doric

Wireless Fiber Photometry

User Manual

Version 1.0.2

Contents

1

System Overview

1.1 Wireless Fiber Photometry System

The Wireless Photometry System (Fig. 1.1 & 1.2) is a cable-free solution to acquire neuronal data without restricting the animal movement. The Wireless Headstage integrates both LED light sources and detectors to excite and collect photometry signals between the *fiber optic Cannula* and the *Console*.

A standard Wireless Fiber Photometry system (Fig. 1.1 & 1.2) contains the following elements:

- The *Wireless Fiber Photometry Headstage*. See section 1.1.1.
- The *Wireless Base-Station*. See section 1.1.2.
- The *Headstage Battery Charger*. See section 1.1.3.
- The *Dummy Headstage*. See section 1.1.4.
- The *Fiber optic cannula*.
- The Neuroscience Console 500 (*NC500*) or Behavior and Bundle Photometry Console 300 (*BBC300*). The table below compares the main features of both consoles.
- The *Doric Neuroscience Studio* software.

Table 1.1: *Comparing consoles for wireless photometry*

	BBC300	**NC500**
SUPPORTING		
# base station per console	4	2
# headstage per base-station	1	4
Max # headstages per console	4	8
COMPATIBILITY		
Wireless Photometry	X	X
Basic Photometry		X
Bundle Photometry	X	X
Miniature Microscopy		X
Electrophysiology		X

