INSTRUMENT DEVELOPMENT GROUP

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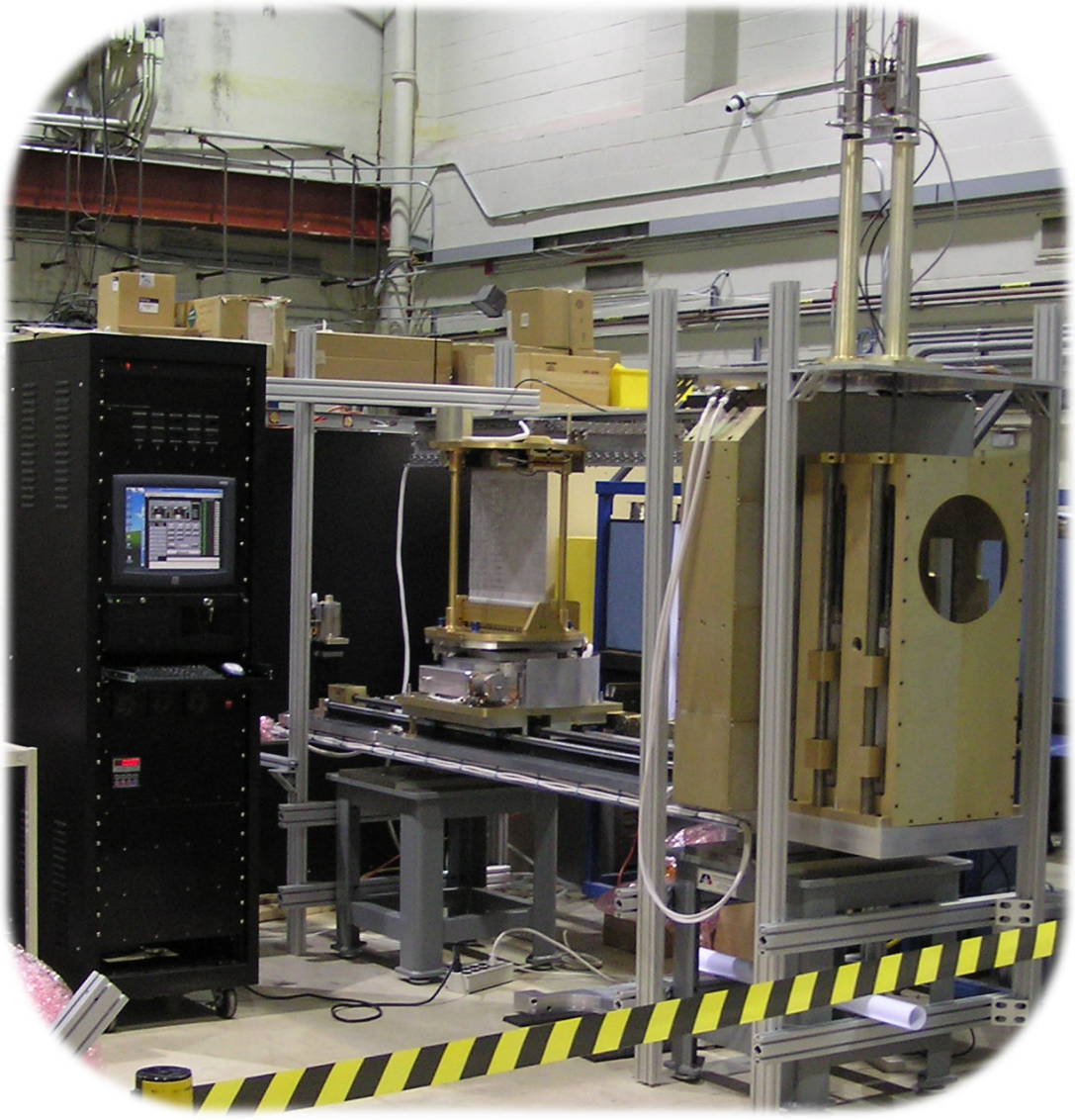
MACS Dual Focusing Monochromator, VBA, DTS and ICX Software Users Guide

Joe Orndorff – August 17, 2005 Software Version 4.26



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Acronyms Used

DFM – Doubly Focusing Monochromator

MACS – Multi-axis Crystal Spectrometer

DAM – Dual Array Monochromator

VBA – Variable Beam Aperture

VBAH, VBAV – VBA Horizontal and VBA Vertical Axes

DTS – DFM Transport System

ICC – Instrument Control Computer

MCC – Monochromator Control Computer

ICX – Incident Beam Collimator Exchanger

Conventions

Text in **[brackets]** represents options.

Text in ***italics*** represents variables that should be replaced with appropriate text.

Introduction

The DFM Control program runs on the Monochromator Control Computer. It was written using National Instruments LabView 7.0. The LabView Database Connectivity Toolset was also used in conjunction with a Microsoft Access database, "DFM_MACS.mdb". The DFM program runs on a PC Windows XP platform. The DFM software was written with the intent of being compatible with several instruments including the BT7 Dual Array Monochromator, the MACS Doubly Focusing Monochromator and a Six Blade Dual Array Monochromator Mockup. National Instruments Application Builder is used to compile the program to create '.dll' and '.exe' files.

The DFM Control program receives commands from the Monochromator Control Computer (MCC) via an RS232 serial port. The MCC then provides the necessary monochromator axis moves and then reports status information back to the ICC.

Hardware

The DFM Control Program is required to control and interface with numerous devices including:

Advanced Micro Systems DR-4MI (modified MAX410) Motor Indexer, twenty-five are used on the MACS-DFM to control all axes. Four are used on the MACS-DAM to control the vertical focusing motors and the linear and rotation stage motors. The DR-4MIs used for blade motor control have been modified to limit the current to 1A at 100% setting.

Advanced Micros Systems CMAX810 Motor Indexer, used to control VBAH, VBAV and DTS axes.

RDP Electrosense E525 LVDT Controller. Each E525 controls two LVDT sensors that monitor vertical focus position. Two LVDTs are located on either side of the MACS-DFM focus bar.

Resolver Readout Boards, custom built by JHU, used to telemeter position of DTS, VBAH and VBAV axes.

AD-Link C588 8-port PCI serial card. One of these cards is installed in each monochromator control PC. It is needed to provide RS232 communications along with the PC's serial ports to the motor indexers, LVDT controller and ICC computer.

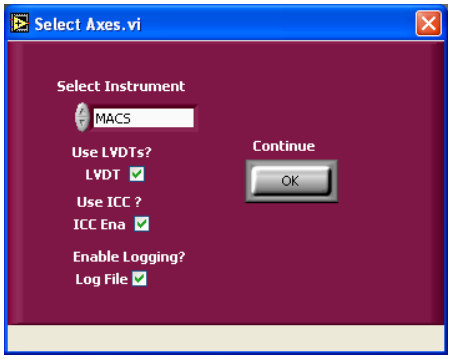
Figure 1

MCC Rack Power-up and Software Startup Procedure

1. Verify that all front and rear panel switches are powered off.
2. Turn on Red switch, located in upper right-hand corner on the front side of the electronics rack. After switching on, it should be illuminated and the LED next to it should be on.
3. Turn on AC power switches (located in back of rack) for 'POWER SUPPLY CABINTET' and 'VERTICAL FOCUS AND TRANSLATION' cabinet. The switches are located in back of the rack. (see Figure1)
4. Note the LVDT electronics needs to be on for 15 minutes before taking stable and accurate readings.
5. Turn on computer via switch located in rear of computer chassis.
6. Open computer front door and push round pushbutton, located to left of drive bays
7. Turn on indexer power switches (located on front panel near top of rack) in the following sequence, monitor current and voltage readings as you power on (Note readings represent status when fully powered on):
   - Logic Power: Voltage = 5V ± 0.2V Current = 1.4A ± 0.050A
   - Focus Power: Voltage = 40V ± 2.0V Current = .4A± 0.100A
   - Blade1 Power: Voltage = 40V ± 2.0V Current = .6A ± 0.100A
   - Blade2 Power: Voltage = 40V ± 2.0V Current = .6A ± 0.100A
   - Blade3 Power: Voltage = 40V ± 2.0V Current = .6A ± 0.100A
   - DTS,VBA: Switch on panel below keyboard tray. There are no meters for these axes.
   - Power on the ICX control box.
8. Allow one minute for all axes to boot up and become stable.
9. Examine LVDT control panel, located on Focus drawer front panel. Press Mode switch 1 then Mode switch 2 to take LVDT readings. Both LVDTs should read 0.000mm ± .0200mm, indicating that both vertical focus axes are homed.
10. Note the DFM electronics rack and ICX box must be fully powered before starting the LabView program. In addition the ICC com port must be connected to the MCC computer.

11. The program is started by executing the 'dfm_main.exe' file.

12. After the program starts, an Instrument selection screen will appear. Select the instrument you are using with the "select Instrument" control. You can also enable/disable the LVDT readout and Logging. When you are finished click "continue"



13. If Logging is enabled, the program will prompt you to create a log file. You can use the default filename and directory or create your own.

14. Next the program will read data from the DFM database and store it in global data arrays.

15. Finally all of the COM ports will be initialized.

16. A main user interface panel will now appear on the screen. The user controls will be grayed out until the initialization process is complete and axis position information is read from all of the indexers.

17. Verify that the proper number of blade axes is shown in the right-hand column and at the bottom of the screen.

18. At this point the software is ready to accept user commands via the touch-screen.

19. Under normal conditions, all of the axes, with the exception of perhaps the VBAH and VBAV, should indicate that they are at their home positions. This ought to be true since all axes should have been homed prior to powering down the electronics rack.

    WARNING, IF INSTRUMENT IS USED WITH BLADE OR FOCUS MOTORS STARTING AT UNKNOWN ROTATIONS, A BLADE CRASH CONDITION IS POSSIBLE.

