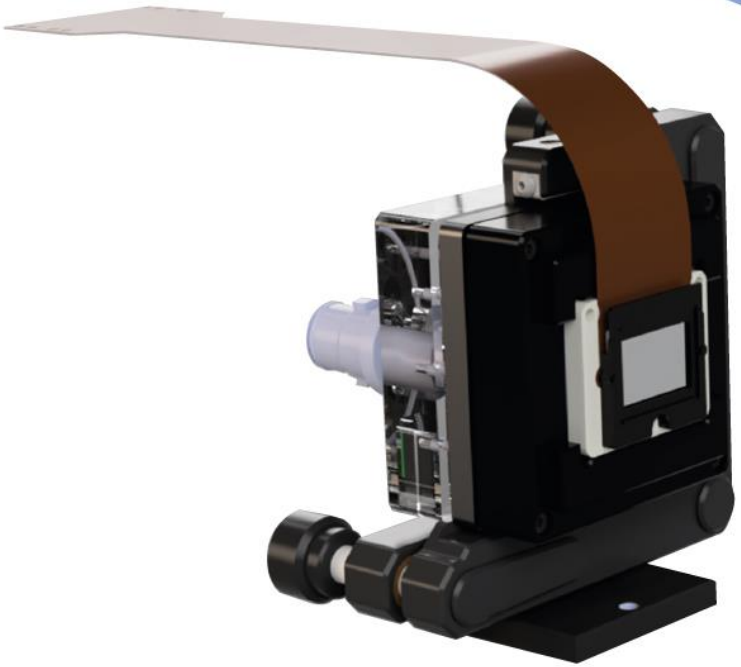
TMS

Thermal Management Systems for HOLOEYE SLMs

Device Operating Instructions



HOLOEYE

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Note

This Instruction explains the correct usage of the device and serves prevention of danger. All persons who apply or use, care of, maintain and control the device have to read and follow it. It is part of the device and should always be at the user's disposal.

* * *

Technical specifications given in this document are subject to change without notification.

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THERMAL MANAGEMENT SYSTEMS

1 Introduction

HOLOEYE Spatial Light Modulators are based on Liquid Crystal micro-displays. Physical properties of LC materials show a temperature dependence and a change in temperature may influence different optical SLM properties (phase shift, switching speed, phase stability...).

SLM displays have their own power dissipation, which varies between products and configurations. To keep the performance / temperature stable, an active thermal management system should be used.

HOLOEYE offers two different active thermal management systems. Both systems use a Peltier element for active temperature controlling. TMS 001 is equipped with a passive heat sink and is the cheaper version. TMS 002 uses an actively water-cooled heat sink for higher temperature differences and higher power dissipation.
The TMS 001 with a passive heat sink is sufficient to stabilize the display temperature at room temperature when using an incident laser power of up to 10 Watt, depending on the reflectivity of the display. For high incident laser power and/or for cooling the display below room temperature, the actively water-cooled system TMS 002 should be considered.

The HOLOEYE Thermal Management Systems act as a display mount. The systems are designed to fit with the current versions of the HOLOEYE PLUTO-2, GAEA-2, and the near future version of LETO Spatial Light Modulator series.

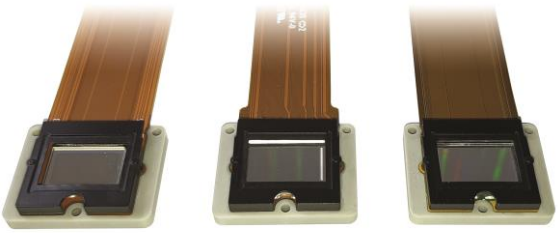


Figure 1: PLUTO-2, LETO and GAEA-2 displays with ceramic package fit to the HOLOEYE Thermal Management Systems TMS 001 and TMS 002.

The up-to date display versions of all these SLM platforms use a standardized display packaging with a ceramic stiffener / back plate with excellent thermal conductivity, see Figure 1. The displays can be mounted using the integrated magnets or by screws if required.

The HOLOEYE Thermal Management Systems are modular and can easily be exchanged dependent on requirements and applications.

2 TMS 001 – Active Thermal Management System with Air-Cooled Heat Sink

The HOLOEYE Thermal Management System TMS 001 is based on a Peltier element (Thermo Electric Cooler) in combination with a passive heat sink and can both cool and heat up the SLM display.
Stabilization of the display temperature against ambient variation is enabled by an active temperature controller. However, the cooling capabilities of TMS 001 are rather limited by the amount of heat load the passive sink can reject to the surrounding air (see section 2.6).

In order to set the target temperature of TMS 001, the controller needs to be connected with a USB cable to a Windows PC. The software HOLOEYE SLM Configuration Manager recognizes the connection to the temperature controller and enables read-out and configuration of the TMS 001. The TMS 001 will hold the selected target cooler plate temperature even if not connected to a PC, and the target temperature value is saved across power-cycles of the temperature controller.

The TMS 001 is designed to operate at room temperature and to keep the display at constant temperature around standard display temperatures (30 °C – 35 °C) or (in special applications) to heat and stabilize the display to elevated temperatures (e.g. 65 °C). For operation at lower display temperatures and/or operation with high-power lasers, the more powerful TMS 002 should be considered.

Figure 2: TMS 001 Thermal Management System Head.

