

metaljet

Safety Control System



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Safety Control System

Manual

Version 2.0

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1. How to use this manual

Before you start to operate the **metaljet** safety control system please read the Manual and the Technical Documentation included in the documentation package carefully.









1.1 Address and support

Should you have questions concerning the system or its use, please contact us via phone or email.

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1.2 Security and handling

When working with the **metaljet** safety control system, observe the following security instructions in order to protect yourself and the instrument from harm.

Hazard	Description
	The metaljet safety control system is intended for indoor use only.
	Do not install the instrument during an electrical storm.
	Never let liquids get inside the instrument. Otherwise, electric shocks or short circuits may result.
	Do not open the safety controller housing without instructions. The device should only be opened by authorized technicians.
	Place the instrument in a dry location that is free of dust and protected from moisture.
	Do not expose the safety controller to strong magnetic fields. They might corrupt the firmware and/or induce unwanted signals.
	Do not expose the safety controller to strong emitters of electromagnetic waves.
	Make sure that the ventilation slits in the safety controller are unobstructed. The ventilation slits provide for air cooling of the safety controller.

1.3 Disclaimer

This document is provided to customers as a courtesy of marXperts GmbH. The described operations require knowledge about mechanical and electrical components and should only be carried out by properly trained persons. While every precaution has been taken in the preparation of this document, marXperts GmbH assumes no responsibility for errors or omissions. Accordingly, marXperts GmbH cannot assume responsibility for damage to electrical or mechanical components of the instrument that occurred while following this guide. The entire risk of the operation remains with the person or institution carrying out the operation.

2. Overview



Figure 1: X-ray diffraction system with Excillum MetalJet generator, mardtb goniostat and Pilatus 3 R 1M detector

The **metaljet** safety control system is an intelligent controller that coordinates the safe operation of the Excillum MetalJet X-ray source safety shutter with the radiation enclosure and other safety devices. Its main function is to ensure that the safety shutter of the X-ray source can only be opened, if the interlock signals that it is safe to do so. The interlock system itself may feed signals from several sources into a unique signal to the Safety Control System. With the **metaljet** system provided by Marxperts, the following conditions must be met:

- the doors of the radiation enclosure are all closed
- the contact switch between the AXO focussing mirror housing and the goniostat (**mardtb**) is closed
- the vacuum pump that evacuates the mirror chamber is turned on and produces a good enough vacuum
- the three safety shutter sensors provide an unambiguous signal
- all shields of the Excillum tower are in place

If either one of those conditions is not met, the interlock signal is turned off and the safety shutter will be closed automatically and cannot be opened until the conditions are satisfied.

The **metaljet** safety control system may communicate with the Excillum generator controller and shares a limited amount of information and functions with external applications. It does not replace the full featured generator control system provided by Excillum, but just offers enough features for typical daily operations.

Upon request, the **metaljet** safety control system can be configured to operate an interlock system that works like a synchrotron hutch. Please see Appendix C ("Alternative configuration") for more details.

For further details, see chapter 5 - Software.

3. Hardware

3.1 Safety shutter controller



Figure 2: Safety controller - front view (2-port version only)

The **metaljet** safety controller comes as a stand-alone box in a 3 HU 19 inch format that fits in the experimental table for X-ray sources built by marXperts or standard 19"-racks. The front side features 4 (1-port version) or 6 (2-port version) user elements. There is also a customized version without any shutter buttons. These devices can only be controlled by software.

1. **Emergency stop:** Will close the shutter immediately and turn off the high voltage of the generator when pushed.
2. **Shutter 1:** Operates the safety shutter on the **right** hand port of the generator. When the shutter is open, a red LED light ring will be lit. The shutter can be opened only if the vacuum signal is present and if the interlock signal is okay. Available only on 2-port version!
3. **Shutter 2:** Operates the safety shutter on the **left** hand port of the generator. When the shutter is open, a red LED light ring will be lit.
4. **Safety switch for shutter 1:** When pushed down, shutter 1 cannot be operated by software (2-port version only).
5. **Safety switch for shutter 2:** When pushed down, shutter 2 cannot be operated by software.
6. **Power switch**



Figure 3: Safety controller - back view

The sockets and connectors at the back side of the **metaljet** safety controller are as follows:

1. **Network:** RJ-45 connector to local LAN. The default IP-address of the controller is set to 192.0.2.112.
2. **Shutter 1:** Handles the safety shutter on the right hand side of the generator. Two sensors for the “closed” state and one sensor for the “open” state provide a feedback for the actual shutter state. Any ambiguity in the shutter states will produce an error condition and will automatically close the shutter. The high voltage will be turned off immediately in case the sensors for the “closed” state don’t coincide. The shutter can be opened only if the vacuum signal is present and if the interlock signal is okay

3. **Tower:** Gets a signal from the generator tower indicating that all shields are properly in place. If that signal is not available, the HV will be turned off immediately.
4. **Interlock 1:** Gets a signal from the interlock system (e.g. radiation enclosure) mounted on the right hand side of the generator. If the signal is not available, the safety shutter of the generator will be closed immediately and cannot be opened until the status of the interlock system is OK. In addition to the doors, this also involves a physical contact between the housing of the mirror and the goniostat: a gap inbetween these hardware components will break the contact and the safety shutter cannot be opened. It also involves a signal from the vacuum pump that evacuates the mirror on the right hand side of the generator.
5. **Interlock 2:** As above, but for the left hand side of the generator (2-port version only).
6. **Shutter 2:** As above, but for the shutter on the left hand side of the generator (missing in figure).
7. **HV Controller:** Connects to the Excillum generator and feeds a signal to the HV generator. Only if a 24 V signal on two separate pins is provided to the generator, the high voltage will be turned on. A power cut or some fault will take off the 24 Volt and immediately turn off the high voltage and hence the X-rays.
8. **Lamps:** Operates the light tower of the generator. Details: see below.
9. **Power:** Main power socket.

