TUTORIAL I

SENSORCOMM 2018
September 16, 2018 to September 20, 2018 - Venice, Italy

"Visible light communications in smart road infrastructures"

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ACKNOWLEDGEMENTS

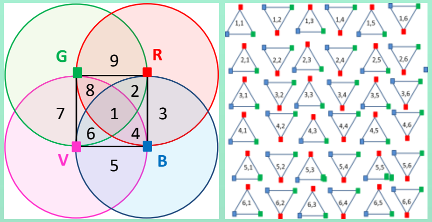
- FCT – ref. UID/EEA/00066/2013
- IPL/2017/EmGraph/ISEL
- IPL/2017/SMART_VeDa/ISEL.

III Work Area:
"Indoor positioning using a-SiCH technology"

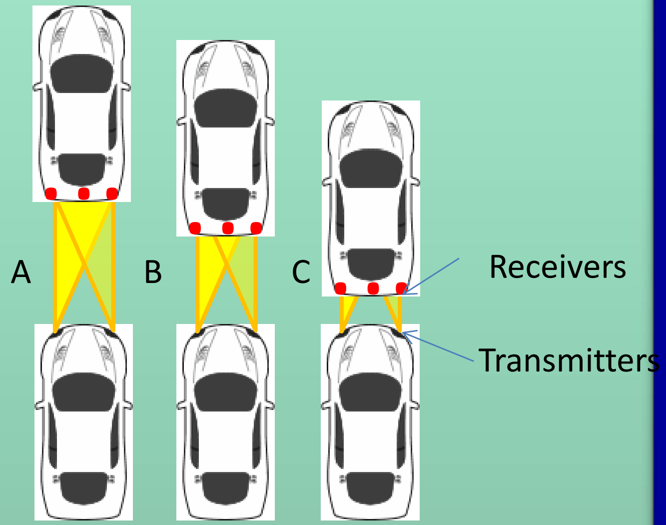
- Positioning, also known as localization, is the process of determining the spatial position of an object or person.
- The leading technologies (GPS and mobile networks) are not suitable for use within buildings.
- The omnipresence of indoor lighting makes it an ideal vehicle for pervasive communication with mobile devices.
- The SiC optical processor for indoor positioning is realized by using a SiC pin/pin photodetector.
- Additional parity logic operations are performed and checked for errors together.

Outline

- **An optical full-adder.**
  Additional parity logic operations
  How do error correcting codes work?
- **Topologies**



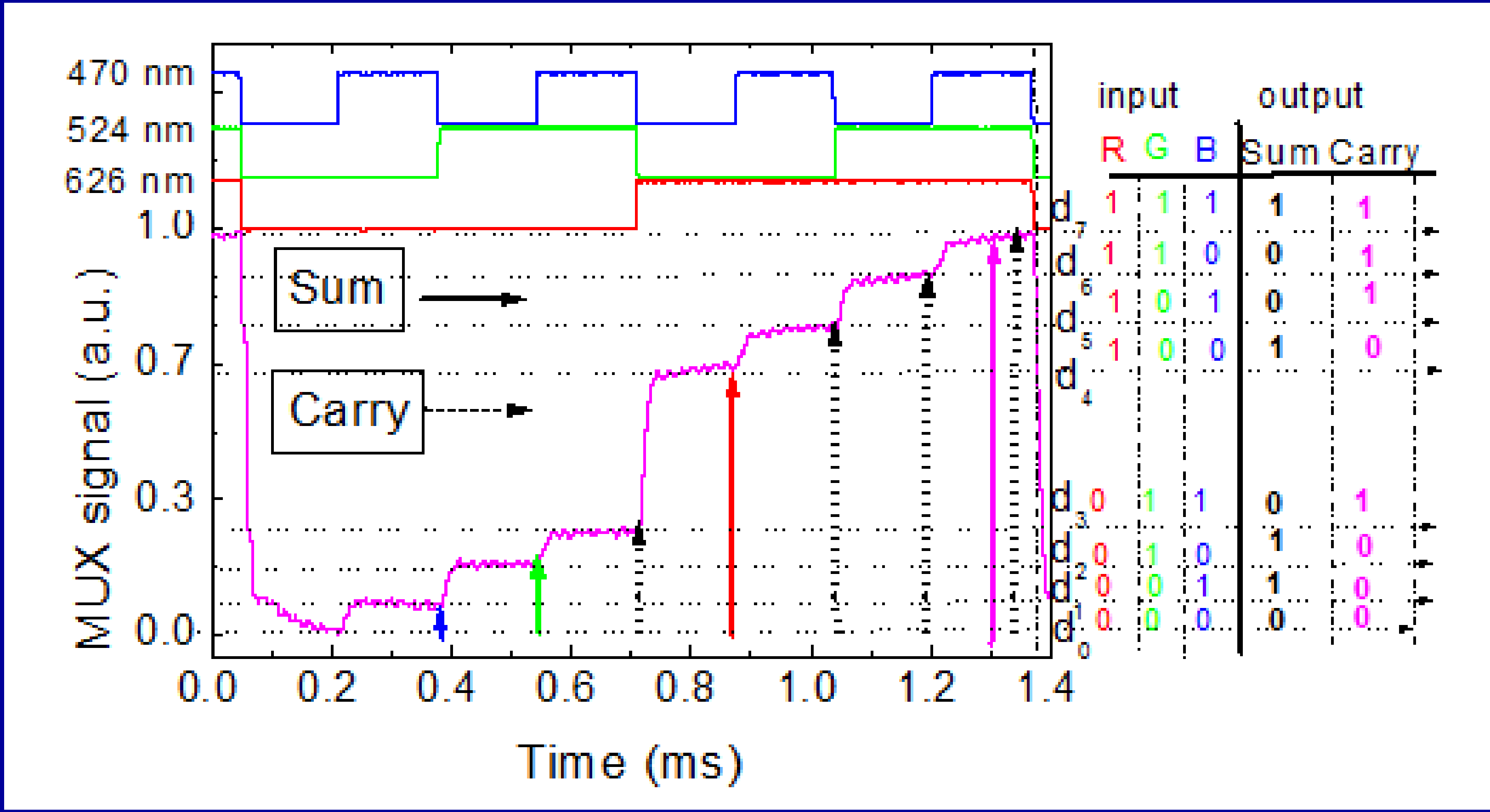
- **System Configuration**
  Transmitter
  Receiver
  Driving range distance