2.1 Deliverables

- TMS 001 head with passive heat sink
- Controller unit
- 12 V power supply + cable
- USB cable
- Manual

Figure 3: Deliverables TMS 001

2.2 TMS 001 Controller Dimensions and Connectors

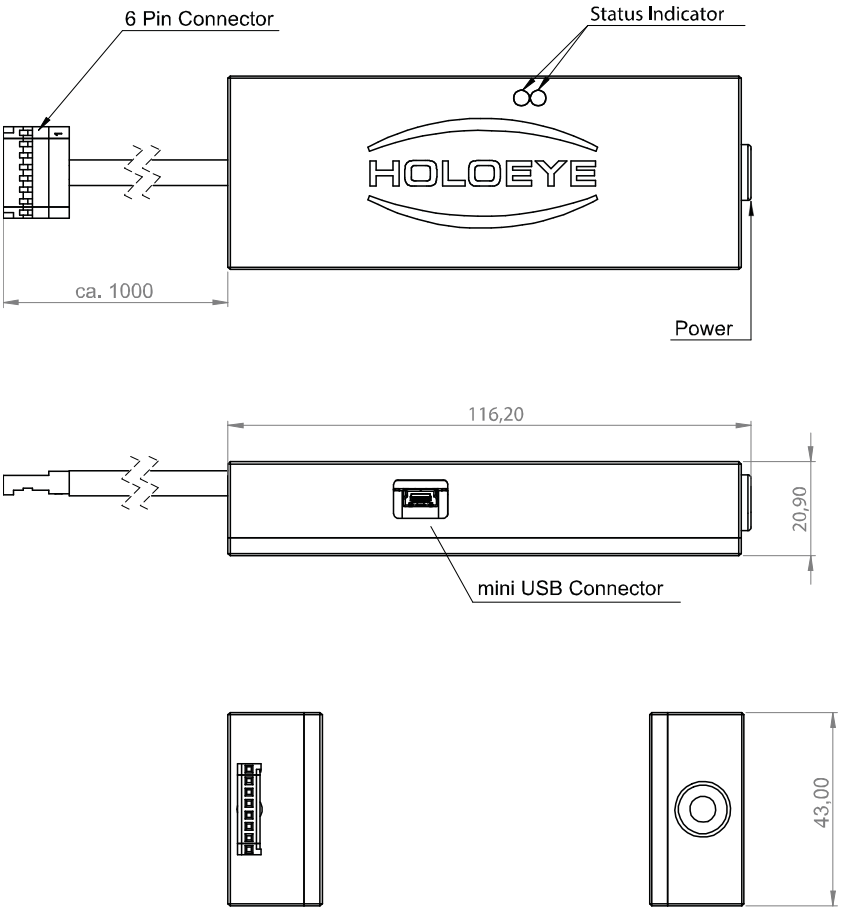


Figure 4: TMS 001 controller dimensions and connectors (unit: mm).

2.3 **TMS 001 Head Dimensions**

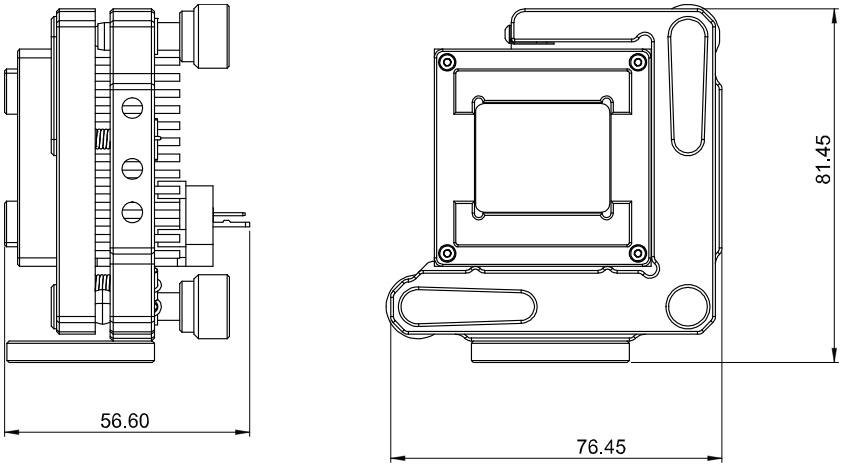


Figure 5: TMS 001 head dimensions (unit: mm).

