Bi-Directional Communication Between Infra-Structure and Mobile Device Based on Visible Light Communication

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OUTLINE

- **Introduction**
- **Optoelectronic characterization**
  - Transmitters
  - Receivers
- **Results and discussion**
  - I2V channel
  - V2I channel
- **Conclusions**

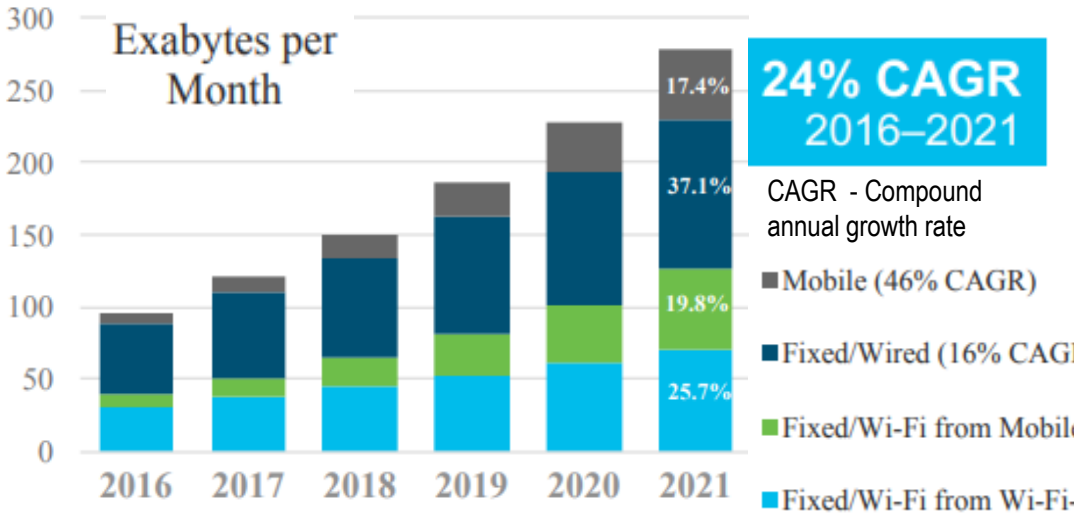
GLOBAL INTERNET GROWTH AND TRENDS

Key Digital Transformers

By 2021

	More Internet Users	More Devices & Connections	FasterBroadband Speeds	More Video Viewing
2016	3.3 Billion	17.1 Billion	27.5 Mbps	73% of Traffic
2021	4.6 Billion	27.1 Billion	53.0 Mbps	82% of Traffic