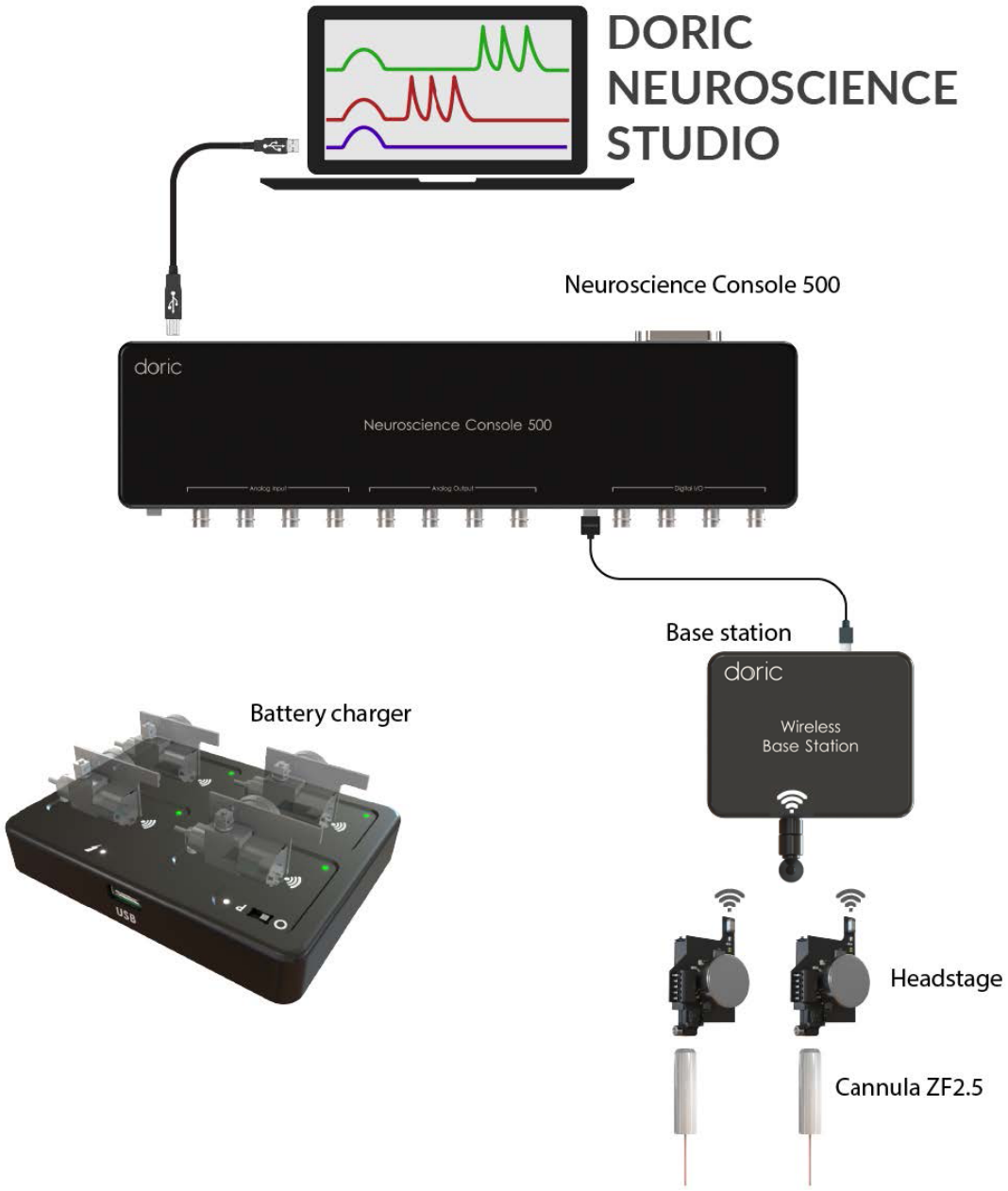


Figure 1.1: *Wireless Fiber Photometry System with NC500*

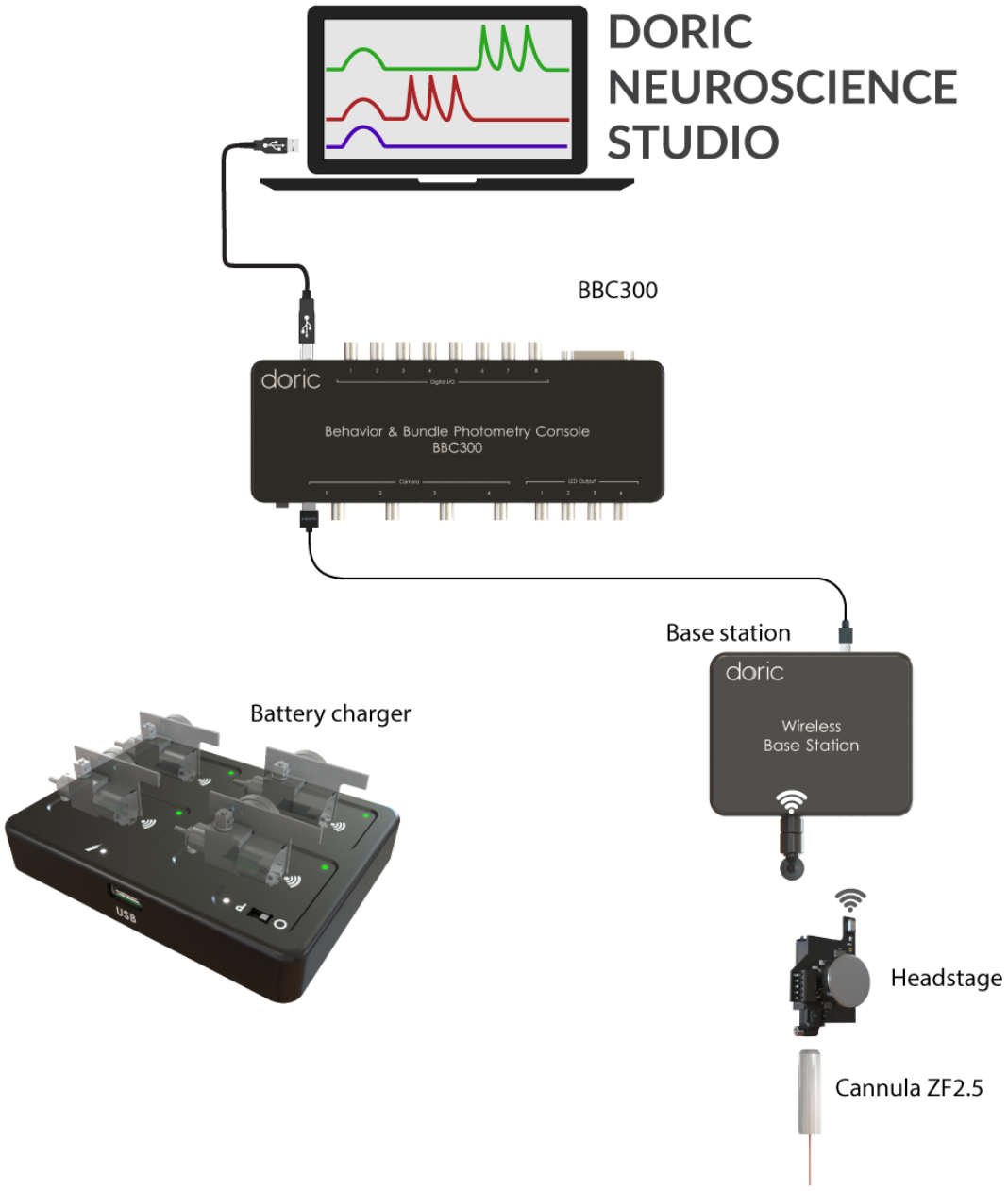


Figure 1.2: *Wireless Fiber Photometry System with BBC300*

1.1.1 Wireless Fiber Photometry Headstage

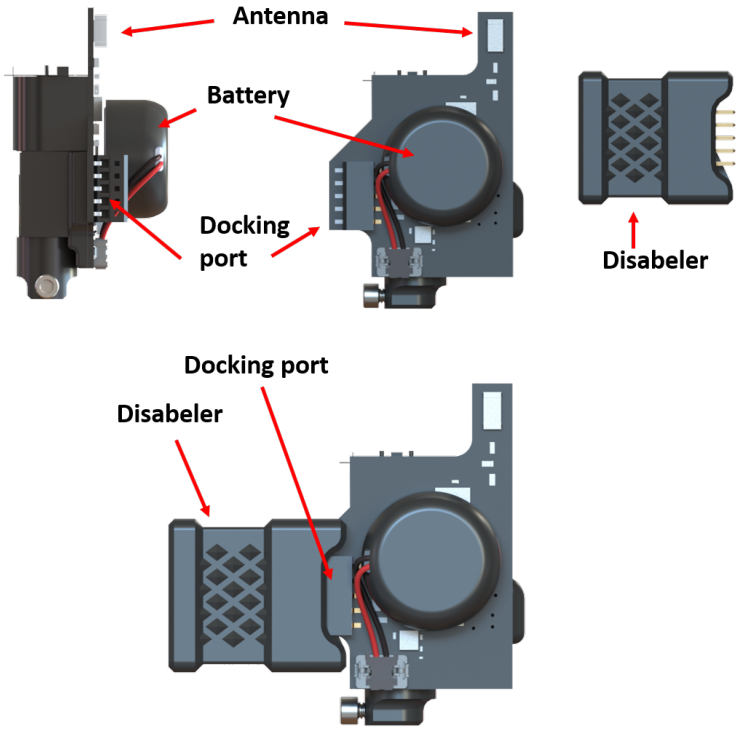


Figure 1.3: *Headstage and disabeler*

The *Wireless Headstage* (Fig. 1.3) is an optic-electronic device that creates the link between the fiber optic cannula and the base-station. It contains LED drivers, two LEDs of choice (isosbestic + biosensor excitation), and a detector to both send light pulses for illuminating the fluorophores and collect the emission wavelengths. The headstage also uses a battery to power the LEDs.

- The **Antenna** (Fig. 1.3) is a small ridge on the side of the headstage used to transmit wireless photometry signal.
- The **Battery** serves as the power source for the headstage operation. Two battery options are available: Type A and Type B, each offering different charge durations and weights. For details, refer to the specification tables below (Tables 3.1, and 3.3). Once the battery is assembled to the headstage, it is ideal to not disconnect it in order to increase the longevity of the device. Indeed, more than 20 disconnect-reconnect cycles can significantly loosen the connector on the headstage. Once the experiment is finished, to save the remaining power of the battery, the headstage should be connected to the battery charger base or the disabeler (Fig. 1.3). Otherwise, the headstage will continue to search for wireless connections and deplete the battery.

  * Upon customer request, it is possible to replace the battery with a larger one for long-term recordings. The larger batteries are more appropriate for recordings in rats.
- The **Headstage connector** (Fig. 1.3), found on the underside of the headstage, links it to the 2.5 mm ferrule cannula via a small screw.
- The **Docking Port** (Fig. 1.3) is used by the *Headstage Charger* to recharge the headstage battery, as well as reprogramming it if necessary.
- The **Disabeler** (Fig. 1.3) is used to disable the wireless connection to reduce battery degradation when the headstage is not used.

1.1.2 Wireless Photometry Base-Station

(a) *Base-Station Front* (b) *Base-Station Back*

Figure 1.4: *Wireless Base-Station*

The *Base-station* (Fig. 1.4) transmits the information among the headstage and the photometry console (NC500 and BBC300).
On the front view (Fig. 1.4a), the base-station contains the following:

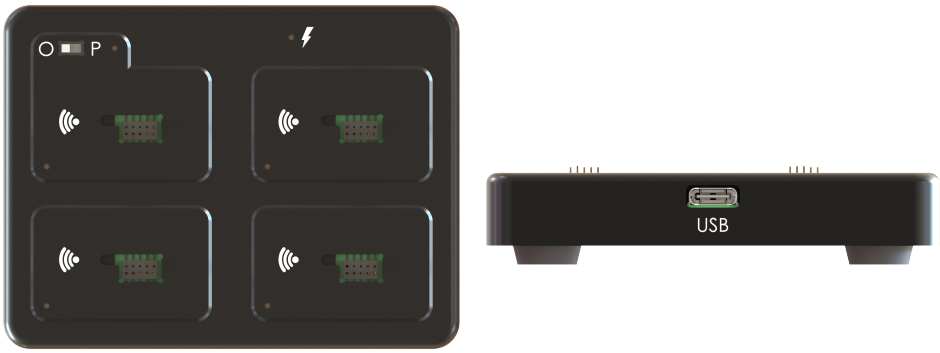
- The **Antenna** communicates with the headstage at 2.4 GHz. The range is up to 2 m distance.
- The **On/Off LED light** displays whether the base-station is on and functioning.
- The **1-4 LED lights** display three different colors each indicating:
  - **Blue**: The headstage is paired with the base-station but not enabled in the Doric Neuroscience Studio (DNS) software.
  - **Green**: The headstage is both paired with the base-station and enabled in the Doric Neuroscience Studio (DNS) software.
  - **All 4 LEDs blinking green**: The base station has been correctly initiated. This will happen for a short period of time at power up (This apply for the NC500 and may change for BBC300).
  - **LEDs 3 and 4 blinking white**: The headstage is on the bootloader mode, which means the firmware can be reprogrammed.

On the back-side view (Fig. 1.4b), the base-station contains two ports:

- The **USB** port is a USB-B input through which the firmware of the base-station channels can be updated. Besides, it can also connect the *Base-station* to the Doric BBC300 console.
- The **DATA** HDMI connector is used to connect the base-station to the NC500 console. Connect the base station to one of two possible *Ephys* HDMI ports.

If the base station is NOT recognized by the computer, refer to the Appendix (Chapter 4) for additional troubleshooting information.

1.1.3 Wireless Headstage Charger



(a) *Charger Top* (b) *Charger back side*

Figure 1.5: *Wireless Headstage Battery Charger*

The *Wireless Headstage Charger* (Fig. 1.5) is used to recharge the headstage battery and shut down the wireless connection. During the pairing process, all unused headstages must be docked on the charger, otherwise they will be detected in-place of the target headstage.

- The **USB-C Connector** behind the *Wireless Headstage Charger* is used to connect it to the console or directly to a computer to supply the power to charge the headstages. When the charger this connected to a power source, the *Status Lights* on top of the *Wireless Headstage Charger* will turn on.
- The four **Docking Ports** are used to recharge up to 4 headstages at a time. When a headstage is connected to a docking Port, its wireless connection is shut down to reduce battery degradation.
- The **Status LED Lights**, on the side of each charging port, displays the connection stage of the headstages.
  - The **Orange** light means no headstage is connected.
  - The **Green** light means the headstage battery is fully charged.
  - The **Red** light means the headstage is connected and charging.
- The **P-O** key across the docking port 1 is a switch that allows users to update the firmware of the headstage. It should always be in "O" for charging purposes. However, if a firmware update of the headstage is required, this key should be on "P" side. In this condition (the small LED light of port one will turn to white color), only one headstage which is connected to the docking port 1, can be updated, and it will automatically appear in the Doric Maintenance Tool software.
- The **Antenna Position Indicator** shows the proper placement of the antenna when docking a headstage to recharge the battery.