- **Conclusions and future trends.**

MUX signal, output levels and truth table SiC full adder

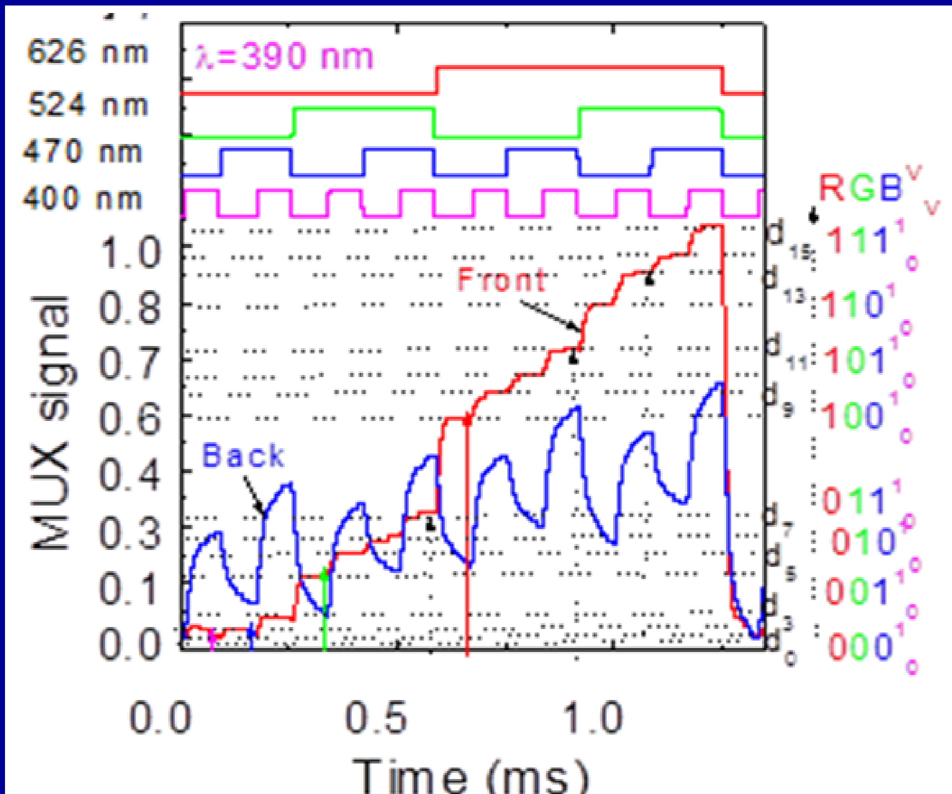
SiC tuneable background nonlinearity-based RGB logic gates

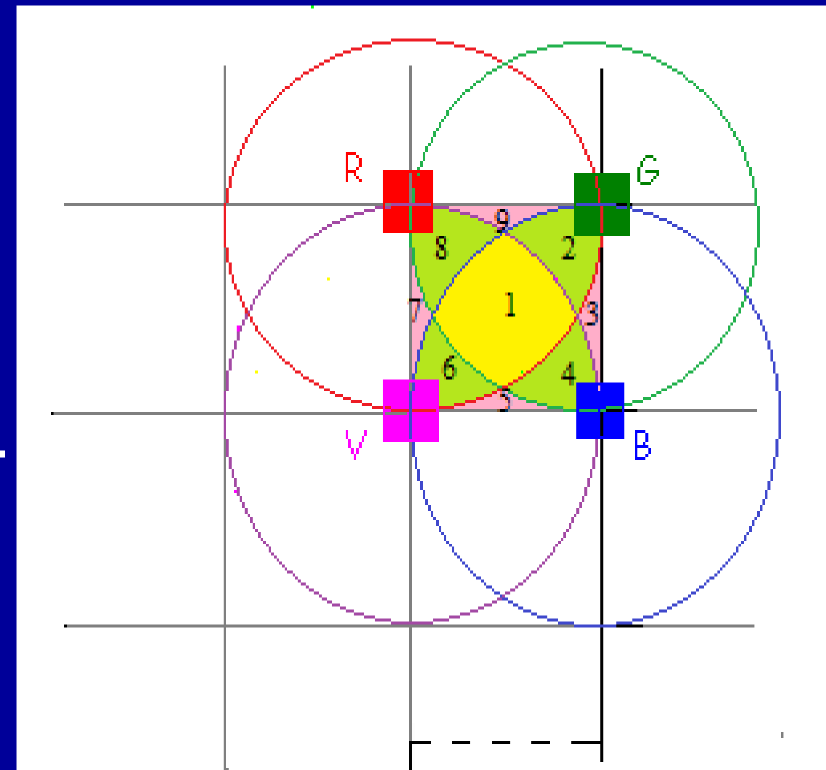


Data shows that when one or all of the inputs are present it corresponds to four different levels (d1, d2, d4, d7), the system behaves as a XOR gate i.e. Sum =1	If two or three input channels are on, the system acts as AND gate. This corresponds to four separate levels (d3, d5, d6, d7) and indicates the presence of CARRY bit

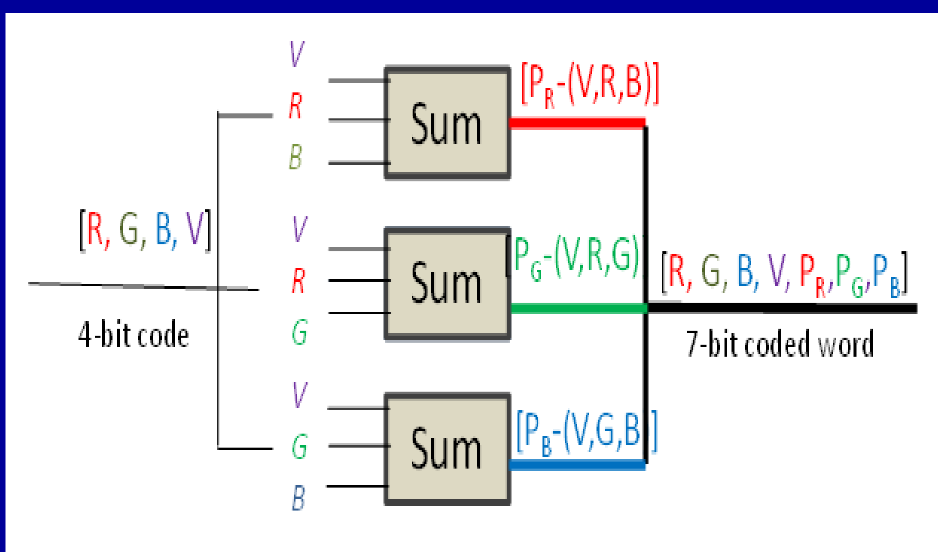
HOW DO SYNDROME NAVIGATOR WORK?

Coder/decoder device





The next closest grid positions



Three-bit additions of violet signal
with two additional bits of RGB
Generated parity bits are SUM bits
Strongly enhanced back signal
levels

HOW DO ERROR CORRECTING CODES WORK?