2.4 Connecting the TMS 001 Thermal Management System

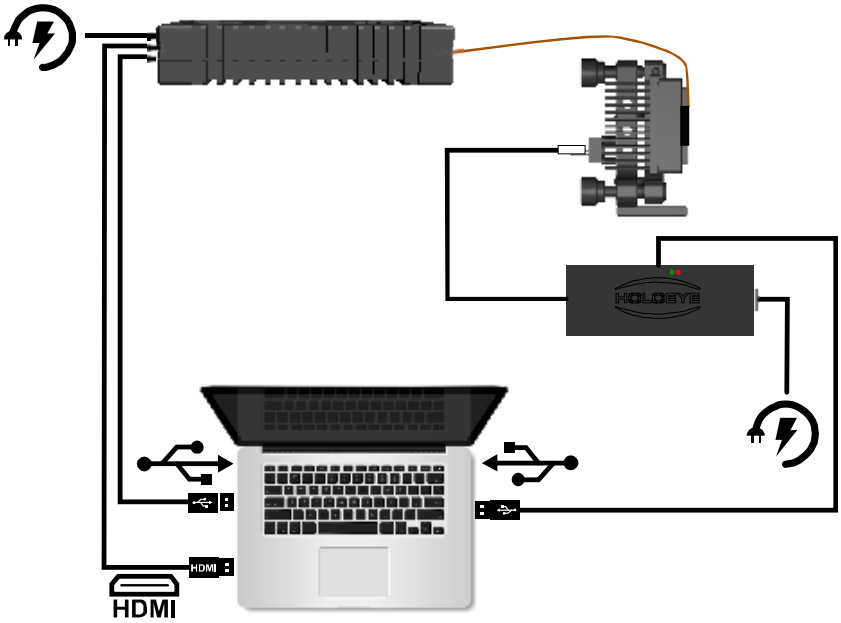


Figure 6: TMS 001 connection scheme

- Connect the 6 pin connector to the TMS 001 head.
- Connect the TMS 001 control box to the computer by USB.
- Connect the power supply for the control box.
- Establish the HDMI connection between the SLM and the computer.
- Connect the SLM to the computer using the USB connection.
- Start the HOLOEYE Configuration Manager software.

2.5 General usage guidelines

The TMS 001 system with a compact passive heat sink is limited in its heat rejection capability. To avoid thermal runaway leading to overheating and emergency switch off, please note the following instructions. The given performance values have been determined for an ambient temperature of 23 °C and without artificial airflow at the heat sink. At higher ambient temperatures, cooling capability of the system will decrease. Any artificial airflow will increase the cooling capabilities.

- *dT*, the difference between sink temperature and cooler plate target temperature must stay below 10 K. However, *dT* may temporarily be higher than 10 K when changing the target temperature. Running the system constantly with *dT* > 10 K may result in thermal runaway, though.
- Observe heat sink temperature in the Configuration Manager software, especially when operating at the edges of heat rejection capacities to avoid thermal runaway.
- If heat sink temperature rises to *dT* > 10 K rather increase target temperature and/or increase airflow at heat sink.
- Keep Target TMS temperature at >= 30 °C for a GAEA-2 display and >= 25 °C for a PLUTO-2 display.
- If a considerable amount of heat (0.1 W – 1 W) is brought into the system by high-power light sources, increase TMS target temperature to >= 30 °C for PLUTO-2 displays and >= 35°C for other displays like GAEA-2. The maximum power loss in the display by laser irradiation can be estimated by:
  (1 – display reflectivity) * (incident laser power)
- The display temperature normally is higher than the cooler plate target temperature (due to inhomogeneous heat dissipation and thermal resistance). The offset depends on the display version and on the displayed content and needs to be taken into account when setting the TMS target temperature.
- Do not heat displays to more than 65 °C.
- Do not hinder airflow around the heat sink.
- At high ambient temperatures > 23 °C observe heat sink temperature for thermal runaway and increase target temperature or increase airflow if necessary.
- If the set target temperature cannot be hold by the TMS, it is driven outside its capabilities and settings need to be checked.

2.6 Cooling limitations and thermal runaway

A Peltier element (Thermo Electric Cooler) produces waste heat while ‘pumping’ heat from its cooled side to the hot side. When cooling a display, this Joule heat adds to the heat transferred to the heat sink. The amount of heat that must be dissipated by the heat sink (in contact with the hot side) thus increases strongly with the cooling current and the temperature difference between cooled and hot side of the element. The cooling capabilities of the passive TMS are thus limited, whereas heating a display with the TMS 001 to temperatures of 40 or 50 °C is no problem.

In the TMS 001 design with the compact purely passive heat sink, the minimum temperature a display can be stabilized to depends on the SLM family (GAEA-2, PLUTO-2, etc.), on the ambient temperature, and air circulation. A certain airflow close to the heat sink may already increase the working range of the passive TMS. Air turbulences, however, may be inconvenient in some optical setups.
Setting the target temperature of the TMS too low will result in thermal runaway of the system. The temperature difference *dT* between sink and cooler plate increases continuously and with that the waste heat the system needs to dissipate. At the maximum heat sink temperature, the TMS 001 will finally switch off to prevent heat damage to the SLM.

A sink temperature rising to more than 10 Kelvin above the target temperature of the cooler plate should be avoided, to prevent continuous up heating of the whole system.

At an ambient temperature of 23 °C, the TMS 001 can cool a HOLOEYE PLUTO-2 display down to 25 °C. As the GAEA-2 display dissipates more heat, the GAEA-2 display can be kept at a constant temperature of 33 °C at 23 °C with the air-cooled TMS 001. If the ambient temperature is higher than 23 °C these values are not guaranteed.

3 TMS 002 – Thermal Management System with Water-Cooled Heat Sink

Even using HOLOEYE's high reflectivity SLM versions (with dielectric mirror), an active thermal management system is required for high-laser power applications. The HOLOEYE Thermal Management System TMS 002 with an active water-cooled heat sink is especially designed for the use with higher laser power.

The TMS 002 uses water to cool the warm side of the Peltier element. It comes in a unit with water reservoir and fan cooled radiator, but can be connected to external water cooling installations, too.

The active cooling of the circulating water allows the system to temperature-control HOLOEYE displays to low temperatures even when a considerable amount of additional heat of several Watts is brought into the system by a high-power light source.

In contrast to the TMS 001 controller, the TMS 002 controller has built-in temperature setting controls, i.e. this system can be operated without a connection to a personal computer.

