Mar345 Image Plate Detector

A) Introduction

The Mar345 Image Plate is a circular detector[1] with a maximum diameter of 345mm. The actual measurement diameter can be selected to be either180, 240, 300 or 345mm. There are two selectable pixel sizes, 150um X 150um or 100um X 100um. The corresponding read out time is different for different choice of measurement diameter and pixel size. Sensitivity of the detector is 1 X-ray photon per ADC unit at 8 keV. The phosphor absorption efficiency is given in the figure below.

Phosphor Absorption Efficiency
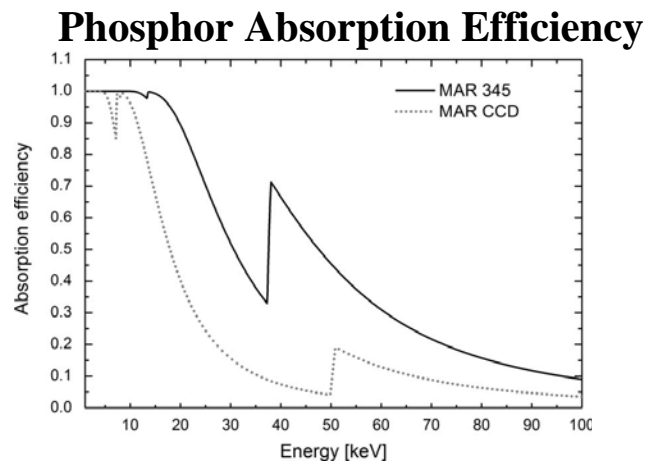
From: http://journals.iucr.org/j/issues/2006/06/00/ea5056/ea5056.pdf.... "For the MAR345, a 207 micron thick phosphor screen made from BaFBr:Eu2+ (density 2.86 g/cm^3) was considered, while for the MARCCD a 45 micron thick phosphor screen made from Gd2O2S:Tb (density 2.9 g/cm^3)[10].

The detector stores an X-ray image as a collection of F-centers in a phosphor screen. The locations of the received X-ray photons are represented by the spatial distribution of the F-centers. The X-ray intensity is calculated in term of the intensity of the fluorescence induced by a He-Ne laser during the read out process.

The detector is controlled by software[2,3], mar345, supplied by the vendor (Mar Research). The control computer runs under linux. It contains two Ethernet cards, one of them talks to the intranet that the control computer is attached to and the other one communicates with the detector through a **red Cat5 cross-over cable.** The Ethernet card that is responsible for intranet connection can use DHCP, that means its address is dynamically assigned during boot up, however, the other card should have a fixed address of 192.0.2.2. The Ethernet address for the detector will always be 192.0.2.1.

The net weight of the detector alone is about 53kg (~120lbs), so care should be taken when handling the detector. Delicate components such as the Be window in front of the

detector can easily be damaged on impact. So it is recommended to have at least two persons to move the detector.
For more specifications on the detector please go to the Mar website:
http://www.marresearch.com

Section B of this document is the general operation principle of an Image Plate (IP). We list out in Section C all the components for the detector system that you should get from the detector pool. Check the list during check out time and please return the system in its entirety after the experiment. Section D and E will guide you through the system set up process step by step. Finally in section F we have listed some reference material for the detector.

B) Principle of operation

The IP utilizes the charge capturing capability of F centers. An F center is one kind of crystal defect in ionic crystals[4], for example NaCl. NaCl crystal has a face-centered cubic (FCC) structure; each ion has 6 nearest neighbors. If a point defect happens to the crystal and a Cl^- is missing from its proper location, the vacant site will lack negative charge because a perfect ionic crystal is macroscopically neutral. The neighboring 6 Na^+ ions will essentially form a trap (an F center) for electrons. Pure alkali halide crystals are transparent throughout the visible region of the EM spectrum, but heating NaCl crystal in the presence of sodium vapor makes the crystal appear yellowish due to the formation of F centers.

The IP of Mar345 is a CR standard ST-V plate manufactured by Fuji Photo Film Company Limited. In order to explain the basic physics of an IP we will use a similar system, Europium-activated $BaFX:Eu^{2+}$ (X = Cl, Br, I) crystal[5-8]. The crystal contain two types of F center, $F(F^-)$ and $F(X^-)$. The corresponding IP is usually made of flexible plastic material intermixed with small size phosphor crystals (~5 µm in size) to a thickness of about 150 µm. The piece of plastic is then laid on a thicker backing material for support.

