

## **Mar165UserGuideV3.doc**

### **Subject:**

This document describes aspects of operation of the Detector Pool's MAR165 CCD detectors.

### **Revision history:**

Original: 3/17/05 (tim)

V2: 7/7/05 added a few comments (sr)

V3: 10/31/06 added info for Mar165C (lmg)

Last updated: 12/14/09 (am)

### **Related Documents:**

MARccd(linux).doc

For more specifications on the detector please go to the Mar website:

<http://www.marresearch.com>

We have several AutoCAD drawings of the mechanical bases.

For a detail of the face plate, front view, see face plate.doc

## A) Introduction

The Mar165 is a circular CCD detector with a diameter of 165mm. The detector uses a single front-illuminated CCD which is cooled to -70C with a cryogenic cooler. The detector acquires images to be stored on a Linux box, supplied by Mar. The frame rate is around .5Hz, or 2s/frame.

From Mar, typical camera spec's include:

- Based on a 4k x 4k CCD sensor with 61 x 61 mm<sup>2</sup> sensitive area.
- Single large fiber-optic taper with a demagnification ratio of 2.7 : 1.
- Single CCD sensor has four (4) amplifiers selected for low noise (9e<sup>-</sup> RMS for 4 sec read time of 2k x 2k image).
- Phosphor screen as imaged onto the CCD-sensor:  
high density Gd<sub>2</sub>O<sub>2</sub>S<sub>2</sub>:Tb phosphor - 165 mm diameter.
- Single floor standing unit contains electronics and cooling equipment.

### 1. **marccd** X-Ray Data Collection System

#### 1.1 165MM CCD DETECTOR

- Monolithic 4k x 4k (4096x4096 pixels) CCD coupled to phosphor by 2.7:1 fiber-optic taper
- Pixel size at CCD = 15µm x 15µm
- Active imaging surface : 165 mm diameter
- Pixel size at phosphor can be binned under software control to give:

2048x2048 (binned 2 x 2)	80 µm pixels
1024x1024 (binned 4 x 4)	160 µm pixels
512x512 (binned 8 x 8)	320 µm pixels

- 4 simultaneous on-chip readout channels
- DQE (Detective Quantum Efficiency) - DQE up to 0.8 for 8 keV-12keV
- PSF (Point Spread Function)      FWHM ~ 100µm  
FW 1%M ~ 300µm
- Gain (electrons/X-ray photon) 6 e<sup>-</sup>/12keV

- **Read noise** -  $9e^-$  at 400kHz readout speed = one 12keV photon equivalent

**Readout Time vs. Resolution and Noise**

		<u>Resolution (pixel size)</u>		
		2048*2048 80 $\mu\text{m}$	1024*1024 160 $\mu\text{m}$	512*512 320 $\mu\text{m}$
<u>Readout speed (Noise)</u>	800kHz x 4 (13 e- RMS)	2.5 sec	1 sec	0.5 sec
	400kHz x 4 (9 e- RMS)	3.5 sec	2 sec	1 sec

- **Dark current** (at standard operating temperature of  $-70^{\circ}\text{C}$ )  $\leq 0.005e^-$  /pixel /second or  $\leq 0.001$  12keV photon /pixel /second.
- **Full well capacity** (Signal level at which linearity breaks down) depends on binning  
2048x2048 : 400k e-/pixels = 65K 12keV photons/pixel
- **Dynamic Range** ( $\sim$  Full Well / Noise) 16 bits  
depends on photon energy, binning, and readout rate, but in most cases the dynamic range will be limited by 16 bit A/D converters, 16 bit data format, and the choice of ADC gain (ADC gain typically set-up for RMS. read noise = 1 ADU (Analogue-to-Digital-Unit))  
 $12\text{keV}, 2048 \times 2048, 200\text{kHz} - 400\text{k} e^-/9e^- = 45000 (\sim 16 \text{ bits})$
- **Phosphor**  $\text{Gd}_2\text{O}_2\text{S}_2:\text{Tb}$   $\sim 40\mu\text{m}$  thick. Replaceable, but not routinely changeable. High accuracy data requires careful factory calibration after phosphor change.
- **Defects** CCD sensors are selected for low noise and low number of cosmetic blemishes. All defects are correctable and permanently mapped and corrected by our factory calibration procedure. Fiber Optic tapers are low Thorium glass with extra mural absorption (EMA) selected for minimal geometric and shear distortions.
- **Physical**