Source: Cisco VNI Global IP Traffic Forecast, 2016-2021



By 2021, 63% of total IP traffic will be wireless *

* Wireless traffic includes Wi-Fi and mobile

5G COMMUNICATIONS

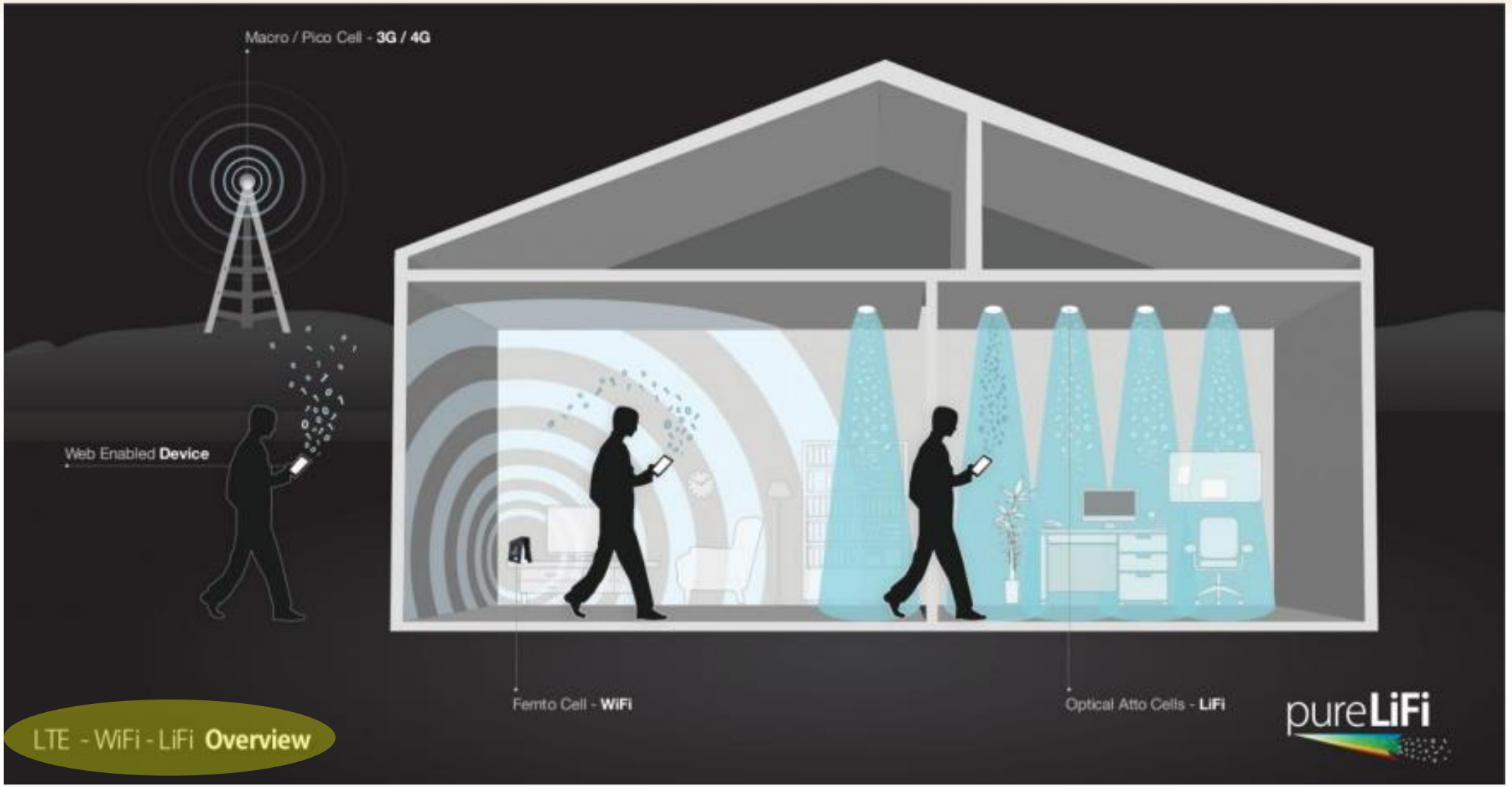
Speed
Latency
Capacity

The Internet of Things

VR, AR and holograms

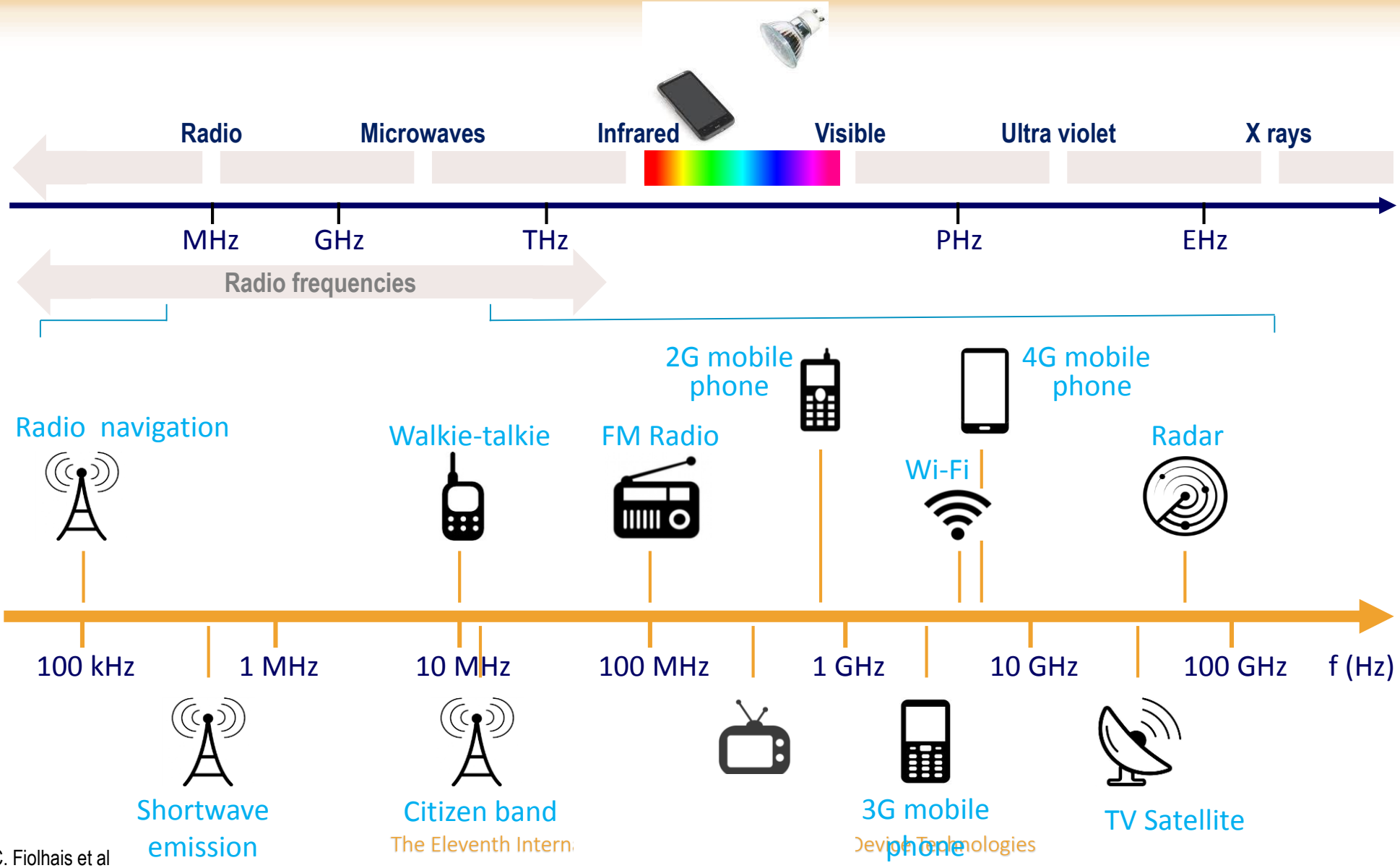
European Commission

TECHNOLOGY INTEGRATION



Source: pureLiFi

COMMUNICATION SPECTRUM

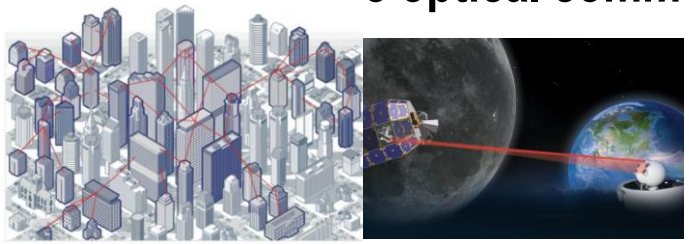


Adapted from "Física 11", C. Fiolhais et al

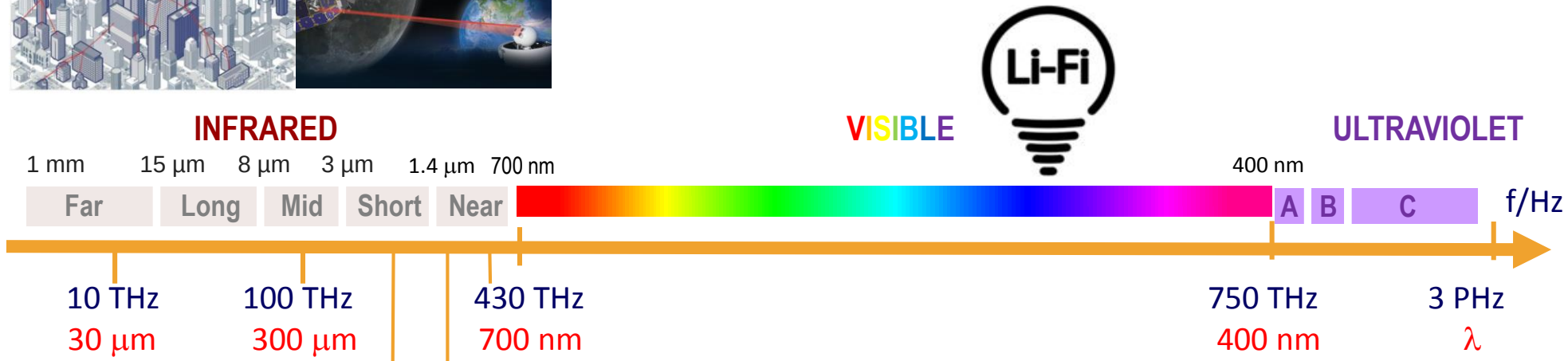
OPTICAL COMMUNICATION SPECTRUM