Figure 7: TMS 002 Thermal Management System Head with a HOLOEYE display attached.

3.1 Deliverables

- TMS 002 head
- Control unit with water depot, radiator, and pump
- Control unit connection cable
- Water tubes
- 24 V power supply + cable
- USB cable
- Manual

Figure 8: Deliverables of TMS 002.

3.2 TMS 002 Controller Dimensions and Connectors

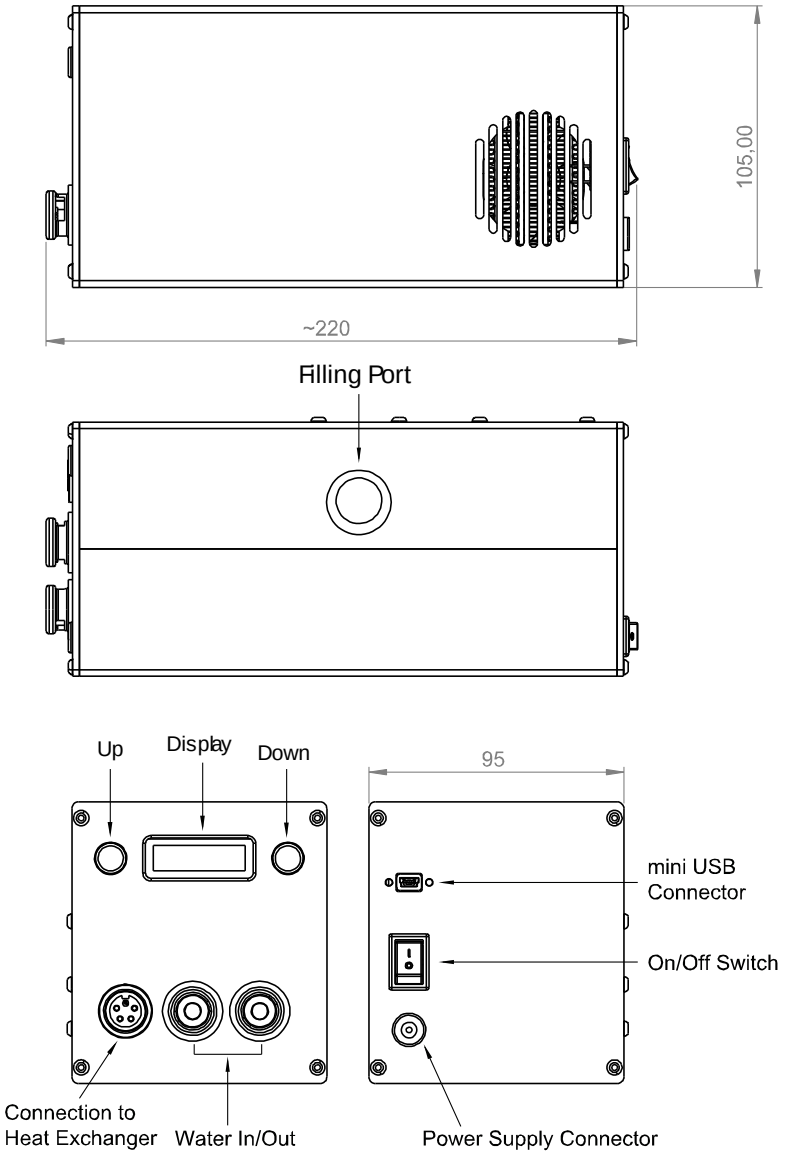


Figure 9: TMS 002 controller dimensions and connectors (unit: mm).

3.3 TMS 002 Head Dimensions and Connectors

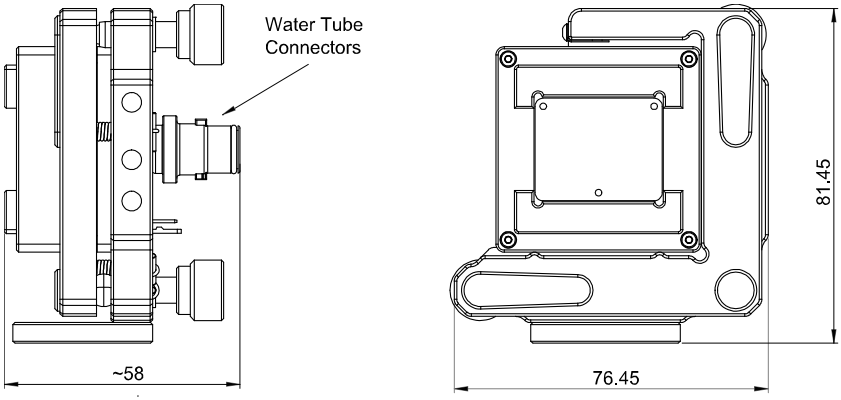


Figure 10: TMS 002 head dimensions and connectors (unit: mm).