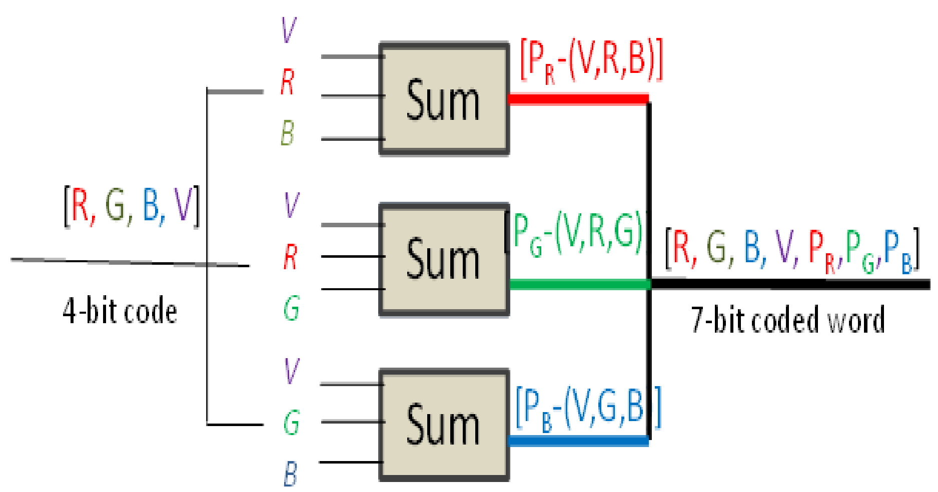
Coder/decoder device

Matrix notation

G Generator matrix

H Parity check matrix

S Syndrome helps the receiver diagnose the “illness” (errors) in the received data.



$$P_R\text{-}(VRB) = V \oplus R \oplus B$$
$$P_G\text{-}(VRB) = V \oplus R \oplus G$$
$$P_B\text{-}(VGB) = V \oplus G \oplus B$$

$$S_i = \begin{bmatrix} r & g & b & v & P_R & P_G & P_B \end{bmatrix} H^T$$

HOW DO ERROR CORRECTING CODES WORK?

Coder/decoder device

$$P_R\text{-}(VRB) = V \oplus R \oplus B$$
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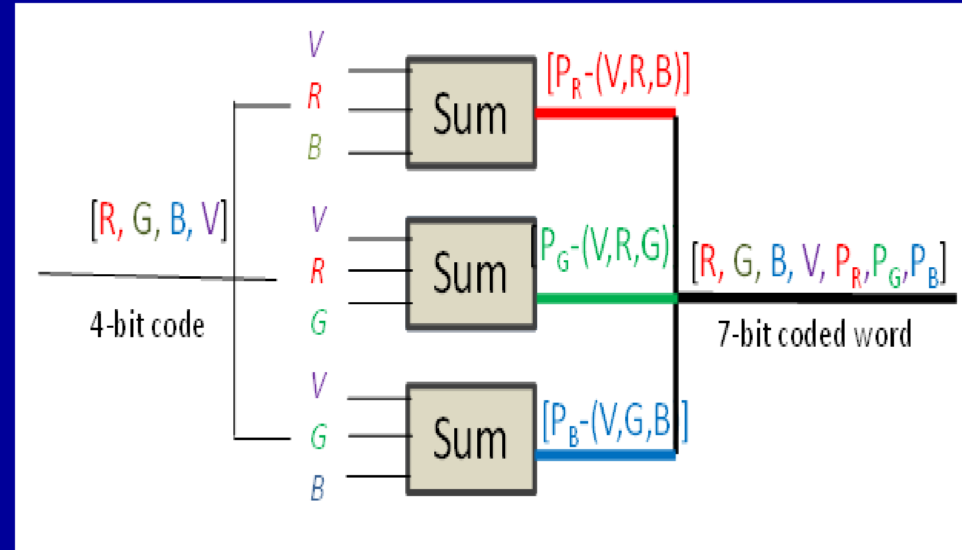
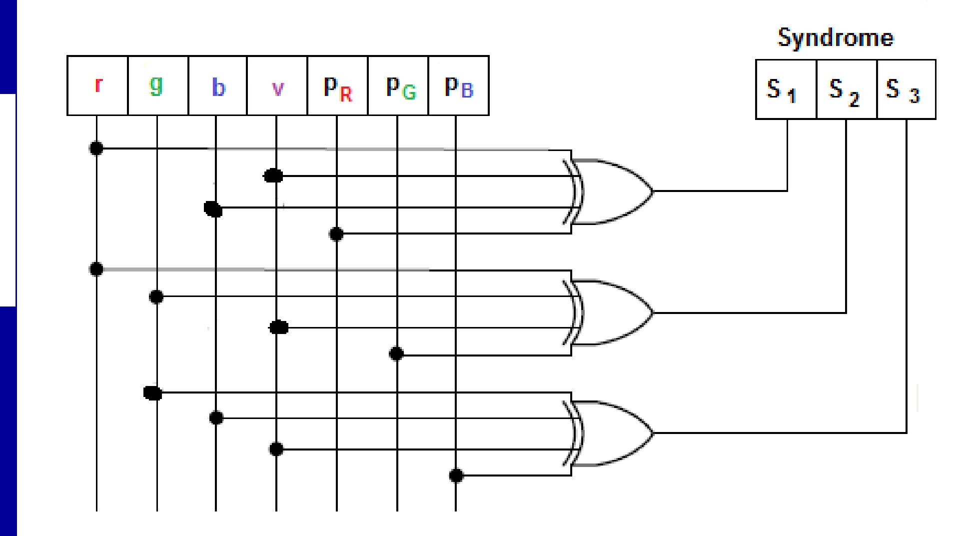
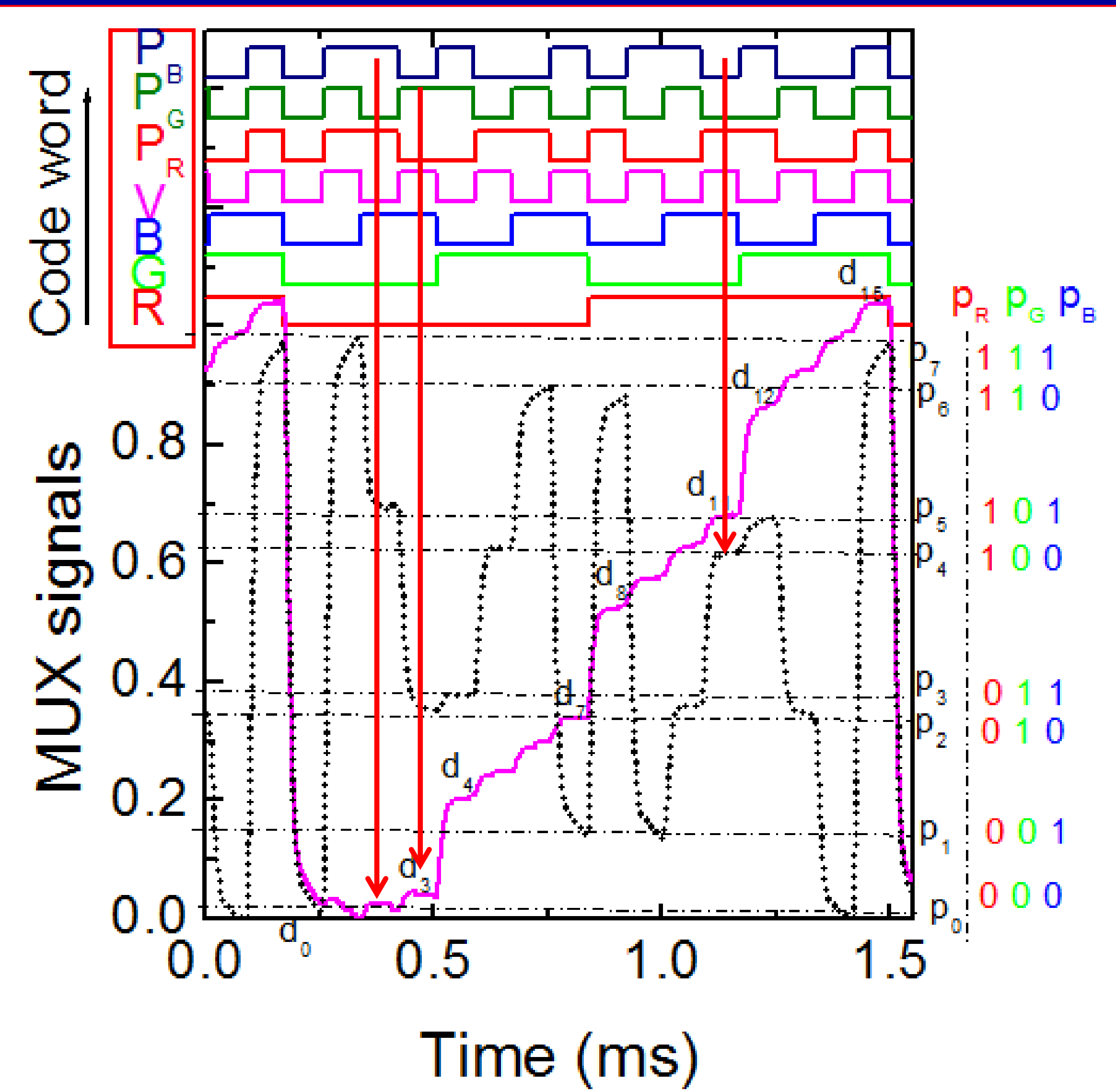