3.2 Signal tower

The signal tower is operated at 24 V and contains 3 or 4 LED lights: 1 x green, 1 x orange, 1 or 2 x red. The lights are lit under the following conditions:

- a. Red light on: shutter 1 is open
- b. Red light on: shutter 2 is open (2-port version only)
- c. Orange light on: the high voltage of the generator is turned on (> 1kV)
- d. Green light on: the controller is powered on



BEWARE



The signal tower is not an active safety device. The LED lights have a very long lifetime and are very unlikely to ever break. But the signal tower does not have sensors supervising the integrity of the LED lamps. Therefore, it cannot be guaranteed that the safety shutters (either 1 or 2) are indeed closed if the corresponding red LED is not lit. There is a limited chance - however small it might be - that just the corresponding light is broken. It is therefore recommended to verify in regular intervals under safe conditions, that the lamps work as expected.

3.2.1 Special signals

The orange light normally indicates if the generator is producing high voltage or not. When turning the safety controller box on or off or when rebooting it, the orange LED produces the following signals:



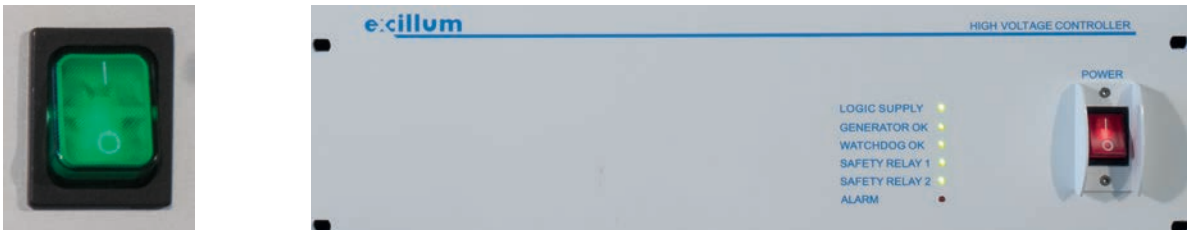
Reboot: 4 x on/off, every 0.50 sec
 Shutdown: 8 x on/off, every 0.25 sec

At the end shutdown sequence, the orange light stays on, regardless of whether the high voltage is turned on or off. Also, the red LED rings on both physical shutter buttons R and L (Figure 1: 2 and 3) stay lit. This is to indicate that the controller is still powered on but shut down. Please note, that during the shutdown and reboot process, the safety shutters will be closed. Shutdown and reboot can only be triggered by software.

For details about reboot and shutdown see chapters 4.2 and 4.3.

4. Usage

4.1 Power up



To power up the system, push the main power button (Figure 1: item 6). This will boot up the controller within approx. 30 seconds. At the end of the boot up sequence, the controller will open two safety relays of the Excillum generator which enables the generator to produce high voltage. Without this signal, the X-ray generator will not be able to turn the high voltage on. Please check at the high voltage generator rack of the Excillum generator that the LED's "Safety relay 1" and "Safety relay 2" are lit (see right Figure above).

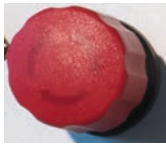
4.2 Shutdown

It is recommended to orderly shutdown the safety control system. Instead of just pushing the main power button (6 in Figure 2), an orderly shutdown can be done only by software that implements this function or from the web control interface (see below). The start of the shutdown sequence will be indicated by the flashing orange LED light (8 x on/off) of the signal tower that normally indicates if the high voltage is turned on or not. Both shutters 1 and 2 will be closed as part of the shutdown sequence. The end of the shutdown will be signalled by the orange LED light being constantly turned on as well as the red LED rings on both shutters 1 and 2, (2 and 3 in Figure 2). Please note, that this does neither say that the high voltage is turned on nor that the shutters are effectively open! It is just an indicator that the shutdown sequence has finished and it is safe to push the main power button (6 in Figure 2). When the power is taken away, all lights of the signal tower and of the safety shutter controller will be turned off.

4.3 Reboot

A reboot of the safety controller is normally not necessary. A reboot can only be triggered by appropriate software that implements this function or from the web control interface (see below). The start of a reboot sequence will be indicated by the flashing orange LED light (4 x on/off) of the signal tower that normally indicates if the high voltage is turned on or not. Both shutters 1 and 2 will be closed as part of the reboot sequence. As part of the reboot sequence, the safety relays for the high voltage generators will be closed for a short time, so the generator will turn off the high voltage. The generation of X-rays must then be restarted by a user process.

4.4 Emergency stop



By pushing the emergency button (1 in Figure 2), the production of X-rays by the generator is interrupted immediately by turning off the high voltage (actually by closing safety relays 1 and 2). The emergency button will stay pushed down until it is released again. While it is pushed down, the safety relays 1 and 2 will stay closed and the generator cannot produce X-rays.

4.5 Operate shutters



Under normal operating conditions, safety shutters 1 and 2 can be operated by pushing the corresponding buttons on the safety controller box (2 and 3 in Figure 2, respectively). If the shutter is open, a red LED ring will be lit around the push button. Also, for shutter 1 the uppermost red LED light on the signal tower will be lit. For shutter 2, the red LED light underneath the one for shutter 1 will be lit. If the shutters are closed, both the red LED rings on the safety controller and the red LED lights on the signal tower will be turned off.