OWC Optical wireless communications

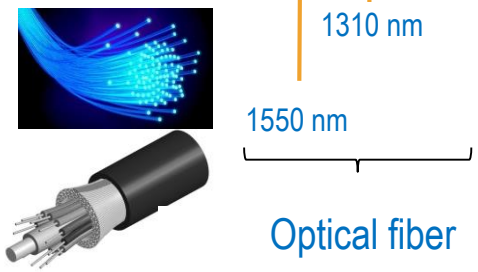
FSO Free space optical comm



VLC Visible Light communication



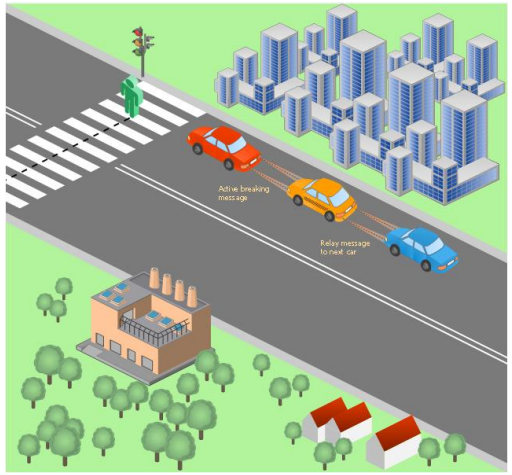
Optical wired communications

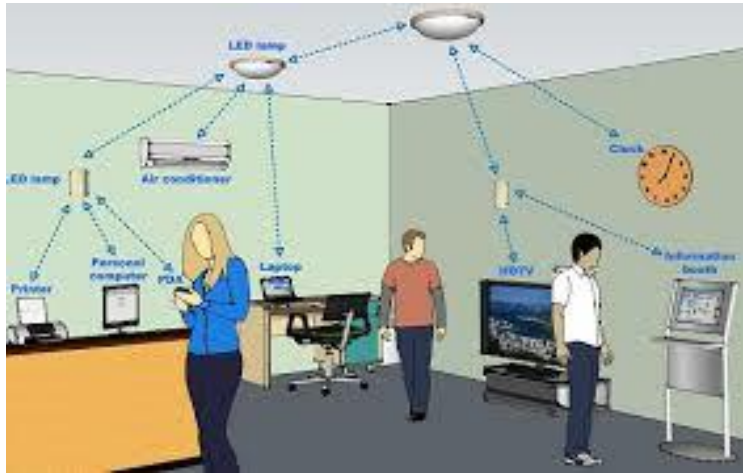


FO Fiber optics communication

VISIBLE LIGHT COMMUNICATION

- Dual operation: light + comm
- Infrastructure advantage
- Increased bandwidth
- Negligible power
- Inexpensive
- Free and non-regulated spectrum
- Security
- Harmless to human health
- No EM interference
- Line of sight condition

