USC University of Southern California

EE 105: Introduction to Electrical Engineering

Lab 5.1

LiFi, sending text over light

Yasser Khan

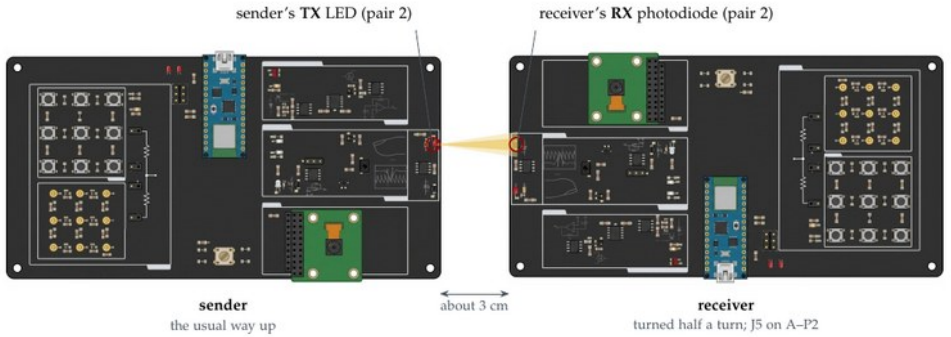
Rehan Kapadia

Today's mission

Send a text file from one board to another with light, then push the link until it breaks.

By the end of this lab you can:

- Run the firmware's own **text link** between two boards
- Measure the **channel**: dark level, noise, LED staircase
- Send a framed message with **OOK**: sync, decode, BER, eye diagram
- Double the bits per symbol with **PAM-4** and find each scheme's speed limit



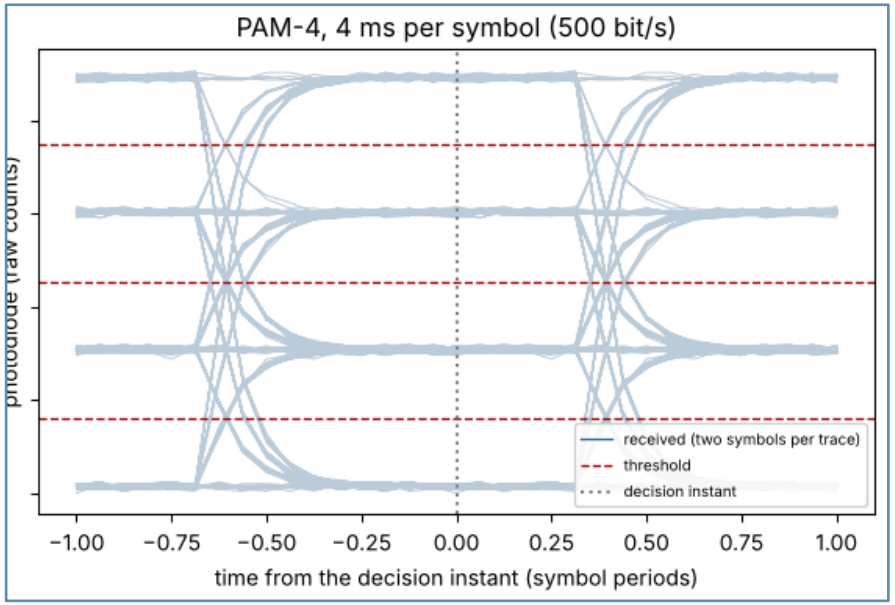
The sender's TX LED shines on the receiver's RX photodiode.

A	B	C	D	E	F
Connect **10 min**	Task 1 **15 min**	Channel **15 min**	OOK **30 min**	Speed **10 min**	PAM-4 **20 min**

Key takeaways

What to remember from this lab, with the numbers that matter.

- **A fixed threshold fails first.** Task 1 decides at 200 counts; the 1 level a few cm away is only 150 to 250
- **A known preamble finds the frame.** Correlate with 0xAA 0x55, then decide each bit once, mid-symbol
- **Zero errors in N bits only shows BER < 3/N:** 0.008 for 360 bits; margins of tens of σ predict far less
- **The receiver is a low-pass filter.** Fall time about 0.65 ms ($\tau = t_f / 2.2$): short symbols shrink the eye
- **PAM-4 doubles the bit rate** at the same symbol period, but each of its three eyes is a third as tall



Expected result of F3 on the simulated board: three PAM-4 eyes, each a third as tall as the OOK eye.