1.1.4 Dummy Headstage

The *Dummy Headstage* is a simplified version of the *Wireless Headstage* that is used to habituate an animal subject to the weight of the headstage. It contains no electronics or other valuable components, and will not function as a *Wireless Headstage*.

2

Getting Started

This chapter provides a step-by-step guide to setting up the wireless photometry system in your lab for the first time. If you require additional assistance or have any questions, please don't hesitate to contact the Doric team for support at **sales@doriclenses.com**.

2.1 Install Software

Doric provides three different software tools for separate functions, as listed below. The first two software are free and necessary, while the third is optional and available as a paid version:

- To operate Doric devices, you will need to install the ***Doric Neuroscience Studio*** (DNS) software on a Windows system. The software is regularly updated, and the latest versions are available for download on the Doric website. The wireless photometry system is compatible with DNS version 6.6.3.0 and above. We recommend using the latest available version to have access to the latest features. As an initial step, download the software and install it on your computer.

  Note: For more information check the DNS manual for the Wireless section under NC500 and BBC300 chapters.

- During installation, a secondary utility called the ***Doric Maintenance Tool*** (DMT) will also be installed automatically. Alternatively, you can download it on the Doric Lenses website. The DMT allows you to monitor the firmware version of your Doric devices and update the firmware when necessary.

- Lastly, the ***danse™*** software is used for post-recording data analysis. It allows you to open recorded files, access signal attributes, and compute $\Delta F/F$ for signal visualization. A paid version of danse is also available, which includes full analysis capabilities and behavioral analysis features, all without requiring any programming knowledge. Watch all available tutorial videos on the Website.

Figure 2.1: *Doric Lenses Softwares*

2.2 Wire up the system

The Wireless Fiber Photometry system is compatible with both the NC500 and BBC300 consoles.

Figure 2.2 and 2.3 provide a general overview of the system wiring with each console. Follow the steps below to set up the hardware:

1. Use the blue USB 3.0 cable to connect the USB 3.0 port on the NC500 or BBC300 console to a USB 3.0 port on your computer. **USB 3.0 connection is important to ensure reliable high-speed data transmission.**
2. Plug the console into a power outlet and turn the power on.
3. Connect the battery charger to your computer using a USB-B to USB-C cable (using USB-C will charge the battery faster).
4. If you have an NC500 console (Figure 2.2): Using the HDMI cable, connect the base station to one of the Ephys ports.
5. If you have a BBC300 console (Figure 2.3): Using the USB-B cable, connect the base station to one of the USB-B ports on the console.

Note: All required cables are included with the hardware shipment.

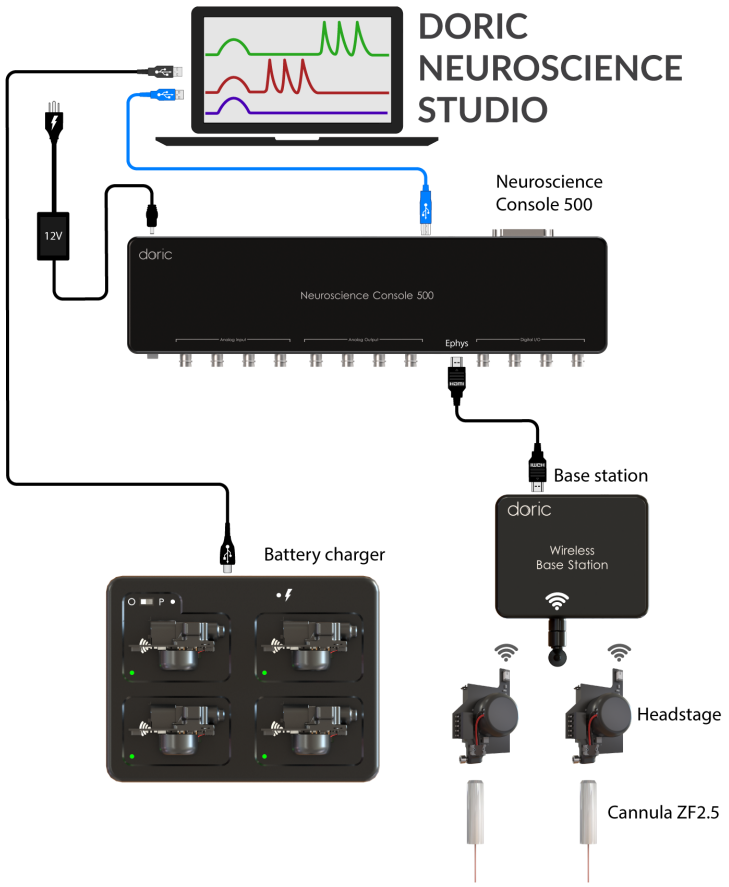


Figure 2.2: *Wireless Fiber Photometry system setup using a NC500 console*

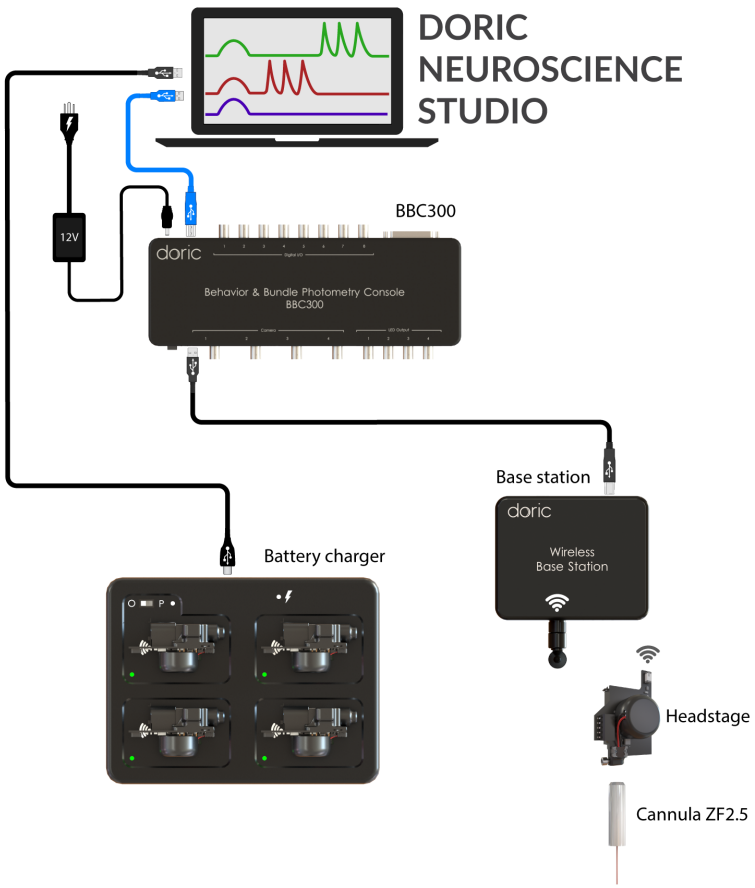


Figure 2.3: *Wireless Fiber Photometry system setup using a BBC300 console*

2.3 Charge Battery

At this step, ensure that the headstage battery is fully charged. To do so, connect the headstage to the battery charger and verify that the indicator light is green, indicating a full charge. For more information, see section 1.1.3.

Note: When connecting the headstage, ensure that the antenna is aligned with the antenna engraving on the charger hardware.

2.4 Make Configurations

Now is the right time to make configurations in the DNS software. Before doing so, ensure that the console is powered on and connected to the base station, and that the headstage is disconnected from both the disabler and the battery charger to be in the operating mode.

1. Open the DNS software. In the "Device Selection" window, select your console (NC500 or BBC300) and click "Connect Device". Once connected, close the window (Figure 2.4).

   Note: The NC500 console may take a few seconds to appear on the list. If it does not show up immediately, wait for a few seconds and then click the "Refresh" button.

