AURORA++ KEYCHAIN FLASHLIGHT · BUILD GUIDE

Build Guide v0.5

Order the parts, install the firmware, assemble — no experience needed



For builders without electronics or programming background.

FlashKa Keychain v0.5 · 2026-10-14

Source: docs/build_guide_v0.5.md (+ docs/firmware.md, section 2)

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Appendix A. How the light works (user manual)

This guide takes you from "I have never ordered a circuit board" to a working flashlight in your hand. You do not need to know electronics or programming. You need patience, a soldering iron and a computer with the Chrome or Edge browser. Read the whole guide once before you order anything.

The finished light: 94.4 × 20 × 16 mm, black anodised aluminium, USB-C charging, a white LED in front, a small green laser below it, and Bluetooth for the phone app.

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0. What you are building

Size	94.4 × 20 × 16 mm, about 50 g with cells
Main light	Luminus SST-20 LED, 3 mA (moonlight) to 2.2 A (turbo, short bursts)
Laser	green 520 nm module, Class 2 (≤ 1 mW), with a hardware safety switch
Battery	two LP601646 lithium-polymer cells in parallel, about 800 mAh
Charging	USB-C, about 300 mA, status shown by a small RGB LED through the lid
Brain	ESP32-C3 module with Bluetooth Low Energy
Phone app	a web page — no app store, works in Chrome/Edge (Android, Windows, Mac, Linux)
Firmware updates	from a web page over the same USB-C cable — no programmer needed

How it is made:

- **The circuit board** (24 × 16.5 mm, 4 copper layers) is made *and fitted with all its small parts* by JLCPCB. You only solder a few wires by hand.
- **The aluminium body** (two parts: tray and lid) is machined and anodised by JLCCNC.
- **Four small plastic parts** are 3D-printed by JLC3DP as one "print kit".
- **The LED board, the laser, the cells, the window and the screws** are bought ready-made (for example on AliExpress).

1. Before you spend money

Cost. The workbook `Aurora_Parts_List_v0.5.xlsx` lists every part and every fee. The short version (prices checked 2026-10-14, delivery to Lithuania):

	one light	per light when you build five
Everything, including shipping, VAT and set-up fees	about **530 USD** (473 EUR)	about **196 USD** (175 EUR)
Tools you may not have yet (one-time)	about 128 USD	

One light is expensive because the fixed costs (assembly set-up, stencils, three parcels from JLC, several AliExpress parcels) are paid once whatever the quantity. JLCPCB makes at least 5 boards and assembles at least 2. Building with friends brings the price down a lot.

Time and the order of the orders. Building takes one afternoon; the waiting takes longer. Order in this sequence (the workbook's sheet *Ordering checklist* has the same steps):

1. **Day 1:** order the bought parts (section 6) and the circuit boards (section 3).
2. **When the cells, the LED board and the laser have arrived** (2–5 weeks from AliExpress): measure them (section 8). They must match the specification — the body is made for them.
3. **Then** order the aluminium body (section 4) and the print kit (section 5); about 10 days.

At every checkout choose shipping with **taxes and duties paid (DDP / "tax included")** — the cost figures above assume it.

Skills. Soldering wires to pads (practise on scrap first), using a small screwdriver, following instructions exactly. Nothing else.

Safety — read this.

- **Lithium cells** can burn if they are short-circuited, punctured, bent or charged wrongly. Never let the red and black wires of a cell touch each other. Never solder on the cell itself — only on the wires. Keep a metal box or a sand-filled pot nearby while you work.
- **The laser** is a real laser. Class 2 is safe for an accidental glance, but never look into it or point it at people, animals, cars or aircraft. Wear 520 nm laser safety glasses while testing. Buy only a module whose seller states **Class 2 / ≤ 1 mW**.
- **The LED gets hot** in turbo. The firmware limits the temperature, but do not cover the light with your hand for minutes in turbo.

2. The files

Everything you upload is ready in the folder `order_files/` of the package, one subfolder per shop — you never have to look for a file anywhere else:

File	What it is	Who gets it
`order_files/1_JLCPCB/Aurora_main_gerbers.zip`	the circuit board drawings	JLCPCB (PCB)
`order_files/1_JLCPCB/BOM_JLCPCB.csv`	list of parts to mount	JLCPCB (assembly)
`order_files/1_JLCPCB/CPL_JLCPCB.csv`	where each part goes	JLCPCB (assembly)
`order_files/2_JLCCNC/Aurora_tray.step` + `Aurora_tray.pdf`	aluminium body + its drawing	JLCCNC
`order_files/2_JLCCNC/Aurora_lid.step` + `Aurora_lid.pdf`	aluminium lid + its drawing	JLCCNC
`order_files/2_JLCCNC/Aurora_marking_class2.dxf`	optional laser marking	JLCCNC
`order_files/3_JLC3DP/Aurora_print_kit.stl`	the four plastic parts on one sprue	JLC3DP
`app/aurora-flasher.html`	the firmware installer (open in Chrome/Edge)	you
`app/aurora-app.html`	the phone/computer app (open in Chrome/Edge)	you
`Aurora_Parts_List_v0.5.xlsx`	every part, price, link and fee	you

(The same files, with all the source data behind them, are also in `production/` and `cad/`.)