When trying to open the shutter, a couple of checks are being done automatically before actually opening the shutter. If a check is negative, the shutter will not open. The following conditions are mandatory:

- all doors of the radiation enclosure are closed
- the vacuum pump that evacuates the focussing mirror is turned on and the vacuum is okay
- the mechanical contact between the mirror housing and the mardtb goniostat is pushed down



If any of these conditions is not met, the shutter will not open. There is no special signal telling which condition is critical. It is recommended to verify in the following order of precedence:

1. Are the doors of the interlock all closed -> see chapter 4.5.1
2. Is the vacuum pump for the mirror housing turned on -> see chapter 4.5.2
3. Is there a physical contact between the mirror housing and the goniostat system - > see chapter 4.5.3

4.5.1 Radiation enclosure



The radiation enclosure is described in detail in another document. Please refer to that document to learn more about the functionality of the radiation enclosure. What is important here is the red LEDs that show the status of each door on the upper frame of the radiation enclosure are all turned off. If all doors are closed, the green LED next to the override key is lit. If any door is open and any red LED is lit, the shutter cannot be opened. If the shutter is already open and one of the doors is opened, the shutter will be closed automatically. For safety reasons, the shutter will not reopen automatically if all doors are closed!



BEWARE: an override key for the radiation enclosure interlock system may circumvent the safety rules for the doors. If the override key is inserted and turned clockwise, the safety control system is told, that all doors are closed regardless of their actual state. Therefore, the override key must be removed in normal operation mode and must be kept away from plain users.

4.5.2 Vacuum pump for focussing mirrors

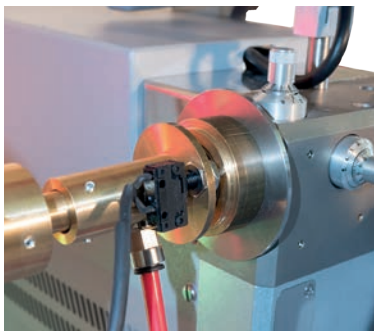


It is critical for the focussing mirrors, that the mirror chamber is either held in vacuum or flooded with inert gas (Helium). If X-rays hit the mirrors, oxidation of the surface will occur in short time under normal atmospheric conditions and heavily affect the performance of the mirrors. The mirrors must therefore stay in an oxygen-free environment. Here, we use a vacuum pump connected to a vacuum sensor, that provides a 5V signal to the safety control box if the vacuum is good. The signal is fed in via connectors 5 and 6 (Figure 3) for ports L and R, respectively. Without that signal, the shutter cannot be opened. If the shutter is already open and the signal vanishes (e.g. because the pump has been turned off), the shutter will be closed automatically. Please note, that the shutter will not reopen automatically once the vacuum is back.



BEWARE: it is possible to feed in some permanent signal into connectors 5 or 6 regardless of the status of the vacuum. In that case, it is solely the responsibility of the user to make sure that the mirrors are not getting damaged!

4.5.3 Contact between mirror housing and goniostat



When the generator is up and running, X-rays will eventually leave the mirror housing. To protect users from getting into contact with the direct beam or just scattering of the direct beam with air or metal surfaces, it is mandatory to keep a direct mechanical contact between the mirror housing and the mardtb goniostat. For this purpose, there is a mechanical switch at the end of the collimation tube (part of the mirror assembly) that needs to permanently be pushed down. This is done by moving the mardtb goniostat close enough to the switch so it gets pushed down. If the contact is not active, the shutter cannot be opened. If for some reason the shutter is already open and the contact gets broken, the shutter is closed automatically. Please note, that the shutter will not reopen automatically if the contact is reestablished!

5. Software

5.1 Overview

The **metaljet** safety control system can be controlled manually, but also by software. The controller handles the following interfaces:

- web access for configuration and control
- GUI (graphical user interface) for Unix & Windows
- apps for iOS and Android

A REST API (application programming interface) is available upon request for programming your own interface.

By default, the **metaljet** controller has 2 fixed IP addresses and a primary address coming from a DHCP-server on the local network. The fixed addresses are:

192.0.2.112 and 192.168.178.112

The addresses may be changed from the web interface (see below). As a last remedy to reach the controller if all other network connections are broken is address 10.9.8.7 (not changeable). The **metaljet** controller should be setup to become a full member of a local network. A full internet connection is desirable for accessing certain functions like contacting the firmware update server although this is not mandatory. For security reasons, only few ports to the outside world are open and the system may be considered to be properly protected from foreign intruders. The following ports are used by the system and must not be blocked by a firewall:

Port	Service	Description
67, 68	DHCP	Required for obtaining IP-address and other network parameters from DHCP server
80	HTTP	Required for access via the web interface
123	NTP	Optional for obtaining system time from public time/date servers
8888	HTTP	REST API, also required for mobile devices
45678	Custom	Required for access via desktop program "metaljet" and for mobile devices

For an initial setup, connect the **metaljet** box with a network cable to a computer and make sure that network (e.g. 192.0.2.0) is visible from this computer. In order to verify that the **metaljet** controller is visible, open a command terminal on your PC.

On Windows, use the „Command Prompt“ app. One of the quickest ways to launch the Command Prompt is to use the Run window (press Win+R on your keyboard to open it). Then, type cmd or cmd.exe and press Enter or click/tap OK.