20. If all axes are not at home, determine the cause of the current configuration before proceeding. Examine the log file, if logging was used. If necessary, command all axes to HOME by pressing the ALL HOME button. Bear in mind that the indexers do not store position information when powered off. They power on assuming indexer count set to zero.

21. It should now be safe to proceed with motor commands.

22. Press the REMOTE/LOCAL button to switch to ICC control. Note the control panel should be hidden when in REMOTE mode.

MCC Rack Power-down Procedure

1. Home the VBAH and VBAV axes if desired.
2. Lower both ICXs. (use ICC cmd ICX1DN and ICX2DN)
3. If under ICC control, press the REMOTE/LOCAL button to return to LOCAL mode.
4. Press the ALL HOME button to home all axes (VBA is not homed by the ALL HOME).
5. Press the EXIT button and wait for program to exit.
6. Power down the rack power supplies in the reverse order in which they were powered.

   Power off DTS/VBA Power, Blade Power, Focus Power and Logic Power.
7. From Windows press START → Shut Down, and power off PC.
8. Turn off AC power switches for 'POWER SUPPLY drawer and 'VERTICAL FOCUS TRANSLATION' drawer. The switches are located in back of the rack. (see Figure1)
9. Turn off Red switch, located in upper right-hand corner on the front side of the electronics rack. After switching off.

DFM Database

Microsoft Access databases are used to store various motor controller setup parameters, axis information, instrument configuration information and telemetry. The database provides a simple user interface as well as a robust software interface to store and manage system information. Most of the tables are stored in global variables when the DFM program initializes. Some table values are updated by various configuration commands and telemetry monitoring commands.

Each DFM will have its own database ("dfm_bt7.mdb", "dfm_macs.mdb", "dfm_mu.mdb").

ICC_Command_Structure Table. This table contains all of the ICC commands. It also contains parameter limits to be used by the DFM control program for bounds checking. An error code is assigned to each command.

Field Name	Data Type	Description
CMD_NUM	Number	Index number assigned to CMD
CMD	Text	Name of CMD
IMMEDIATE	Yes/No	Command Type
SYS_CMD	Yes/No	Is this command a system level or axis level command
IS_P1_USED	Yes/No	Is Parameter 1 used?
P1_DEFAULT	Number	Default value for P1
P1LOW	Number	Lowest allowed value for P1
P1HI	Number	Highest allowed value for P1
IS_P2_USED	Yes/No	Is Parameter 2 Used?
P2_DEFAULT	Number	Default value for P2
P2LOW	Number	Lowest allowed value for P2
P2HI	Number	Highest allowed value for P2
ERROR_CODE	Number	Error Code associated with sending this command

ICC_CMD_Structure

CMD_NUM	CMD	IMMEDIATE	SYS_CMD	IS_P1_USED	P1_DEFAULT	P1LOW	P1HI	IS_P2_USED	P2_DEFAULT	P2LOW	P2HI	ERROR_CODE
0	ABORT	True	Yes	False	0	0	0	False	0	0	0	5300
1	HOME	False	No	False	0	0	1	False	0	0	0	5302
2	RADIUS	False	No	True	9000	900	9000	False	0	0	0	5303
3	MOVE	False	No	True	0	-10000	10000	False	0	0	0	5304
4	SLEW_POS	False	No	True	0.001	0.001	10	False	0	0	0	5305
5	SLEW_NEG	False	No	True	0.001	0.001	10	False	0	0	0	5306
6	STEP_POS	False	No	True	0.001	0	10000	False	0	0	0	5307
7	STEP_NEG	False	Yes	True	0.001	0	10000	False	0	0	0	5308
8	DFM_GO	False	Yes	False	0	0	0	False	0	0	0	5309
9	DFM_MOVING	True	Yes	False	0	0	0	False	0	0	0	5310
10	POSITION	True	No	False	0	0	0	False	0	0	0	5311
11	STATUS	True	No	False	0	0	0	False	0	0	0	5312
12	SET_OFFSET	True	No	True	0	0	1	True	0	-1000	1000	5313
13	READ_OFFSET	True	No	True	0	0	1	False	0	0	0	5314
14	DFM_LOAD	False	Yes	True	0	35	130	True	0	0	180	5315
15	DFM_HOME	False	Yes	False	0	0	0	False	0	0	0	5316
16	UP	False	No	False	0	0	0	False	0	0	0	5317
17	DOWN	False	No	False	0	0	0	False	0	0	0	5318
18	READ_ERROR	True	Yes	False	0	0	0	False	0	0	0	5320
19	ICX1UP	False	Yes	False	0	0	0	False	0	0	0	5321
20	ICX1DN	False	Yes	False	0	0	0	False	0	0	0	5322
21	ICX2UP	False	Yes	False	0	0	0	False	0	0	0	5323
22	ICX2DN	False	Yes	False	0	0	0	False	0	0	0	5324
23	ICXSTATUS	True	Yes	False	0	0	0	False	0	0	0	5325
24	ICXERROR	True	Yes	False	0	0	0	False	0	0	0	5326
25	RESOLVER	True	No	False	0	0	0	False	0	0	0	5327

AMS Indexer Command Table. This table contains all of the indexer commands. It also contains parameter limits to be used by the DFM control program for bounds checking. An error code is also associated with each command. All indexers in the MCC rack were purchased from AMS so they share most of the same commands.

	Field Name	Data Type	Description
🔑	CMD_NUM	Number	Index number assigned to CMD
	FTN	Text	Name of CMD
	CMD	Text	CMD Character
	ASCII_VAL	Number	ASCII value of CMD Character
	NV_BYTES	Number	Number of NV Bytes used by CMD
	IS_P1_USED	Yes/No	Is Parameter 1 used?
	P1_DEFAULT	Number	Default value for P1
	P1LOW	Number	Lowest allowed value for P1
	P1HI	Number	Highest allowed value for P1
	P1_FORMAT	Text	Text Format string for P1
	IS_P2_USED	Yes/No	Is Parameter 2 Used?
	P2_DEFAULT	Number	Default value for P2
	P2LOW	Number	Lowest allowed value for P2
	P2HI	Number	Highest allowed value for P2
	P2_FORMAT	Text	Text Format string for P2
	DEF	Yes/No	Command Type
	IMMEDIATE	Yes/No	Command Type
	PROG	Yes/No	Command Type
	HW	Yes/No	Command Type
	GBL	Yes/No	Command Type
	ERROR_CODE	Number	Error Code associated with sending this command

Indexer_CMD_Structure

CMD_NUM	FTN	CMD	ASCII_VAL	NV_BYTES	IS_P1_USED	P1_DEFAULT	P1LOW	P1HI	P1_FORMAT	IS_P2_USED	P2_DEFAULT	P2LOW	P2HI	P2_FORMAT	DEF	IMMEDIATE	PROG	HW	GBL	ERROR_CODE
0	ABORT	ESC	27	0	False	0	0	0	%f	False	0	0	0	%f	False	True	False	False	True	5000
1	SOFT STOP	@	64	1	True	0	0	1	%d	False	0	0	0	%d	False	True	True	False	True	5001
2	SOFTWARE RESET	^C	3	0	False	0	0	0	%d	False	0	0	0	%d	False	True	False	False	True	5002
3	PORT READ/WRITE	A	65	2	True	0	0	129	%d	False	0	0	0	%d	False	True	True	False	False	5003
4	SET JOG SPEEDS	B	66	0	True	30	0	255	%d	True	200	0	255	%d	True	True	True	False	False	5004
5	CLEAR AND RESTORE	C	67	0	True	0	0	9	%d	False	0	0	0	%d	True	False	True	False	False	5005
6	DIVIDE RESOLUTION	D	68	2	True	0	0	8	%d	False	0	0	0	%d	True	False	True	False	False	5006
7	SETTING TIME DELAY	E	69	2	True	100	0	255	%d	False	0	0	0	%d	True	True	False	False	False	5007
8	FIND HOME	F	70	3	True	400	20	20000	%d	True	0	0	1	%d	False	True	True	False	False	5008
9	GO	G	71	3	True	0	0	17912048	%d	True	0	0	1	%d	False	True	True	True	False	5009
10	RESOLUTION MODE	H	72	2	True	1	0	1	%f	False	0	0	0	%d	True	True	False	False	False	5010
11	INITIAL VELOCITY	I	73	3	True	400	20	20000	%d	False	0	0	0	%d	True	True	True	False	False	5011
12	PRIMARY AND SECONDARY JUMP	J	74	4	True	0	0	1791	%d	True	0	0	255	%d	False	False	True	False	False	5012
13	RAMP SLOPE	K	75	3	True	10	0	255	%d	True	10	0	255	%d	True	True	True	False	False	5013
14	LOOP ON PORT	L	76	4	True	0	0	17912048	%d	True	0	0	5	%d	False	True	True	False	False	5014
15	MOVE AT FIXED VELOCITY	M	77	3	True	0	-20000	20000	%d	False	0	0	0	%d	False	True	True	False	False	5015
16	SET ORIGIN	O	79	1	False	0	0	0	%d	False	0	0	0	%d	False	True	True	False	False	5016
17	PROGRAM MODE	P	80	0	True	0	0	1791	%d	False	0	0	0	%d	False	True	False	False	False	5017
18	QUERY STORED PROGRAM	Q	81	0	True	0	0	1791	%d	False	0	0	0	%d	False	True	False	False	False	5018
19	RELATIVE INDEX	R	82	0	True	0	-8388607.99	8388607.99	%7.2f	False	0	0	0	%d	False	True	True	False	False	5019
20	STORE PARAMETERS	S	83	0	False	0	0	0	%f	False	0	0	0	%d	False	True	False	False	False	5020
21	TRIP POINT	T	84	5	True	0	-8388608	8388608	%d	True	0	0	255	%d	True	False	True	False	False	5021
22	SLEW VELOCITY	V	86	3	True	400	20	20000	%d	False	0	0	0	%d	True	True	True	False	False	5022