SETUP

Two boards, same settings on both, right edges facing a few centimeters apart.



1 **S10 → Module 3**
On both boards: the biosensing block.

2 **J5 → A-P2**
Pins 2-3 on both boards: A6 reads the RX photodiode. One-board loopback: P1-A.

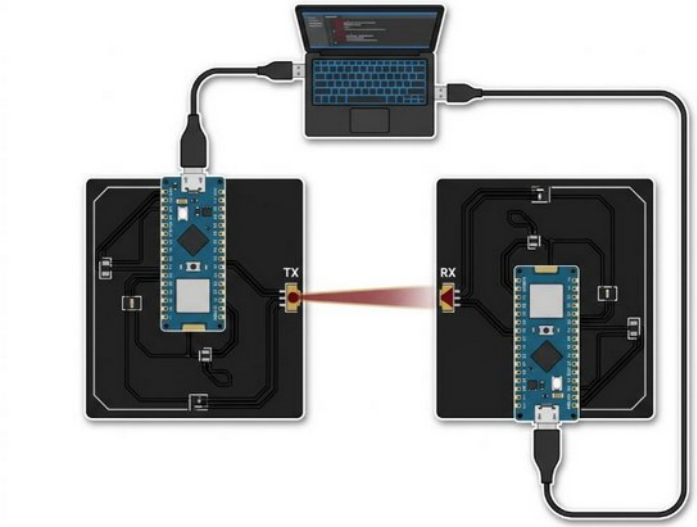
3 **Right edges facing**
A few cm apart, one board turned half a turn: TX points at RX.

4 **Choose SETUP**
"two": both boards on one laptop; or "partner" or "one".

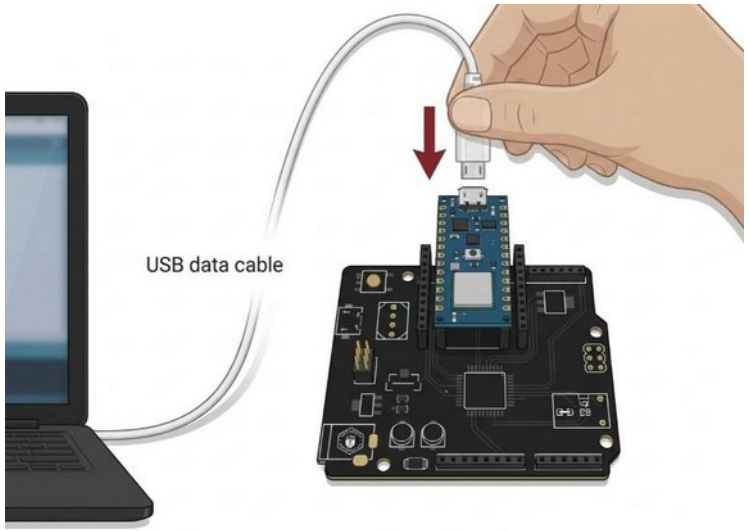
Part A: Choose your setup and connect

Line the boards up, plug both in, set SETUP, run the first cell.

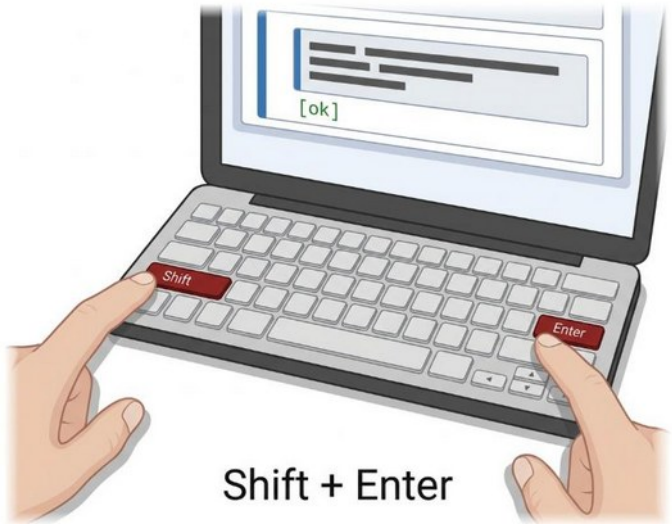
PART A **Goal: A1 · DO** connect both boards and decide who sends (SETUP, ROLE).