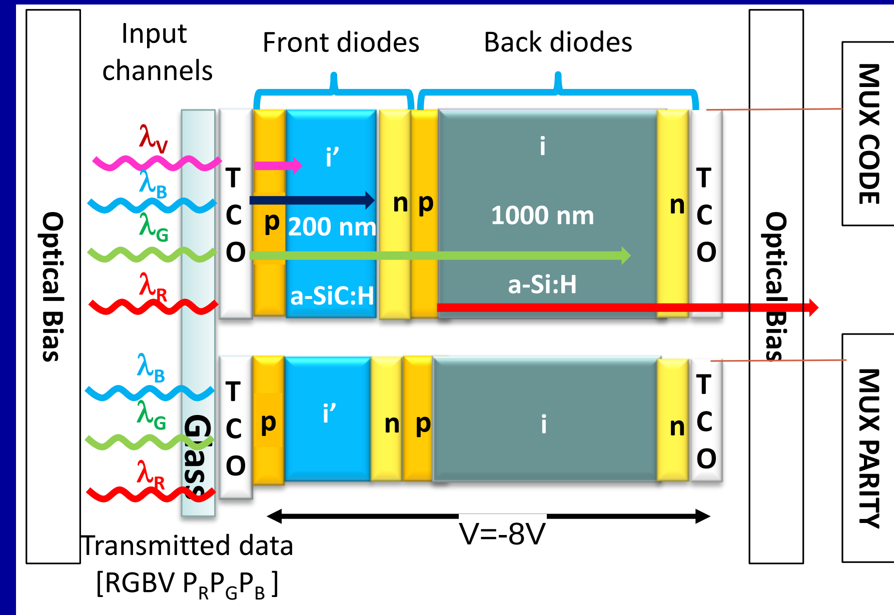
$$S_i = [r \quad g \quad b \quad v \quad P_R \quad P_G \quad P_B]H^T$$



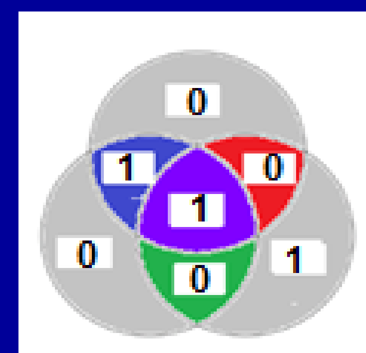
Matrix notation
Generator matrix G
Parity check matrix H
Syndome helps the receiver diagnose the “illness” (errors) in the received data.
The hardware syndrome generator implementation

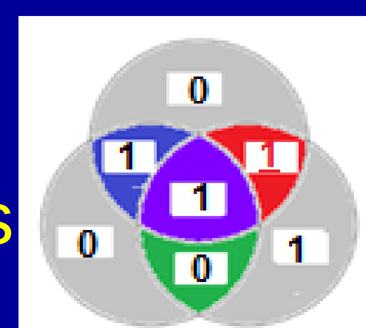
Device configuration and operation

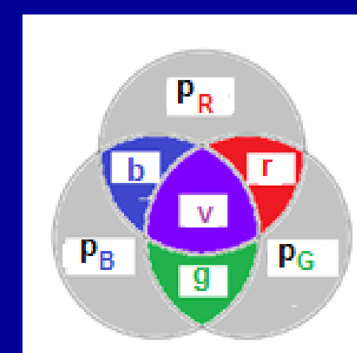




(Intuitive representation)