Detector Head

Dimensions 21.5 cm Diameter x 34 cm  
Weight approx. 20 kg

Electronics/Cooling Assembly

Dimensions H x W x D = 72 cm x 43 cm x 64 cm  
Weight approx. 60 kg

**MAR CCD SYSTEM.** The Mar detector system includes the following items: CCD Head, Cryo-chiller cabinet, heater, fiber optic cable, Linux computer, cables and gas lines. The detector is connected to a cabinet containing electronics and cryo-chiller with several hoses and cables. *None of the hoses or cables between the detector head and chiller cabinet should be disconnected; the connectors are fragile.* The detector head is evacuated to about .5Torr. If this pressure rises above 1Torr, the system should be pumped out. *Do not cool the detector if pressure is above 1Torr, or ice may freeze on the CCD.*

The detector is controlled by software, mar165, supplied by the vendor (Mar Research). The control computer runs under the RedHat implementation of Linux. The computer communicates to the Mar with an orange fiber optic cable (or a black communications cable, in the case of Mar165\_C\_DP00197) that can be routed into a hutch, so the PC can be outside

the hutch. The PC uses an Ethernet card to connect to the network (device eth0), using DHCP. Some users prefer to set a hard IP address. Some Mar computers have a second Ethernet card, eth1, that is unused.

## B) Our Detectors and Accessories

As there are three detectors, we include a list of items for each detector. When checking out the detector to a user, give them all of the items on this list, except the toolkit (unless they specifically ask for it).

When giving out the detector, the camera head, and chiller are cabled together with many cables and hoses. **DO NOT DISCONNECT ANY OF THESE HOSES OR CABLES.** Disconnecting hoses could release flammable cooling gasses. Disconnecting cables could damage the detector, if done when power is on.

The detector pool has made custom carts, “MARs Rovers,” to move the detectors from one sector to another.

The following tables are lists of all the equipment associated with the three Mar 165 detectors in the detector pool.

Table 1. **Mar165 A**

DP00022	Mar 165 (CCD camera) unit A
DP00023	Computer (Mar ImagePlate software)(Linux)
DP00024	ViewSonic 20" LCD Monitor
DP00097	Mounting stand for Mar165 (DP00022)
DP00104	Mouse for computer DP00023
DP00119	Spectral Inst. Inc. line heater for Mar165a
DP00108	Tools for Mar CCD, unit A
DP00120	Chiller for Mar165a
	Orange fiberoptic cable.

Table 2. **Mar 165 B**

DP00051	Mar 165 (CCD camera B)
DP00052	Chiller for Mar165b
DP00053	Spectral Inst. Inc. line heater box for Mar165b
DP00055	Computer for Mar165b
DP00056	Monitor for Mar165b
DP00101	Aluminum Base Plate 1 of 2 for Mar165b
DP00102	Aluminum Base Plate 2 of 2 for Mar165b
DP00054	Tools for MAR CCD unit B
DP00103	Keyboard for Mar165b
	Orange fiberoptic cable

**Table 3. Mar 165 C – Note: this detector does use a fiber optic cable, but rather a black copper high-density connector.**

DP00197	Mar 165 (CCD camera C)
DP00198	Black communications cable
DP00199	Tools for MAR CCD unit C
DP00200	Computer for Mar165C
DP00201	Monitor for Mar165C
	Chiller for Mar165C
	Spectral Inst. Inc. line heater box for Mar165C

A picture of the whole detector (what needs to be sent to the user) is shown in Fig 0.



Fig. 0 Mar detector system, including chiller cabinet, CCD head, heating unit, hoses, cables, orange fiber optic cable. Don't mess with cables or hoses connected to CCD head. Computer not shown, as they all look the same. When delivering detector, take the cart shown in the picture, and the computer/monitor.