1 Right edges facing, TX at RX



2 Plug in both USB data cables



3 Set SETUP, run the first cell

You should see: an **[ok]** line for each board. With SETUP = "two" the first board found sends and the second receives; tx, rx = rx, tx swaps them.

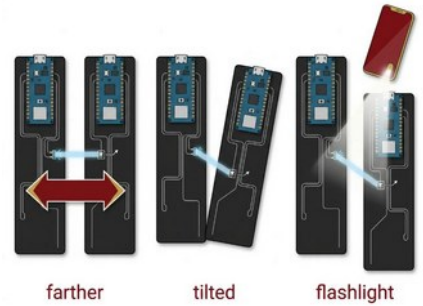
Part B: Task 1, the firmware's text link

communications send repeats a text on LED pair 2; communications receive decodes it.

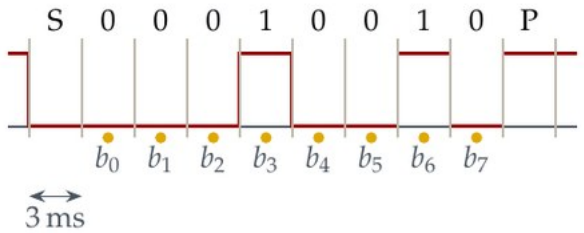
PART B

Goal: get the text link working, then break it on purpose.

- **B1 · DO** Run the cell: the sender repeats the test message for 15 s
- Slide the boards until the message repeats **cleanly**
- Then move them apart, tilt one, shine a phone flashlight on RX; rerun each time



Farther, tilted, flashlight: what fails first?



One character: start slot, 8 bits LSB first, stop slot, 3 ms each.

You should see: *This is a test transmission!* repeating cleanly. As the boards move apart, the fixed **200-count** threshold fails first.

Check (Checkpoint 1): the Task 1 message arrives cleanly (one-board setup: the C1 staircase shows light instead).

Part C: Channel check

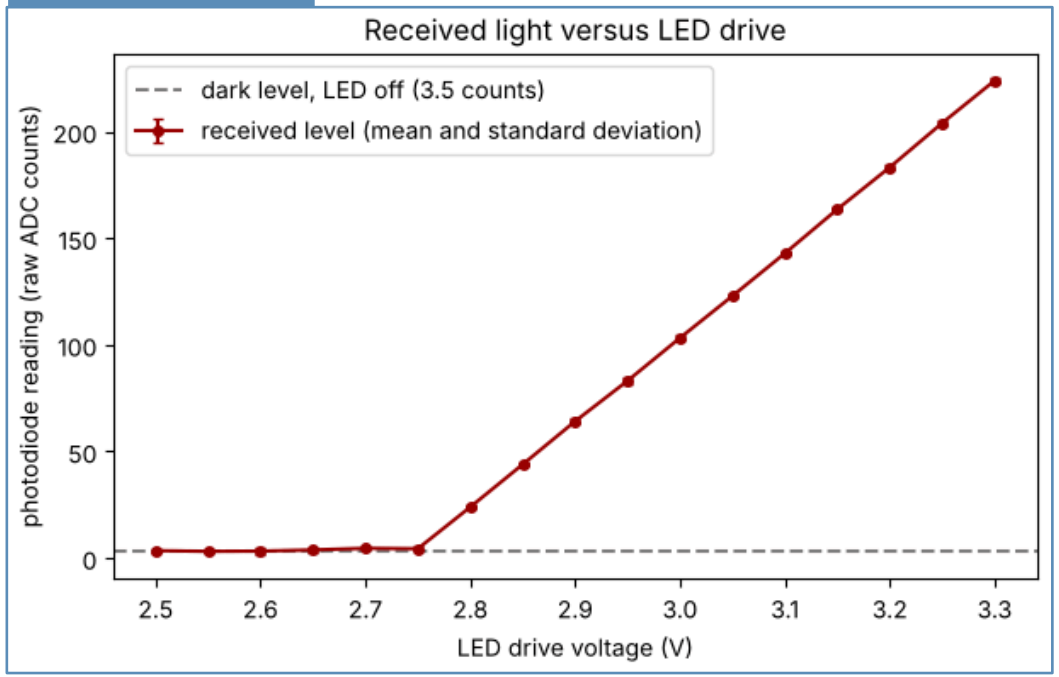
Measure what the receiver sees before you choose any light levels. Then keep still.