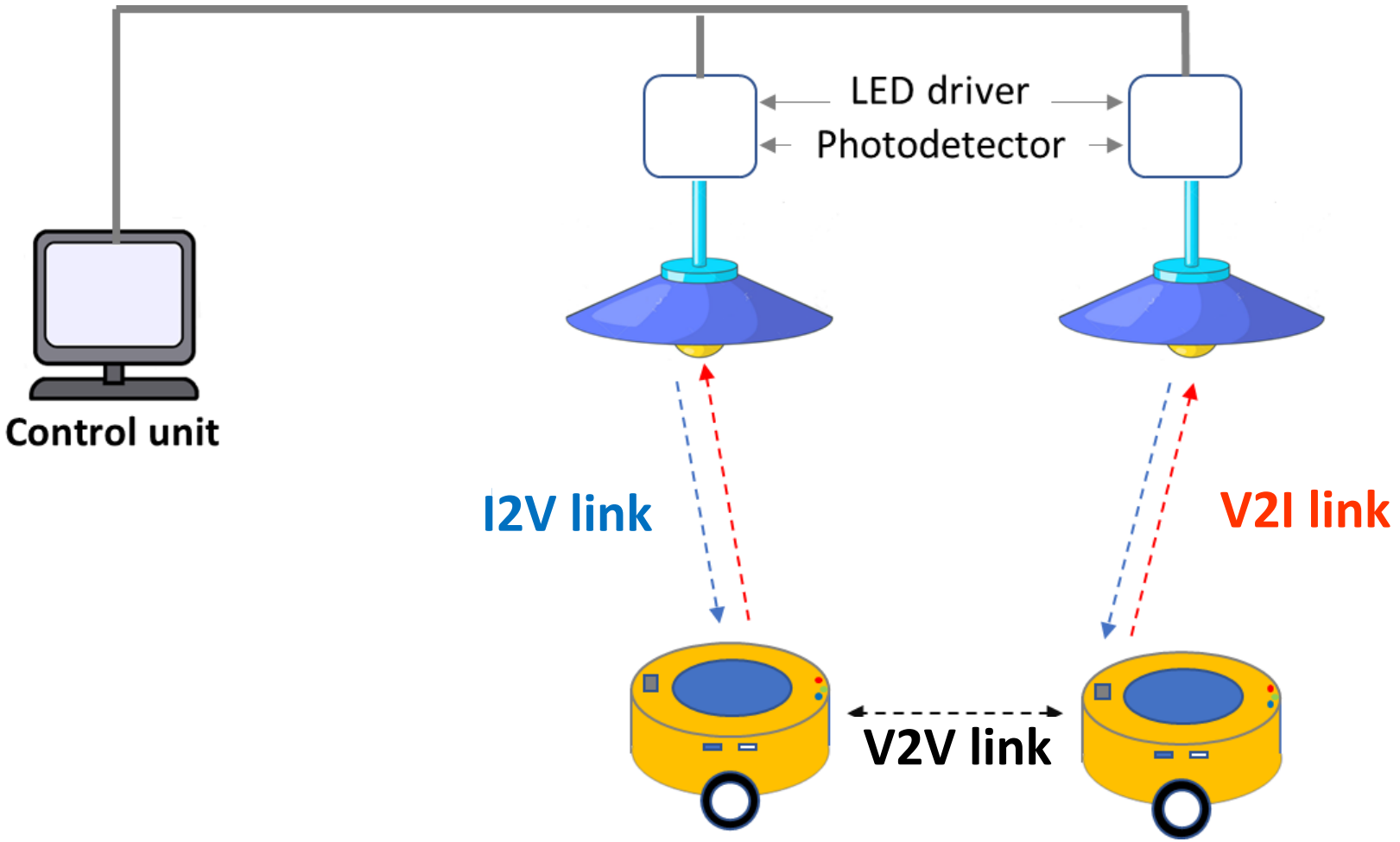




MOTIVATION

- ✓ Use of autonomous vehicles to grab goods and carry them to the packaging station
- ✓ Navigation along pre-defined routes
- ✓ COOPERATIVE APPROACH: bidirectional communication

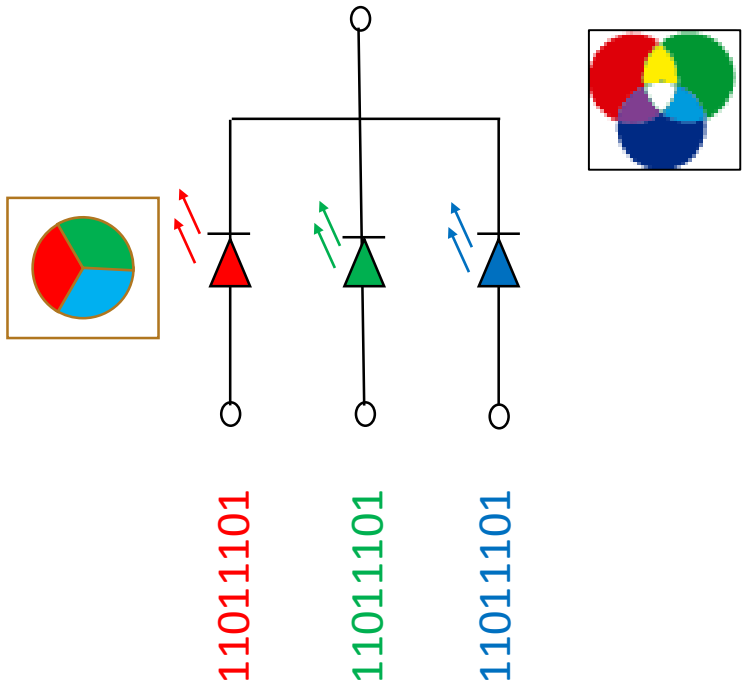
COMMUNICATION LINKS



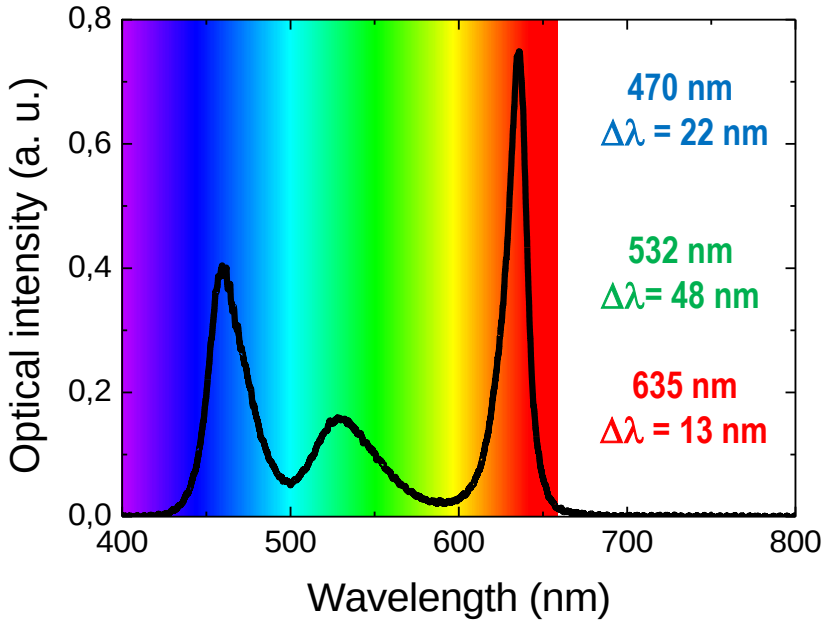
- I2V lamps to autonomous robots
- V2I: robots to lamps
- V2V: robots to robots