Indexer_CMD_Structure																			
CMD_NUM	FTN	CMD	ASCII_VAL	NV_BYTES	IS_P1_USED	P1_DEFAULT	P1LOW	P1HI	P1_FORMAT	IS_P2_USED	P2_DEFAULT	P2LOW	P2HI	P2_FORMAT	DEF	IMMEDIATE	PROG	HW	GBL	ERROR_CODE
23	WAIT TIME	W	87	3	True	0	0	255	%d	False	0	0	0	%d	True	False	True	False	False	5023
24	EXAMINE PARAMETERS	X	88	0	False	0	0	0	%f	False	0	0	0	%d	False	True	False	False	False	5024
25	HOLD/RUN CURENT	Y	89	0	True	5	0	100	%d	True	25	0	100	%d	True	True	False	False	False	5025
26	READ POSITION (NON ENCODER)	Z	90	0	True	0	0	1	%d	False	0	0	0	%d	False	True	False	False	False	5026
27	READ NVM ADDRESS	[	91	0	True	0	0	2048	%d	True	0	0	255	%d	False	True	False	False	False	5027
28	READ LIMITS/HARDWARE	]	93	0	True	0	0	1	%d	False	0	0	0	%d	False	True	False	False	False	5028
29	+ INDEX	+	43	5	True	0	0.01	8388607.99	%7.2f	False	0	0	0	%d	False	True	True	False	False	5029
30	- INDEX	-	45	5	True	0	0.01	8388607.99	%7.2f	False	0	0	0	%d	False	True	True	False	False	5030
31	READ MOVING STATUS	^	94	0	False	0	0	0	%f	False	0	0	0	%d	False	True	False	False	False	5031
32	NVM DIRECT WRITE	\	92	0	True	0	0	2048	%d	True	0	0	255	%d	False	True	False	False	False	5032
33	DEADBAND ENABLE	d	100	3	True	0	0	255	%d	False	0	0	0	%d	True	True	False	False	False	5033
34	ENCODER RESOLUTION	e	101	0	True	0	0	2000	%d	False	0	0	0	%d	False	True	False	False	True	5034
35	FIND ENCODER INDEX MARK	f	102	2	True	0	0	1	%d	False	0	0	0	%d	False	True	True	False	False	5035
36	HUNT RESOLUTION	h	104	2	True	4	0	8	%d	False	0	0	0	%d	True	True	False	False	False	5036
37	SECONDARY JUMP	j	106	4	True	0	0	1791	%d	True	0	0	255	%d	False	False	True	False	False	5037
38	SPECIAL TRIP	k	107	5	True	0	-8388608	8388608	%f	True	0	0	56	%d	False	True	True	False	False	5038
39	LIMIT POLARITY	l	108	0	True	0	0	3	%d	False	0	0	0	%d	True	False	False	False	False	5039
40	SET ORIGIN	o	111	0	False	0	0	0	%f	False	0	0	0	%d	True	False	False	False	False	5040
41	QUERY PROGRAM AS LIST	q	113	0	True	0	0	1791	%d	False	0	0	0	%d	True	False	True	False	False	5041
42	STALL RETRY COUNT	r	114	0	True	0	0	255	%d	False	0	0	0	%d	True	True	True	False	False	5042
43	STALL FACTOR	s	115	0	True	0	0	255	%d	False	0	0	0	%d	True	True	False	False	False	5043
44	STALL TEST DELTA	t	116	0	True	0	0	255	%d	False	0	0	0	%d	True	True	False	False	False	5044
45	HUNT VELOCITY	v	118	0	True	400	20	8000	%d	False	0	0	0	%d	True	True	False	False	False	5045
46	OUTPUT CR LF	y	121	0	False	0	0	0	%f	False	0	0	0	%d	False	True	True	False	False	5046
47	READ ENCODER POSITION	z	122	0	True	0	0	1	%d	False	0	0	0	%d	False	True	False	False	False	5047

Error_Code Table. Stores error codes and error descriptions to be displayed in the event of a program error.

Error_Codes	
Code	Description
5000	Error Sending ABORT CMD
5001	Error Sending SOFT STOP CMD
5002	Error Sending SOFTWARE RESET CMD
5003	Error Sending PORT READ/WRITE CMD
5004	Error Sending SET JOG SPEEDS CMD
5005	Error Sending CLEAR AND RESTORE CMD
5006	Error Sending DIVIDE RESOLUTION CMD
5007	Error Sending SETTING TIME DELAY CMD
5008	Error Sending FIND HOME CMD
5009	Error Sending GO CMD
5010	Error Sending RESOLUTION MODE CMD
5011	Error Sending INITIAL VELOCITY CMD
5012	Error Sending PRIMARY AND SECONDARY JUMP CMD
5013	Error Sending RAMP SLOPE CMD
5014	Error Sending LOOP ON PORT CMD
5015	Error Sending MOVE AT FIXED VELOCITY CMD
5016	Error Sending SET ORIGIN CMD
5017	Error Sending PROGRAM MODE CMD
5018	Error Sending QUERY STORED PROGRAM CMD
5019	Error Sending RELATIVE INDEX CMD

Error_Codes	
Code	**Description**
5020	Error Sending STORE PARAMETERS CMD
5021	Error Sending TRIP POINT CMD
5022	Error Sending SLEW VELOCITY CMD
5023	Error Sending WAT TIME CMD
5024	Error Sending EXAMINE PARAMETERS CMD
5025	Error Sending HOLD/RUN CURRENT CMD
5026	Error Sending READ POSITION (NON-ENCODER) CMD
5027	Error Sending READ NVM ADDRESS CMD
5028	Error Sending READ LIMITS/HARDAWARE CMD
5029	Error Sending + INDEX CMD
5030	Error Sending - INDEX CMD
5031	Error Sending READ MOVING STATUS CMD
5032	Error Sending NVM DIRECT WRITE CMD
5033	Error Sending DEADBAND ENABLE CMD
5034	Error Sending ENCODER RESOLUTION CMD
5035	Error Sending FIND ENCODER INDEX CMD
5036	Error Sending HUNT RESOLUTION CMD
5037	Error Sending SECONDARY JUMP CMD
5038	Error Sending SPECIAL TRIP CMD
5039	Error Sending LIMIT POLARITY CMD
5040	Error Sending SET ORIGIN (encoder) CMD
5041	Error Sending QUERY PROGRAM AS LIST CMD
5042	Error Sending STALL RETRY COUNT CMD
5043	Error Sending HUNT VELOCITY CMD
5044	Error Sending STALL TEST DELTA CMD
5045	Error Sending HUNT VELOCITY CMD
5046	Error Sending OUTPUT CR LF CMD
5047	Error Sending READ ENCODER POSITION CMD
5100	Error - Command parameter out of range
5101	Error - Serial port timed out
5102	Error - Indexer echo check failed
5103	Error - Indexer busy
5104	Error - Indexer address verification failed
5105	Error - Did not receive "#" symbol after CR
5106	Error - reading sign on message
5107	Error - Motor Limit detected
5108	Error - Initializing Indexers. Make sure power is applied and cable OK then Restart
5109	Error - Writing Blade Angle to BLADE_ROT_TLM Table
5110	Error - Axis Move failed to reach target
5112	Error - Blade Relative Move CMD failed to reach target
5113	Error - Focus Relative Move CMD failed to reach target
5114	Error - Reading indexer parameters
5115	Error - Abort command failed to stop motion
5116	Error - Cannot issue blade command unless vertical focus is at home
5117	Error - Cannot issue move command, motion is in progress
5118	Error - Focus Index Move CMD failed to reach target
5119	Error - Motion still progress
5120	Error - Emergency Stop CMD Issued (Move Timed Out)
5121	Error - Set Origin CMD failed
5122	Error - Reading from DFM Database
5123	Error - Setting focus hold current
5124	Error - Allowed number of Serial Port retries exceeded
5125	Error - Slew CMD Failed
5126	Error - Relative Index CMD Failed
5127	Error - Writing to Log File
5128	Error - Reading Motor Position
5129	Error - Find Home CMD Failed
5130	Error - Set Origin CMD Failed
5131	Error - Serial Read CMD Failed

Error_Codes	
Code	**Description**
5132	Error - Retry Limit Reached
5133	Error - Character Limit Reached
5134	Error - E525 Not in proper state
5135	Error - E525 Command Echo
5136	Error - Blade crash loopback check failed
5137	Error - Writing Indexer Telemetry to DB
5138	Error - Serial port conflict
5141	ICC Error - Reading N-Bytes from ICC
5143	Error - Elevator not in proper position
5144	Error - FOCUS_SYNC command not allowed
5145	Error - Only one array can be focused at one time
5146	Error - Focus motors at different rotations
5147	Error - radius parameter out of range
5148	Error - Move could result in blade crash
5300	ICC Error - ABORT Command
5301	ICC Error - RESUME Command
5302	ICC Error - HOME command
5303	ICC Error - RADIUS command
5304	ICC Error - MOVE command
5305	ICC Error - SLEW_POS command
5306	ICC Error - SLEW_NEG command
5307	ICC Error - STEP_POS command
5308	ICC Error - STEP_NEG command
5309	ICC Error - DFM_GO command
5310	ICC Error - DFM_MOVING command
5311	ICC Error - POSITION command
5312	ICC Error - STATUS command
5313	ICC Error - SET_OFFSET command
5314	ICC Error - READ_OFFSET command
5315	ICC Error - DFM_LOAD command
5316	ICC Error - DFM_HOME command
5317	ICC Error - UP/DOWN CMD only valid for Elevator
5318	ICC Error - Down
5319	ICC Error - Read Error
5320	ICC Error - ICX1_UP
5321	ICC Error - ICX1_DN
5322	ICC Error - ICX2_UP
5323	ICC Error - ICX2_DN
5324	ICC Error - ICX_STATUS
5326	ICC Error - ICX_Error
5327	ICC Error - Resolver
5400	ICC Error - Bad ICC command string
5401	ICC Error Only Focus_Sync Moves allowed
6004	Error - E525 INVALID NUMERIC DATA
6005	Error - LVDT reading does match Indexer Position

Indexer_Parameters Table. Stores all of the indexer setup parameters such as Initial Velocity Slew Velocity etc. The data in this table is useful for calculating expected motor run times which can in turn be used to calculate motor timeouts.