3. Order 1 — circuit boards with parts mounted (JLCPCB)

1. Make an account at **jlcpcb.com** and log in.
2. Click **Order now** (or "Instant quote") and **Add gerber file**. Choose `order_files/1_JLCPCB/Aurora_main_gerbers.zip`. Wait until the picture of the board appears (24.0 × 16.5 mm should be detected automatically).
3. Set these options (leave everything not listed at its default):

Option	Choose
Base material	FR-4
Layers	**4**
PCB qty	5 (the minimum)
PCB thickness	**0.8 mm**
PCB color	green (cheapest; others are fine)
Surface finish	**ENIG** (flat gold pads — needed for the Bluetooth module)
Outer / inner copper	1 oz / 0.5 oz
Via covering	Tented
Min via hole size/diameter	the value JLCPCB detects (0.2 mm hole, 0.45 mm via: no surcharge)
Remove order number	No (the default) — JLCPCB prints a small number on a free spot; it is hidden in the body

4. Scroll down and switch **PCB Assembly** on:

Option	Choose
PCBA type	**Standard** (parts on both sides need Standard)
Assembly side	**Both sides**
PCBA qty	2 (the minimum) — or as many lights as you build, if more
Tooling holes	Added by JLCPCB
Confirm parts placement	**Yes** (an engineer checks the orientation of every part — recommended)

5. Click **Next**, then upload **BOM** = `order_files/1_JLCPCB/BOM_JLCPCB.csv` and **CPL** = `order_files/1_JLCPCB/CPL_JLCPCB.csv`. Click **Process BOM & CPL**.
6. The parts list appears. Every line should show a matched part with stock. If a part is out of stock, the workbook (sheet *Main PCB BOM*) names the alternative — the only one you are likely to need is the Bluetooth module: **C2838502** (ESP32-C3-MINI-1-N4) can be replaced by **C41349510** (ESP32-C3-MINI-1-H4X), same footprint, same firmware. (A few small parts had low *retail* stock on 2026-10-14 — C15850, C15195, C1525, C11702, C485117; JLCPCB's assembly stock is separate and usually fine. The workbook's stock notes list a substitute.)
7. **Placement preview.** JLCPCB shows the board with every part drawn on it. For each chip, the small dot or line that marks pin 1 must sit on the pin-1 mark of the board. If one is turned, select it and use *Rotate*. Look closest at the parts whose drawing in JLCPCB's library is often turned against KiCad's: the Bluetooth module **U4**, the small chips **U1, U2, U3, U5**, the transistors **Q1, Q2, Q4, Q5**, the USB-C socket **J1** and the tiny RGB LED **LED3**. Do not worry if you are unsure: with "Confirm parts placement" an engineer checks it and sends you a picture before production.
8. Save to cart, pay. The board order (5 boards, 2 of them assembled, all parts included) costs about 170 USD before shipping and VAT (the workbook, sheet *JLCPCB order*, shows every line). Choose a shipping method with taxes paid (DDP).

> **Why the gold surface (ENIG)?** The Bluetooth module sits on a big flat ground pad under its belly. Tin (HASL) surfaces are bumpy and the module can end up crooked. ENIG costs a few dollars more and avoids that.

4. Order 2 — the aluminium body (JLCCNC)

1. Go to **jlccnc.com**, log in with the same account, *Instant quote → CNC machining*.
2. Upload `order_files/2_JLCCNC/Aurora_tray.step` **and** `Aurora_tray.pdf` from the same folder — JLCCNC matches the drawing to the 3D file by its name, which is why both are called `Aurora_tray` (the drawing carries the threads and tolerances JLCCNC needs). Do the same for the lid: `Aurora_lid.step` + `Aurora_lid.pdf`.
3. For both parts choose:

Option	Choose
Material	Aluminum **6061-T6**
Surface finish	**Bead blasting + anodizing, black**
Tolerance	ISO 2768-m (standard)
Threads	yes — write in the remark: "4 × M1.6×0.35 in the tray, 1 × M2×0.4, see drawing; tapped before anodising, screws must fit after finishing (drawing note 3)"
Quantity	one of each per light (+1 spare tray if you want a safety margin)

4. Optional: **laser marking** with `order_files/2_JLCCNC/Aurora_marking_class2.dxf` on the bottom face (the laser warning text). Only if your laser module really is Class 2.
5. JLCCNC answers with a price within a day. If they say M1.6 threads are not possible, accept plain holes: the drawing gives the tap-drill size, and you cut the thread yourself with an M1.6 hand tap (about 5 USD).

5. Order 3 — the plastic parts (JLC3DP)

1. **jlc3dp.com → Instant quote**, upload `order_files/3_JLC3DP/Aurora_print_kit.stl`. (Only if your laser module is 4.5 mm instead of 6 mm thick, also upload `Aurora_laser_sleeve.stl`.)
2. Material: **SLA resin, 8001 (translucent)**. The kit contains the RF window (lets the Bluetooth signal and the status LED through the aluminium lid), the button cap, the LED spacer ring and the antenna spacer, joined by thin rods. You cut them apart with side cutters at home.
3. Quantity: one kit per light (they are cheap — order one spare kit).