OPTOELECTRONIC CHARACTERIZATION: TRANSMITTERS

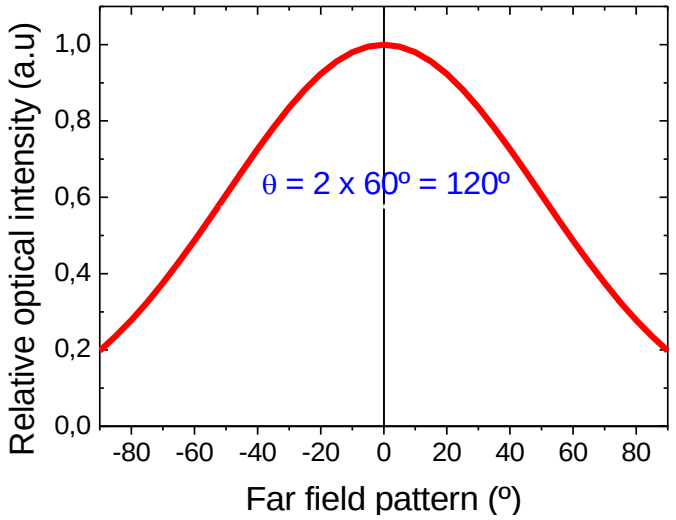
White RGB LEDs



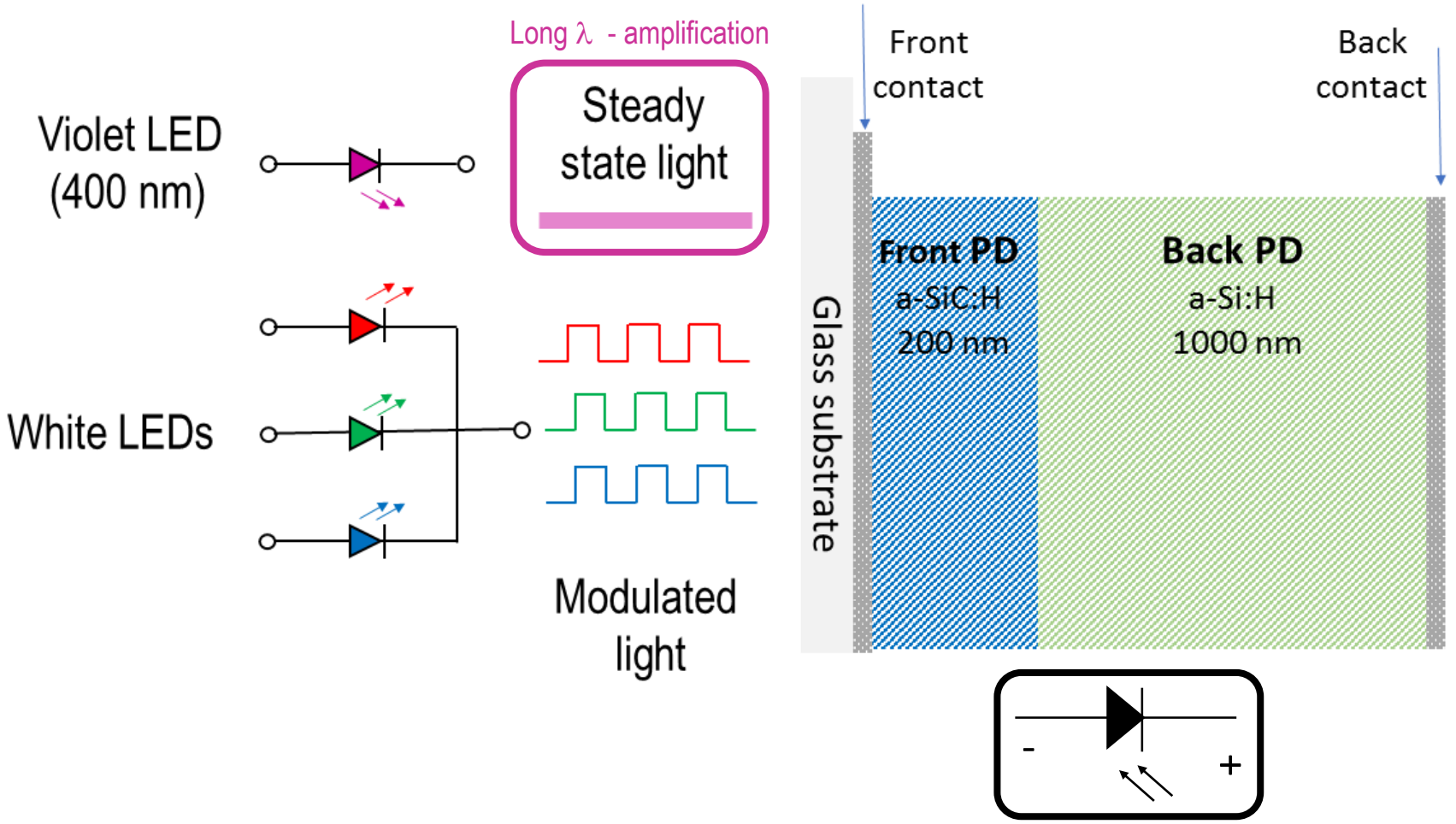
Spectral output



Viewing angle

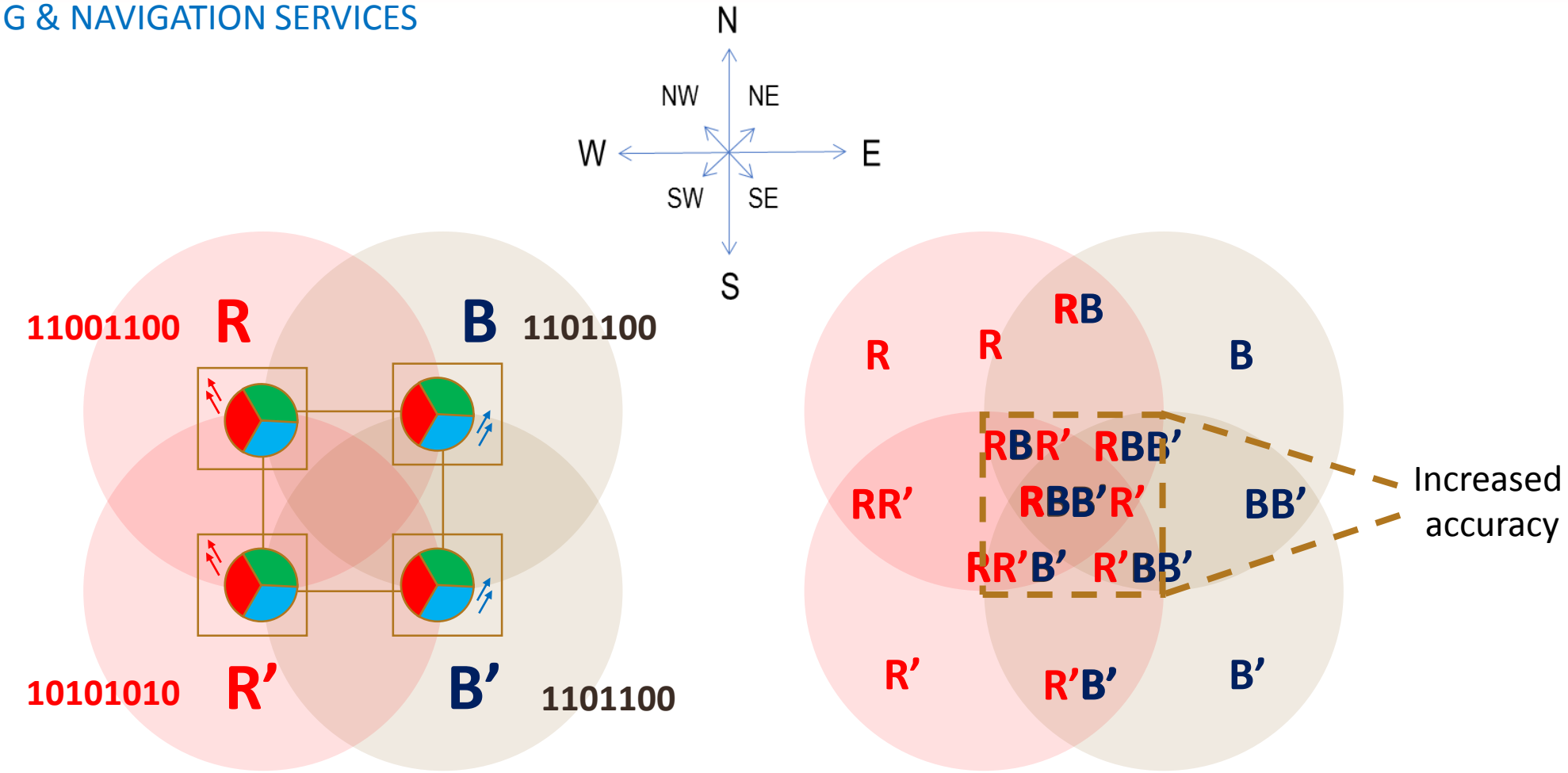


OPTOELECTRONIC CHARACTERIZATION: RECEIVER

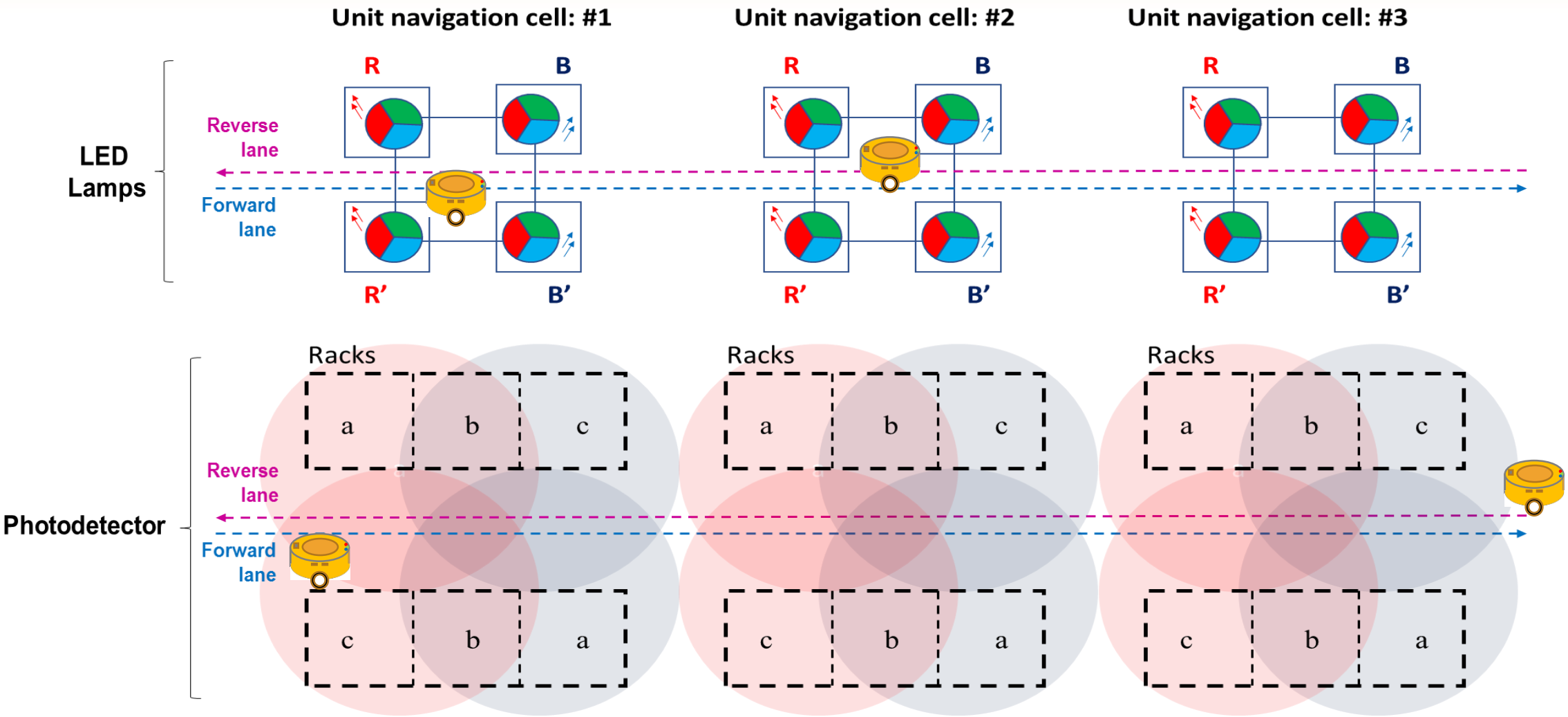


LAMP GEOMETRY AT THE INFRA-STRUCTURE

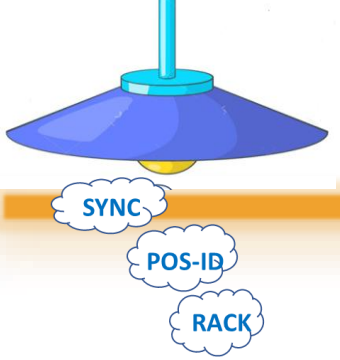