PART C

Goal: measure the dark level and the LED staircase, then choose the OOK levels.

- **C1 · RUN** Dark level (LED off), then the staircase: LED drive 2.5 to 3.3 V in 0.05 V steps
- **C2 · ANSWER** Turn-on voltage, OOK levels, threshold halfway

Expected result · C1



You should see: dark level below about **20 counts**, noise below **3 counts**; light starts near **2.75 V**; staircase peak **150 to 250 counts**.

Part D: On-off keying

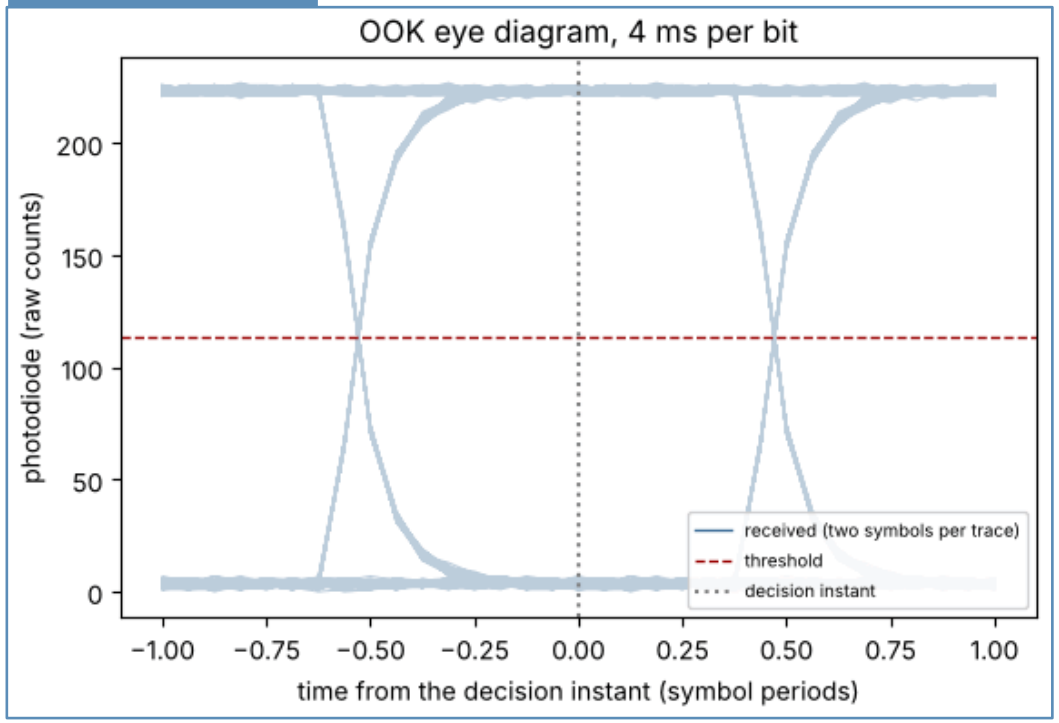
One bit per symbol, 4 ms each: a 392-bit frame with marker bytes at both ends.

PART D

Goal: send the message with OOK, find the start, decode it, count the errors.