Field Name	Data Type	Description
Number	Number	Indexer Number
RM	Number	Resolution Mode
SRC	Number	Stall Retry Count (0 to 255)
DR	Number	Divide Resolution (0=full, 1=1/2, 2=1/4…8=1/256)
SJS	Number	Slow Jog Speed (0 to 7650 steps/sec)
HJS	Number	High Jog Speed (0 to 7650 steps/sec)
RSA	Number	Ramp Slope Accel (0 to 255)
RSD	Number	Ramp Slope Decel (0 to 255)
TP	Number	Trip Point (+/- 8,388,607)
TPA	Number	Trip Point Address (0 to 255, 0 = off)
Hi	Number	Hold Current (0 to 100%)
Ri	Number	Run Current (0 to 100%)
ST	Number	Settle Time (0 to 2550ms)
ER	Number	Encoder Resolution (0,50 to 2000 lines)
SF	Number	Stall Factor (0 to 100%)
DB	Number	Dead Band (0 to 255 steps or counts)
SI	Number	Stall Interval (0 to 255 steps)
Vi	Number	Initial Velocity (20 to 20,000 steps/sec)
SV	Number	Slew Velocity (20 to 20,000 steps/sec)
HV	Number	Hunt Velocity (20 to 8,000 steps/sec)
HR	Number	Hunt Resolution (0=full, 1=1/2, 2=1/4…8=1/256)
Sel	Text	Selected Indexer Address

IndexerParameters

Number	RM	SRC	DR	SJS	HJS	RSA	RSD	TP	TPA	Hi	Ri	ST	ER	SF	DB	SI	Vi	SV	HV	HR	Sel
1	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	A
2	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	B
3	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	C
4	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	D
5	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	E
6	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	F
7	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	G
8	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	H
9	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	I
10	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	J
11	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	K
12	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	L
13	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	M
14	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	N
15	0	0	1	90	210	10	10	-8388608	0	0	30	20	0	0	0	0	499	6005	6005	3	O
16	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	P
17	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	Q
18	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	R
19	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	S
20	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	T
21	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	U

IndexerParameters																				
Number	RM	SRC	DR	SJS	HJS	RSA	RSD	TP	TPA	Hi	Ri	ST	ER	SF	DB	SI	Vi	SV	HV	HR	Sel
22	0	0	3	90	210	10	10	-8388607	0	0	40	20	0	0	0	0	199	800	800	3	V
23	0	0	3	90	210	10	10	-8388608	0	0	60	20	0	0	0	0	196	3490	3490	3	W
24	0	5	5	90	600	0	0	-8388608	0	0	20	20	0	8	30	5	782	7206	680	5	Z
25	0	0	3	90	210	10	10	-8388608	0	0	40	20	0	0	0	0	998	4487	4487	3	X
26	0	0	3	90	210	10	10	-8388608	0	0	40	20	0	0	0	0	998	4487	4487	3	Y
27	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	a
28	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	b
29	0	0	1	90	210	10	10	-8388608	0	0	100	20	0	0	0	0	499	6005	6005	1	c

Indexer Assignment Table. This table assigns system level parameters to each motor axis.

Field Name	Data Type	Description
Add_Char	Text	Physical Address character used by AMS control chip
Name	Text	Indexer Name i.e. "Blade1"
COM_Port	Number	Com port assigned to this indexer
GH	Number	Gear Head Ratio (1 = not used)
MSR	Number	Motor Steps per revolution
ENCSF	Number	Encoder Scaling Factor
HomeDir	Number	Direction for home command (0 = Positive 1 = Negative)
TRUE_HOME_A	Number	Offset angle from actuator home position to true positon Top Array
TRUE_HOME_B	Number	Offset angle from actuator home position to true positon Bottome Array
Backlash	Number	Amount of Backlash for this motor
BKLashDir	Number	Move direction in which backlash is taken up (0 = Positive 1 = Negative)
Units	Text	Engineering units used for axis i.e. mm, deg, cm etc.
Enabled	Yes/No	Is this axis currently enabled
Indexer_Type	Text	MFG Part Number of Indexer
Polarity	Number	(0 = Positive 1 = Negative) Modifies Direction of motion to accomodate system coords

INDEXER_ASSIGNMENTS																	
Number	Add_Char	Name	COM_Port	GH	MSR	ENCSF	HomeDir	TRUE_HOME_A	TRUE_HOME_B	Backlash	BKLashDir	Units	Enabled	Indexer_Type	Polarity	NEG_LMT	POS_LMT
1	A	BLADE1	3	450.62963	200	1	1	-8.58	-8.58	1.00	0	deg	Yes	DR-4MI	0	-180	180
2	B	BLADE2	3	450.62963	200	1	1	-7.18	-7.18	1.00	0	deg	Yes	DR-4MI	0	-180	180
3	C	BLADE3	3	450.62963	200	1	1	-7.43	-7.43	1.00	0	deg	Yes	DR-4MI	0	-180	180
4	D	BLADE4	3	450.62963	200	1	1	-7.70	-7.70	1.00	0	deg	Yes	DR-4MI	0	-180	180
5	E	BLADE5	3	450.62963	200	1	1	-7.54	-7.54	1.00	0	deg	Yes	DR-4MI	0	-180	180
6	F	BLADE6	3	450.62963	200	1	1	-7.39	-7.39	1.00	0	deg	Yes	DR-4MI	0	-180	180
7	G	BLADE7	3	450.62963	200	1	1	-7.65	-7.65	1.00	0	deg	Yes	DR-4MI	0	-180	180
8	H	BLADE8	4	450.62963	200	1	1	-6.71	-6.71	1.00	0	deg	Yes	DR-4MI	0	-180	180
9	I	BLADE9	4	450.62963	200	1	1	-5.43	-5.43	1.00	0	deg	Yes	DR-4MI	0	-180	180
10	J	BLADE10	4	450.62963	200	1	1	-8.28	-8.28	1.00	0	deg	Yes	DR-4MI	0	-180	180
11	K	BLADE11	4	450.62963	200	1	1	-7.30	-7.30	1.00	0	deg	Yes	DR-4MI	0	-180	180
12	L	BLADE12	4	450.62963	200	1	1	-7.00	-7.00	1.00	0	deg	Yes	DR-4MI	0	-180	180
13	M	BLADE13	4	450.62963	200	1	1	-6.79	-6.79	1.00	0	deg	Yes	DR-4MI	0	-180	180
14	N	BLADE14	4	450.62963	200	1	1	-8.68	-8.68	1.00	0	deg	Yes	DR-4MI	0	-180	180
15	O	BLADE15	5	450.62963	200	1	1	-8.84	-8.84	1.00	0	deg	Yes	DR-4MI	0	-180	180
16	P	BLADE16	5	450.62963	200	1	1	-8.57	-8.57	1.00	0	deg	Yes	DR-4MI	0	-180	180
17	Q	BLADE17	5	450.62963	200	1	1	-7.49	-7.49	1.00	0	deg	Yes	DR-4MI	0	-180	180
18	R	BLADE18	5	450.62963	200	1	1	-8.42	-8.42	1.00	0	deg	Yes	DR-4MI	0	-180	180
19	S	BLADE19	5	450.62963	200	1	1	-7.85	-7.85	1.00	0	deg	Yes	DR-4MI	0	-180	180
20	T	BLADE20	5	450.62963	200	1	1	-7.18	-7.18	1.00	0	deg	Yes	DR-4MI	0	-180	180
21	U	BLADE21	5	450.62963	200	1	1	-8.73	-8.73	1.00	0	deg	Yes	DR-4MI	0	-180	180
22	V	TRANSLATION	6	70.8661	200	1	0	1.50	1.50	0.00	0	mm	Yes	DR-4MI	0	-20	20
23	W	ROTATION	6	360	200	1	0	0.20	0.20	0.00	0	deg	Yes	DR-4MI	0	-180	180
24	Z	ELEVATOR	6	141.7323	200	1	0	0.00	0.00	0.00	0	mm	No	CMAX-810	0	-344	0
25	X	FOCUS1	6	100	200	1	0	4.00	4.00	0.00	0	deg	Yes	DR-4MI	1	0	180

INDEXER_ASSIGNMENTS																	
Number	Add_Char	Name	COM_Port	GH	MSR	ENCSF	HomeDir	TRUE_HOME_A	TRUE_HOME_B	Backlash	BKLashDir	Units	Enabled	Indexer_Type	Polarity	NEG_LMT	POS_LMT
26	Y	FOCUS2	6	100	200	1	0	4.80	4.80	0.00	0	deg	Yes	DR-4MI	1	0	180
27	A	VBAH	8	70.886	200	1	0	2.00	2.00	0.00	0	mm	Yes	CMAX-810	1	1	362
28	B	VBAV	8	70.886	200	1	0	2.00	2.00	0.00	0	mm	Yes	CMAX-810	1	1	362
29	C	DTS	8	85.039	200	1	1	-6.35	-6.35	0.00	0	mm	Yes	CMAX-810	1	-1127	670

SYS_PARAMETERS table. Stores general system parameters.