### C) Physical Connection

- 1) Secure the detector in the proper location in the experimental setup. The chiller cabinet and CCD go into the hutch. Run the communications cable (orange fiber optic for A and B, black interface for C) out of the hutch to the lab floor, where the Linux box resides.
- 2) Connect communications cable to jack on Linux box, and jack on chiller cabinet. (Fig. 1, 2)
- 3) Turn on detector, by sticking your finger into hole in metal cabinet. Feel for rocker switch, and flip switch. Note that the rocker switch is on a power strip with 110V outlets. Look in the hole before blindly feeling around. (Fig. 3) Also check power switches on the front of chiller (these should have been left on by the previous user).
- 4) For A and B, turn on white line heater box. C has a built in heater. (Fig. 4)
- 5) Boot computer.



Fig.1 Orange cable.



Fig.2 Jack for orange cable.



Fig3. In hole is power switch.



Fig 4. Turn on heater unit.

## D) Software Start Up (and Shut Down)

- 1) Log on to computer. Username: marccd, Password:marccd.
- 2) Open new terminal.
- 3) Note: There is a readme file with useful information.
- 4) Type marccd to start Mar software. You should get the main GUI for the Mar CCD system. Upon startup, the software may warn of a detector error. If so, click "OK."
- 5) Verify pressure. The pressure inside the evacuated CCD camera should be below 1Torr. It is shown on the main software window near the top. **If not, DO NOT START THE COOLING.** Just shut down the system and page the Detector Pool at 2-9490. At night, call 2-0101. The detector needs to be pumped out.
- 6) Reboot detector: Select menus: Configure→Detector. A window should appear. At the bottom, click REBOOT button. Answer YES/OK to any redundant questions. Answer YES to restart cooling. Click "DISMISS" to close the window. This window has buttons to turn cooling on and off. Leave it on.

- 7) Test Detector: Acquire single frame by selecting menus: Acquire→ Single Frame. Enter exposure time of 1s, and hit START. You should see an image appear on the main window.
- 8) Start Remote Control: Select menus Acquire→Remote Control. A window comes up with 4 fields which must be filled in. The proper parameters are default in the Mar 165 A unit, but must be altered for the B unit (this will be fixed later; contact detector pool personnel for assistance). Hit the Start button to start Remote control. If the parameters are wrong, the mar software can freeze, requiring a restart.
- 9) Start EPICS. Open a new terminal and type start\_epics. This starts a soft IOC, and MEDM. IF the computer is networked properly, the PVs will be served to EPICS.
- 10) Test EPICS. In the MEDM window, acquire a background image, by selecting “frametype=background” and clicking the Start button (middle, low in the MEDM window). Select “normal” and click Start again. You should see the marccd software take images.
- 11) To shut down detector system: Exit the software on the Linux box. In hutch, turn off the detector by inserting your finger into the hole in the chiller, and switching off the rocker switch. Turn off the white heater box. Shut down the computer. It is easy. Don’t worry about any complicated procedure to warm the CCD. Just turn everything off.

Note: BNC to 4-pin Lemo custom cable (made by BTS) is for hardware shutter control. 4-pin side goes into the back of the controller socket labeled “aux. control”

### **E) To change amplifier readout mode.**

- 1) Typically, the MarCCD is readout with four separate amplifiers (i.e., four quadrants). Sometimes, these four quadrants are not equal (this is just a baseline level and can drift) and causes problems for low signal levels. This is most often a problem with the mar165-C. You can fix this by having the detector readout from only one amplifier, but the readout time will be four times longer. Follow the steps below to change the readout pattern on the MarCCD:
  - i. Go to Options → Program Mode → Administrator
    - (1) Password is marccd (don’t hit return, click ok with mouse)
  - ii. Configure → Detector
  - iii. Change “Readout Pattern” to desired value:
    - (1) 0x1 for single channel readout
    - (2) 0xf for four channel readout
  - iv. Make sure chiller is on and “Cooler Power” button is checked/enabled above reboot button
  - v. Hit “Save” button
  - vi. Hit “Close” button
  - vii. Go to Options → Program Mode → Normal (quits Administrator mode)

### **F) Common Issues**

- 1) ***1 x 1 binning does not exist!!!!*** The minimum binning is 2 x 2 !!!! You can change this via the EPICS interface.
- 2) If your file size is only 4096 bytes, then you probably did not take an initial background, which marccd stores in the controller memory!!!!