On Mac, use the Terminal app in /Applications/Utilities. On Linux, use the default command window of your window manager. In the command window, type:

```
ping 192.0.2.112
```

You should see a positive response like:

```
PING 192.0.2.112 (192.0.2.112): 56 data bytes
64 bytes from 192.0.2.112: icmp_seq=0 ttl=64 time=0.834 ms
```

If you are not getting a positive reply but something like:

```
Request timeout for icmp_seq 0
```

you are not seeing the **metaljet** controller and you will have to check the settings of your network card and/or your routing parameters. Please note, that if you use a patch cable to directly connect your PC with the **metaljet** box, it will have to be a so called „crossover“ cable. If you use plain 1:1 patch cables, you will have to connect both your PC and the **metaljet** controller to a hub or switch.

If you can ping the **metaljet** controller, you are ready to start the web interface from your favorite browser.

5.2 Web interface

The web interface presents information about the **metaljet** safety control system. This is where you configure all of the settings for operating the system. Desktop programs and mobile apps allow only for operating the shutter but not IP-addresses, etc...

The user interface can be opened from any computer or mobile device connected with the **metaljet** box. The settings you configure are saved in the **metaljet** controller.

- Start a web browser on your computer.
- Enter „192.0.2.112“ in the address field of the browser and hit return
- The metaljet web interface opens

5.2.1 Password protection

The **metaljet** user interface is protected from unauthorized and unwelcome access by a password. Only users who know the password can access the user interface. This protects all settings and all information in the **metaljet** box. The **metaljet** controller features 3 user levels for different purposes. All come with a separate password. As a factory setting all passwords are set to “metaljet”.

Level	Password	Description
default	-	User cannot obtain status nor send commands
mar	metaljet	User is allowed to open and close the shutter
admin	metaljet	User can fully configure the instrument

On the login page of the web interface only users “admin” and “mar” are allowed to login.

After initial login, we strongly recommend changing the default passwords for all user levels on the corresponding page (see below). When leaving the configuration page, it is strongly recommended to logout, otherwise any person using the same web browser session will have access to the configuration parameters without being asked again for the password. After explicitly logging out, you will be asked again for a password to gain access to the configuration pages.



Be sure to use a password you can remember easily. If you forget the password, the only way to access the **metaljet** controller is to restore the factory settings. All settings made during operation will be overwritten. Then you can open the user interface again in order to reconfigure your settings or restore the settings you saved during previous operation.

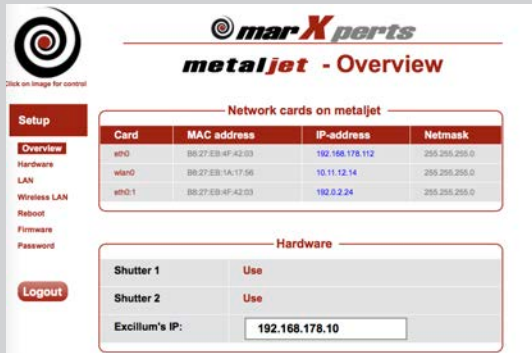
5.2.2 Connection to Excillum controller

The **metaljet** safety controller does not need to communicate with the Excillum controller. However, it is strongly suggested to let this happen. The safety controller will get status information (HV, current, vacuum, operation mode) from the generator and is able to send a handful of basic commands like going to full power or to standby or turning the HV generator off. The MetalJet controller needs to know the IP-address of the Excillum controller. It should be on the same network, e.g. 192.0.2.10. The easiest way to achieve this is to have DHCP server that supplies IP-addresses to both controllers at boot time. You still would have to find out which IP-address the Excillum controller is actually using and enter this information in the configuration as shown below (section Hardware).

5.2.3 Configuration and control

After logging in as user „admin“ the web user interface gives access to the following configuration pages:

Page **Description**



Overview

Network cards on metaljet

Card	MAC address	IP-address	Netmask
eth0	88:27:E8:4F:42:03	192.168.178.112	255.255.255.0
wlan0	88:27:E8:1A:17:56	10.11.12.14	255.255.255.0
eth0.1	88:27:E8:4F:42:03	192.0.2.24	255.255.255.0

Hardware

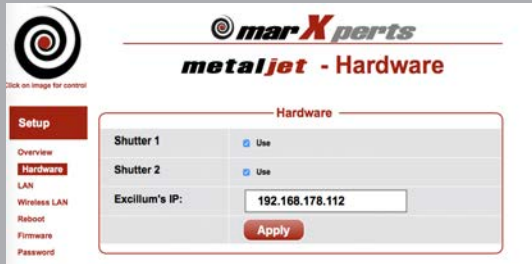
Shutter 1: Use

Shutter 2: Use

Excillum's IP: 192.168.178.10

Overview:

Shows the IP-address of the network adapter and the currently configured parameters for the use of a single shutter or both shutters as well as the IP address of the Excillum controller.



Hardware

Shutter 1: Use

Shutter 2: Use

Excillum's IP: 192.168.178.112

Apply

Hardware:

Set the following parameters here:

- **Shutter 1:** option to use or ignore shutter 1 (right hand port)
- **Shutter 2:** option to use or ignore shutter 2 (right hand port)
- **Excillum's IP:** IP-address of Excillum controller. Must be on the same network as the *metaljet* box.