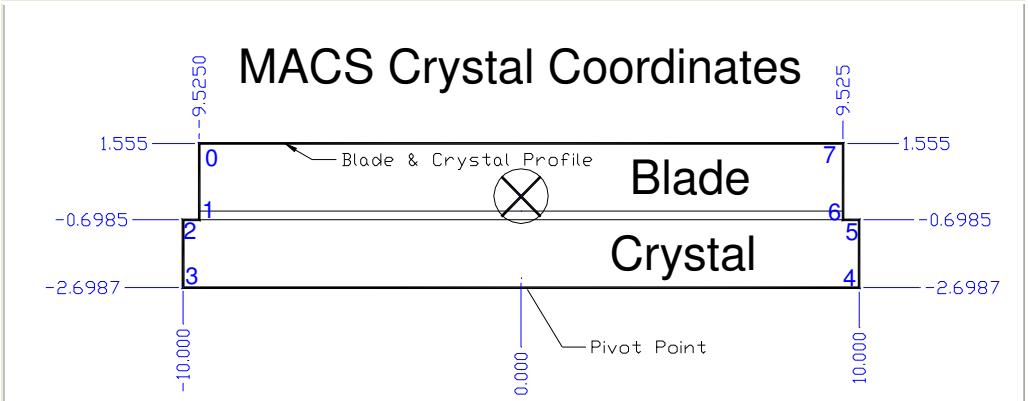
SYS_PARAMETERS			
ID	PARAMETER	VALUE	DESCRIPTION
1	LVDT_TOL	1	Allowed error between Y displacement and LVDT read
2	CAM_RADIUS_A	2.565	Cam radius of focus motor A
3	CAM_RADIUS_B	2.526	Cam radius of focus motor B
4	VERT_RADIUS_MIN	900	Min Focus Radius
5	VERT_RADIUS_MAX	10000	Maximum Focus Radius
6	C2	0	Spare Constant
7	NUM_BLADES	21	Number of blades in instrument
8	ICC_COM_PORT	2	COM port to communicate with ICC Computer
9	LVDT_COM_PORT	7	COM port to communicate with LVDT Controller
10	BLADE_SPACING	21	Center-to-center distance between blades
11	L0_REF	6200	L0 at reference position
12	DRUM_TO_DFM_REF	775	Drum to DFM distance at reference
13	DRUM_TO_SAMPLE	900	Drum to Sample distance
14	BLADE_LENGTH	444.004	Length of blade from pivot to pivot (inf focus)
15	BLADE_THICKNESS	1.999	Maximum thickness of blade (at center)
16	2THETA_MIN	35	Minimum allowed 2 theta value
17	2THETA_MAX	130	Maximum allowed 2 theta value
18	RESOLVER_COM_PORT	9	COM port to communicate with Resolvers
19	ICX_COM_PORT	10	COM port to communicate with ICX system
20	CRYSTAL_SPACING	21	Vertical crystal spacing in mm
21	CRYSTALS_PER_BLADE	17	# Crystals mounted on each blade
22	CRYSTAL_ANG_TOL	0.05	Allowed crystal angular position error

Look up table. Stores commanded radius to motor rotation angle look-up table. Also included is LVDT response to be used for future closed loop control. The software uses a linear interpolation of this table to determine proper vertical focusing (FOCUS1 or FOCUS2 motor rotation).

LOOK_UP_TABLE			
RADIUS	ANGLE1	ANGLE2	LVDT
900	144.011	145.82	4.657
925	131.513	136.827	4.417
950	129.015	130.131	4.206
975	122.519	123.388	3.971
1000	117.68	118.391	3.783
1025	113.681	114.343	3.622
1050	109.685	110.297	3.456
1075	106.189	106.801	3.307
1100	102.76	103.304	3.158
1125	99.763	100.307	3.026
1150	96.776	97.261	2.893
1175	94.268	94.763	2.781
1200	91.771	92.266	2.668
1225	89.273	89.768	2.555
1250	87.275	87.77	2.466
1275	85.327	85.772	2.378
1300	83.279	83.774	2.286
1325	81.281	81.776	2.197
1350	79.283	79.778	2.107
1375	77.535	78.03	2.031
1400	76.037	76.531	1.965
1425	74.538	74.984	1.898
1450	73.04	73.485	1.832
1475	71.791	72.236	1.778
1500	70.493	70.981	1.723
1550	67.995	68.49	1.617
1600	65.498	65.993	1.512

LOOK_UP_TABLE			
RADIUS	ANGLE1	ANGLE2	LVDT
1650	63.999	64.494	1.45
1700	61.502	61.996	1.348
1750	59.504	59.998	1.27
1800	57.956	58.5	1.211
1850	56.405	56.86	1.15
1900	55.057	55.611	1.1
1950	53.559	54.112	1.045
2000	52.06	52.614	0.991
2100	49.813	50.366	0.911
2200	47.565	48.118	0.834
2300	45.468	46.12	0.765
2400	43.47	44.123	0.701
2500	41.971	42.624	0.655
2600	40.624	41.375	0.615
2700	39.125	39.887	0.571
2800	37.577	38.378	0.528
2900	36.667	37.379	0.505
3000	35.631	36.63	0.477
3500	31.005	31.901	0.36
4000	27.509	28.602	0.284
5000	23.976	25.229	0.215
6000	20.381	21.983	0.155
7000	17.883	19.485	0.119
8000	15.989	17.989	0.096
9000	14.5	14.5	0.080
10000	0	0	0

Crystal Coordinates – Defines the vertices of one of the copper crystals. Used for blade crash determination and visual display panel.



CRYSTAL_COORDS

ID	x	y
0	-9.525	1.555
1	-9.525	-0.6985
2	-10	-0.6985
3	-10	-2.6987
4	10	-2.6987
5	10	-0.6985
6	9.525	-0.6985
7	9.525	1.555

Global Variables

Since LabVIEW doesn't really support a constants type of variable, global variables are used to store constant values. They are also used to contain array structures loaded from the DFM database tables during program initialization. The majority of the DFM Control Program routines are state machine structures. Global variables provide a means of writing and displaying telemetry information in separate threads.

- Local Mode (Boolean). True if in local command mode, False if being commanded by the ICC.
- ICC Command Array (Cluster array). Contains all of the ICC system commands and parameters read from the ICC Command Table in the DFM database.
- Indexer Command Array (Cluster array). Contains all of the AMS indexer commands and parameters read from the Indexer Command Table in the DFM database.
- LVDT Enable (Boolean). Shows whether or not the LVDTs are to be used.
- Instrument Used (Enumerated). Describes which instrument is being used (MACS-DFM, BT7, Mockup etc.).
- Focus Display Telemetry (Cluster array). Holds the telemetry for the two focus axes.
- Blade Display Telemetry (Cluster array). Holds the telemetry for all of the blade axes.
- Translation Display Telemetry (Cluster). Holds the telemetry for the linear translation stage axis.
- Rotation Display Telemetry (Cluster). Holds the telemetry for the rotation stage axis.
- Elevator Display Telemetry (Cluster). Holds the telemetry for the elevation axis.
- Ports Enabled (Boolean array). Contains a list of which communication ports are used.
- Log File Reference (Ref Num). Reference to file used for command and TLM logging.
- Database Reference (Ref Num). Reference to the DFM database.
- ICC COM Port (Integer). Reference to the COM port used to talk to the Interface Control Computer.
- LVDT COM Port (Integer). Reference to the COM port used to talk to the LVDT controller.
- Indexer Assignments (Cluster array). Contains all of the axis system parameters read from the Indexer Assignment Table in the DFM database.
- LVDT Tolerance (Float) Allowable LVDT error in mm.
- Abort Command (Boolean). Used to halt all motion throughout the program.
- Moving Status (Cluster). Contains the current state of motion for a selected axis.

- Moving Status (Boolean). Derived from the Moving Status Cluster, set high whenever an axis is in motion.
- Error Codes (Cluster Array). Contains error codes and error descriptions. Read from 'Error_Code' table in DB at start of program.
- Cam Radius A (Double). Radius of cam used with focus motor1. Used in AngleToRadius.vi.
- Cam Radius A (Double). Radius of cam used with focus motor2. Used in AngleToRadius.vi.
- Look up Table. Stores vertical radius to motor rotation translation data.
- Logging (Boolean). Enables/disables logging.

Remote Mode - Instrument Control Computer (ICC) commands.

The ICC communicates with the Monochromator Control Computer (MCC) via a serial communications port. This is set in the global variable 'ICC COM Port'.

Initially the program starts in Local Mode, meaning the user controls the instrument via the touchscreen. By clicking on the Remote/Local button the MCC can be configured to accept commands from the ICC. Note the user control panel will be hidden when in Remote Mode.

The ICC will send two types of commands, Motion commands and immediate commands. Once a command has been received, an acknowledge response will be sent (see commands below for details) .

The command structure is Command [axis] [parameter1] [parameter2]<CR/LF>.

All angles are in degrees and all distances are in millimeters.

If an error is encountered in the command or command parameters, and error message will be returned ex. ERR:5000@MOVE ROTATION 370.

If an error is encountered during a command, the error will be sent as a response to the subsequent command.

The abort command always gives an 'OK' response.

Note: All motion commands can be interrupted by an ABORT command.

Command	Function	Parameter1	Example
ABORT	**Abort all motion**	**n/a**	**ABORT<CR/LF>**
	Type **Immediate**	Parameter2 **n/a**	MCC Response **OK@ABORT<CR/LF>**
Description: The abort command immediately stops any motion in progress. The abort command toggles the state of the ABORT global variable, all motion routines use this as cause for termination. Sufficient time should be allowed after an abort command for all motion routines to terminate. A resume command is required after an ABORT to allow subsequent ICC commands to be accepted. The RESUME command does NOT resume a previously commanded motion; it only allows command operations to resume.			

Command	Function	Parameter1	Example
DFM_GO	**Initiate a stored move seq.**	**n/a**	**GO<CR/LF>**
	Type **Motion**	Parameter2 **n/a**	MCC Response **OK:@GO<CR/LF>**
Description: Moves all axes to accommodate the 2θ focus position commanded in the DFM_LOAD command. Warning: A successful DFM_LOAD must precede a DFM_GO command.			