6. Order 4 — parts you buy ready-made

Search these on AliExpress (or any electronics shop). The workbook has a link example and the typical price for each. Order them first (section 1) and **measure what you receive** before you order the aluminium body.

Part	Exact specification	Quantity per light
LiPo cells	**LP601646** (6.0 × 16 × 46 mm), 3.7 V, about 400 mAh, **with protection board and wire leads**, rated for at least **2 C** continuous (0.8 A per cell; 3 C if you want the Extreme profile); the whole cell including its protection board must fit 6.0 × 16 × 47 mm	2 (+1 spare)
LED board	**Luminus SST-20** (white, 5000–6500 K) on a **10 mm** round copper DTP board, **1.6 mm** thick	1
Laser module	520 nm green, **6 × 12 mm** body, **with a built-in constant-power (APC) driver for a 3.0–4.2 V supply** (the board gives it the cell voltage), **Class 2 (≤ 1 mW)**, with wires	1
Window	glass or PMMA disc **10 mm × 1.0 mm** (AR-coated "flashlight lens" is best)	1
Lid screws	**M1.6 × 4 mm countersunk**, stainless (A2)	4 (+4 spare)
Laser set screw	**M2 × 2 mm set screw, cup point** (M2 × 2.5 also fits; longer ones stick out of the bottom)	1
Wire	**28 AWG PTFE**, red and black (usually sold as 5 m rolls; one light needs about 0.3 m)	—

Part	Exact specification	Quantity per light
Thermal paste or 0.15 mm thermal tape	for the LED board	a little
Kapton tape, thin double-sided foam tape	insulation, cells	a little
Clear 5-minute epoxy or UV resin	RF window and front window	a little
Split ring or lanyard	through the tail slot	1

7. Tools

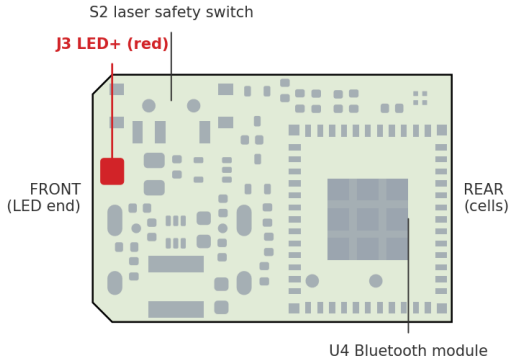
Tool	Why
Soldering iron with a fine tip (a temperature-controlled one, e.g. Pinecil or TS101)	the wires
Desoldering braid (wick)	to remove solder if a joint goes wrong
Digital caliper	measure the cells, the LED board and the laser before you order the body
Solder 0.5 mm with flux core, plus a flux pen	clean joints on small pads
Fine tweezers, side cutters, wire stripper (or a sharp knife)	wires, print kit
Small screwdriver for M1.6 countersunk screws (check the head type you bought)	lid
0.9 mm hex key (for the M2 set screw)	laser
Multimeter	check cell voltage and polarity
Laser safety glasses for 520 nm	laser test
USB-C cable that carries data	firmware — many cheap cables only charge
Computer with **Chrome or Edge** (Windows, macOS, Linux or ChromeOS)	firmware installer
Isopropyl alcohol, cotton swabs	cleaning flux

8. When the parcels arrive — check

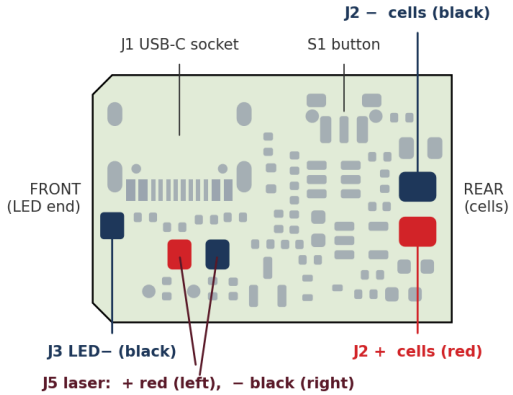
- **Boards:** look at both sides under good light (a phone camera zoom works). No part missing, no part crooked, no solder bridges between pins of the Bluetooth module.
- **Body:** the PCB must drop into the tray (section 12.8 shows how) and the lid must close flat. The four lid threads must accept a screw by hand.
- **Cells:** measure each with the multimeter: 3.6–4.2 V is normal for new cells. Size with the protection board: at most 6.0 × 16 × 47 mm. **The two cells should be within 0.1 V of each other** (0.05 V is ideal) before you connect them.
- **LED board:** 10.0 mm diameter, 1.6 mm thick, the "+" and "−" marks are readable.
- **Laser:** 6.0 mm diameter, ≤ 12 mm long. Red wire = +, black wire = −.

The pads you will solder. Front end = the end with the LED pad J3 (the head of the light); rear end = the end with the cell pads J2. Keep this picture next to you:

TOP side (lid side, with the Bluetooth module) — seen from above



BOTTOM side (with the USB-C socket) — board turned over along its long edge



red = + (plus), dark blue = − (minus); grey = other pads. J3 is one pad on each side at the same spot: LED+ on top, LED− underneath.