The mechanism of X-ray detection by $BaFX:Eu^{2+}$ crystal has been proposed by Kenji Takahashi et al[9]. When an X-ray photon is absorbed by an IP, the process will cause electron transfer from the valence band to the conduction band of the crystal. Some of those events will correspond to the ionization of Eu^{2+} to Eu^{3+} ion. The transferred electron may then captured by one of the F centers and temporarily stored there. The captured electron can subsequently be released by a process called photon stimulated luminescence (PSL), in which the crystal is locally irradiated with He-Ne laser (λ = 632.8nm). The purpose of the laser photons is to provide activation energy for the trapped electron to get away from the F center. The electron then recombines with a Eu^{3+} ion and gives out a characteristic radiation, with $\lambda \sim 390$nm, that corresponds to an electron transition from the 5d to the 4f orbital of the Eu^{2+} ion. The visible photon emitted is then analyzed by a photomultiplier tube with adjustable gain. The intensity of the visible light signal given out is linearly proportional to the intensity of the absorbed X-ray over a wide dynamic range.

Mar Research uses a proprietary read out mechanism for their Mar345 IP system. Before an exposure, the IP is locked down by an internal electromechanical latch. The IP is then exposed to X-ray signal. The information on the IP is then read out using a mechanism that is similar to that of a computer hard drive. The reading head contains a stimulating laser, a collector cup and a photomultiplier. The reading head drives down from the edge to the center of the plate while the image plate spins according to a pre-determined speed profile. The stored information is then read out pixel by pixel by the reading head. Mar calls this process a spiral scan. The driving motion of both the read head and the plate ensures a constant pixel read out time over a large area of the plate. The maximum rotation speed of the plate is 3800rpm. The pixel size is determined by the beam size of the stimulating laser for this particular detector.

After relevant data have been read the whole IP can be erased, and therefore returned to its ground state, by illuminating the plate with the three built in halogen lamps. The erase process is the same as doing a read scan but no data are collected. It is always a good idea to do a plate erase before taking data.

C) Detector and Accessories

The detector contains the following items from the detector pool:

Mar345a)

| DP00037	Mar 345 (Image plate)
DP00038	Computer (BSI)(EPIC)(Linux)
DP00099	Front cover for Mar345a
DP00106	Red pneumatic cart for Mar345a
DP00118	Red Cat5 cable for Mar345a **(Cross-Over)**

Mar345b)

DP00100	Mar 345 (Image plate)
DP00028	BSI monitor and keyboard assembly
DP00069	Computer (Mar Image Plate software)(Linux)
DP00107	Red pneumatic cart for Mar345b
DP00098	Front cover for Mar345b
DP00116	Red Cat5 cable for Mar345b **(Cross-Over)**
DP00122	Mouse for Mar345b

D) Physical Connection

    1) Secure the detector in the proper location in the experimental setup.
    2) Make sure both the detector and the control computer are turned off.
    3) Make an Ethernet connection between the detector and control computer as in Figure 1. ***This is a cross-over cable and not a standard network cable!!!***

Connection from control computer to internet (standard network cable).
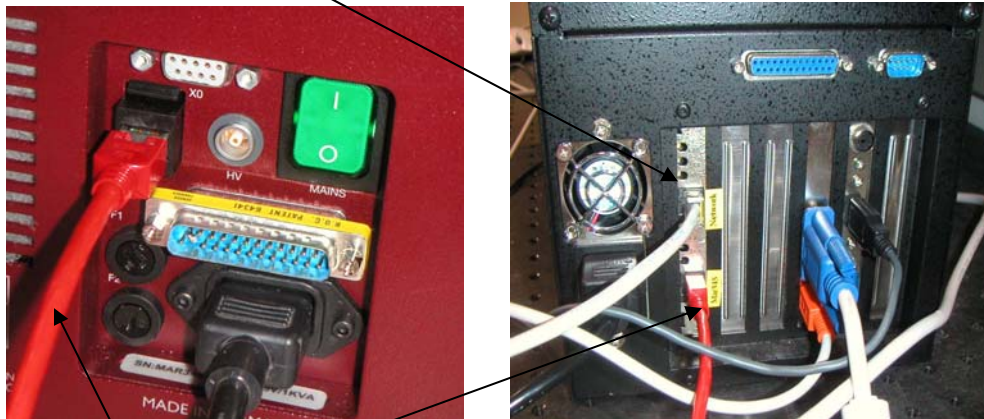
Ethernet connection from detector to control computer. (Cross-over cable)

Figure 1. The detector is on the left hand side and the control computer is on the
    right. Connect a Cat5 cable from the detector's RJ45 connector to the Ethernet connector 1 on
    the back of the computer. Connect Ethernet 0 of the computer to the intranet.

E) Software Start Up

    1) Switch on the detector.
    2) Switch on the control computer.
    3) ***OPTIONAL:*** *When the computer operating system, in this case RedHat Linux, is mounting all its peripherals there should be status lines on the screen saying that*

        "bringing up Ethernet 0   ……………………… Ok "

"bringing up Ethernet 1 ……………………… Ok ".