LAN

Network cards @ metaljet

Card	MAC address	IP-address	Netmask
eth0	88:27:E8:4F:42:03	192.168.178.112	255.255.255.0
wlan0	88:27:E8:1A:17:56	10.11.12.14	255.255.255.0
eth0.1	88:27:E8:4F:42:03	192.0.2.24	255.255.255.0

Network card: eth0

IP-address: 192.168.178.112

Netmask: 255.255.255.0

Gateway (optional): 192.168.178.1

DNS server (optional): 192.168.178.1

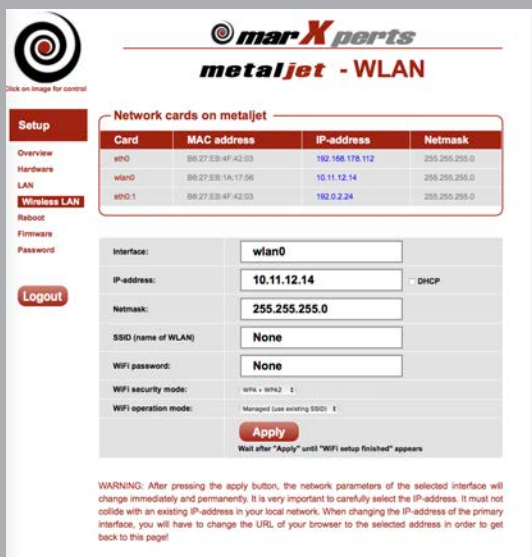
Apply

WARNING: After pressing the apply button, the network parameters of the selected interface will change immediately and permanently. It is very important to carefully select the IP-address. It must not collide with an existing IP-address in your local network. When changing the IP-address of the primary interface, you will have to change the URL of your browser to the selected address in order to get back to this page!

LAN:

Configure your local network here. In case of doubt, get valid parameters from your local system administrator. The primary interface does not listen to a DHCP server and must be assigned a static IPv4 address and a matching netmask. Unless a gateway and DNS server is assigned, the *metaljet* box cannot contact the firmware update server and public NTP servers for obtaining its system time.

- **IP-address:** valid static IPv4 address
- **Netmask:** e.g. 255.255.255.0 for class C networks
- **Gateway:** IP-address of gateway to internet
- **DNS server:** Name or IP-address for local or public domain name resolution server



WLAN

Network cards on metaljet

Card	MAC address	IP-address	Netmask
eth0	88:27:E8:4F:42:03	192.168.178.112	255.255.255.0
wlan0	88:27:E8:1A:17:56	10.11.12.14	255.255.255.0
eth0.1	88:27:E8:4F:42:03	192.0.2.24	255.255.255.0

Interface: wlan0

IP-address: 10.11.12.14 DHCP

Netmask: 255.255.255.0

SSID (name of WLAN): None

Wifi password: None

Wifi security mode: WPA + WPA2 1

Wifi operation mode: Managed (use existing SSID) 1

Apply

Wait after "Apply" until "Wifi setup finished" appears

WARNING: After pressing the apply button, the network parameters of the selected interface will change immediately and permanently. It is very important to carefully select the IP-address. It must not collide with an existing IP-address in your local network. When changing the IP-address of the primary interface, you will have to change the URL of your browser to the selected address in order to get back to this page!

WLAN:

Configure your (optional) Wifi card here.

- **IP-address:** static IPv4 address (or select DHCP)
- **Netmask:** e.g. 255.255.255.0, not required for DHCP mode
- **SSID:** Name of Wifi network to connect to or to create yourself
- **Wifi password:** Choose password or leave empty
- **Security mode:** supported modes are WPA, WPA2, WEP and None
- **Wifi operation mode:** managed (= connect to existing Wifi network) or master (= access point for independent network)

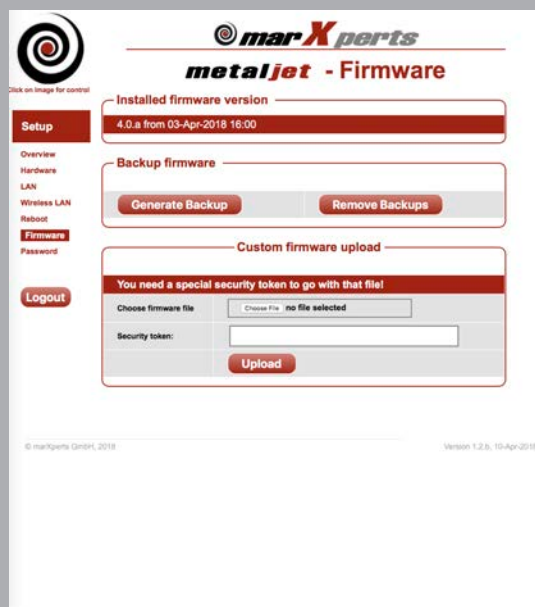
Page Description



Reboot:

On this page you can trigger a reboot or shutdown of the controller instead of using the push buttons on the front panel.

It may be necessary under certain circumstances to reboot the device if network parameters have changed.



Firmware:

Here is where you can see the version of the firmware currently installed. If there is a full internet connection, you will see the latest firmware version that is available for download.

If you want to make a safety copy of your firmware, press the “Generate Backup” button and the system will start to produce a backup file and present it for download. To see the list of backups, you will have to manually refresh the browser page. Only then, you will obtain a link for downloading the backup. Since disk space is limited in the controller you should not produce too many backups and remove the backup once it has been downloaded. The backup may be used under certain conditions to restore information of the device.

The last section on this page allows for loading a custom firmware file for dealing with special situations. These custom firmware files require an individual security token and will be provided only if necessary.



Password:

Here is where you can modify the individual password for the user levels “mar” and “admin”.

Please keep note of those passwords. If you lost them, the only way to recover is by doing a “Factory reset” which is going to reset all passwords to “metaljet”. See chapter 5.2.4 to learn more about the “Factory reset” which cannot be done by software but only on the instrument.