The two sides of the board. Red pads are +, dark blue pads are −. The small "+" and "−" printed on the board are tiny and partly covered by solder mask — trust the picture.

9. Step 1 — Prepare the cells

The flashlight takes its power from the cells — also while you install the firmware. So the cells come first.

1. **Check polarity.** Red = +, black = −. Confirm with the multimeter (red probe on the red wire: the reading must be positive).
2. **Match the voltages.** Both cells within 0.1 V. If they differ more: solder only the fuller cell (steps 3–6), install the firmware (section 10) and charge it until the LED is steady green; unsolder it, do the same with the other cell; then both are full and equal.
3. **Check the board for a short.** Set the multimeter to the beep (continuity) setting and touch the two J2 pads (see the picture above): it must **not** beep. If it beeps, stop and look at the board under a magnifier — do not connect the cells.
4. Shorten the wires to about **40 mm** (cut **one wire at a time** — cutting both at once with the same cutter short-circuits the cell!). Strip 2 mm, twist, tin with solder.
5. Twist the two red wires together and the two black wires together (still one at a time).
6. **Solder to the board** — the cell pads J2 are the two big pads near the rear end on the **bottom side** (the side with the USB-C socket). **J2 + (red wires)** is the pad nearer the edge with the slide switch S2; **J2 − (black wires)** is the pad nearer the middle of the board (see the picture). Put a little flux on the pad, hold the tinned wire on it, touch with the iron for 2–3 seconds. Red first, then black.
7. The board is now powered. Nothing lights up yet — the firmware is not installed. Lay the board and cells on a non-metal surface.

> **If anything gets hot, smells or smokes:** pull the cells away with pliers by the wire, put them in the metal box. A reversed cell destroys the board — that is why step 1 matters.

10. Step 2 — Install the firmware (no experience needed)

The firmware is the program that runs in the flashlight. You install it from a web page, through the flashlight's own USB-C socket. Nothing to download, nothing to install on your computer.

You need: the board with the cells soldered on (step 1), a USB-C cable **that carries data**, and a computer with **Google Chrome** or **Microsoft Edge**. (Firefox and Safari cannot do this, and phones cannot flash.)

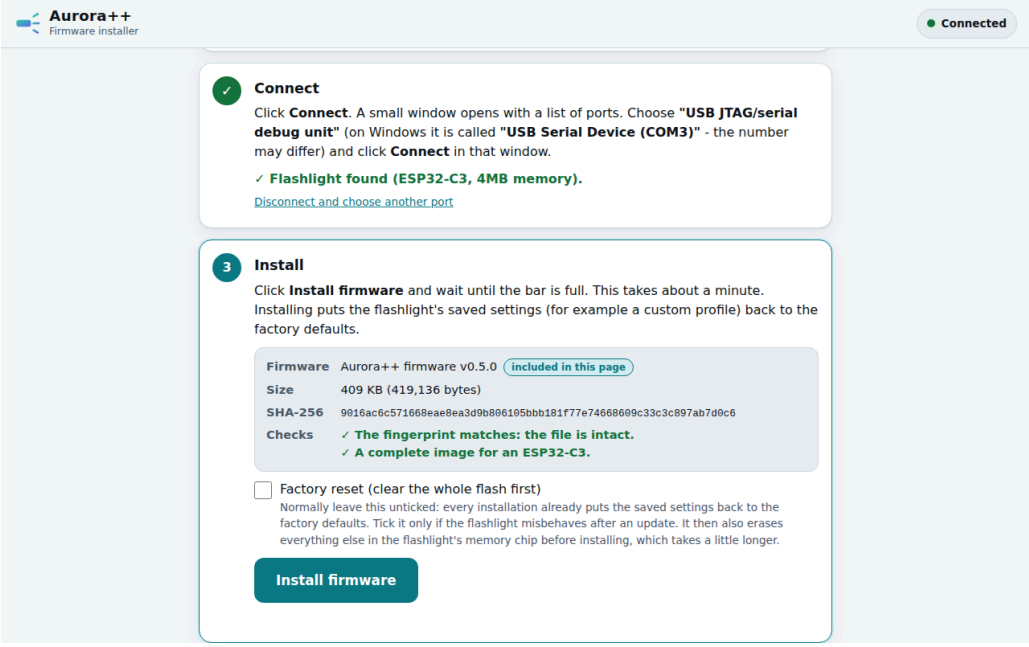
1. Open the installer. Open `app/aurora-flasher.html` from the package in Chrome or Edge (double-click the file; if it opens in another browser, right-click → *Open with* → Chrome). If someone has put the package on a website (see `docs/web_apps.md`), you can open the same page from there instead.

2. Plug in. Connect the flashlight's USB-C socket to the computer. The status LED starts breathing red slowly (charging) — if the firmware was not installed yet, it may stay dark; that is normal.

3. Connect. Click **Connect**. A small browser window lists the serial ports. Choose:

- on Windows: **"USB Serial Device (COM3)"** (the number can differ),
- on macOS: **"USB JTAG/serial debug unit"** (`cu.usbmodem…`),
- on Linux/ChromeOS: **"USB JTAG/serial debug unit"** (`ttyACM0`).

and click **Connect** in that window. The page says **"Flashlight found (ESP32-C3, 4MB memory)"**.