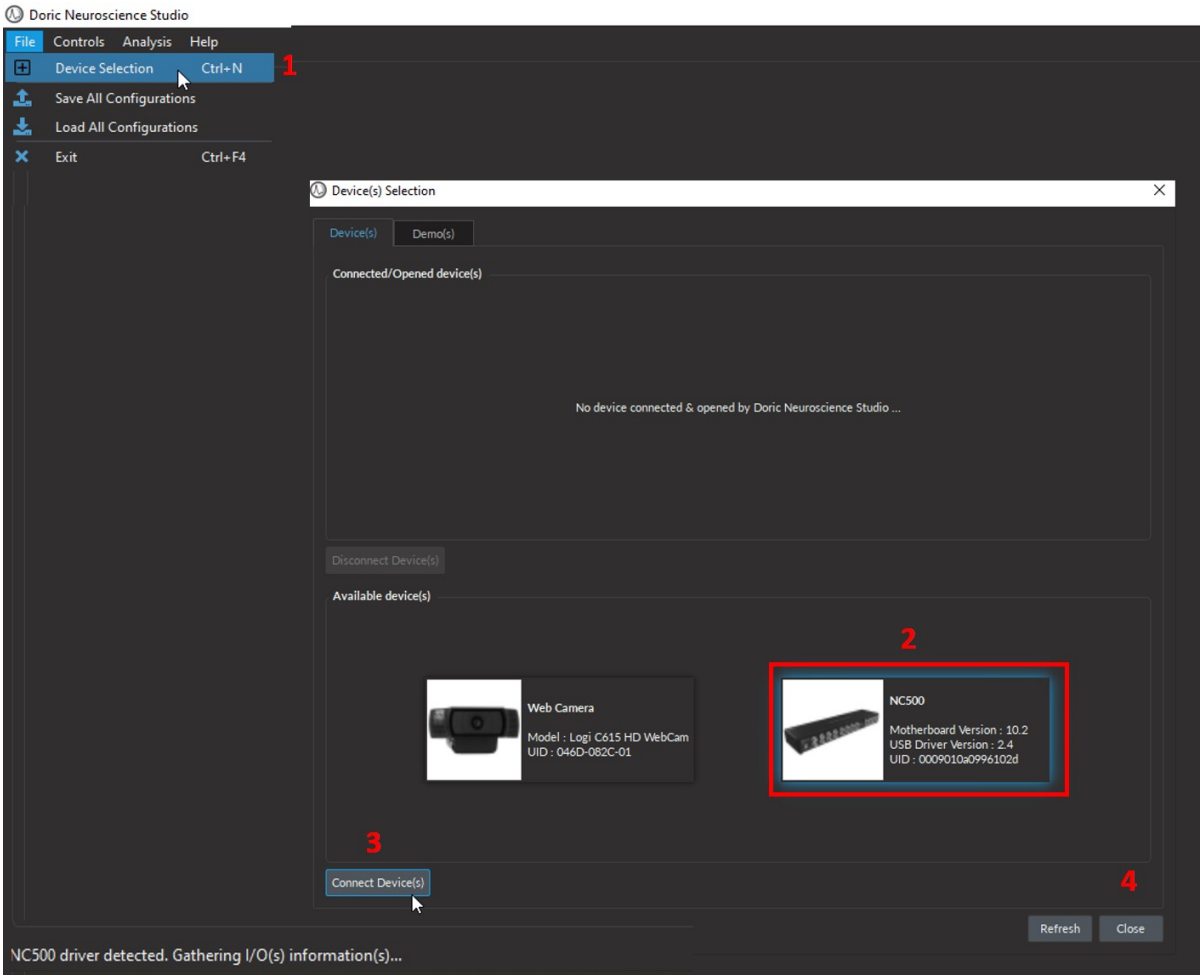


Figure 2.4: *Device Selection*

2. Now, in the console's "Configuration" tab, click on "Add Channel". Then, in the "Devices" menu, select the "Wireless" option (Figure 2.5).

   Note: This window will be grayed out if the base station is not connected or if the firmware version is incompatible.

3. Start with the default "Comm. Channel" and click the "+" key (Figure 2.5).

   Note: In Comm Channel, you have 9 selectable options ranging from 10 to 100. Each time the base station is set up for data acquisition, the user can freely choose any of these channels. However, some channels may be occupied by nearby devices (e.g., cell phones, laptops), which can create noise and weaken the wireless link. In such cases, selecting a different channel is recommended.

4. Now in "Headstage ID" drop-down list, select the right headstage (Figure 2.6).

5. Once a headstage is selected, the **battery level** and **signal quality** are displayed (Figure 2.7, 1).

   Signal quality is determined by the Comm. Channel you selected before and can be in three ranges:

   - Good quality: 0 to -40 (indicated in blue)
   - Medium quality: -40 to -50 (indicated in yellow)
   - Low quality: -60 or less (indicated in red)

   If the signal quality is low (indicated in red or orange), ensure the following:

   - The headstage is within 2 meters of the base station.
   - There are no metal or liquid-containing objects between the headstage and the base station.

- The base station is not placed on a metal surface.

If above solutions do not help, we recommend testing other "Comm. Channel" until you can find one that stays at good **signal quality** during recording.

6. Once headstage is selected, the LED's information will be displayed in a dedicated box (Figure 2.7, 2,3). Verify the wavelength of each LED (Figure 2.7, 5), and if desired, change the default Lock-in signal name to something more intuitive (Figure 2.7, 4).

   The power percentage is also displayed in each LED box (Figure 2.7, 6). You can select an initial power percentage here; however, you will need to measure the actual power output using a power meter later and adjust the value if necessary. The lower the power of the LED used, the longer the headstage battery will last.

7. Below the LED information, the default name for the raw signal is displayed. This can be modified by the user if desired (Figure 2.7, 7).

8. If you need to record the angular velocity of head movement, you can enable **High Performance IMU** option (Figure 2.7, 8). Acceleration data is always recorded by default. Note that enabling angular velocity recording may slightly increase battery usage.

9. When you apply all changes, **Pair** the head stage, and then click **Add** to make the configuration.

   Note: For more information check the DNS manual for the wireless photometry sections under the NC500 and BBC300 chapters.

   Note: If you pair a headstage but forget to add its channel before closing the configuration window, the headstage will remain paired to the base station. As a result, reopening the configuration window will no longer show this headstage as an available option for configuration. To resolve this, you must unpair the headstage—either by using the Disabler tool or by connecting it to the charger. This will cause the headstage to reappear in the available Headstages list, allowing you to create a new configuration for it. Please stay informed, as we may introduce a new solution for this condition in an upcoming software release.