Control:

The control page can be obtained after logging in as user ‘mar’ or ‘admin’ by clicking the marXperts spiral logo in the upper left corner of each page of the web interface. By clicking on to the police light, the shutter opens or closes, depending on its current state. An open shutter is indicated by a red light. If the shutter is closed, the police light status is grey.

The LED lights in the row underneath show the status of the interlock system (enclosure, vacuum, contact mirror-goniostat)

The LED lights in the last row show the status of the high voltage generator safety relays. Green means: okay.

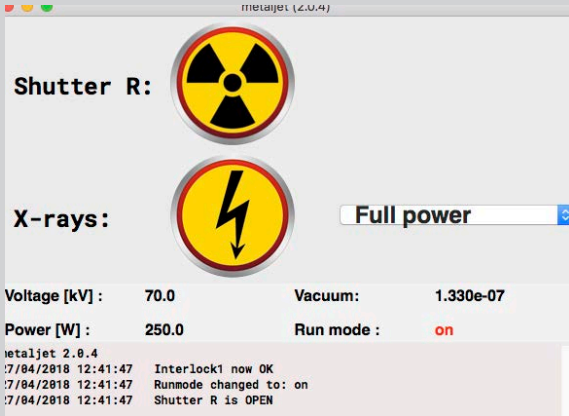
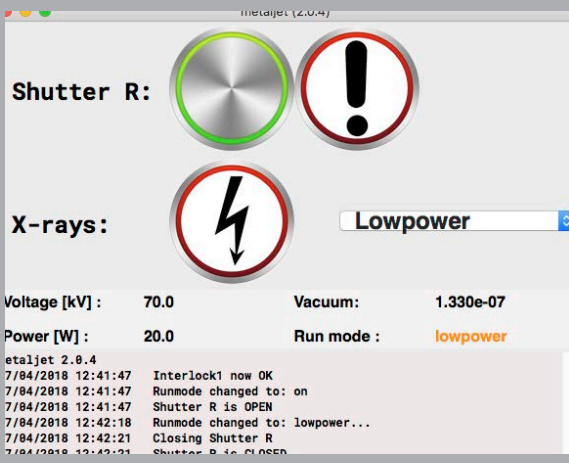
5.3 Desktop apps

5.3.1 Python GUI

The **metaljet** safety control system can be operated from any browser from any PC provided that the controller box is member of your local network. While most configuration parameters are only available from the web interface, monitoring the current status of the system and doing basic operations like opening and closing the shutters may be easier to do with a dedicated application. The program is called „metaljet“. Executables are available for:

- Ubuntu & Redhat Linux
- Mac OS X >= 10.12
- Windows >= 10

The GUI depends on other system components, in particular Python3 libraries “tk”, “numpy” and “requests”. For Windows, a Python3 installation is expected to be installed in C:\Python3xx.

Page	Description
	<p>The uppermost push button allows for opening and closing shutter 1 or shutter 2 (or both, depending on configuration). If the shutter is open, a radiation symbol is shown,.</p> <p>The high voltage indicator in the row below becomes white in low power mode and disappears if the high voltage is turned off. From the X-ray menu, it is possible to change the run mode of the generator: either full power, low power or X-rays turned off. In the area below, the most relevant run parameters of the generator are shown.</p>
	<p>An exclamation mark next to the shutter means, that the interlock system is in alarm condition. Check the doors of the radiation enclosure, the vacuum and the physical contact between mirror and mardtb as described above. If the alarm condition is gone, the exclamation mark will disappear automatically. While the interlock is not okay, the shutter cannot be opened.</p>

5.3 Mobile apps

For Android versions ≥ 7 (Nougat) and for iOS ≥ 9.0 there is a mobile app in the Google Play Store and Apple Store, respectively. Please search for „metaljet“. Please note, that the mobile app can talk to the **metaljet** box only if the mobile device is connected to the same network as the **metaljet** box, i.e. the IP-address given in the mobile app (see below) must be visible by the mobile device. In case of doubt, ask your local network administrator how to achieve this.

Page	Description										
<table border="1"> <thead> <tr> <th colspan="2">Excilium Generator</th> </tr> </thead> <tbody> <tr> <td>X-rays:</td> <td>Off Low Full</td> </tr> <tr> <td>HV [kV]</td> <td>70.00</td> </tr> <tr> <td>Power [W]</td> <td>250.0</td> </tr> <tr> <td>Vacuum [mbar]</td> <td>1.330e-07</td> </tr> </tbody> </table>	Excilium Generator		X-rays:	Off Low Full	HV [kV]	70.00	Power [W]	250.0	Vacuum [mbar]	1.330e-07	<p>The push buttons allows for opening and closing shutter R or shutter L (or both, depending on configuration). If the shutter is open, a radiation symbol is shown,.</p> <p>The shutter status is also indicated by the police light in the row below. A red light means that the shutter is open.</p> <p>Depending on the configuration, the section below shows the most relevant information about the MetalJet generator, i.e. the current run mode, the current high voltage and current settings and the current vacuum. It is possible to put the generator into standby mode (X-rays: Low), into full power mode (X-rays: Full) or to turn the X-rays entirely off (X-rays: Off) by selecting the corresponding button. Any further details must be handled elsewhere.</p>
Excilium Generator											
X-rays:	Off Low Full										
HV [kV]	70.00										
Power [W]	250.0										
Vacuum [mbar]	1.330e-07										
	<p>By swiping left, you get the “Settings” page of the app. Here, you will have to set the IP-address of the MetalJet shutter control box (default: 192.0.2.112) and the port to talk to (8888). You may also have to provide the password for user “mar” or “admin” and select the user role.</p> <p>You also have a choice of several settings for the looks of the user interface. At present, a push notification mechanism is implemented into the app, but there are currently no events that will actually trigger a message. Hence, for the time being it does have no effect whether you choose to use push notifications or not. This might change in future versions of the mobile apps.</p>										

Appendix

A - Connectors

The connectors at the back of the safety control box are chapter 3.1 and shown in Figure 3. The pin settings for the connectors are described here in detail.