4. Install. Click **Install firmware**. A progress bar runs for about one minute. Do not unplug while it runs.

5. Done. The page says the installation is complete. Unplug the cable and plug it in again. The status LED breathes red (charging) or shows steady green (full).

That's it. To update the firmware later, do exactly the same with a newer installer page. Installing resets the saved settings (your custom profile) to the factory defaults.

If "Connect" shows no port

- **The cable.** Most failures are charge-only cables. Try another cable — one that can move files to a phone is a data cable.
- **Another USB port**, directly on the computer (not through a hub).
- **Windows 7/8** have no built-in driver for this USB serial port; use Windows 10/11.
- **Linux:** your user must be allowed to use serial ports: `sudo usermod -a -G dialout $USER`, then log out and in again.

If the port appears but connecting or installing fails

Force the chip into its built-in installation mode (it cannot be broken this way):

1. Unplug the USB cable.
2. **Press and hold the flashlight button** (the side button S1 — on the bare board it is the small black switch on the bottom side, at the edge next to the USB-C socket).
3. While holding it, **plug the USB cable in**. Keep holding for about a second, then release.
4. Click **Connect** again and choose the port. Then **Install firmware**.
5. When it is done, unplug and replug (or press the button once).

Why this works: plugging in USB restarts the chip (a small circuit on the board does that), and a chip that starts with the button pressed waits for new firmware instead of running the old one.

What happens inside (for the curious)

The ESP32-C3 has a USB port built in. The installer page uses your browser's *Web Serial* feature and the open-source **esptool-js** to write one file (`aurora-fw-v0.5.0-merged.bin`, 419,136 bytes — bootloader, partition table and program) to address 0 of the module's 4 MB flash memory. The page checks the file's fingerprint (SHA-256) before writing.

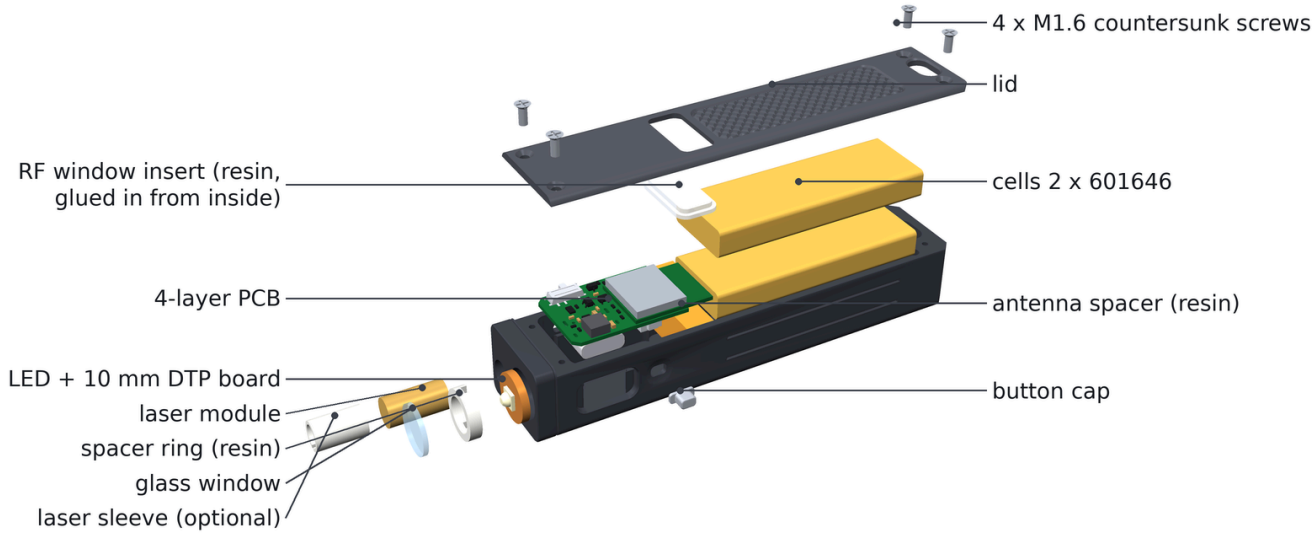
11. Step 3 — Test on the bench (lid open, nothing in the body yet)

1. **Bluetooth.** On a computer with Bluetooth, open `app/aurora-app.html` in Chrome or Edge (a phone needs the app from a web address — see section 14). Press the flashlight button three times quickly: the RGB LED blinks blue twice — Bluetooth is on for 2 minutes. In the app, click **Connect**, choose **Aurora-XXXX**. You see the battery percentage, the voltage and the temperature.
2. **LED (optional, quick).** Solder the LED board temporarily with two wires (LED+ to the **top** pad J3, LED− to the **bottom** pad J3, same spot on both sides of the board). Click the button once: low light. **Do not run high levels on the bench** — without the aluminium body the LED board has nothing to shed heat into. Unsolder again.
3. **Charging.** Plug USB in: the RGB LED breathes red, later steady green.

12. Step 4 — Assemble

Work on a clean towel. The order matters, because some joints cannot be reached later.