3.4 Connecting the TMS 002 Thermal Management System

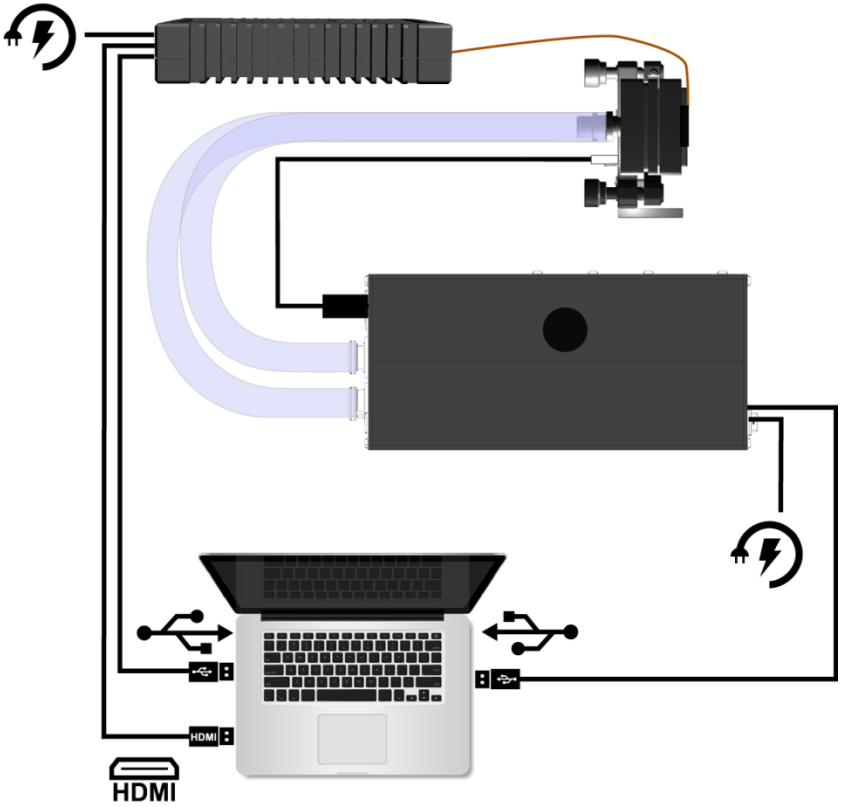


Figure 11: TMS 002 connection scheme.

- Connect the 6 pin connector to the TMS 002 head and to the control unit.
- Connect the tubes between the TMS 002 head and the control box.
- Connect the TMS 002 control box to the computer by USB.
- Connect the power supply for the control box.
- Establish the HDMI connection between the SLM and the computer.
- Connect the SLM to the computer using the USB connection.

- Start the HOLOEYE Configuration Manager software.

3.5 Filling

Before you switch on the control unit, you have to fill-up the liquid container. Please only use the supplied cooling liquid, which contains water and anti-corrosive protection additives.

- Open the cap on top of the control box.
- Fill in cooling liquid until the container is full (you can check the fluid level at the viewing slot at the side of the control box).
- Switch on the control box. The system starts to pump the liquid into the tubes.
- After the tubes are filled with water, switch of the system and add water until the container is full again.
- Close the filler cap.

Please make sure to use an anti-corrosion fluid with additives for protection against algae and corrosion (e.g. “Aquatuning AT-Protect Clear” for PC cooling systems) or at least distillated water.

3.6 General usage guidelines

The actively cooled system is much more powerful than the passive system. Still, only a small water reservoir and radiator have been implemented for the sake of compactness. Depending on ambient temperature, thermal runaway continuously heating up the cooling liquid may occur under extreme circumstances. To avoid emergency switch off, please note the following instructions. At ambient temperatures above 25 °C, cooling capability of the system may be lower than the values given here.

- Avoid water condensation or even freezing at the display by exaggerated down cooling. The TMS 002 is capable to cool HOLOEYE displays below 0 °C. This is not recommended, however.

- *dT*, the difference between cooling water temperature and cooler plate target temperature should stay below 30 K. Running the system with *dT* > 30 K may result in thermal runaway.
- Observe water temperature displayed at the front of the TMS control box or in the Configuration Manager software, especially when operating at the edges of heat rejection capacities to avoid thermal runaway.
- If heat sink temperature rises to *dT* > 30 K increase target temperature.
- The amount of heat brought into the system by high power light sources that can be compensated by the TMS 002 depends on the chosen TMS target temperature. See Fig.12 for acceptable values of heating by optical irradiation.The maximum power loss in the display by laser irradiation can be estimated by:
  (1 – display reflectivity) * (incident laser power)
- The fact that the TMS can handle the power of a high-power laser does not imply that the display can handle it. Please contact technical support for the power handling capabilities of your specific HOLOEYE SLM.
- The display temperature normally is higher than the cooler plate target temperature (due to inhomogeneous heat dissipation and thermal resistance). The offset depends on the display type and on the displayed content and needs to be taken into account when setting the TMS target temperature.
- Do not heat displays to more than 65 °C.
- Do not hinder airflow at the fan openings in the controller housing.
- At high ambient temperatures > 25 °C, please observe the water temperature for thermal runaway and adjust settings if necessary.
- If the set target temperature cannot be hold by the TMS 002, it is driven outside its capabilities and settings need to be checked.