A.1 Generator (1 in Figure 3)

Connector with 44 pins. This connector only uses pin1, 10, 12 and 34.

- Pin 1: 24V permanent
- Pin 10: 24V to activate safety relay 1 of the Excillum generator
- Pin 12: 24V to activate safety relay 2 of the Excillum generator
- Pin 34: GND

If the safety relays are not activated, the Excillum generator will immediately shut down the high voltage generator and turn the X-ray generation off.

A.2 Tower (2 in Figure 3)

Connector with 4 pins. Handles signals from contacts of the Excillum generator tower.

- Pin 1: 24V input for interlock circuit 1
- Pin 2: 24V output for interlock circuit 1
- Pin 3: 24V input for interlock circuit 2
- Pin 4: 24V output for interlock circuit 2

A.3 Interlock 1 (3 in Figure 3)

Connector with 2 pins. Receives signal from interlock system on the right hand side of the generator table. Pin1 is 5V, pin 2 is GND.

A.4 Interlock 2 (4 in Figure 3)

Same as A.3, but for the left hand side of the generator

A.5 Shutter 1 (8 in Figure 3)

Connector with 26 pins. Operates the X-ray shutter on the right hand side of the generator. The following pins are used:

- Pins 6/16/25: GND
- Pin 7: 24V
- Pin 11/13/20: Input shutter status open/close
- Pin 14: 5V
- Pin 17/18: 24V for solenoid
- Pin 19/26: Tower interlock circuit

A.6 Shutter 2 (9 in Figure 3)

As A.5 but for the shutter on the left hand side of the Excillum generator.

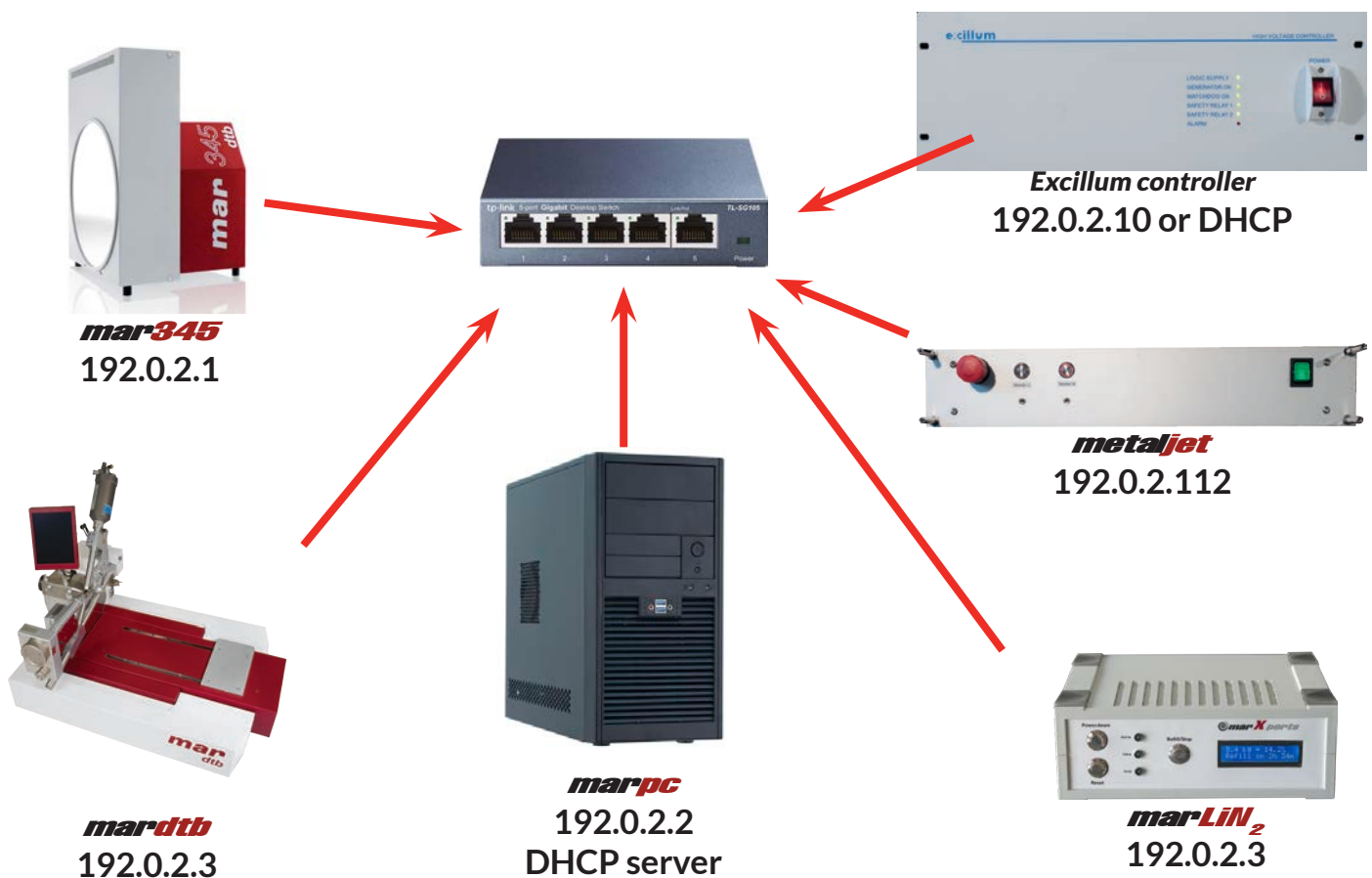
A.7 Lamps (10 in Figure 3)