POSITIONING & NAVIGATION SERVICES



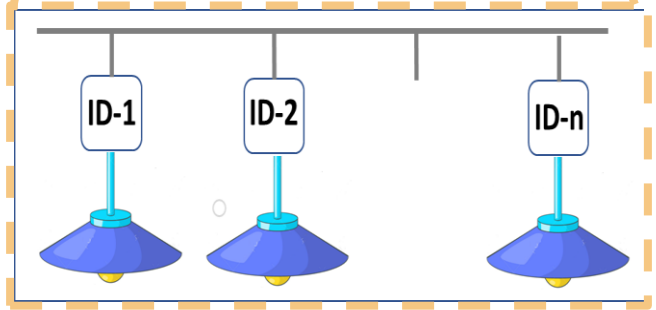
NAVIGATION CELLS

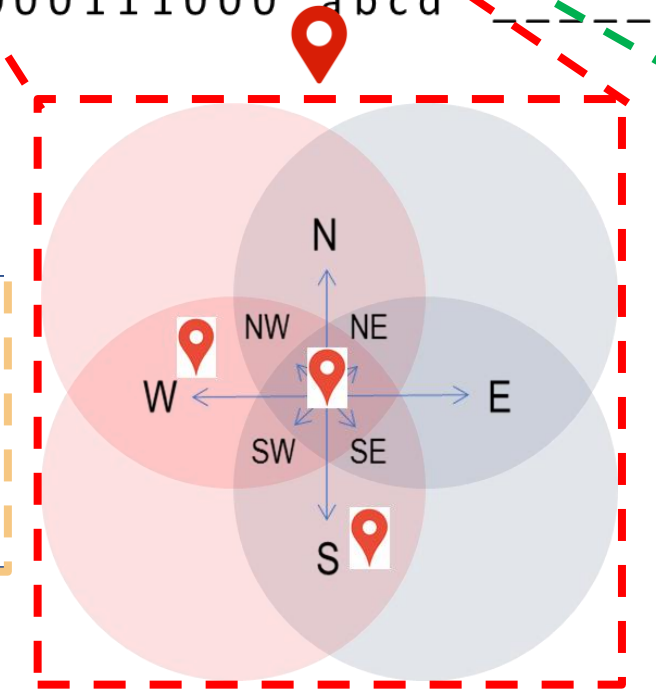


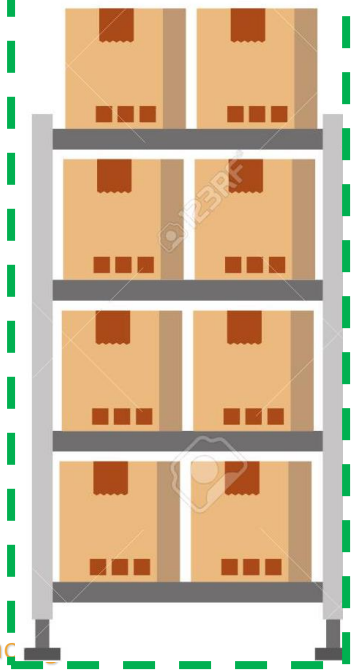
I2V CHANNEL



I2V	SoT (4 bits)	CELL ID (12 bits)	POSITION (12 bits)	RACK (4 bits)	MESSAGE (28 bits)	EoT (4 bits)
R & B:	1100	0XXXX00YYYY0	111111000000	abcd	----------	0011
R' & B':	1100	0XXXX00YYYY0	111000111000	abcd	----------	0011