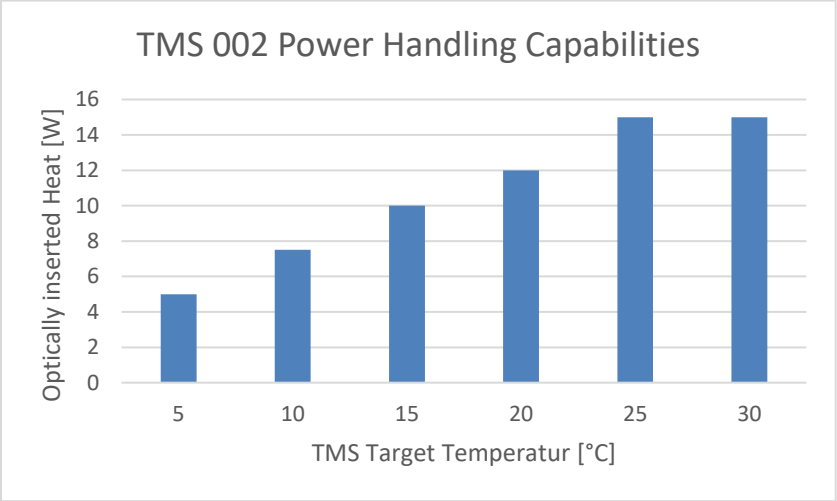


Figure 12: Amount of heat the TMS 002 can compensate. The optically inserted heat is the part of high power radiation, which is absorbed by the display.

TMS – SOFTWARE

4 Thermal Management System Software

4.1 Requirements

This part of the manual describes the software features of a HOLOEYE Thermal Management System (TMS).
The HOLOEYE TMS is controlled through the HOLOEYE Configuration Manager software shipped with the SLM. You need to connect the TMS controllers USB port to the PC properly and install Windows drivers for the virtual serial ports.

Currently only PLUTO-2 and GAEA-2 Configuration Managers in version 2.0 and later supports connecting to the TMS. Please make sure you use at least this version.

4.2 Connection to Configuration Manager Software

All supported HOLOEYE Configuration Managers automatically detect any connected HOLOEYE Thermal Management Systems.
If no SLM is connected and a HOLOEYE TMS is found (see Figure 12), you can also use the TMS independently of the SLM. If an SLM is detected the software will connect to both at the same time. This allows adjusting the actual SLM display temperature through the TMS. If only the TMS is connected without the SLM, the TMS can still regulate the cooler plate temperature.

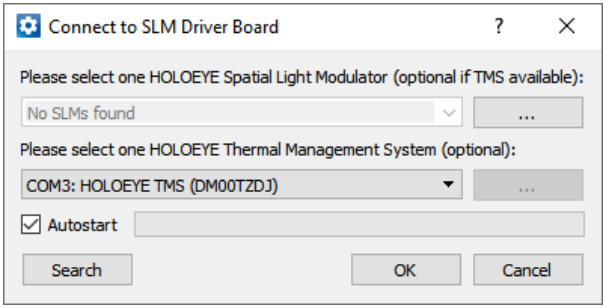


Figure 12: Connection Dialog of HOLOEYE Configuration Manager automatically detects any connected HOLOEYE TMS.

If the “Autostart” box is checked, the dialog will automatically accept in case the last used connection settings are found again. Before the autostart is accepting the dialog, the progress bar beneath the “Autostart” check box indicates a timeout duration of 5 seconds. During this timeout, you can change the settings and stop the ongoing autostart. After the progress bar is at 100%, the dialog will close and the software will connect to the selected devices.

If the COM port of the HOLOEYE TMS could not be detected automatically, please make sure the USB-COM port driver is installed properly. If it is still not detected correctly, but the COM port is available in the system, please try to manually connect to the TMS by using the “…” button beneath the TMS selection box and enter the COM port name manually.

For additional info about installing the USB COM port drivers, please refer to the Configuration Manager manual.

4.3 Thermal Management Tab

If you start the Configuration Manager software with a HOLOEYE TMS connected, an additional tab will open. On this tab you can configure the TMS options and use the regulation of the display temperature through the TMS (see Figure 13).

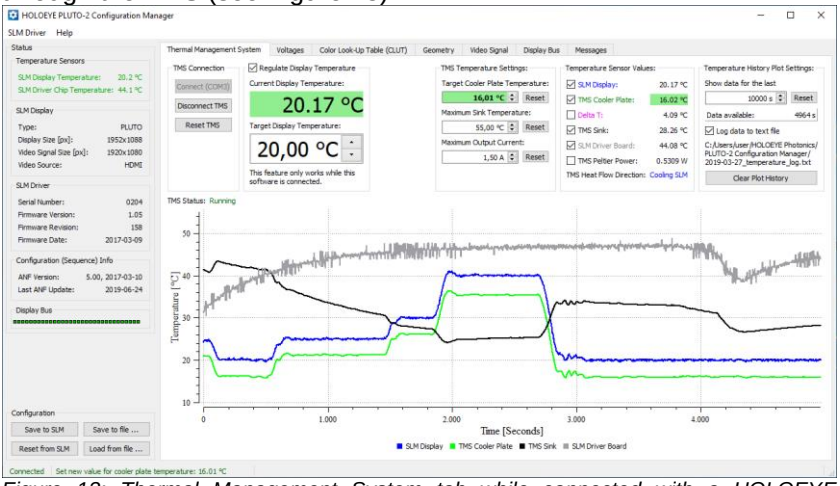


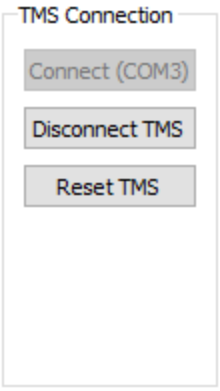
Figure 13: Thermal Management System tab while connected with a HOLOEYE PLUTO-2 SLM.