## **G) Troubleshooting (based on common problems)**

- 1) *Can't take picture.*  
The detector is off, or needs reboot.  
The detector is not communicating with the PC. Check fiberoptic cable.  
If you can take a picture from marccd, but not EPICS, then restart the Mar remote control server, restart the EPICS server. IF that fails there is probably a network problem.
- 2) *What if I have to reboot computer?*  
You can safely reboot the Linux box without damaging the CCD detector. Just leave the detector on, and reboot the computer. The detector will take care of itself. When restarting marccd, you must reboot the detector as in (3) below.
- 3) *What if I have to turn off and on the detector?*  
See above instructions (C&D). Just turn off the detector, then turn it on. Reboot the detector from marccd software menu Configure→Detector, REBOOT.
- 4) *Can't get Spec to control detector.*  
Detector is not running server, or detector is not on network, or on wrong subnet. Check to see if mar server is running, EPICS is running. Check subnet with ifconfig.
- 5) *EPICS PVs white in MEDM.*  
This happens when the soft IOC is not working right. Reboot the soft IOC. If that does not fix it then check the network. If the PC is not on the network correctly, the IOC will not serve the PVs properly, even to a local EPICS client. Fix the network.
- 6) *What is wrong with the Network?*  
Because of ANL's enhanced computer security, getting the Mar onto the network at a beamline is an issue. The most common problem is that the subnet at the beamline does not recognize the MAC address of the detector PC. Type ifconfig to get the MAC address. Set up the detector for DHCP (it should already be). A Sysadmin person must configure the network to allow the Mar to get onto the subnet. As firewalls are constantly changing, and the detector moves all around the ring, the network always breaks. The best advice is to test the detector in the morning, so computer people can fix the network after lunch.
- 7) *Pressure reads ???*  
The CCD detector is not communicating with the PC. Restart everything, to try to get the system working again. Go through the aforementioned startup procedure.
- 8) *Detector will not turn on.*

This happens when fuses inside the chiller cabinet blow. Call DP staff to replace fuses. [Spare fuses are located in the toolkit for the detector. The fuse is located inside the power strip.]

**H) Mounting from linux computers with sudo.** We have setup sudo on most of the linux computers. This allows you run admin commands as a regular user (e.g., as marccd or mar345). If you type *sudo -l* in an x-terminal, you will get a list of commands that you can run with sudo. You might be prompted for the local user password (e.g., marccd's or mar345's). Then, run any of the commands listed by *sudo -l*, just put sudo in front of it. You must also make sure that the permissions on the server side are set properly (e.g., open for everyone to read/write). Some examples:

- 1) `sudo /bin/mount -t nfs users-nfs2.xor:/export/8-ide-a/MAR_A /mnt/8-ide-a`
- 2) `sudo /sbin/mount.cifs //hpcat21/16bmb /home/marccd/mnt/16BMB -o username=16bmb_user`
- 3) `sudo smbmount //chemcars47/data /home/marccd/mnt/15id -o username=chematuser/cars_nt_domain,gid=marccd,uid=marccd`
- 4) `sudo /sbin/mount.cifs //red.xor.aps.anl.gov/raid /home/marccd/mnt/34ide/ -o username=reduser,uid=marccd,gid=marccd,rw`

## **I) Who to call**

Detector Pool engineers at 2-9490 (M-F 9-5)

Computer Support at 2-9273 (M-F 8:30-5) or 630-740-0806 (off hours)

Floor Coordinator or MCR Operator at 2-0101 (off hours)