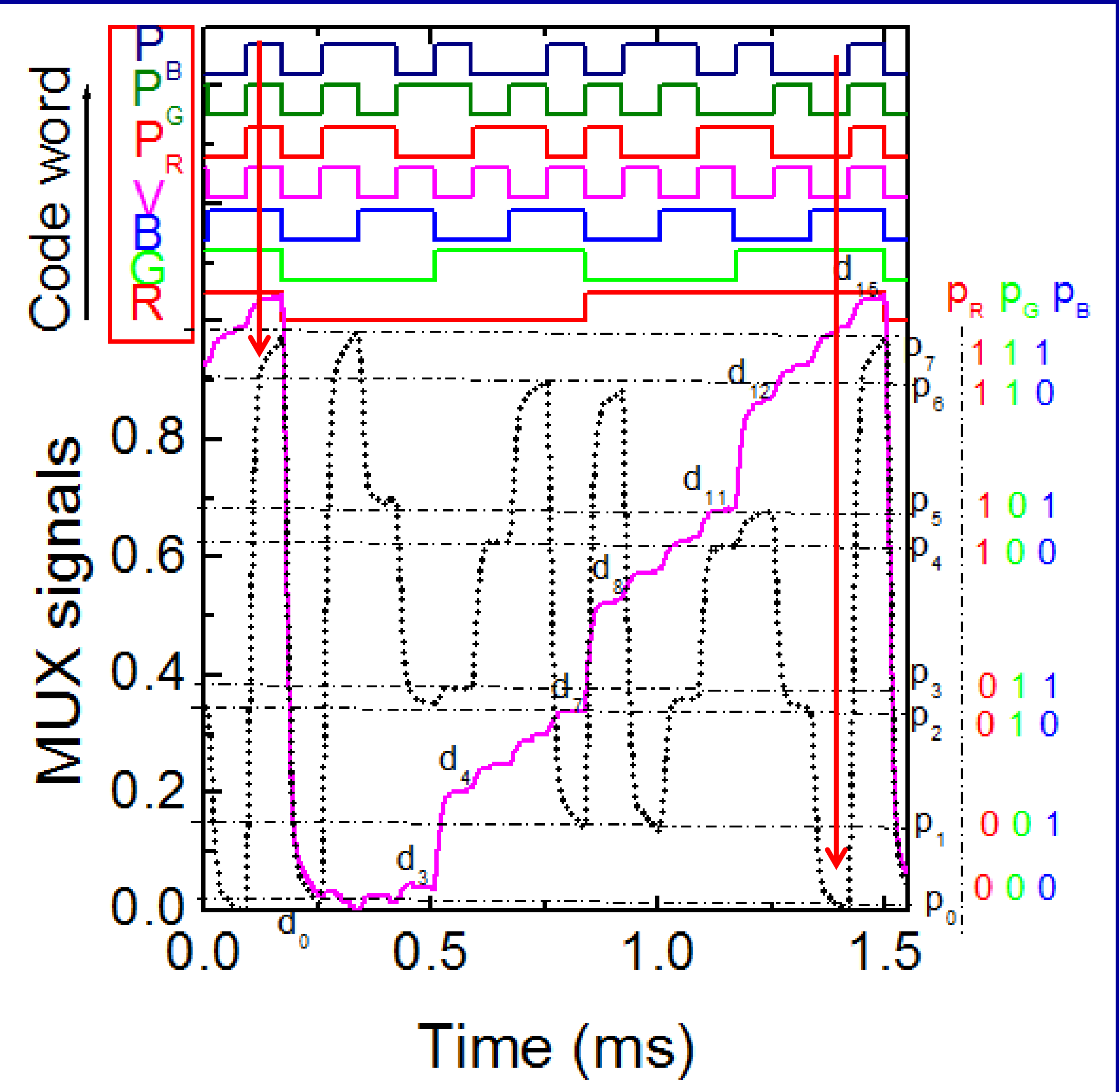




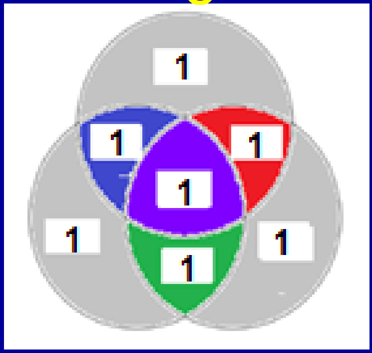


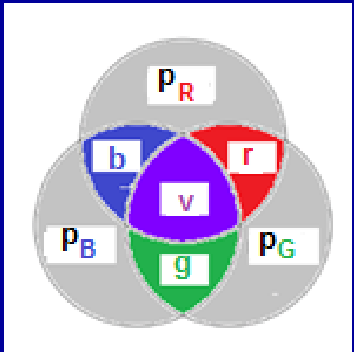
Code and parity MUX/DEMUX signals

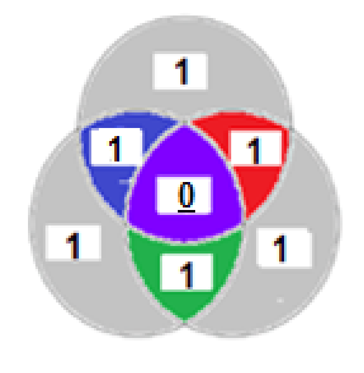
Design of SiC syndrome generators



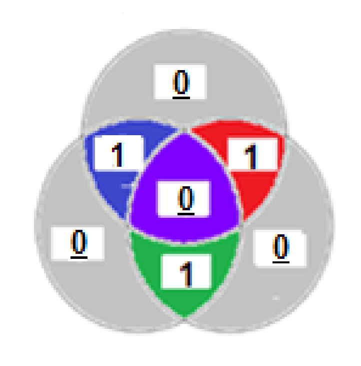
Message without error







VIOLET BIT CORRUPTED



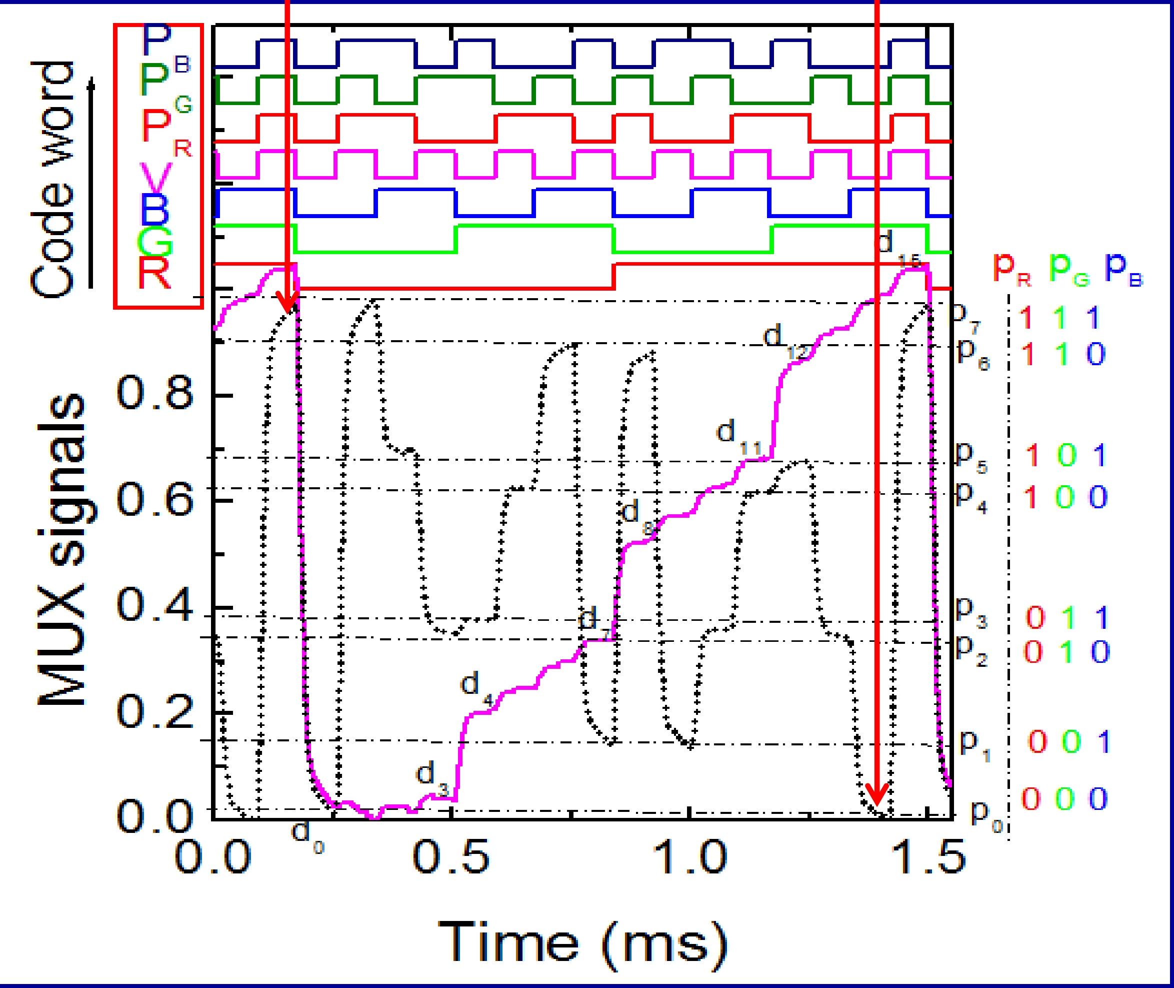
Parity bits recalculated