Command	Function	Parameter1	Example
DFM_HOME	**Move all axes to home**	**n/a**	**DFM_HOME<CR/LF>**
	Type **Motion**	Parameter2 **n/a**	MCC Response **OK:@DFM_HOME**
Description: Moves all DFM axes to their home position. This command does not home the VBA or ICX. Warning: The home command will require several separate moves for some axes, this includes: initial move to zero position, backlash take-up, and bouncing off of limit switches and reversing direction. Note: The ELEVATOR axis is not included in this command.			
Axis Type	**Axis Name**	**Home Location**	

Vertical focus motor (rotary)	FOCUS_SYNC	Infinite focus (focus bar displacement at 0mm)
Blade motor (rotary)	BLADE1, BLADE2….BLADEn	Face of crystal orthogonal to motor mounting bar
Translation Stage motor (linear)	TRANSLATION	At CENTER position (middle of travel)
Rotation Stage motor (rotary)	ROTATION	Array rotated so that focus bar is orthogonal to incident beam
DFM Transport System	DTS	0mm Orthogonal to MBT and Beam line

Command	Function	Parameter1	Example
DFM_MOVING	**Checks for DFM motion**	**n/a**	**DFM_MOVING<CR/LF>**
	Type **Immediate**	Parameter2 **n/a**	MCC Response **OK:1@DFM_MOVING<CR/LF>**
Description: Used to determine if any axes on the DFM are in motion. Zero Indicates axes not in motion, one indicates axes are in motion			

Command	Function	Parameter1	Example
HOME	**Move axis to home**	**Axis**	**HOME BLADE1<CR/LF>**
	Type **Motion**	Parameter2 **n/a**	MCC Response **OK:@HOME BLADE1<CR/LF>**

Prerequisite: For blade crash protection, focus motors must be at infinite focus (home) in order to command a blade motor to home position.

Verification: Home sensor indicator must be activated at completion of move.

Description: Axes are commanded to their zero position, and then an indexer home command is issued. If a limit is detected, motion is reversed and the home command continues. If a home position can't be achieved, the command times out and an error is generated.

Axis Type	**Axis Name**	**Home Location**
Vertical focus motor (rotary)	FOCUS_SYNC	Infinite focus (focus bar displacement at 0mm)
Blade motor (rotary)	BLADE1, BLADE2….BLADEn	Face of crystal orthogonal to motor mounting bar
Translation Stage motor (linear)	TRANSLATION	At CENTER position (middle of travel)
Rotation Stage motor (rotary)	ROTATION	Array rotated so that focus bar is orthogonal to incident beam
Variable Beam Aperture Door	VBAH	34.4mm Aperture
Variable Beam Aperture Door	VBAV	34.7mm Aperture
DFM Transport System	DTS	0mm Orthogonal to MBT and Beam line

Command	Function	Parameter1	Example
ICX1UP	**Raises ICX1 Collimator**	**n/a**	**ICX1UP<CR/LF>**
	Type **Motion**	Parameter2 **n/a**	MCC Response **OK:@ICX1UP<CR/LF>**
Description: Raises the ICX1 Collimator. Note the collimator is pneumatically controlled and can only be positioned either up or down. Magnetically controlled read switches can be monitored to telemeter position information.			

Command	Function	Parameter1	Example
ICX1DN	**Lowers ICX1 Collimator**	**n/a**	**ICX1DN<CR/LF>**
	Type **Motion**	Parameter2 **n/a**	MCC Response **OK:@ICX1DN<CR/LF>**
Description: Lowers the ICX1 Collimator. Note the collimator is pneumatically controlled and can only be positioned either up or down. Magnetically controlled read switches can be monitored to telemeter position information.			

Command	Function	Parameter1	Example
ICX2UP	**Raises ICX2 Collimator**	**n/a**	**ICX2UP<CR/LF>**
	Type **Motion**	Parameter2 **n/a**	MCC Response **OK:@ICX2UP<CR/LF>**
Description: Raises the ICX2 Collimator. Note the collimator is pneumatically controlled and can only be positioned either up or down.			

Magnetically controlled read switches can be monitored to telemeter position information.

Command	Function	Parameter1	Example
ICX2DN	**Lowers ICX2 Collimator**	**n/a**	**ICX2DN<CR/LF>**
	Type **Motion**	Parameter2 **n/a**	MCC Response **OK:@ICX2DN<CR/LF>**
Description: Lowers the ICX2 Collimator. Note the collimator is pneumatically controlled and can only be positioned either up or down. Magnetically controlled read switches can be monitored to telemeter position information.			

Command	Function	Parameter1	Example
ICXSTATUS	**Position switch status**	**n/a**	**ICXSTATUS<CR/LF>**
	Type **Motion**	Parameter2 **n/a**	MCC Response **OK:@ICXSTATUS<CR/LF>**

ICX1	ICX2	Value
DN	DN	0A
UP	DN	09
UP	UP	05
DN	UP	06

Command	Function	Parameter1	Example
MOVE	**Move to absolute position**	**angle or linear-pos**	**MOVE BLADE1 2.23<CR/LF>**
	Type **Motion**	Parameter2 **n/a**	MCC Response **OK:@MOVE BLADE1 2.23<CR/LF>**
Description: Moves an axis to and absolute position. The distance is specified either in degrees or millimeters, depending on the axis being commanded.			

Axis Type	Axis Name	Lower Limit	Upper Limit
Vertical focus motor (rotary)	FOCUS_SYNC	0º	+180º
Blade motor (rotary)	BLADE1, BLADE2….BLADEn	0º	+360º
Translation Stage motor (linear)	TRANSLATION	-19mm	+19mm
Rotation Stage motor (rotary)	ROTATION	0º	180º
Variable Beam Aperture Door	VBAH	1mm	362mm
Variable Beam Aperture Door	VBAV	1mm	362mm
DFM Transport System	DTS	670mm	-1127mm

Command	Function	Parameter1	Example
POSITION	**Checks for axis position**	**n/a**	**POSITION TRANSLATION<CR/LF>**
	Type **Immediate**	Parameter2 **n/a**	MCC Response **OK:20.23@POSITION<CR/LF>**
Description: Relays the current position of a given axis. Position is in angles for rotation axes and mm for linear axes. For Focus1 and Focus2 axes, position indicates radius of focus in mm.			

Command	Function	Parameter1	Example
RADIUS	**Move to radius of focus**	**radius (int)**	**RADIUS FOCUS_SYNC 6022<CR/LF>**
	Type	Parameter2	MCC Response

	Motion	**n/a**	**OK:@RADIUS FOCUS_SYNC 6022<CR/LF>**
Prerequisite: The selected axis must be FOCUS_SYNC. RADIUS value must be in range for instrument i.e. MACS range is 900mm to 10,000mm. Description: The RADIUS command is used to provide vertical focusing of the DFM array. The radius value is converted to rotation of FOCUS1, FOCUS2 motors. A look up table is used to determine the appropriate motor rotation based on the radius specified. Verification: If the LVDTs are used, their values are compared with the expected focus bar translation for the commanded radius.			

Command **READ_ERROR**	Function **Reads back error code**	Parameter1 **n/a**	Example **READ_ERROR<CR/LF>**
	Type **Immediate**	Parameter2 **n/a**	MCC Response **OK:5000@DFM_READ_ERROR<CR/LF>**
Description A READ_ERROR command should be sent after an error is flagged in the status register. The error code will be sent from the MCC to the ICC. The READ_ERROR command also clears the error code.			

Command **READ_OFFSET**	Function **Read home offset from DB**	Parameter1 **ARRAY (0,1)**	Example **READ_OFFSET BLADE1 1<CR/LF>**
	Type **Immediate**	Parameter2 **n/a**	MCC Response **OK:-7.02@READ_OFFSET 1<CR/LF>**
Description: Reads the currently stored home position offset from the DFM database (see the SET_OFFSET command). In the case of linear stages the offset will be in mm. Array 0 selects top array, 1 selects bottom array. Note: The true home offset values are different for the top and bottom arrays.			

Command **SET_OFFSET**	Function **Set offset from sensor home position**	Parameter1 **ARRAY (0,1)**	Example **SET_OFFSET BLADE1 0 -7.02<CR/LF>**
	Type **Immediate**	Parameter2 **ANGLE (+/-1000)**	MCC Response **OK:@SET_OFFSET BLADE1 0 -7.02**
Description: Stores a new home offset angle/distance in the database. This offset represents the distance from the sensor home position to the optimized home position. In the case of linear stages the offset will be in mm. Values can range from -1000 to +1000. Array 0 selects top array, 1 selects bottom array. Warning: The DFM software must be restarted after the SET_OFFSET command so that the new database values can be read. Subsequently a HOME command has to be issued to the axis so that the new home position can be obtained.			

Command **SLEW_NEG**	Function **Slew in negative direction**	Parameter1 **Velocity(deg/sec)**	Example **SLEW_NEG BLADE1 2.00<CR/LF>**
	Type **Motion**	Parameter2 **n/a**	MCC Response **OK:@SLEW_NEG BLADE1 2.00<CR/LF>**

Description: Moves an axis at constant velocity in the negative direction. A slew command needs to be terminated with an ABORT command, followed by a Resume Command.
Prerequisites: Focus axes must be at home for blade slew commands. Blades must be at home for Focus slew commands.
Warning: Extreme caution should be used when issuing slew commands since they represent open ended moves. Also take into account that a slew command does not include backlash take-up. This will cause some inaccuracies with the blade axes and the translation stage.

Axis Type	**Axis Name**	**Positive Motion Direction**
Vertical focus motor (rotary)	FOCUS1, FOCUS2	
Blade motor (rotary)	BLADE1, BLADE2….BLADEn	
Translation Stage motor (linear)	TRANSLATION	
Rotation Stage motor (rotary)	ROTATION	

Command **SLEW_POS**	Function **Slew in positive direction**	Parameter1 **Velocity(deg/sec)**	Example **SLEW_POS BLADE1 2.00<CR/LF>**
	Type	Parameter2	MCC Response

	Motion	**n/a**	**OK:@SLEW_POS BLADE1 2.00<CR/LF>**

Description: Moves an axis at constant velocity in the positive direction. A slew command needs to be terminated with an ABORT command.
Prerequisites: Focus axes must be at home for blade slew commands. Blades must be at home for Focus slew commands.