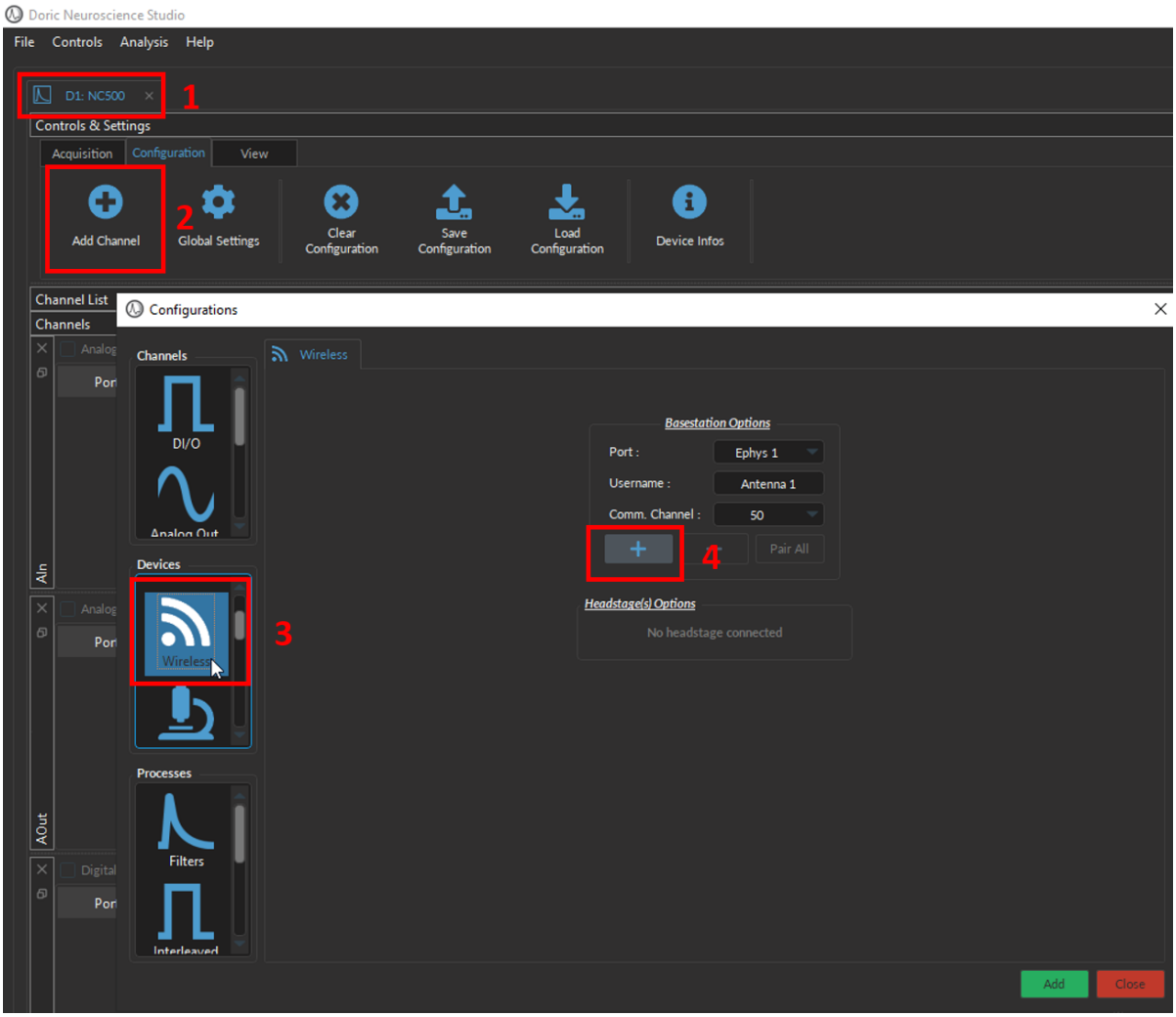


Figure 2.5: *Add base station*

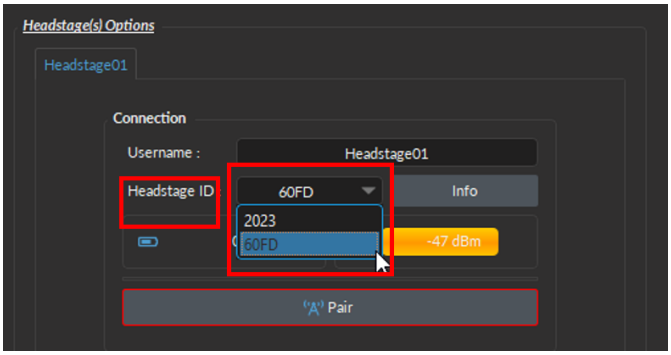


Figure 2.6: *Select Head stage*

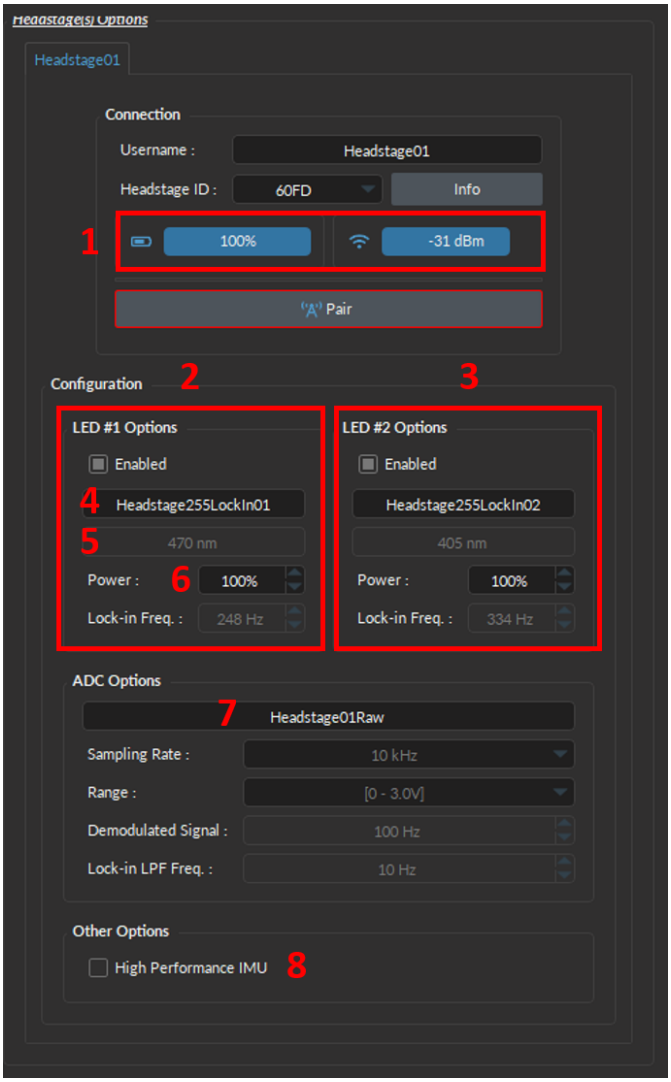


Figure 2.7: *Headstage settings*

2.5 Measure Power

The headstage box includes two test ferrules with different diameters: 200 µm and 400 µm. Select the ferrule that matches the diameter of your cannula. Note that both ferrules have a numerical aperture (NA) of 0.66.

Follow the steps below to connect the test ferrule to the headstage and measure the optical power (Figure 2.8):

1. Loosen the screw on the headstage.
2. Insert the selected test ferrule.

   Important: The ferrule has one chamfer side and one flat (sharp-cut) side. The chamfer side should be inserted into the headstage (Figure 2.9).
3. Tighten the screw to secure the ferrule.
4. To measure the power of each LED individually:
   - Go to the **Configuration** tab and click **Edit** (Figure 2.10).
   - Set the power of one LED to 0% to isolate the other.
   - Run the system in **Live** mode and measure the output power using a power meter.

5. If the measured power is too low, go back to the **Edit** section and adjust the **LED Power Percentage**. Repeat the measurement until the desired power is reached.
6. Repeat the process for the second LED.
7. Once both LEDs are properly configured, loosen the screw and remove the test ferrule.
8. Now the configuration file is ready, and you can save this configuration file. In the future, after adding devices, simply open the saved configuration file to record data.