The tab shows the current SLM temperatures together with the current TMS temperatures and plots the history of the sensor data since connected. It allows changing target temperature values.

The plot in Figure 13 shows the sensor data over almost 5000 seconds, while the target display temperature was set to multiple values (20°C, 25°C, 30°C, 40°C, and 20°C). Figure 13 was created using the “Regulate Display Temperature” feature, see chapter 4.3.2. The SLM driver and the TMS sink temperature both vary due to a varying environment temperature, and at the same time the SLM display temperature and the cooler plate temperature are stabilized at the selected temperature values.

Below follows a more detailed description of the multiple options.

4.3.1 TMS Connection Box



The TMS Connection box has three buttons: “Connect TMS”, “Disconnect TMS”, and “Reset TMS”.

The software starts collecting data when the TMS (and optionally the SLM) is connected. By using the button “Disconnect TMS” the collection of data and any automatic adjustment is temporarily disabled.

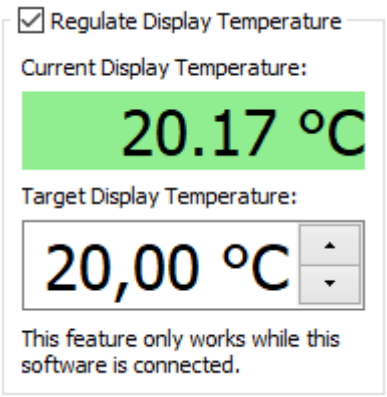
While the TMS is disconnected in the software, disconnecting the TMS hardware USB cable does not interrupt the software.

The “Reset TMS“ button should be used in case the TMS controller reports any error condition (see TMS Status below this box). The reset will clear just all TMS error messages shown in the UI. That means before resetting the device, you should investigate the cause of the error.

4.3.2 Regulate Display Temperature Box

This is a convenience feature for an easy adjustment of the display temperature.
To use this feature, please make sure that both the TMS and the SLM are connected and detected properly by the Configuration Manager software to ensure that the software receives all information needed to regulate the target cooler plate temperature of the TMS to reach a specific selected target display temperature.

To activate this feature, please check the box “Regulate Display Temperature”. When activated, the software will automatically maintain the selected target display temperature by setting the target cooler plate temperature of the TMS out of the measured difference (“Delta T” in the TMS values and plot).



Inside the box, the current SLMs display temperature is shown on top. Select a target display temperature and wait until the current display temperature indicator turns green (which is the case if the display temperature is reached within +/- 1 °C).

At the start of the Configuration Manager software the current SLM display temperature is rounded to full degrees and is used as the initial target display temperature. This is done to prevent any unexpected changes due to connecting the software.

Each time the software applies a new target cooler plate temperature to the TMS controller due to the automatic regulation, a green colored message with the new temperature value pops up. The message includes the time of the event.

The TMS controller hardware stores the target temperature for the cooler plate of the TMS head (see chapter 4.3.3). After powering-on, the TMS controller will directly start to regulate the cooler plate

temperature to reach the target value set in the previous session (independent of any software connection). However, the TMS controller has no information about the actual display temperature. Anyway, when using the same hardware, the display temperature should be more or less the same like in the previous session.

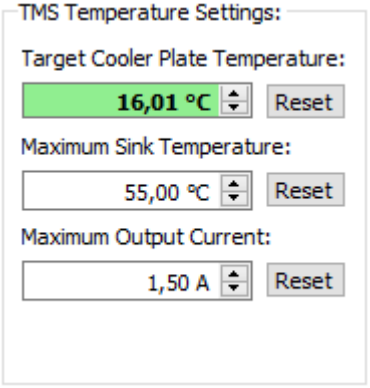
There is always a little temperature difference between the cooler plate temperature and the display temperature (Delta T), because the display is generating some heat, and there is always a finite thermal resistance greater than zero between the display and the cooler plate. Therefore, the display temperature is always a little higher than the cooler plate temperature.

While this feature is enabled, the process of searching a stable condition requires some time. This also means it may make the temperature unstable in case of varying ambient temperature conditions.

For better long-term stability and faster adjustment, we recommend switching off this feature after the display temperature was reached and let the TMS controller hold the target cooler plate temperature instead (as described in chapter 4.3.3).

The state of the feature being enabled or disabled is saved across executions of the software. By default, the feature is disabled.

4.3.3 TMS Temperature Settings Box



At the “Target Cooler Plate Temperature” select box the target temperature for the cooler plate (display mount on head of TMS) can be set. The TMS will regulate the current of the Peltier element so that the display mount temperature stays at the selected target temperature.

This process works without connecting a computer or an SLM to the TMS hardware. The select box will get a green background color as

soon as the absolute difference between the actual and the selected target cooler plate temperature is smaller than 0.25 °C. Otherwise, the color will change to yellow.

If you activated the “Regulate Display Temperature” feature (see chapter 4.3.2), the value is changed automatically. If you want to set it manually, please disable the “Regulate Display Temperature” feature.

The reset button will set the target cooler plate temperature to 25°C, which can be reached under normal environment conditions.

4.3.4 Additional TMS Controller Settings

There are two additional settings for the TMS controller available in the “TMS Temperature Settings” box:
The maximum heat sink temperature, and the maximum output current to the Peltier element. Both values can always be reset to their defaults with the buttons beneath the value edit box. The defaults are 50 °C for the maximum sink (water) temperature and 3.9 A for the maximum Peltier current. The default values are appropriate for most cases, so please try to use them first.