That means both of the Ethernet cards on the host computer are mounted successfully.

4) **Username: mar345**
   Password: XXXX (DP Staff will provide this for you in person)

5) ***OPTIONAL:*** *You can test the connection to the mar345 by using the ping function to check the communication between the control computer and the detector. At the command prompt type "ping 192.0.2.1". Then you should get the following message,*

> *PING 192.0.2.1: 56 data bytes*
> *64 bytes from 192.0.2.1: icmp_seq=0 ttl=255 time=1ms*
> *….*
> *….*

If you received the above message the communication between the computer and the detector is working. Ctrl-C to stop the pinging.

6) Verify that MAR_SCANNER_NO environment variable matches the serial number of the mar345 that you are using (e.g., 255 or 274). To do this, run this command from an x-terminal:
   i. **env | grep MAR_SCANNER_NO**
   ii. If it does not match, please contact DP staff. You can also edit the file called: /home/mar345/tables/MAR_SCANNER_NO to match the mar345 serial number. Then, close all x-terminals and open new ones and double check that the environment variable is set properly.

7) In an x-term window, after the command prompt type "**mar345**". The mar345 detector will warm up and a large clicking noise will be heard when finished; then the main screen will appear. The noise is due to the activation of the electromechanical latch that holds the Image Plate in position.
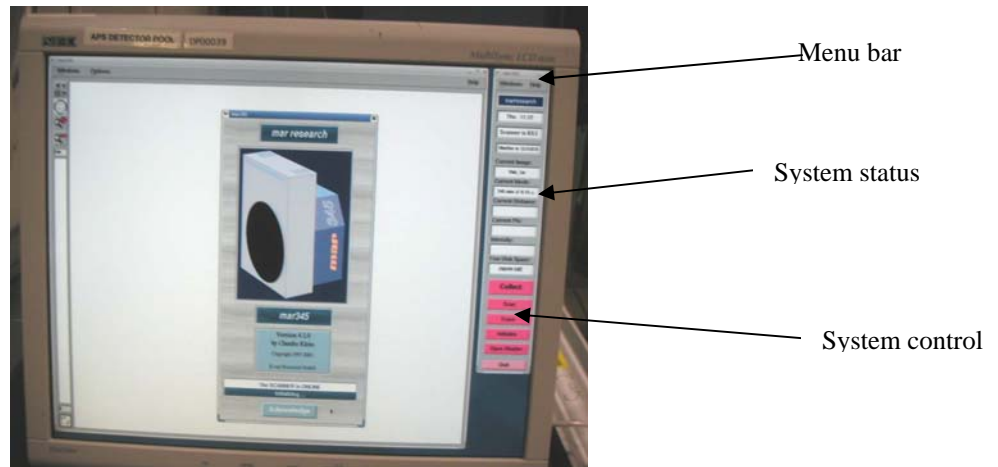
Figure 2. Main screen of the Mar345 control software. The larger white display area is for the display of image after scanning. The narrow tool bar at the right hand side consists of three sections: the menu bar, the system status information section and the system control section.

8) Recall that the mar345 is storage phosphor system. The mar345 has 2 main operations: **scan** and **erase**. The mar345 is always exposing. So, to readout an exposure, what you are doing is just scanning the image plate. This will effectively erase the signal in the image plate. There is also a function called "erase" which will shine a bright halogen lamp inside the detector to erase the image. The different functions that are available on the menu bar and system control section are described in detail in the mar345 Program Manual provided by Mar Research.

9) **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 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:

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

F) References

1) MarResearch, Mar345 : Technical Specifications
2) Claudio Klein, The mar345 Software Guide **Version 1.2**, (2001)
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4) Charles Kittel, Introduction to Solid State Physics **7th Edition**, 499 (1996)
5) Yoshiyuki Amemiya, J. Synchrotron Rad. **2**, 13 (1995)
6) Junji Miyahara, Kenji Takahashi, Yoshiyuki Amemiya, Nobui Kamiya, Yoshinori Satow, Nucl. Instr. and Meth. **A246**, 572 (1986)
7) M. Yuste, L. Taurel, M. Rahmani, D. Lemoyne, J. Phys. Chem. Solids **37**, 961 (1976)
8) K. Takahashi, J. Miyahara, Y. Shibahara, J. Electrochem. Soc. **132**, 1493 (1985)
9) Kenji Takahashi, Katsuhiro Kohda, Junji Miyahara, Yoshihiko kanemitsu, Koji Amitani, Shigeo Shionoya , J. Luminescence **31&32**, 266 (1984)
10) J. Jakoncic, M. Di Michiel, Z. Zhong, V. Honkimaki, Y. Jouanneau and V. Stojanoff, *Anomalous diffraction at ultra-high energy for protein crystallography. J. Appl. Cryst.* (2006). **39**, 831-841