Lens alone

For energies **below 8.28 keV**, the 429 µm pre-focusing lens stack is **not allowed**, regardless of transfocator setting. For **8.28 keV to 10.02 keV**, use of the 429 µm pre-focusing lens stack alone (without a transfocator lens in the beam) is **not allowed**.

If the 429 µm XRT lens is inserted and any transfocator lens is inserted, the allowed energy depends on the effective radius of the transfocator lens stack that is inserted. The FEL energy/effective radius pair may not be in the red area shown below.



Trip Limits for MFX Transfocator with 750 µm XRT Lens alone

For energies **below 5.96 keV**, the 750 µm pre-focusing lens stack is **not allowed**, regardless of transfocator setting. For **5.96 keV to 8.02 keV**, use of the 750 µm pre-focusing lens stack alone (without a transfocator lens in the beam) is **not allowed**.

If the 750 µm XRT lens is inserted and any transfocator lens is inserted, the allowed energy depends on the effective radius of the transfocator lens stack that is inserted. The FEL energy/effective radius pair may not be in the red area shown below.