The maximum sink temperature is the temperature of the heat sink of the TMS head (or in case of TMS 002 the temperature of the water) above which the TMS controller will switch off and report an error condition (until reset manually).

This behavior is used to prevent the system from a runaway condition, which may happen at large temperature differences between the cold and the hot side of the Peltier element. At some point, such a condition would also result in a temperature increase at the display. This is to be avoided. The setting for the maximum heat sink temperature allows configuring the point at which the system interrupts such a runaway condition.

The maximum output current limits the current and therefore also the power at the Peltier element. Reducing the current also reduces residual heat loss, because the efficiency of the Peltier element increases when using lower currents. The TMS controller does not switch into an error condition in case the desired current exceeds the maximum current setting but instead it just limits the current.

In most cases, the default values will work well. In the following we show some possible reasons for manually adapting the TMS controller settings:

- **Increased environment temperature:** An increase in environment temperature will also result in an increase of the lowest reachable display temperature. The system might switch off too early with the default 50 °C maximum sink temperature when operated in an ambient temperatures > 45°C. You can increase the limit to up to 80 °C. Please keep in mind that higher temperature can be harmful when touching the sink.

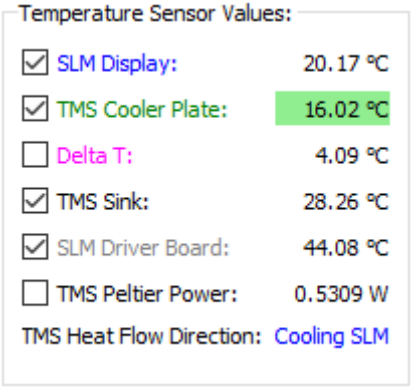
- **Cooling to and stabilizing at low temperatures:** Both systems, the TMS 001 (air-cooled) and TMS 002 (water-cooled), improve efficiency by lowering the current of the Peltier element. Due to the lower heat loss, less heat needs to be dissipated by the cooler. Therefore, lower display temperatures can be reached. However, lowering the Peltier current also decreases regulation speed. If you accept waiting much longer to reaching the desired temperature, you can reach a few degrees less.

  The default value of 3.9 A will result in a fast regulation process, but is not optimal for reaching low temperatures over a longer period. Reducing this value to e.g. 0.5 A or 1 A may already make a difference in the lowest stable temperature reachable. The value can be lowered up to 0.1 A.

- **Cooling to low temperatures for a short duration:** By increasing the maximum heat sink (water) temperature and using the maximum Peltier current, it is possible to reach lower temperatures for the cooler plate over a short duration. Due to the higher power applied to the Peltier element, the heat sink (water) will heat up fast and the system switches off soon.

  The air-cooled system can be improved with a fan blowing to the heat sink, which can also be switched off during a short measurement in case the mechanical vibrations disturb.

4.3.5 Temperature Sensor Values Box

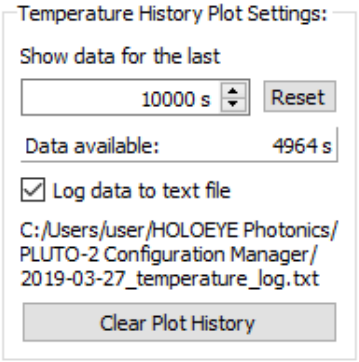


This box lists all available sensor data. Each sensor value has a check box in front to enable or disable the plot for the value.

The “SLM Display” and “SLM Driver Board” temperatures are reported from the SLM hardware. The “Delta T” value is calculated as the difference between the “SLM Display” temperature and the “TMS cooler plate” temperature. All other values are reported from the TMS controller. The “TMS Peltier Power” is plotted into an extra graph, which is hidden until enabling this plot. The “TMS Heat Flow Direction“-label shows whether the Peltier element is cooling down or heating up the cooler plate of the display holder.

The background color of the “TMS Cooler Plate” value is either yellow or green, like the “Target Cooler Plate Temperature” edit field in the box “TMS Temperature Settings”.

4.3.6 Temperature History Plot Settings Box



This box enables configuring the plot and data history. The number of data points shown in the plot can be limited. The plot always shows the data from now to now minus the number of seconds set at the select box. The plot never shows more data than available. The available amount of seconds is shown below the select box.

In addition you can log all sensor

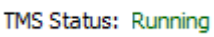
values. The path for the log file is fixed as C:\Users\<name>\HOLOEYE Photonics\<SLM name> Configuration Manager\<date>_temperature_log.txt.

All available data for one day is written to this file. You can disable the log feature by unchecking the “Log data to text file” box. The check state is saved across executions of this software, i.e. this feature can be disabled at all.

The button “Clear Plot History” only clears the plots in the UI and does not delete any data from the log file. The plot cannot show any data from the log file. If you want to see the logged history, you must plot it manually out of the log file using any external software, like LibreOffice Calc, Microsoft Excel, or any other suitable software.

4.3.7 TMS Status

This label shows any errors reported by the Thermal Management System controller. The errors should be self-explaining.



If the system runs without problems, it shows “Running” in green text. If any error occurred, the text color of the label turns to red.

To clear the error state, please use the “Reset TMS” button in the “TMS Connection” box.

If you have any further questions, please get in contact with HOLOEYE:

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