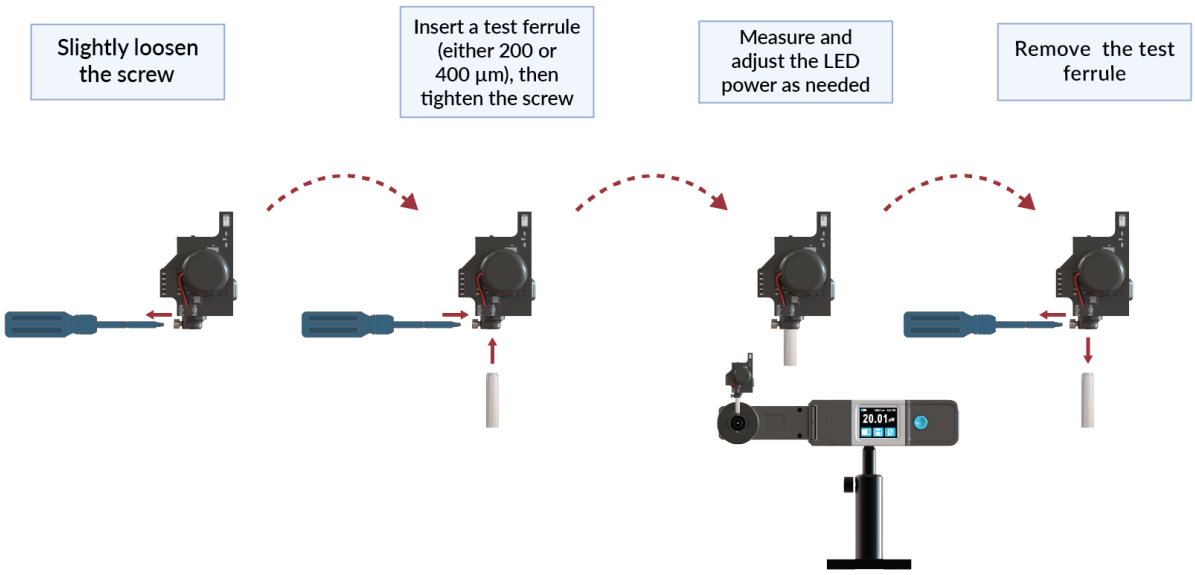


Figure 2.8: *LED Power Measurement*

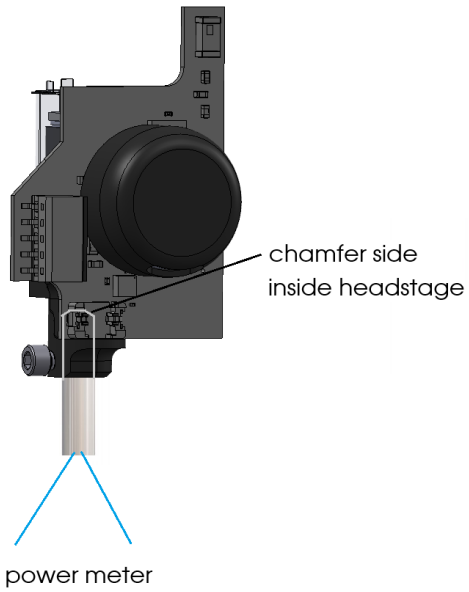


Figure 2.9: *LED Power Measurement*

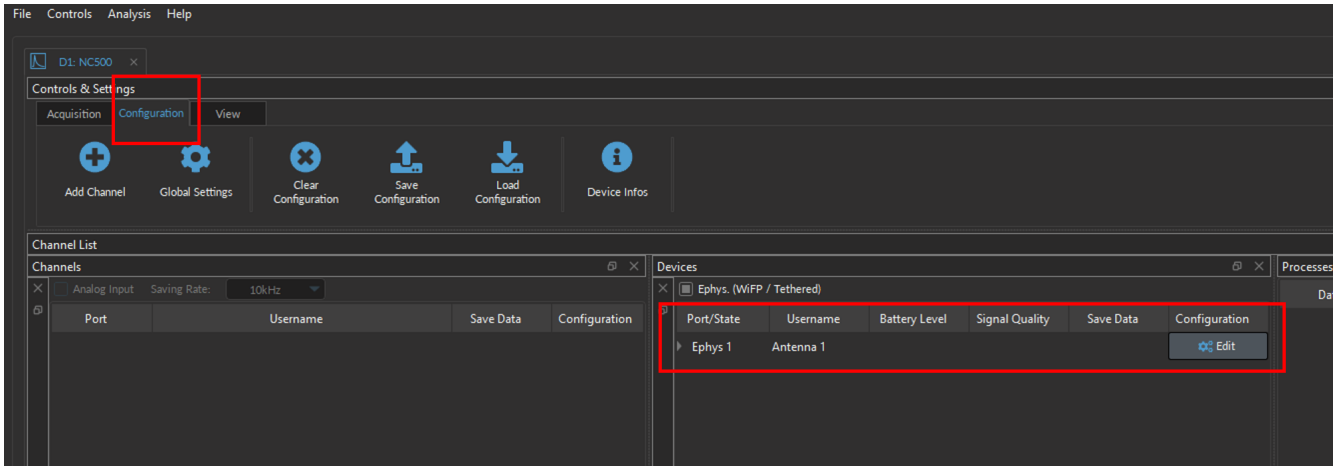


Figure 2.10: *Access to LED Power Change*

2.6 Connecting Headstage to the Animal

Once the configuration file is prepared and the power levels are correctly set, the headstage can be connected to the animal to begin acquiring photometry data. Follow the steps below to connect the headstage (Figure 2.11):

1. Loosen the screw on the headstage.
2. Carefully connect the headstage to the implanted cannula in the mouse's brain directly.
3. Tighten the screw to ensure a secure connection.

Note: To balance the weight of the headstage, we recommend positioning the battery side toward the back of the animal.

Note: A dummy headstage can be used prior to the actual recording session to train the mice and help them acclimate to the weight of the headstage.

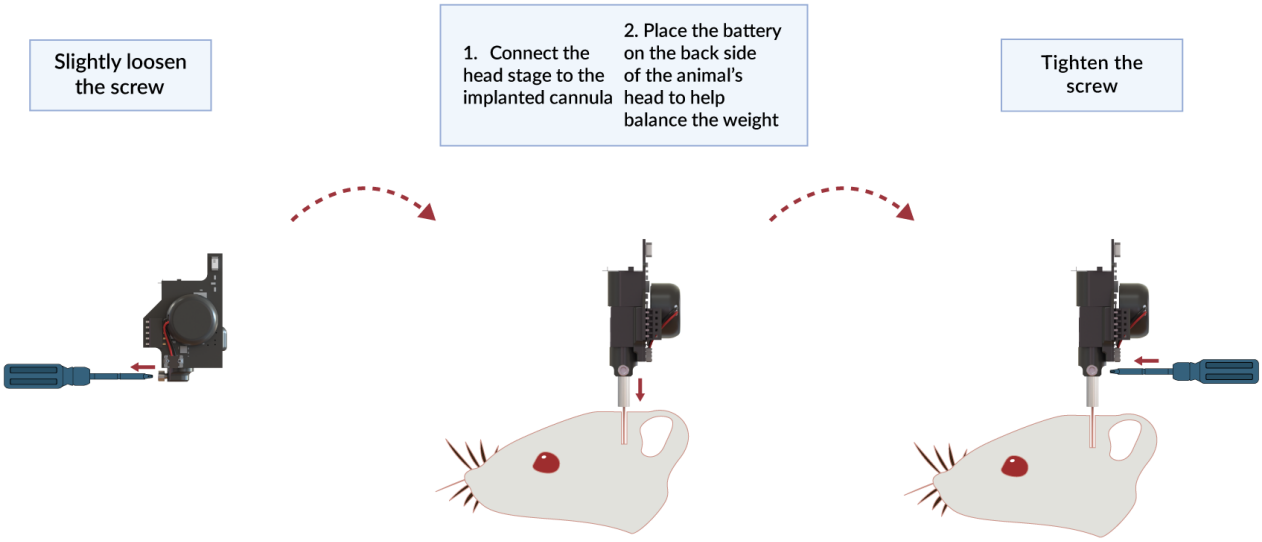


Figure 2.11: *Connecting Headstage to the Animal*

2.7 Data Acquisition

Once the configuration is complete, proceed to the **Acquisition** tab in the console to begin data recording.

For real-time signal monitoring, use the **Live** option. To record data, click the **Record** button. Before saving, you can specify the destination folder and file index using the **Saving Options** button (Figure 2.12, 1).

Important Notes:

1. **Signal Colors:** Each signal is initially displayed using a randomly assigned color. To make the visualization more intuitive, you can change the color of any channel. Simply click on the color box next to the desired channel, choose a new color (e.g., green, pink), and save the changes (Figure 2.12, 2).
2. **Detector Saturation:** The signal detector saturates at 3 V. To avoid signal distortion and maintain data integrity, ensure that raw signals do not reach this level. Saturated signals may lose their shape and become unreliable for analysis. For experiments involving injected mice, it is recommended to keep raw signals below 2 V to provide adequate headroom for signal fluctuations without risk of saturation.
3. **Lock-in Signal Ranges:** The typical voltage range for lock-in amplifier signals (Iso and Green) lies between 0.1 V and 0.9 V, which aligns with values observed by most users during standard recordings.

   Note: The Lockin isosbestic and green signals are the ones you need for DF/F analysis.

Note: The signal in Figure 2.12 is recorded in ambient light, it might not be a good example of actual recording in mice.

Note: For more information check the DNS manual for the photometry sections under NC500 and BBC300 chapters.