Warning: Extreme caution should be used when issuing slew commands since they represent open ended moves. Also take into account that a slew command does not include backlash take-up. This will cause some inaccuracies with the blade axes and the translation stage.

Axis Type	**Axis Name**	**Positive Motion Direction**
Vertical focus motor (rotary)	FOCUS_SYNC	
Blade motor (rotary)	BLADE1, BLADE2….BLADEn	
Translation Stage motor (linear)	TRANSLATION	
Rotation Stage motor (rotary)	ROTATION	

Command	Function	Parameter1	Example
STATUS	**Checks for axis status**	**n/a**	**STATUS TRANSLATION<CR/LF>**
	Type	Parameter2	MCC Response
	Immediate	**n/a**	**OK:10001000@STATUS<CR/LF>**

Response is an 8bit Boolean text stream with MSB on the left and LSB on the right (see below).

Axis Type	**MSB 7**	**BIT6**	**BIT5**	**BIT4**	**BIT3**	**BIT2**	**BIT1**	**LSB 0**
BLADE	HOME	MIN Position	MAX Position	Watchdog	Low Volt	Soft Stop	n/a	DFM_error
FOCUS	HOME	-Limit	+Limit	Watchdog	Low Volt	Soft Stop	n/a	DFM_error
TRANSLATION	HOME	-Limit	+Limit	Watchdog	Low Volt	Soft Stop	n/a	DFM_error
ROTATION	HOME	-Limit	+Limit	Watchdog	Low Volt	Soft Stop	n/a	DFM_error
ELEVATOR	HOME/UP	-Limit	+Limit	Watchdog	Low Volt	Soft Stop	DOWN	DFM_error

Command	Function	Parameter1	Example
STEP_NEG	**Step in negative direction**	**Step-size(deg or mm)**	**STEP_NEG BLADE1 2.00<CR/LF>**
	Type	Parameter2	MCC Response
	Motion	**n/a**	**OK:@STEP_NEG BLADE1 2.00<CR/LF>**

Description: Move negative amount relative to current position.

Warning: Care should be taken not to issue step commands that would command axes past their limits (see MOVE command).

At the completion of a step command, position information should be read back from MCC to maintain accurate position status. Since stepper motors are not infinite resolution devices, numerous step commands may accrue significant error.

Axis Type	**Axis Name**	**Positive Motion Direction**
Vertical focus motor (rotary)	FOCUS_SYNC	
Blade motor (rotary)	BLADE1, BLADE2….BLADEn	
Translation Stage motor (linear)	TRANSLATION	
Rotation Stage motor (rotary)	ROTATION	

Command	Function	Parameter1	Example
	Step in positive direction	**Step-size(deg or mm)**	**STEP_POS BLADE1 2.00<CR/LF>**

STEP_POS	Type **Motion**	Parameter2 **n/a**	MCC Response **OK:@STEP_POS BLADE1 2.00<CR/LF>**
Description: Move positive amount relative to current position. Warning: Care should be taken not to issue step commands that would command axes past their limits (see MOVE command). At the completion of a step command, position information should be read back from MCC to maintain accurate position status. Since stepper motors are not infinite resolution devices, numerous step commands may accrue significant error.			

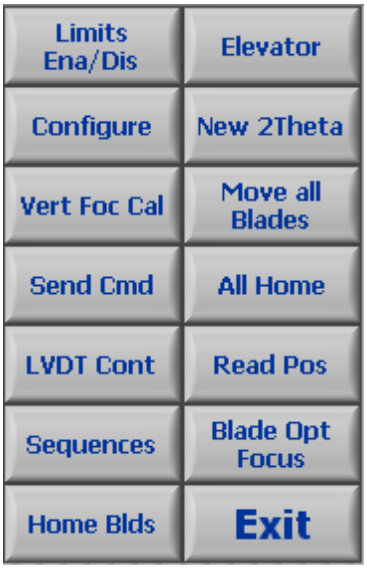
Axis Type	**Axis Name**	**Positive Motion Direction**
Vertical focus motor (rotary)	FOCUS_SYNC	CCW rotation of the motor cam shaft (looking at motor face). Focus bar moves towards smaller radii of focus.
Blade motor (rotary)	BLADE1, BLADE2….BLADEn	CCW blade rotation from birds-eye view
Translation Stage motor (linear)	TRANSLATION	Monochromator moves towards source
Rotation Stage motor (rotary)	ROTATION	Monochromator rotates CCW from birds-eye view
Elevator Motor (linear)	ELEVATOR	Motion is up with respect to the floor

Local Mode

In Local Mode DFM commands can be entered via the touch screen.

Press the Remote/Local button to return to local mode, control panels should be visible.

Below is the motor control panel. These commands only move one axis at a time, selected by the Select Axis button. The currently indicated axis is the one that will be moved.



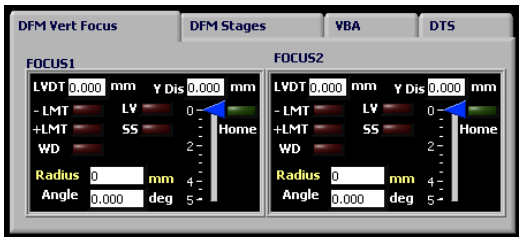
Slew, Step, Radius and Absolute move values are selected using the corresponding keypad button. This will bring up a numeric display allowing you to enter values using the touchscreen.

- System command panel. This command panel contains a variety of different commands for performing calibrations and multi-axis moves.
- Limits Ena/Dis – allows the user to disable blade crash detection circuit (password protected). Use with extreme caution.
- Elevator – Not used for MACS
- Configure – Loads indexer configuration panel.
- New 2Theta – Brings up panel that allows blade 2θ focusing.
- Vert foc Cal – Performs vertical focus calibration.
- Move all blades – Brings up panel that allows all blades to be positioned at a given angle.
- Send Cmd – Brings up panel that allows low level indexer commands to be issued (password protected).
- All Home – Sends all axes (except elevator) to home position.
- LVDT Cont – Brings up LVDT Control Panel.
- Read Pos – Reads current position and status of all axes.
- Sequences – Brings up test panel that allows repetitive testing of a single axis.
- Blade Opt Focus – Brings up panel that allows optical blade focusing, with crystals orthogonal to beam.
- Home Blds – Homes all blade axes.
- Exit – Exit the LabView program.

Abort button, will abort motion regardless of whether in Local or Remote mode.

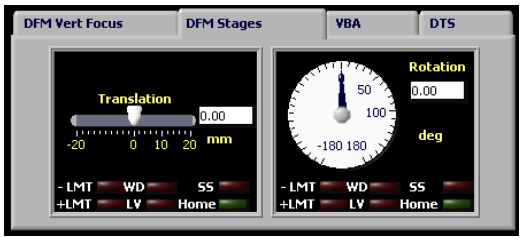
Telemetry Displays - valid for both Local and Remote operation.

Focus telemetry displays



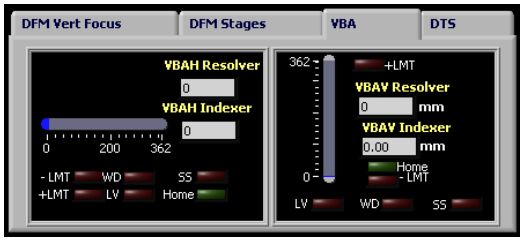
- Focus1 is located to the upper left of the array and Focus2 is on the upper right.
- Radius refers to Vertical focus radius of the blades
- LVDT indicates vertical translation of the focus bar

DFM Rotation and Translation Stages



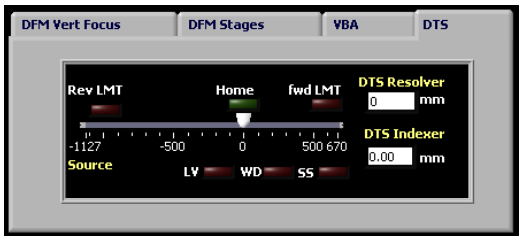
- Rotation represents rotation of the entire DFM
- Translation represents linear travel of the DFM orthogonal to a tangent line on the Rowland circle

VBA telemetry panel



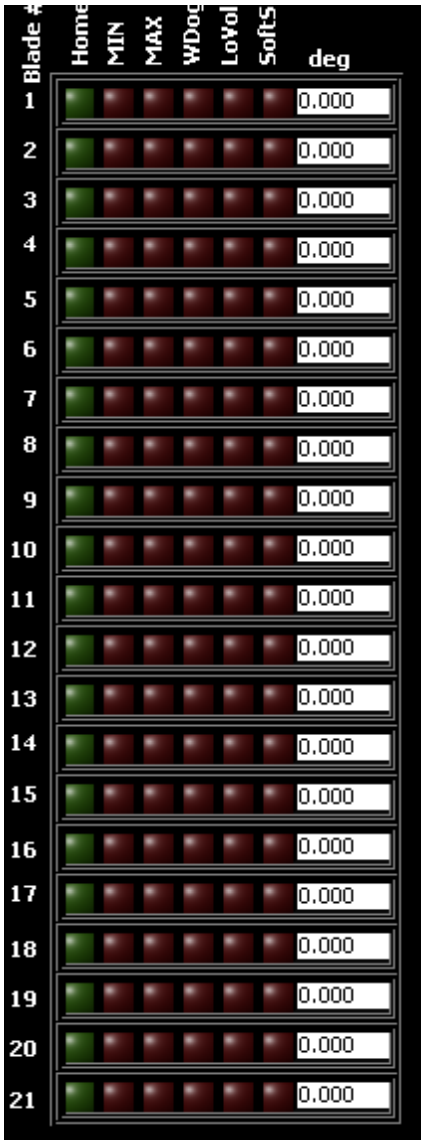
- VBAH – Variable Beam Aperture Horizontal doors move horizontally towards and away from one another.
- VBAV – Variable Beam Aperture Vertical doors move vertically towards and away from one another