12.0 Make it safe first. The cells are connected, so the board is live. Push the knob of the slide switch **S2 towards the front (LED) end — SAFE** — and lock the light with **four quick clicks** (red ×3). It stays locked until section 13.



Exploded view: window, spacer ring and LED board go into the head from the front; the laser below them; the PCB with the cells drops into the tray; the antenna spacer sits behind the PCB; the lid with its translucent RF window closes everything with four screws.

12.1 Cut the print kit. Cut the four parts off their rods with side cutters, close to the part, and trim the stubs with a knife: RF window (the flat stepped plate), button cap (the tiny plunger), spacer ring (the ring) and antenna spacer (the U-shaped block).

12.2 LED board. Solder a red wire (60 mm) to the **+** pad and a black wire (60 mm) to the **−** pad of the LED board, on the LED side, with the wires pointing away from the board's centre. Hold the board so that **+ is at 12 o'clock** (top, lid side) and − at 6 o'clock.

12.3 Into the head. From the front of the body, push the red wire into the **upper** groove of the big bore and on through the upper hole into the inside of the body; the black wire through the **lower** groove and hole. Put a thin layer of thermal paste (or the thermal tape) on the back of the LED board and push the board to the bottom of the bore, wires pulled gently from inside.

12.4 Spacer ring and window. Insert the spacer ring (its notches go over the two solder joints), then the glass window. Fix the window with three tiny dots of clear epoxy or UV resin at its edge. Keep the glass clean.

12.5 Laser. Push the module into the small bore below the LED from the front, wires first, until its front sits 0.2–0.3 mm behind the front face (no thermal paste needed — a Class 2 module makes almost no heat). Tighten the **M2 × 2 set screw** from the bottom of the body with the 0.9 mm hex key — gently, the module body is soft brass.

12.6 Button cap. From inside, push the button cap into the small rectangular hole in the control-side wall (flange inside).

12.7 Wires to the board (bottom side first).

- **Laser:** J5 is the pair of pads side by side on the bottom side (see the picture in section 8): **red to the pad nearer the front (LED) end (+)**, black to the other one (−). Shorten the wires so that about 15 mm of slack remains.
- **LED black (−):** to the **bottom** pad of **J3** (front end of the board).
- **LED red (+):** to the **top** pad of **J3** (same position, other side) — you can also do this one after the board is in, the top side stays reachable.

12.8 Board in. The slide switch S2 sticks out of the board edge on the side opposite the USB-C socket.

1. Tilt the board a little (about 5°) with the **S2 side low**, front end towards the head.
2. Push the front edge under the head step, guide the S2 knob into its slot in the side wall.
3. Lower the USB-C side: the USB-C socket, the button switch (behind the cap) and the edge of the board drop into their openings and onto the ledges.
4. Press the button from outside: it must click (the RGB LED gives a short red flash — the light is still locked, as it should be).

12.9 Antenna spacer and cells. Push the U-shaped antenna spacer in behind the board: the module's antenna (it sticks out of the board's rear edge) sits in the U, the cell wires pass through the notch. Put a strip of Kapton over each cell's protection board. Lay both cells into the bay behind the spacer, **flat, one on top of the other** (the bay is two cells high), the end with the protection board and the wires towards the PCB, and put a strip of foam tape on top so that the lid holds them without rattling.

12.10 Lid. Glue the RF window into the lid from inside (epoxy on the flange, not on the top face) and let it cure. Put the lid on and fasten the four **M1.6 × 4** screws — **snug only**, the threads are in aluminium and strip easily.

12.11 Thread a split ring or a lanyard through the slot in the tail.

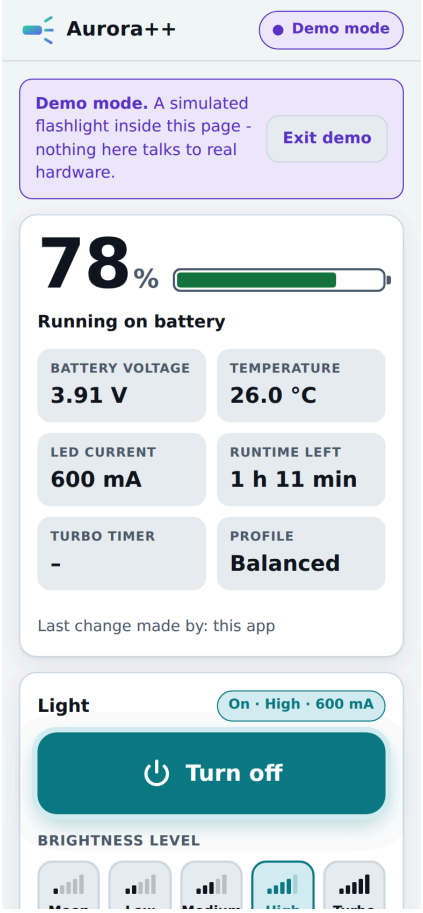
13. Step 5 — First use

- **One click:** on (Low the first time). **One click** again: off.
- **Hold** while on: steps Low → Medium → High.
- **Double click:** turbo for 45–60 s, then it steps down by itself.
- **Laser:** with the light off, **click, then click-and-hold**: the laser is on while you hold. The small slide switch S2 in the side wall must be **armed** — knob pushed **towards the tail** (away from the LED). With the knob towards the LED the laser cannot come on, whatever the software does: the switch cuts the laser's control line in hardware. **Check it once, with the safety glasses on and the light pointed at a wall** (unlock first: four clicks, green ×3): knob towards the LED → the gesture must do nothing; knob towards the tail → the laser comes on. If the laser comes on with the knob towards the LED, your switch works the other way round: then *towards the tail* is SAFE — mark the safe side on the body with a dot of paint and remember it.
- **Triple click** (off): Bluetooth for 2 minutes. **Four clicks:** lockout (red ×3); four clicks again unlocks (green ×3).