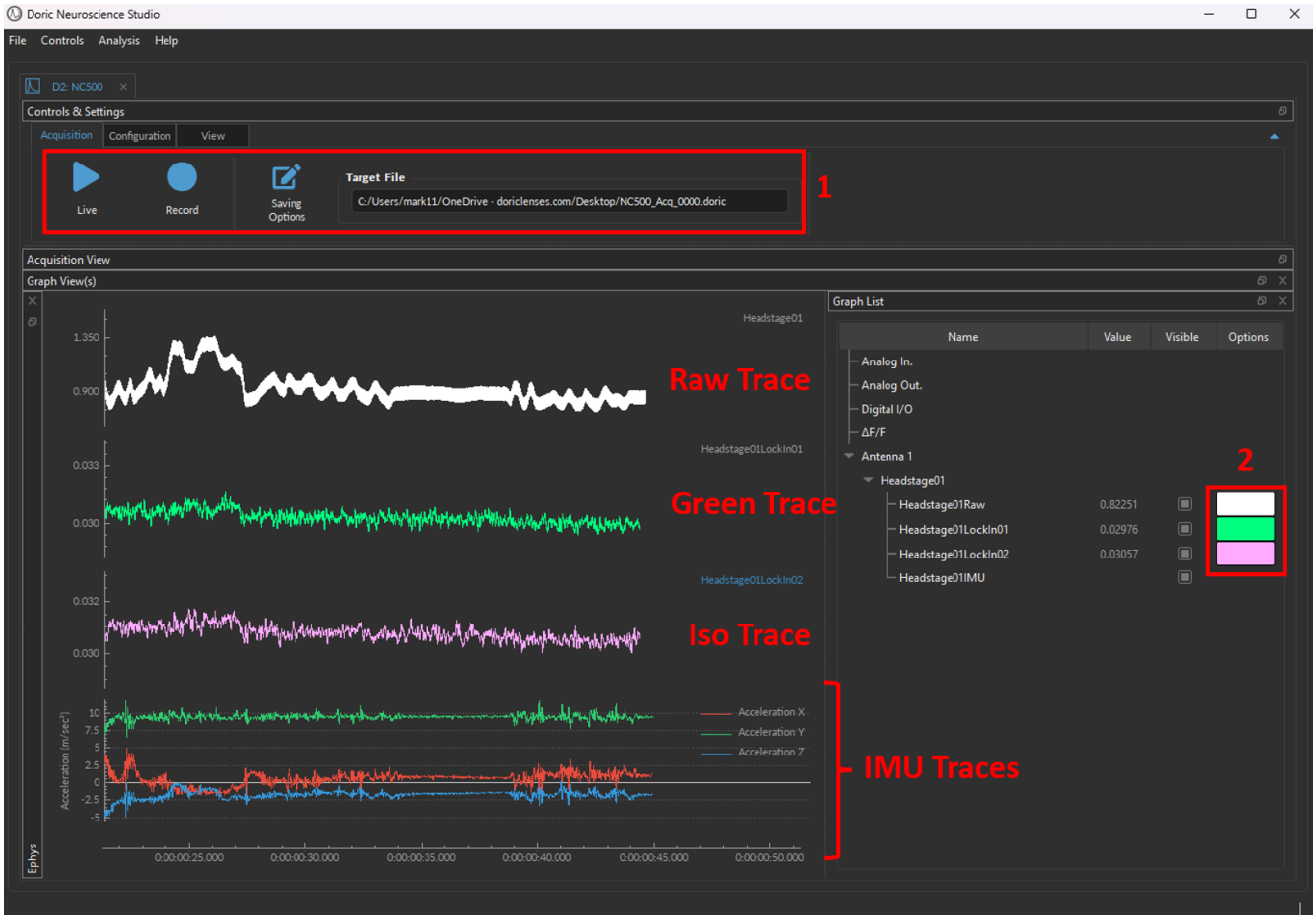


Figure 2.12: *Acquisition Window*

Signal Visualization Adjustments

To customize the view of the signal display:

- Disable the ***Optimal Zoom*** setting in the **View** tab to manually control zoom levels.
- During live or recorded acquisition, zoom along the Y-axis by holding the `Shift` key and scrolling with the mouse.
- To adjust the time window (X-axis), go to the **View** tab and set the desired duration in the *Time* window.

2.8 Open recorded files

Once a signal has been recorded, it can be opened for post-acquisition visualization and analysis.

To do this, download the Doric Analysis software *danse*^{TM} (available for free). After installing the software, open your recorded data file by using the designated **Open** button, as shown in the interface.

The loaded data will appear on the right-hand panel. To explore the file structure:

- Right-click on the `DataAcquisition` entry and select **Expand**. This will reveal the hierarchical structure of the recorded data.

To inspect metadata:

- Select the `NC500` node, then click on the **Attributes** tab to view recording details such as start and stop times (Figure 2.13, left: 1, 2).
- Selecting any of the lock-in amplifier signals (e.g., Iso, Green) and navigating to the **General Info** tab will display additional information such as data dimensions and related parameters (Figure 2.13, right: 1, 2).

To visualize a specific signal:

- Check the box next to the signal name.
- Click **Load** to display the signal in the main viewer (Figure 2.13, right: 1, 3).

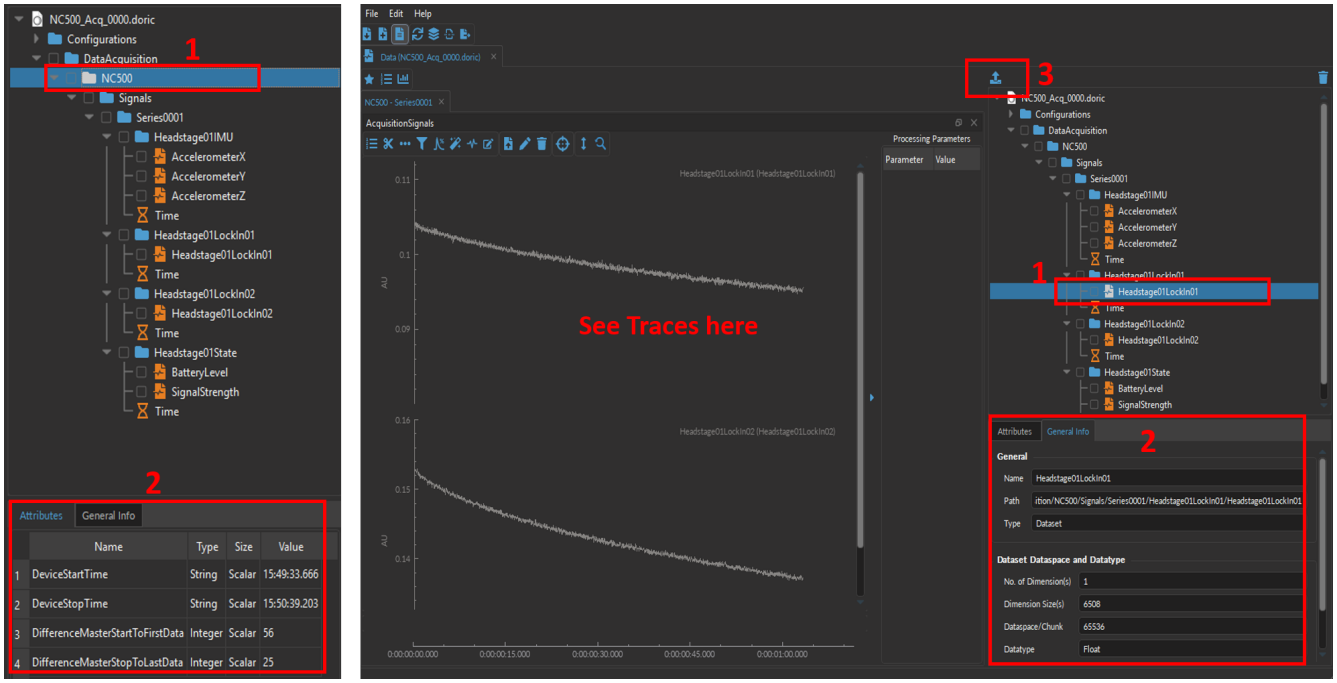


Figure 2.13: *Load Data in danse*^{TM}

2.9 Analyzing data

You can use danse™ to calculate and display the $\Delta F/F$ signal, remove artifacts from the signal, among others. In fact, danse™ is a dedicated data analysis software that automates the analysis of neural and behavior data, without any coding required. Specifically, it can do group analyses, accounting for the experimental designs (trials, groups, treatments, sex, etc.). The software can import and align behavior data recorded from many different formats (videos, csv, DIO, etc.) and sources (Ethovision, ANY-Maze, DeepLabCut™, etc.). Learn more:

- **Tutorial Video:** https://neuro.doriclenses.com/pages/video
- **Solution Page:** https://neuro.doriclenses.com/pages/data-analysis-solutions
- **DEMO Webinar Registration:** https://neuro.doriclenses.com/pages/webinar
- **Free-Trial Activation Key:** https://neuro.doriclenses.com/pages/danse-free-trial

3

Specifications

Table 3.1: *Wireless Headstage General Specifications*

SPECIFICATIONS	**VALUE**	**NOTES**
Dimensions	Height 29.38 mm	
	Width 19.24 mm	
	Thickness 15.29 mm	
Mass	4.55 g	With 40 mAh battery A
	3.68 g	With 23 mAh battery B
	2.95 g	Without battery
Battery A life	2 hr	With 2 LEDs at 100% power
	4 hr	With 2 LEDs at 25% power
Battery B life	1 hr	With 2 LEDs at 100% power
	1.5 hr	With 2 LEDs at 25% power
Transmission Frequency	2.4 to 2.5 GHz	
RF Data Speed	2 Mbps	
Sampling Rate	10 kHz	On each channel
ADC Resolution	14 bits	
Saturation level	~ 6 nW	
Detector Bandwidth	0 - 500 Hz	
Roll-off rate for low-pass filter	-40 dB / decade	
Detector Sensitivity	~ 0.48 V / nW	@ 520 nm
Operation distance	0-2 m	For optimal performance
Maximum LED Power	405 / 415 nm = 100 µW	With 400 µm fibre
	470 nm = 150 µW	
	560 nm = 20 µW	

Note: 25% LED Power = 19 µW @ 405 nm; 43 µW @ 470 nm.
100% LED Power = 80 µW @ 405 nm; 120 µW @ 470 nm.