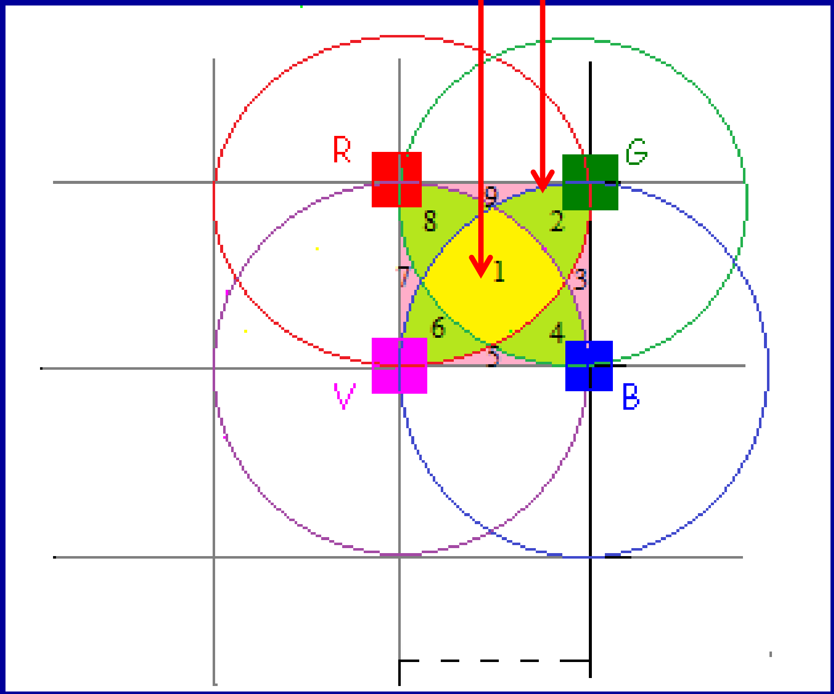
ADDING PARITY BITS

S= [1 1 1]

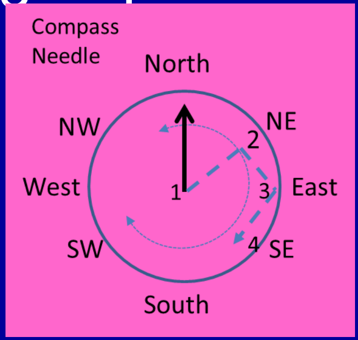
Syndrome for violet bit

Design of SiC syndrome generators



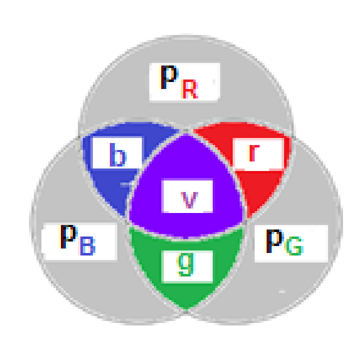


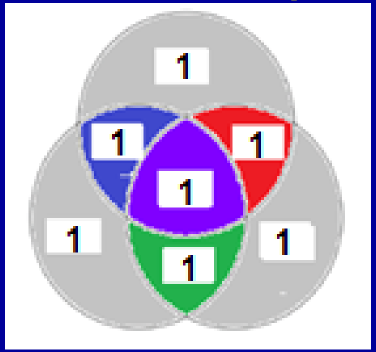
The next closest grid positions

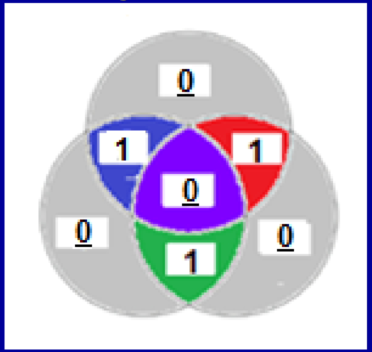


(Intuitive representation)

(Parity bits recalculated)