The complete button table, the RGB LED colours and the protection behaviour are in `docs/firmware.md`, chapter 2 (the user manual).

14. The app

On a computer (Windows, Mac, Linux, ChromeOS with Bluetooth): open `app/aurora-app.html` in Chrome or Edge. **On a phone** the page must come from a web address (https): put the `app` folder on GitHub Pages once — free, about 10 minutes, step by step in `docs/web_apps.md`, section 4 — and open that address in Chrome on Android or in the free **Bluefy** browser on an iPhone. Bluetooth is only on while the light is on, 2 minutes after it was switched off, after a triple click, or while USB is connected — so switch it on (or triple-click) before you tap **Connect**.



- **Battery, voltage, temperature, runtime left** at the top.
- **On/Off and the levels** — the button on the light always wins: for 3 s after you press it, the app cannot switch or dim the light ("the button has priority").
- **Profiles:** *Extreme* (maximum light for short bursts — 2.2 A turbo for 45 s), *Balanced* (default), *Endurance* (longest battery life, the LED never runs above 300 mA), *Custom* (your own: every level, the turbo current and time, the temperature limit, the battery limits — then **Save to flashlight**).
- **Demo mode** shows the app without a flashlight.

15. Troubleshooting

What you see	What to do
Nothing at all when you click	Charge it (USB).
A short red flash when you click	Locked: four clicks unlock it (green ×3).
Five fast red blinks	Battery empty: charge it.
One red blink when you ask for turbo	Too hot — turbo is refused near the temperature limit. Wait.
Light gets dimmer by itself	Normal: turbo time over, or temperature / battery protection.
App: "the button has priority"	Wait 3 seconds after pressing the button, then try again.
App finds no flashlight	Bluetooth is off to save power: triple-click the light, then *Connect*.
Installer: no port	Data cable, other USB port (section 10).
Installer: connection fails	Hold the button while plugging in (section 10).
Red LED flickers briefly when it starts	Normal (the boot message runs over that pin).
Laser does not come on	S2 must be armed (knob towards the tail); the gesture is click + click-and-hold from off; it stops above 60 °C, below 3.2 V and after 60 s.
USB does not charge	The charger pauses above 45 °C and below 0 °C, and while the LED runs above 500 mA.

16. Where to read more

- `docs/firmware.md` — how the firmware works, the user manual, the bench test plan.
- `docs/ble_protocol.md` — the Bluetooth protocol (for anyone who wants to write their own app).
- `docs/web_apps.md` — the app and the installer, and how to put them on GitHub Pages.
- `docs/bom_notes.md` — where every price in the workbook comes from.
- `docs/ch12_v0.5_bluetooth_redesign.md` — the design story of v0.5 (why every decision was made).

Appendix A. How the light works (user manual)

From `docs/firmware.md`, section 2. Every gesture, colour and protection rule of the firmware v0.5.0.

A.1 Button

Click = press shorter than 0.4 s. Clicks belong together while the pause between them is shorter than 0.4 s. *Hold* = press of 0.4 s or longer. Contacts are debounced (25 ms).

Light is OFF	
1 click	On at the remembered level (Moon / Low / Medium / High). With the profile's "remember" flag off: Low.
Hold	On in Moon (keeps Moon while held; Moon becomes the remembered level).
2 clicks	Turbo (High if the profile has no turbo; High plus one red blink if the board is within 5 °C of the profile's temperature limit).
Click, then click-and-hold	**Laser** while held (max 60 s; see 2.5). The main LED stays off.
3 clicks	Opens a 120 s Bluetooth window, RGB blinks blue twice, the light stays off.
4 clicks	Lockout on (red x3) / off (green x3).

Light is ON	
1 click	Off (settings are saved if they changed).
Hold	Steps Low -> Medium -> High -> Low ... The first step happens when the press becomes a hold (0.4 s), then every 0.6 s while held. From Moon or Turbo the cycle continues at Low. The level you stop at is remembered.
2 clicks	Turbo on; 2 clicks again: back to the previous level. Refused (one red blink) within 5 °C of the temperature limit.
3 clicks	Battery check on the RGB LED: 1-5 blinks (one per started 20 %) in green (> 50 %), yellow (20-50 %) or red (< 20 %).

In lockout	
4 clicks	Unlock (green x3).
anything else	Ignored; clicks give one short red flash, holds give nothing (a button pressed in a pocket stays dark).

Every button action blocks app commands that switch or dim the light for 3 s (the button always wins), and a button action cancels an exact current set by the app.