- **D1 · EDIT** text_to_bits: UTF-8 bytes, 8 binary digits each
- **D3 · EDIT** find_start: the peak of the correlation with the preamble
- **D5 · EDIT** sample_mid: one sample mid-symbol; count the errors
- **D6 · EDIT** Noise margins and averaging
- **D2, D4, D7 · RUN** Send, correlation plot, eye diagram

Expected result · D7



You should see: the message with **0 errors in 360 bits**: report BER < 3/360 = **0.008**, and a wide open eye.

Check (Checkpoint 2): a small BER and an open eye.

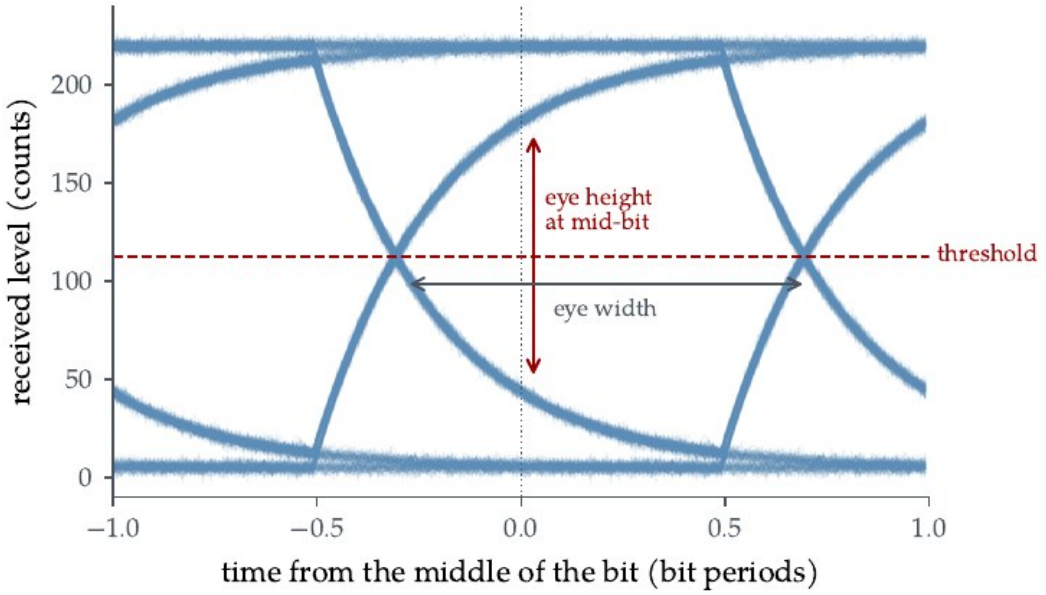
Part E: Speed

The receiver's amplifier is a low-pass filter: shorter symbols close the eye.

PART E

Goal: send the same frame at 4, 2, 1 and 0.5 ms per bit.

- **E1 · RUN** The speed test: BER, eye height and the eye at each period
- **E2 · EDIT** Fall time t_f from 90 % to 10 %; τ = t_f / 2.2
- R_b,max ≈ 1 / (2 t_r): compare it with your eye heights



Eye height at the decision instant, eye width along the threshold.

You should see: the eye shrinks as the bit time falls (simulator **215, 208, 175, 119** counts at 4, 2, 1, 0.5 ms); fall time about **0.65 ms**, τ about **0.3 ms**.