Connector with 5 pins. Operates the lamps in the light tower of the Excillum generator:

- Pin 1: 24V
- Pin 2: Red LED for shutter 2
- Pin 3: GND
- Pin 4: Red LED for shutter 1
- Pin 5: Orange LED for HV on/off

B - Network integration

The **metaljet** safety controller is sitting close to the Excillum high voltage generator and goniometers or detectors provided by marXperts. All these components have network ports and can therefore be operated from network based programs. It is convenient and strongly suggested that all components are sitting on the same network so they can easily be operated from the PC that drives the goniometer and detector. For a long time all PC's that operate either the **mar345** detector or the **mar_{dtb}** goniometer and other components are equipped with a dedicated network card set to IP address 192.0.2.2. The **metaljet** safety controller has a default address of 192.0.2.112 lying on the same network and the **marLiN₂** liquid nitrogen refill unit is set to 192.0.2.111. The Excillum high voltage generator by default receives its address from a DHCP server, but it can also be set individually from the Excillum control interface (not described here - please look up the Excillum documentation for details). We do recommend to set the Excillum generator to a fixed address 192.0.2.10 or to run a DHCP server on the PC controlling the detector and/or goniometer and connect all components via a switch like in the following example:



It is strongly suggested to set the Excillum controller to a fixed IP address like 192.0.2.10 and configure the **metaljet** safety controller to use that address (see page 11, section Hardware). If the **metaljet** safety controller knows the IP-address of the Excillum controller, it will try to talk to it at boot time and will know the current operation parameters like voltage, vacuum, etc.. When running a DHCP-server on the PC controlling the components, you can find out what IP-address the Excillum controller has received with command:

```
nmap -sn 192.0.2.1/24
```

This command will list all hosts on network 192.0.2.x and it should be straightforward to identify the Excillum controller.

C - Alternative configuration

The *metaljet* safety controller may be configured with an interlock device operating like a synchrotron hutch. In this configuration, there are 3 states:

- **INACTIVE:** The interlock device is inactive. The green LED of the signal tower is lit to indicate that the shutter is closed and there is no possibility to accidentally open it. The orange and red LEDs are turned off.
- **ACTIVATION:** The interlock device is activated by pushing a button in the surveillance area of the X-ray device. An alarm (buzzer) goes off as well as a flash light and stays on for a configurable amount of time (default 30 seconds). All LEDs of the signal tower are turned off until the end of the activation time. The shutter can still not be opened.
- **ACTIVE:** The alarm and the flashing light are turned off. The orange LED light of the signal tower is lit, the green LED stays off. The operation of the X-ray shutter is enabled. When opened, the red LED is lit.

If at any time during the ACTIVATION period or the ACTIVE period the signal of the interlock device is turned off, the X-ray shutter will be automatically closed and operation of the shutter will be disabled. The green LED of the signal tower is turned on, the orange and red LED's are turned off. To reenale the shutter, the described procedure must be repeated.

On page „Hardware“ of the web interface (see page 11), it is possible to adjust the time for the warning period. It may even be set to zero. However, this would undermine the concept of the interlock device.

D - Desktop app downloads

The **metaljet** safety controller can be controlled by program „metaljet“ that is available for Linux, Windows and (upon request) for macOS. The program expects to find the metaljet safety controller at IP-address 192.0.2.112 by default. If this is not the correct address, create a file „metaljet.cfg“ on Linux or „metaljet.ini“ on Windows in the user’s home directory with the following setting:

```
[metaljet]
host=aaa.bbb.ccc.ddd
```

where aaa.bbb.ccc.ddd is the IP-address for the metaljet safety controller

Windows >= 10:

The Windows distribution is a single installer that contains all the required components for a standalone installation. Please download the following file:

<https://marxperts.com/pub/metaljet/metaljet-4.0.1-installer.exe>

After download, execute the installer.

Linux:

The software is based on Python >=3.5. Python is a modular system that comes with a limited set of components contained in the default packages. The metaljet program depends on a few modules that may have to be installed. Typically, the modules come packaged with the Linux distribution.

On Debian/Ubuntu make sure to install the following packages from the default repositories:

```
sudo apt install python3-pip python3-tk python3-numpy python3-pycurl python3-requests python3-simplejson python3-dateutil
```

On RHEL/Centos use the following commands instead:

```
sudo yum install python3-tkinter
sudo yum install python3-numpy
sudo yum install python3-requests
sudo yum install python3-pycurl
```

Please download one of the following files for your Linux distribution:

Linux version	Python version	Link
RHEL/CentOS 8	3.6	https://marxperts.com/pub/metaljet/metaljet-4.0.1-py36-none-any.whl
Debian 10	3.7	https://marxperts.com/pub/metaljet/metaljet-4.0.1-py37-none-any.whl
Ubuntu 20.04	3.8	https://marxperts.com/pub/metaljet/metaljet-4.0.1-py38-none-any.whl
Ubuntu 22.04	3.10	https://marxperts.com/pub/metaljet/metaljet-4.0.1-py310-none-any.whl

To install the downloaded package, use a command like:

```
pip3 install metaljet-4.0.1-py38-none-any.whl
```

Run the program, by typing: „metaljet“.