From deep sleep the first press wakes the chip; the firmware knows the button woke it and counts that press, so single, double (turbo), triple and quadruple clicks and the hold work from sleep. (Very fast double clicks may be seen as one click if the second press starts and ends while the chip is still booting, ~0.2 s.)

A.2 Levels and profiles

	Extreme	**Balanced (default)**	**Endurance**	**Custom**
Moon / Low / Medium / High	3 / 40 / 250 / 900 mA	3 / 30 / 200 / 600 mA	2 / 15 / 100 / 300 mA	set by the app, default = Balanced
Turbo	2200 mA for 45 s	1200 mA for 60 s	none (turbo = High)	
After the turbo time	900 mA	600 mA	—	
Temperature limit	55 °C	50 °C	45 °C	40-70 °C
Low-voltage step-down	3.30 V	3.35 V	3.40 V	3.10-3.60 V
Cell current limit	2600 mA	1600 mA	800 mA	200-3000 mA
Flags	turbo, remember, battery display	turbo, remember, battery display	remember, battery display	

The profile is chosen in the app (there is no button gesture for it).

A.3 Turbo

Turbo runs at most the profile's turbo time, then the light steps down to the profile's step-down current (the app shows "automatic" as the reason). Two clicks then return to the level used before turbo; two more clicks start a new turbo. Thermal derating, the cell current limit and low-voltage protection apply on top at all times.

A.4 RGB status LED

Highest priority first:

Pattern	Meaning
Red x3 / green x3	Lockout on / off
Cyan x3	"Identify" from the app
Blue x2	Bluetooth window opened (3 clicks while off)
1-5 blinks green / yellow / red	Battery check (3 clicks while on)
One red blink	Request refused (turbo too hot, laser not allowed, switch-on refused)
Five fast red blinks	Battery empty: switched off, or switch-on refused
Short red flash	Click while locked
Green / yellow / red for 2 s after switch-on	Battery > 50 % / 20-50 % / < 20 % (profile flag)
Red slow breathing (3 s)	USB connected, charging
Green steady	USB connected, charge complete
Red blink every 4 s (light on)	Battery below 10 %
Cyan (dim) steady	App connected
Blue double blink every 3 s	Bluetooth window open, nobody connected

The red LED also flickers briefly at every boot: the bootloader prints on U0TXD = GPIO21, which is the red cathode (hardware choice). The firmware suppresses the ROM banner after deep sleep.

A.5 Laser

Click, then click-and-hold while the light is off: the laser is on while the button stays held — at most 60 s per press (release and repeat the gesture to continue). It goes off above 60 °C or below 3.20 V and stays off until the button is released. Never in lockout, never from Bluetooth. The slide switch S2 must be armed as well; the firmware cannot see or override S2.

A.6 Protection (what you notice)

- **Hot**: above the profile's temperature limit the brightness falls smoothly, reaching Low 15 °C above the limit; above 70 °C Moon; above 80 °C the light switches off and cannot be switched on again until it has cooled below 75 °C.
- **Battery low**: below the profile's step-down voltage (measured with the LED running) the light drops one level every 5 s; below 3.10 V Moon; below 3.00 V it switches off (five red blinks) and refuses to switch on until the battery rests above 3.30 V or USB is connected. Choosing a level again lifts the step-down; it comes back if the voltage is still low.
- **Cell current**: the estimated battery current `V_LED(I)·I / (0.9·V_BAT)` with `V_LED = 2.75 V + 0.15 V/A·I` is kept below the profile's limit (the output is reduced).

A.7 Charging

USB-C charging at ~300 mA (nominal; the SoC estimate assumes 280 mA) between 0 °C and 45 °C (resumes 2 °C inside the window after a temperature pause). Charging pauses while the LED runs above 500 mA. Plugging USB in resets the MCU (VBUS-edge reset), keeps it awake and keeps Bluetooth reachable while connected. Without firmware (e.g. a completely flat cell) the charger trickles at 10 mA.

A.8 Battery percentage and runtime

The percentage comes from the LiPo open-circuit curve (4.20 V = 100 % … 3.30 V = 0 %) with a load correction of +0.12 V per A of estimated cell current while the LED is on (and -0.12 V/A of charge current while fast-charging), filtered so that it does not jump (at most 0.5 %/s, small dead band, and it only moves "backwards" for differences above 3 %). "Charge complete" reads 100 %. Runtime = 800 mAh x SoC / (estimated LED cell current + 20 mA for the MCU and radio); the MCU term matters at Moon, where the LED itself draws ~2 mA from the cell.

A.9 Bluetooth windows and sleep

The radio advertises only in windows: while the light is on; 120 s after it is switched off (by anything); 120 s after 3 clicks; while USB is connected; while an app is connected and 30 s after it disconnects; or as long as the app asks with KEEPALIVE. Advertising is fast (100 ms) for the first 30 s, then slow (500 ms).

When the light is off, no window is open and no USB is connected, the MCU goes to deep sleep (LED_EN, LASER_ON and the RGB LED off first). The button or plugging in USB wakes it. If the button is held down in lockout for 10 s (pocket), the MCU sleeps without the button as a wake source and checks it every 20 s instead.