Table 3.2: *Wireless Fiber Photometry Base-Station Specifications*

SPECIFICATIONS	VALUE	NOTES
Dimensions	Height 28.50 mm	Without antenna
	Width 108 mm	
	Thickness 87 mm	
Antenna dimension	Length 108.5 mm	
	Diameter 9 mm	
Mass	230 g	
Transmission Range	Up to 2 m	
Wireless Frequency Band	2.4 - 2.5 GHz	
Number of Headstage	Up to 4	With NC500 console
	1	With BBC300 console
Base Station Interface	HDMI	With NC500 console
	USB-B	With BBC300 console

Table 3.3: *Wireless Fiber Photometry Battery Charger Specifications*

SPECIFICATIONS	VALUE	NOTES
Dimensions	Height 84 mm	
	Width 63.47 mm	
	Thickness 17.07 mm	
Mass	170 g	
Charger Interface	USB-C	
Charger Power Supply	AC/DC adapter 5 Watt (5 V, 1 A)	with 1 meter cable USB-C to USB-A
Charger Headstage Capacity	4	
Batteries chemistry	Lithium polymer battery 4.2 V	
Charging current	50 mA	
Battery recharge time	∼60 min	For a 40 mA (battery A) battery

4

Appendix

When using the **BBC300** console with a Base-station on a new computer for the first time, it is very likely that the Base-station will **NOT** be recognized properly by the computer.

Below are the instructions to install the correct driver for the Base-station to ensure proper functionality.

1. Verify that the device is correctly connected by ensuring the white LED next to the SMA connector remains steadily illuminated (Figure 4.1).

Figure 4.1: *The white LED on the Base-Station indicating that the device is powered on.*

2. On the computer, access the **Device Manager** by typing its name in the Windows search bar and selecting it from the results (Figure 4.2).
3. Check if *Wireless Base-station* appears under the *Other devices* tab with an exclamation mark (Figure 4.3).
    - If it appears with an exclamation mark, proceed with updating the USB driver.
    - If it does not appear, the issue is not related to the USB driver update.
4. Open *Zadig*. This software is installed as part of the Doric Neuroscience Studio installation. By default, it can be found in: `C:\Program Files\Doric Lenses\Doric Neuroscience Studio\drivers\utils` under the name `zadig-2.5.exe`.
5. Select *Wireless Base-station* from the dropdown menu (see label 1 in Figure 4.4).
6. Click on *Install Driver* (see label 2 in Figure 4.4).

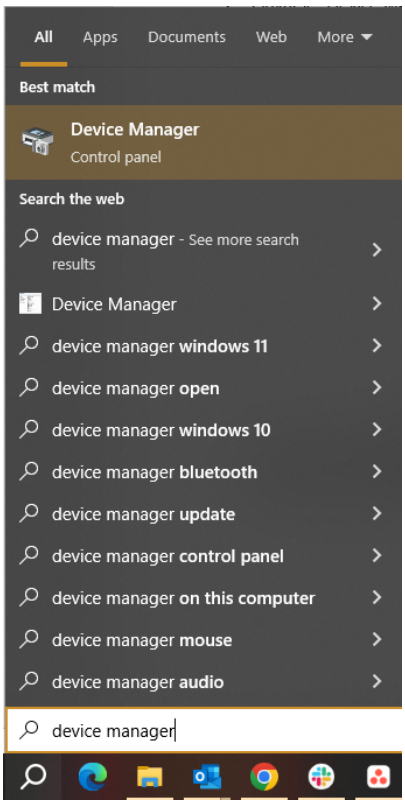


Figure 4.2: *Find the Device Manager by Windows search bar.*

7. Once the installation is complete, confirm that *Wireless Base-station* appears under the *Universal Serial Bus devices* tab in Device Manager (Figure 4.5).

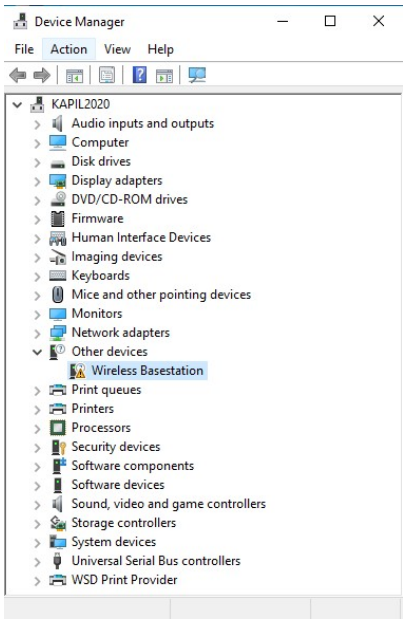


Figure 4.3: *Missing USB driver for Wireless Base-station in Device Manager.*

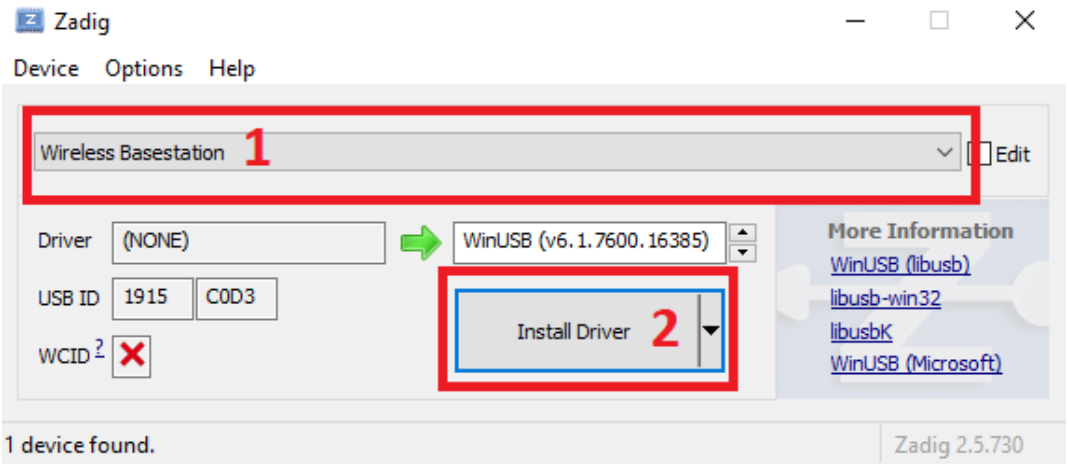


Figure 4.4: *USB driver installer for Wireless Base-station.*

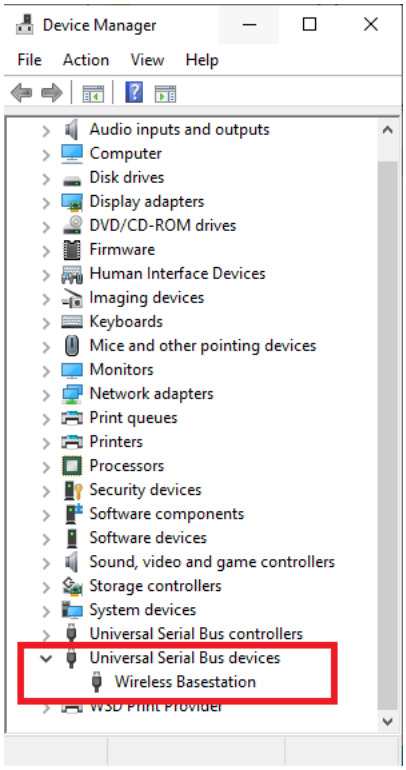


Figure 4.5: *Wireless Base-station displayed in Device Manager after successful USB driver installation.*

5

Support

5.1 Maintenance

The product does not require any maintenance. Do not open the enclosure. Contact Doric Lenses for return instructions if the unit does not work properly and needs to be repaired.

5.2 Warranty

This product is under warranty for a period of 12 months. Contact Doric Lenses for return instructions. This warranty will not be applicable if the unit is damaged or needs to be repaired as a result of improper use or operation outside the conditions stated in this manual. For more information, see our Website.

5.3 Contact us

For any questions or comments, do not hesitate to contact us by:

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