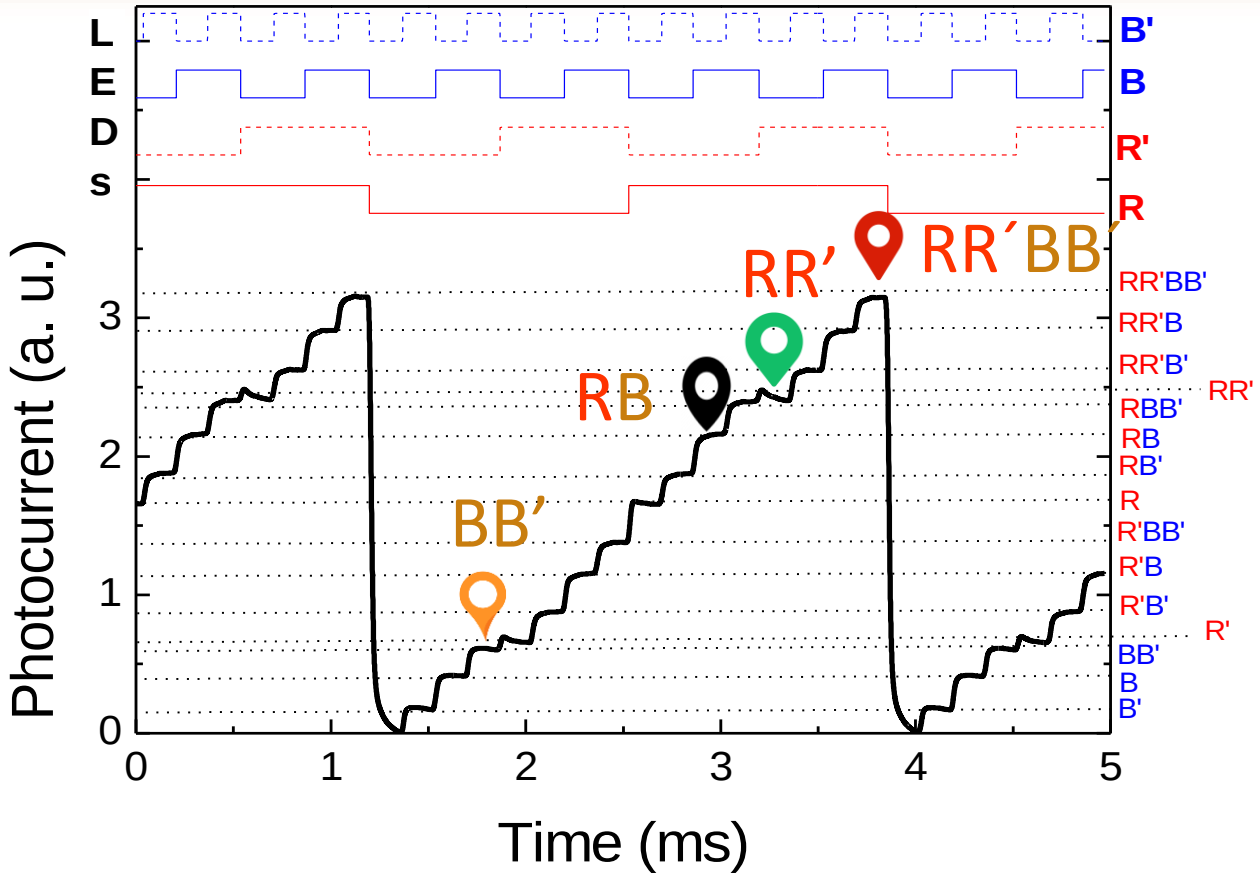


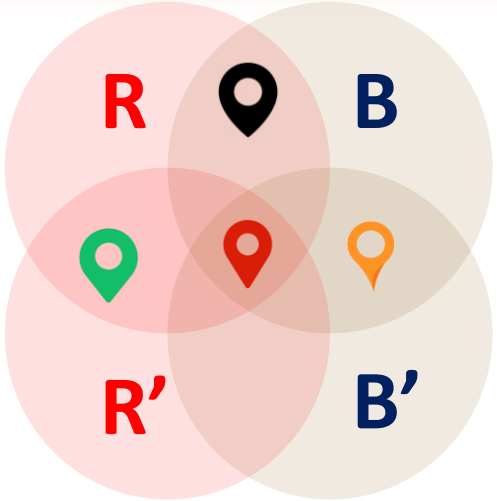


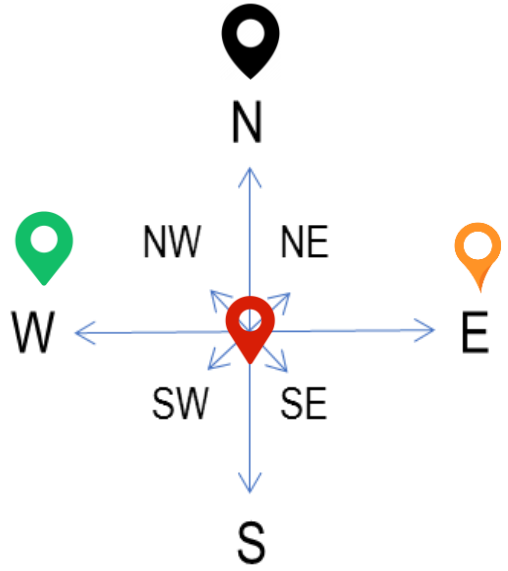


ON-OFF Keying

I2V CHANNEL

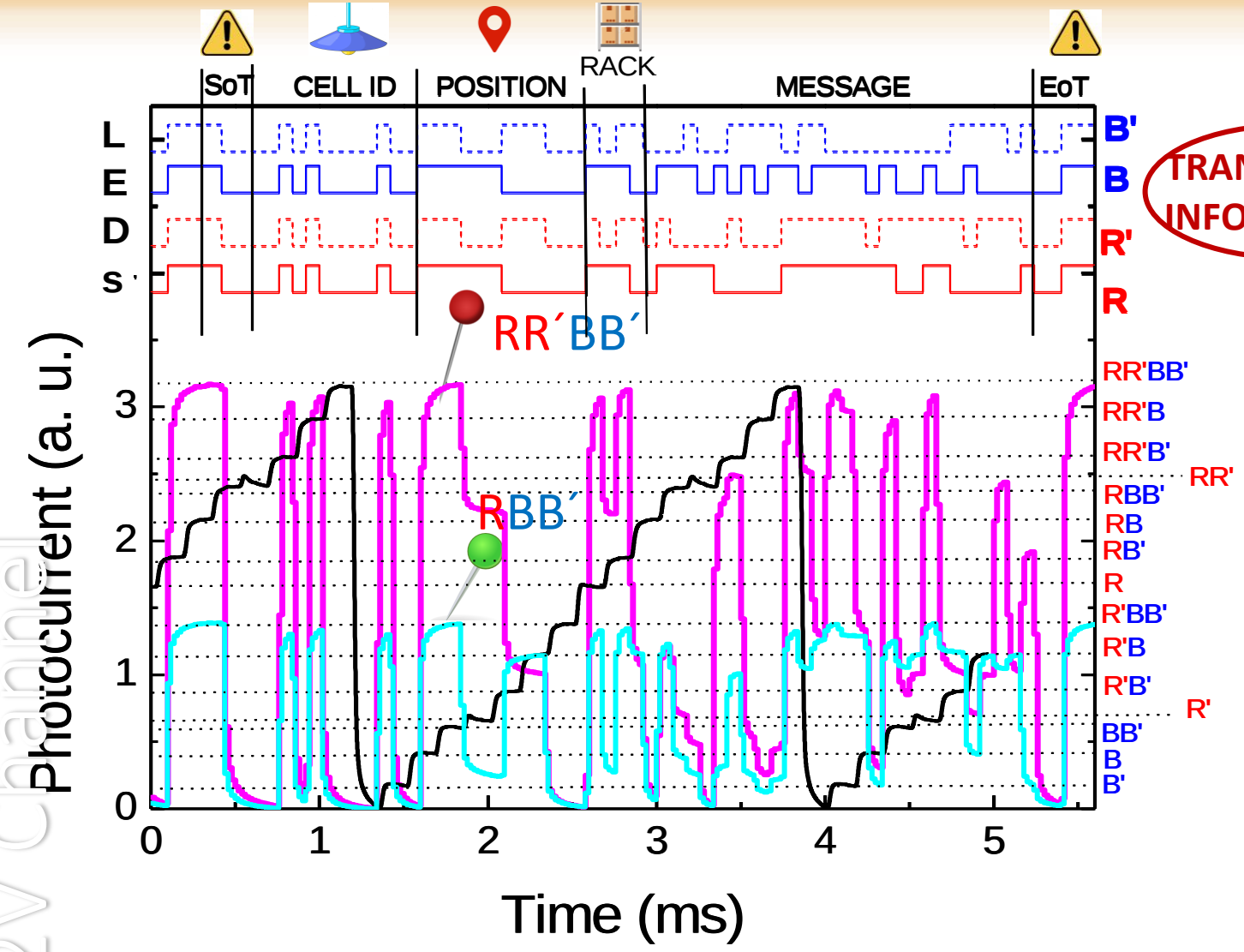




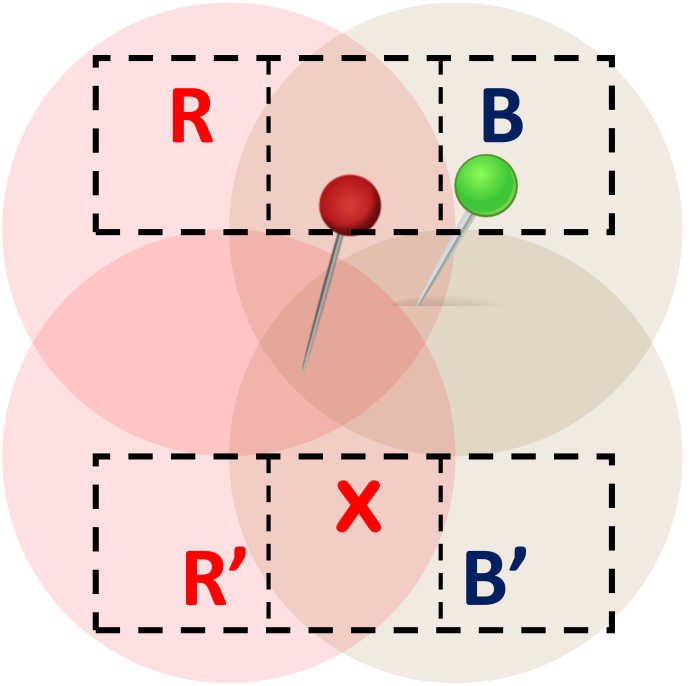


- Simultaneous modulation of **4** emitters
- The resultant optical signal is a combination of 4, 3, 2 or 1 optical signals → **16** possible photocurrent levels
  (The driving current of each LED emitter was adjusted to provide different levels of photo excitation)

I2V CHANNEL



TRANSMITTED INFORMATION



CELL ID: 001010000100
Line: $0101_{|2}$ ($5_{|10}$)
Column: $0010_{|2}$ ($2_{|10}$)