Part F: PAM-4, two bits per symbol

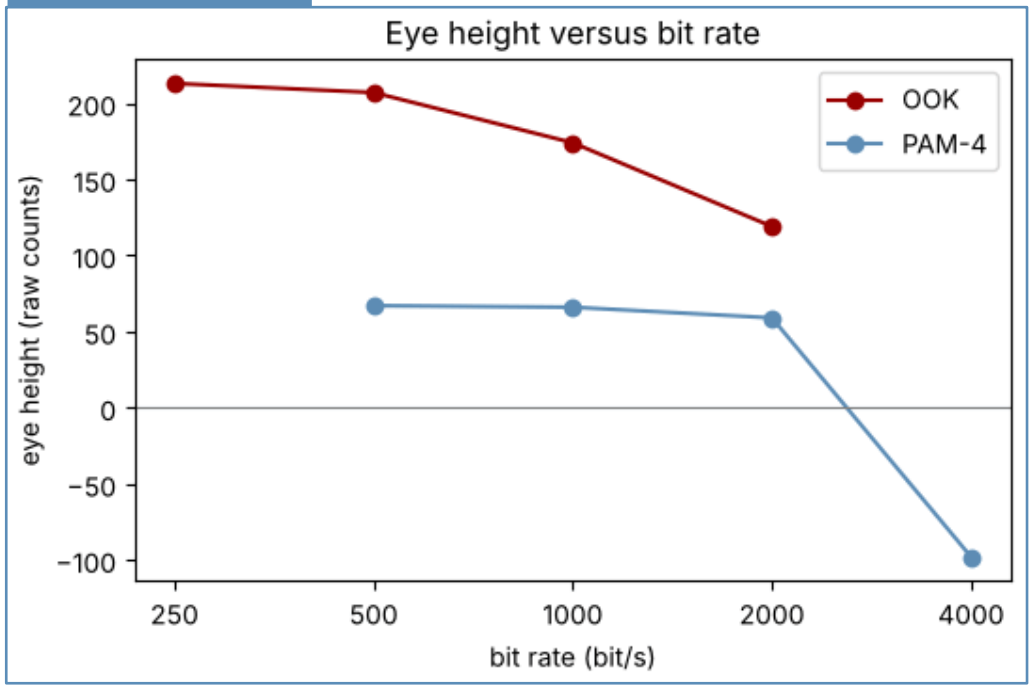
Four levels: half the symbols, twice the bit rate, levels closer together.

PART F

Goal: send the message with PAM-4 and compare it with OOK at the same bit rate.

- **F1 · ANSWER** Evenly spaced **received** levels; three thresholds
- **F2 · EDIT** Bits to symbols and back, MSB first
- **F3 · RUN** Send at 4 ms: errors, levels, both eyes
- **F4 · RUN** PAM-4 speed test, compared with OOK

Expected result · F4



You should see: 196 symbols; PAM-4 error-free at 4, 2 and 1 ms per symbol in the simulator, failing at 0.5 ms. Eye height about **68** counts against **215** for OOK.

Check (Checkpoint 3): the PAM-4 message is decoded, and the BER and eye-height plot compares OOK with PAM-4.

Stuck?

Check these first. If the fix does not help, raise your hand.

Task 1 garbles the message
Move the boards closer and align TX with RX: the on level must pass 200 counts.

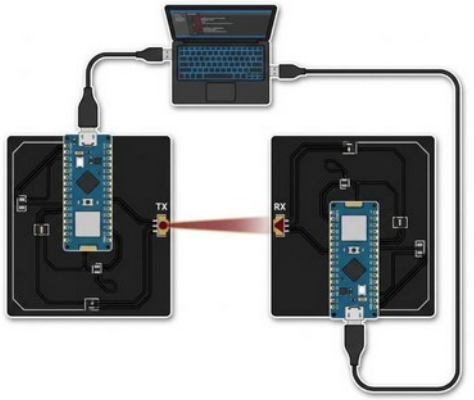
No light reached the receiver
J5 on A-P2 and S10 on Module 3 on both boards; check the alignment.

Garbled text in Parts D to F
Lamps or sunlight fired the trigger early: shade the receiver.

C1 readings change a lot
The other LED is still sending from B1: wait for it to stop.

The partner setup hangs
The receiver runs each BOTH LAPTOPS cell first, the sender right after.

Sender and receiver swapped
Run tx, rx = rx, tx after connecting.