DTS telemetry panel



- DTS – DFM Transport System moves the DFM linearly along the beam axis. Home represents when the DFM is at reference position

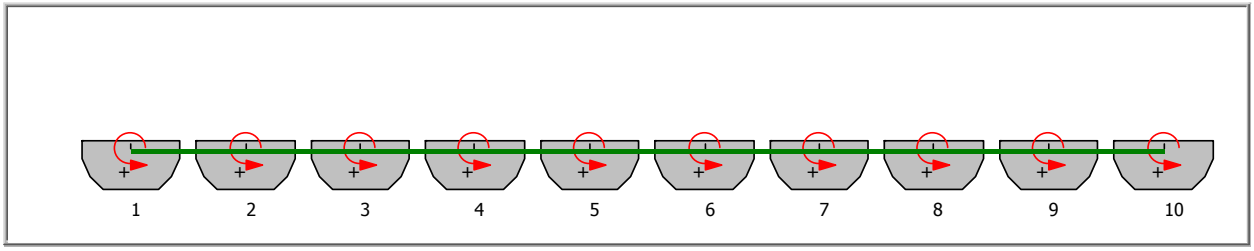
Blade indexer telemetry panel



Telemetry includes:

- Blade number
- Home Indicator – Blades inline with focus bar.
- Min Max limit indicator
- Indexer Watchdog timeout error
- Indexer Low Voltage Brownout error
- Soft Stop indication
- Angle relative to home position

Blade focus and rotation display. This represents a cross section that defines a plane through the center of the crystal array parallel to the floor. Positive blade rotation is in the counter-clockwise direction. As vertical focus increases, the crystals will move towards the top of the screen, away from their axis of rotation.



Blade Crash

A blade crash failure occurs if two or more blades contact one another, this can occur by either an improper focus or blade move command being sent to the DFM, or an electro-mechanical failure in a blade or focus motor, or motor indexer. A Blade Crash Detect circuit monitors for this condition and, in the event of a failure, issues limit errors to the blade and focus motor indexers thereby stopping any current motion.

If a blade crash occurs, a positive and negative limit will be sent to all blade and focus axes. Motion will be stopped immediately. The initial indication will be a limit error for the FOCUS1 indexer. Next the blade crash detect loop will sense the error and do a limit check on all blade and focus axes. This will cause a positive and negative limit indication to be displayed for all of these axes.

Blade Crash Recovery

1. Note if the limit indication was caused by a tilt in the focus bar (LVDTS) reading varies by more than .2mm then go to the 'Focus Bar Tilt Recovery procedure' (below).

   To recover from a blade crash you must first switch to 'LOCAL' commanding mode by pressing the 'REMOTE/LOCAL' button. Next, you can disable limits by pressing the 'Limits Ena/Dis' button. At the password prompt enter "NISTENG" then click on 'disable limits' in the pop-up dialog box. The red limit indications on the screen should now clear. If not press the 'Read Pos' button to update telemetry.

2. You can now do moves to recover from the blade crash. WARNING, after each recover move you must re-enable limits to see if the limit condition still exists. Extreme caution is required to ensure no further damage. If the problem can't be resolved with small moves, the DFM will have to be removed and serviced.

3. First defocus the array to remove any blade curvature, monitor the LVDT readout (LED display on rack) to ensure that the focus bar deflection is decreasing (going towards zero).

4. Next, with limits enabled, each blade should be moved to its home position. Once the cause of the failure is ascertained, and all axes are verified to be at their home position, it is safe to go back to remote commanding by the ICC.

Focus Bar Tilt Recovery

1. Bar Tilt causing limit indication. In this case you need to disable LVDT limits by pressing the LVDT Cont Button. Next enter password “nisteng”.

2. An LVDT control panel will load. Press the ‘LVDT Limits Off’ button and wait for limits to be disabled.

3. Home the Focus_Sync axis.

4. Troubleshoot to determine the cause of the bar tilt.

5. Open the LVDT Panel and turn limits back on by pressing the ‘Set LVDT Lims’ button. Wait for limits to be set.

Error Codes

When in Local Mode, error messages will pop up on the screen as they occur.

When in Remote Mode, bit zero will be set in the Status Register. The error can then be read back using the Read_Error command.

In both cases error messages are recorded in the log file

DFM Calculations

Motor Steps: Steps = (θ* (Motor Steps-per-Revolution/Divide Resolution) * Gearhead Ratio)/360. ex. Divide Resolution = 1/32, Motor Steps per Revolution = 200, Gearhead Ration = 100 , θ = 90º. Motors Steps would be 160,000.

- Radians to degrees: Radians = Degrees*(π)/(180),

- Ydisplacement is the distance traveled by the focus bar. Ydisplacemnt = Cam Radius * (1- cos(Theta(rad)))

Energy to 2θ Calculation

1) Planks Constant h=6.626010x10-34
2) Mass of Neutron m=1.675x10-27
3) Joules per eV = 1.602x10-19
4) Atomic Distance of Pyrolitic Graphite dpg=3.354210x10-10
5) Energy (meV)

$$\mathrm{Two\theta_{MACS.}}(E) := 2\cdot\mathrm{asin}\left(\frac{h}{2\cdot d_{pg}\cdot\sqrt{2\cdot m\cdot E\cdot\frac{JoulesPer\_eV}{1000}}}\right)\cdot\frac{180}{\pi}$$

6) Note: Energy is in meV. This is why there is a divide by 1000 term

Focusing

1) Number of Blades Blades = 21
2) Indexing Variable i=0 to 21
3) Blade spacing in mm Spacing = 21
4) Blade offset from center of array $\rho(i) := Spacing\cdot\left(\left(i - \frac{Blades - 1}{2}\right)\right)$
5) Convert to Radians $Two\theta := TwoTheta\_Deg\cdot\frac{\pi}{180}$
6) Calculate θ from 2θ Value $\theta := \left(\frac{Two\theta}{2}\right)$
7) Distance from center of Drum to center of DFM when Two θ = 90 (at reference)
8) Drum_to_DFM_Distref = 1000
9) L0_ref = 824
10) Distance from center of DFM to Sample

11) (L0) when Two θ = 90 (at reference)

12) Drum_to_Sample_Dist = 2200

13) Distance from Center of Drum to Sample

14) Calculate L0 $L_0 := L_{0\_ref} - \text{Drum\_to\_DFM\_Dist}_{ref} \cdot \cot(\text{Two}\theta)$

15) Calculate L1 $L_1 := \text{Drum\_to\_Sample\_Dist} + \text{Drum\_to\_DFM\_Dist}_{ref} \cdot \csc(\text{Two}\theta)$

16) L0=6.815x103 L1=3.943 x 103

17) Calculate Rowland Circle Radius $R_h := \frac{\sqrt{L_0^{\,2} + L_1^{\,2} + 2 \cdot L_0 \cdot L_1 \cdot \cos(\text{Two}\theta)}}{2 \cdot \sin(\text{Two}\theta)}$ $R_h = 8.976 \times 10^3$

18) Calculate Radius of Vertical Focus $R_v := \frac{2 \cdot \sin(\theta)}{\left(\frac{1}{L_0} + \frac{1}{L_1}\right)}$ $R_v = 1.502 \times 10^3$

19) Calculate DFM array rotation $\xi := \operatorname{atan}\left(\frac{\sin(\text{Two}\theta)}{\cos(\text{Two}\theta) + \frac{L_1}{L_0}}\right)$

20) If minus, add to π $\xi := \begin{bmatrix} \xi & \text{if } (\xi \geq 0) \\ (\pi + \xi) & \text{if } \xi < 0 \end{bmatrix}$ $\xi \cdot \frac{180}{\pi} = 22.31$

Fixed Wavelength Focusing

1) Calculate individual Blade Angles $\psi_{(i)} := \left[\operatorname{acot}\left[\cot(\xi) - \frac{\rho(i)}{(L_0 \cdot \sin(\xi))}\right] - \theta\right] \cdot \frac{180}{\pi}$

2) Remove the 'acot' to make LabView Happy $\psi_{(i)} := \left[\operatorname{atan}\left[\frac{1}{\cot(\xi) - \frac{\rho(i)}{(L_0 \cdot \sin(\xi))}}\right] - \theta\right] \cdot \frac{180}{\pi}$

3) Simplify Equation $\psi_{(i)} := \left[\operatorname{atan}\left[\frac{L_0 \sin(\xi)}{(\cos(\xi) \cdot L_0 - \rho(i))}\right] - \theta\right] \cdot \frac{180}{\pi}$

4) Numerator of atan ftn $y := L_0 \cdot \sin(\xi)$

5) Denominator of atan ftn $x(i) := \cos(\xi) \cdot L_0 - \rho(i)$

6) atan2 ftn to handle full range $\psi_{(i)} := \left(\text{atan2}(x(i), y) - \theta\right) \cdot \frac{180}{\pi}$

7) Correct for proper blade rotation polarity $\psi_{(i)} := \psi_{(i)} \cdot (-1)$

For Point-to-Point Focusing

$$\psi_{(i)} := \left[\theta - \xi - \left[\frac{1}{2} \cdot \left(\text{atan}\left(\frac{\rho(i) \cdot \sin(\theta)}{L_0 - \rho(i) \cdot \cos(\theta)} \right) + \text{atan}\left(\frac{\rho(i) \cdot \sin(\text{Two}\theta - \xi)}{L_1 + \rho(i) \cdot \cos(\text{Two}\theta - \xi)} \right) \right) \right] \right] \cdot \frac{180}{\pi}$$