Top emitters: 111 0
Bottom emitters: 101 1

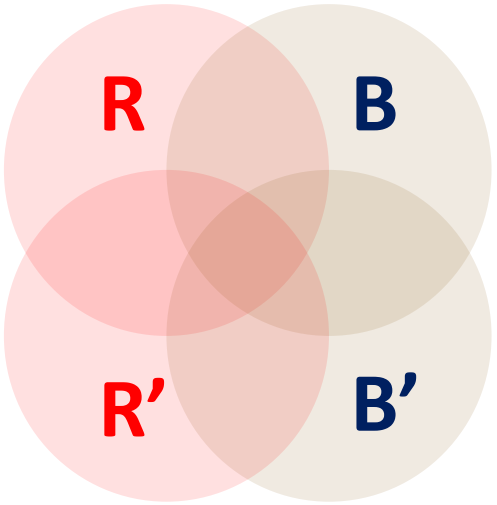
I2V Channel

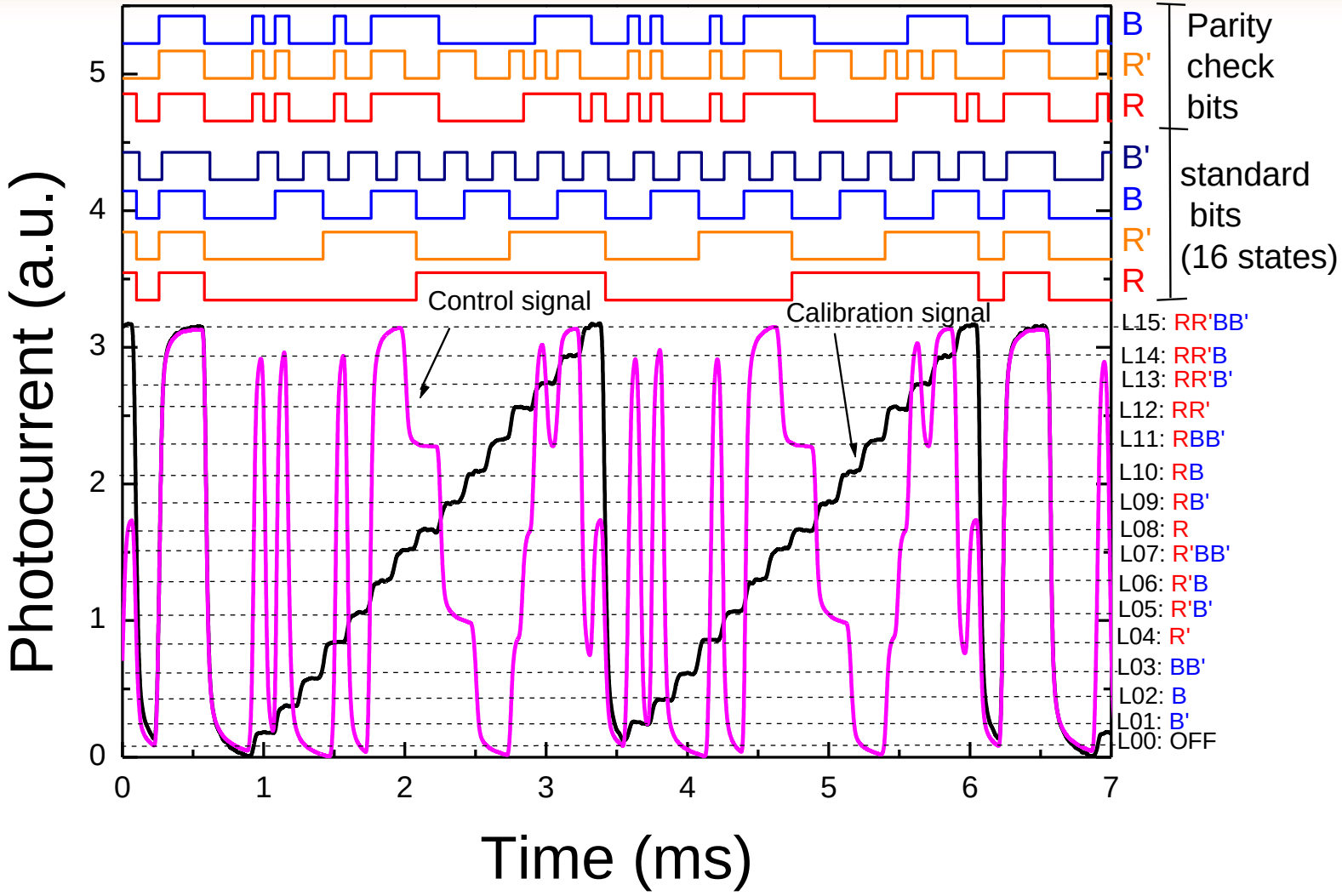
PARITY CHECK BITS

$P1 = R + R' + B'$

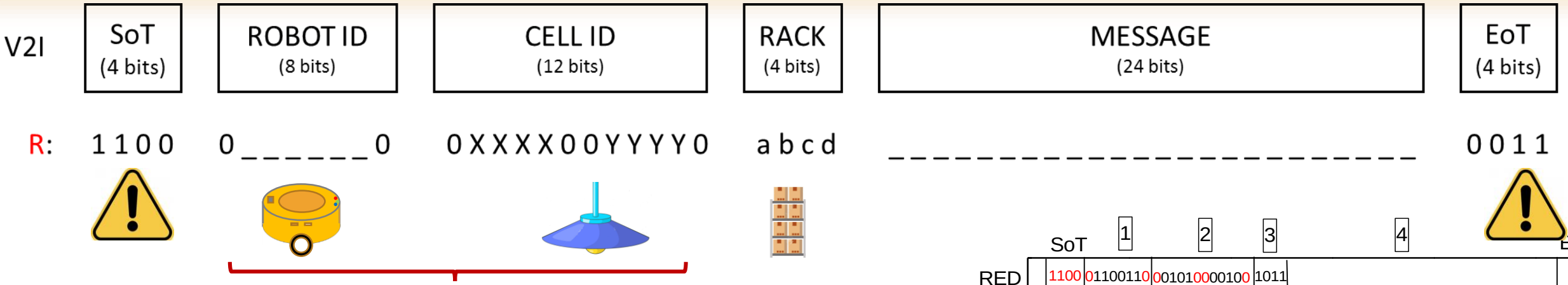
$P2 = R' + B + B'$

$P3 = R + B + B'$



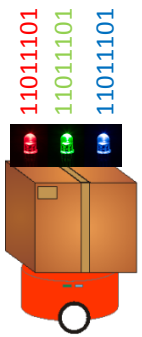


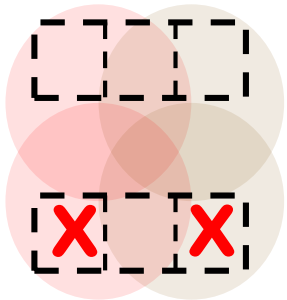
V2I CHANNEL



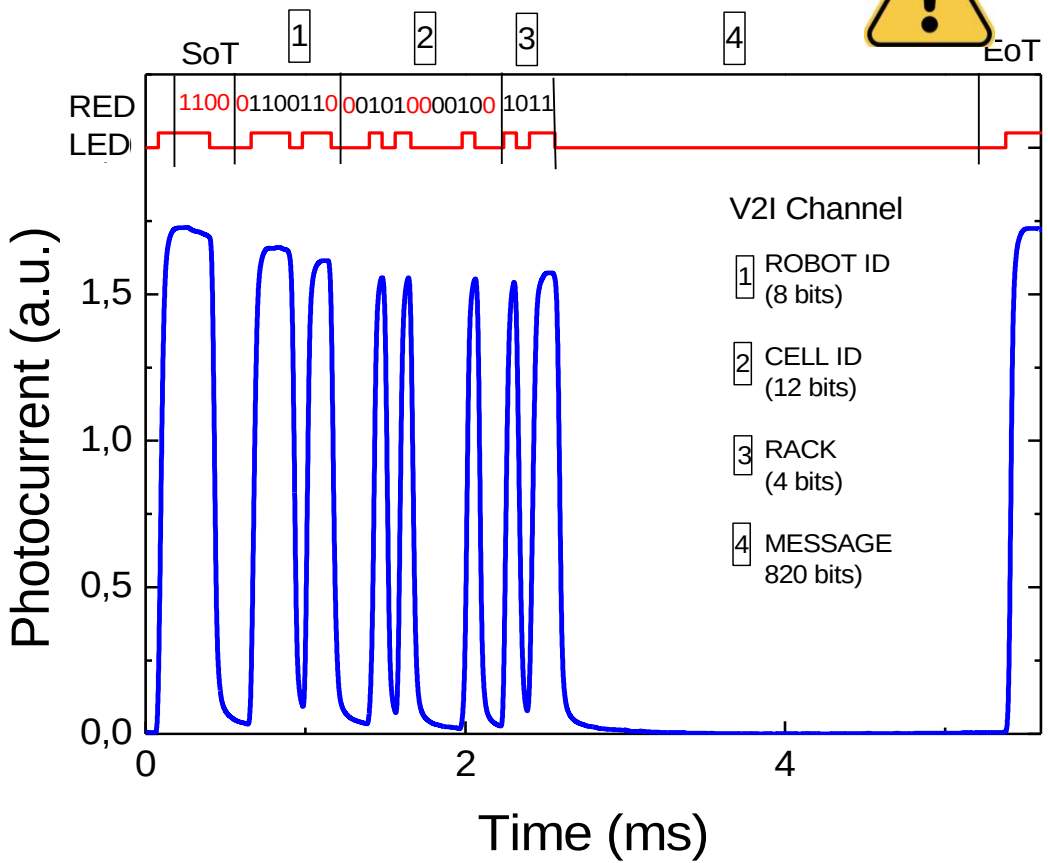
ID of both partners

- ROBOT ID: $01100110_{|2}$ ($118_{|10}$)
- CELL ID: $1100_{|2}$ ($5_{|10}$) & $0010_{|2}$ ($2_{|10}$)
- RACK: items from rack a and c located at the south direction (forward lane) were removed





(5,2)



CONCLUSIONS

- ✓ Bi-directional communication using VLC has been addressed in a robot navigation system inside a warehouse.
- ✓ Different links were proposed to establish I2V and V2I communication.
- ✓ Definition of specific codes for each link using 64 bits word. ON-OFF Keying modulation.
- ✓ I2V link – positioning and navigation information using 4 emitters.
- ✓ V2V link - data transmission using a single emitter.
- ✓ Flickering effects were addressed by suitable control of the amount of transitions to zero.
- ✓ Implementation of bit error control schemes.
- ✓ **Future work**
  - ✓ Analysis of the system under other background illumination sources (noise, photodiode saturation…).