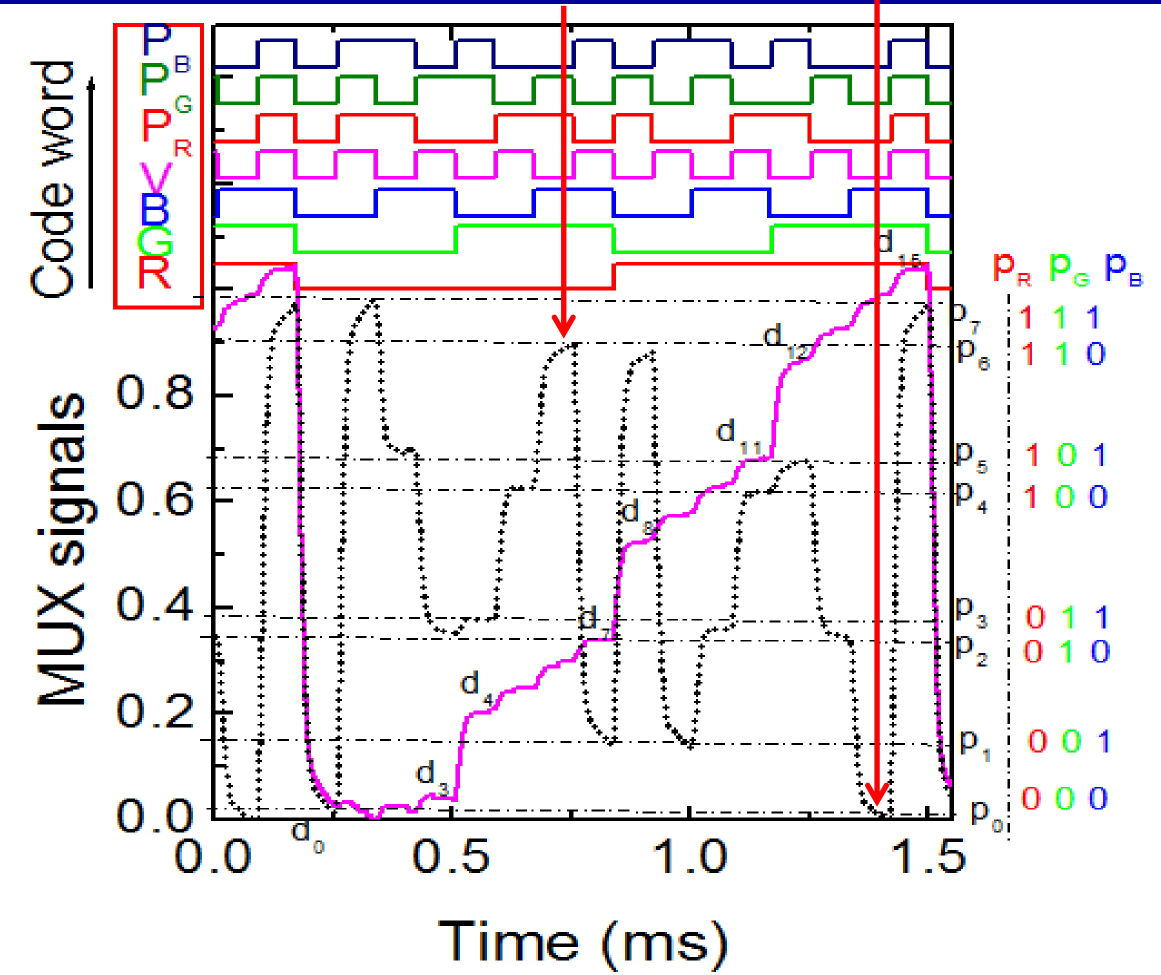


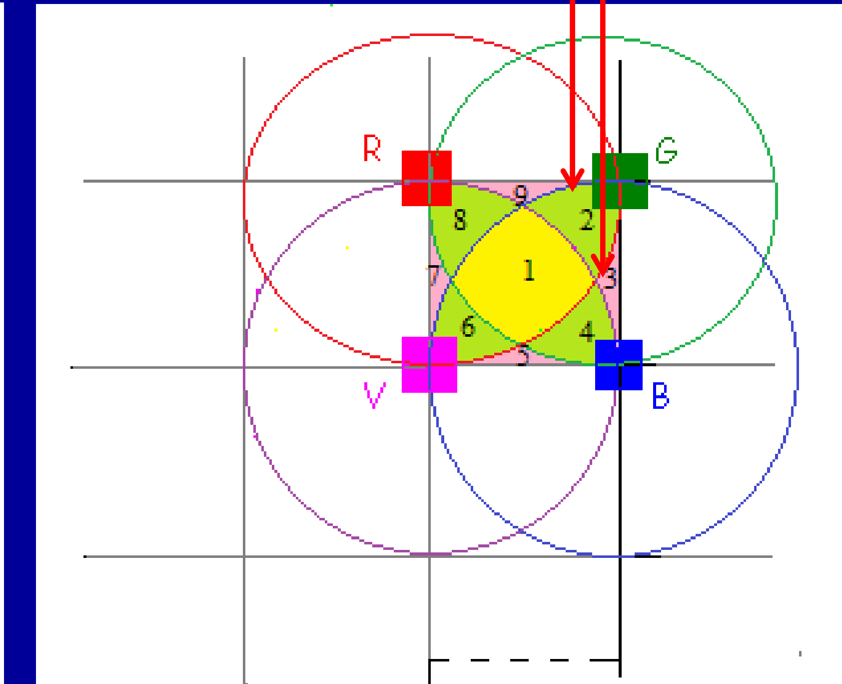
ADDING PARITY BITS

S= [1 1 1]