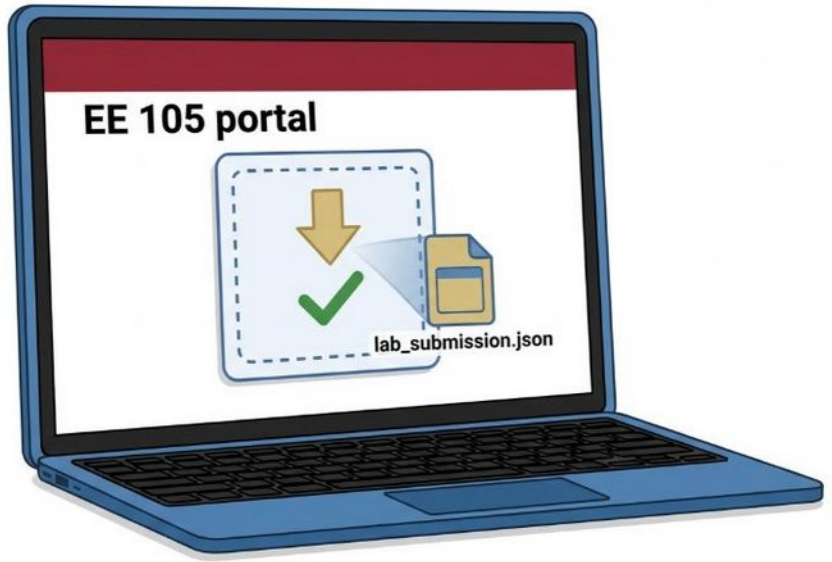
Right edges facing, a few cm apart, TX at RX.

Submit your results

The last cell saves your results in one file. Upload it on the course portal.

`lab5.1_submission.json`

1. **Save · RUN** (partner setup: on the receiver's laptop)
2. It writes **lab5.1_submission.json**; partners: the receiver sends a copy to the sender
3. Log in at **ee105.org/portal** with your student ID and portal PIN; open Lab 5.1
4. Each of you uploads the file under your own login



ee105.org/portal

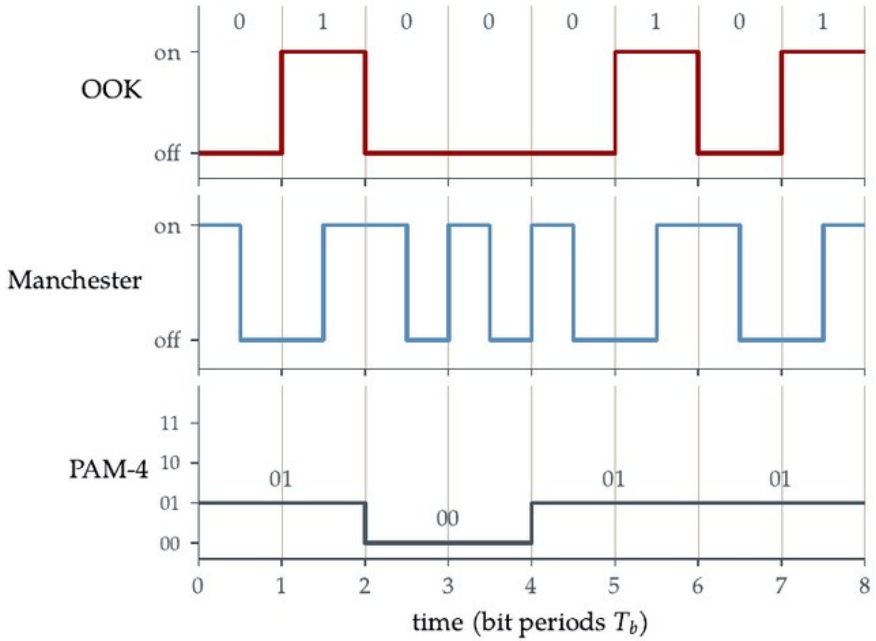
Check: before you leave, put J5 back on **P1-A** on both boards (the position Lab 3.2 uses).

Lab complete

You built an optical link and measured how fast and how far it goes.

You built:

- A text link over light between two boards
- Framing, synchronization and decisions in Python
- BER and eye diagrams at four speeds
- A PAM-4 link with two bits per symbol



OOK and PAM-4 send the same bits.

Did you know?

LiFi was popularized by Harald Haas in a 2011 TED talk. In 2023 the IEEE added light communication to the WiFi family of standards as IEEE 802.11bb (Chapter 5).

Next

Lecture 22, sensor fusion: combining sensors, shown in class. This was the last lab: J5 back on P1-A.