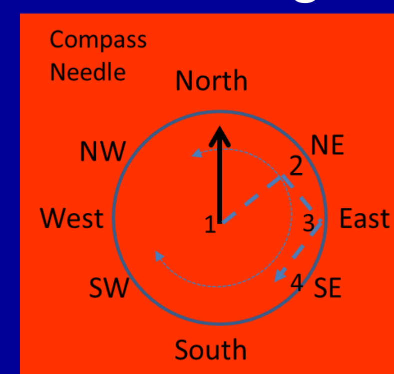
Syndrome linked to violet bit

Design of SiC syndrome generators

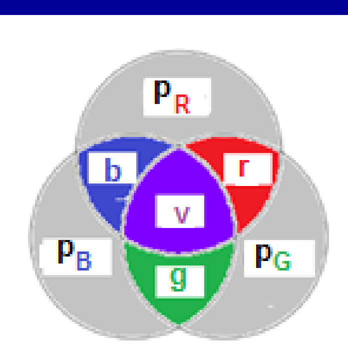


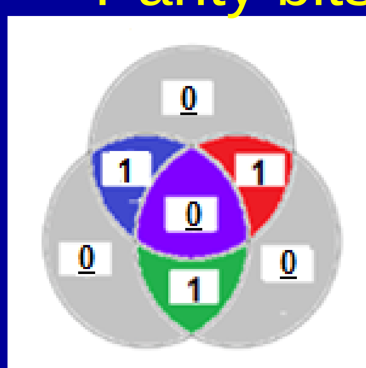


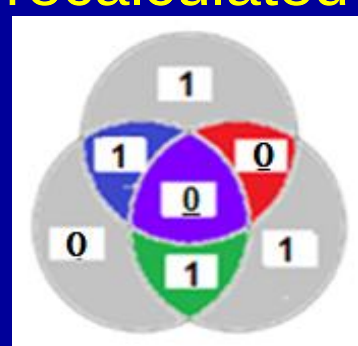
The next closest grid positions



Parity bits recalculated





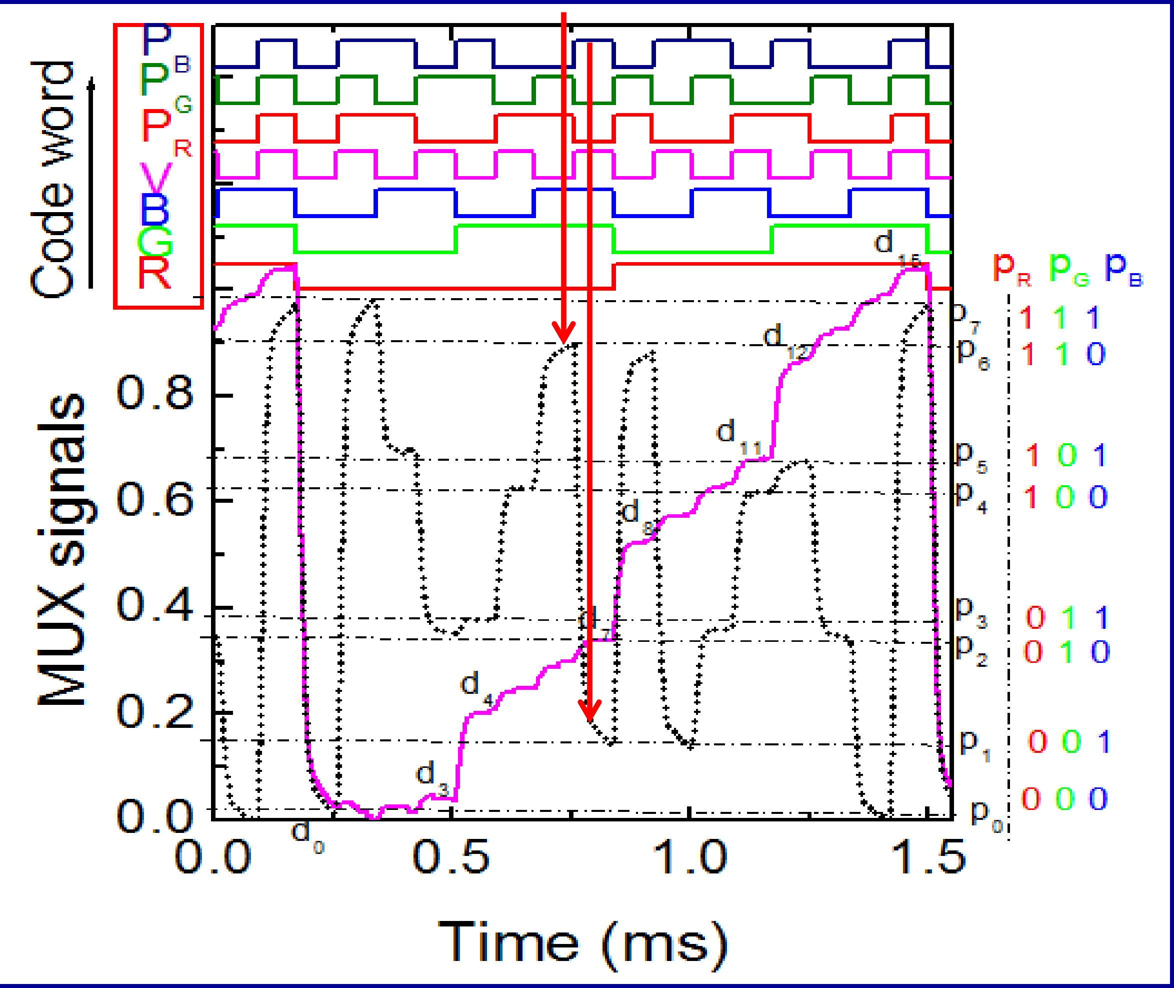


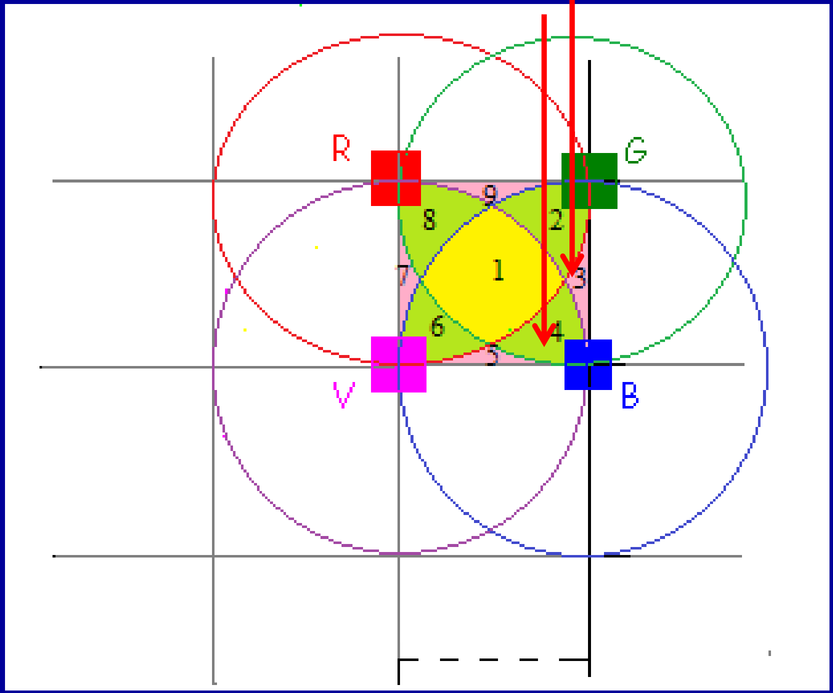
ADDING PARITY BITS

S= [1 1 0]

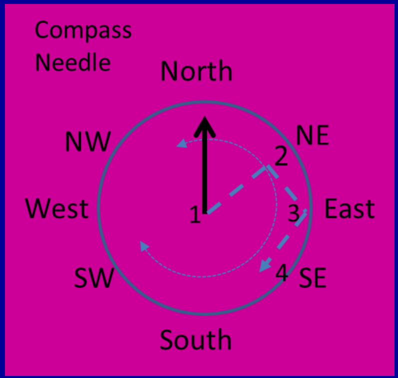
Syndrome linked to red bit

Design of SiC syndrome generators

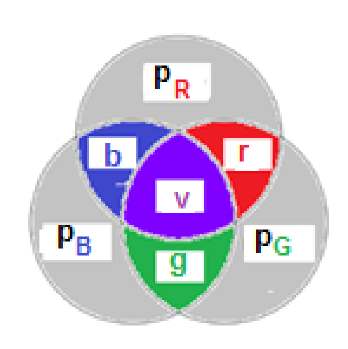


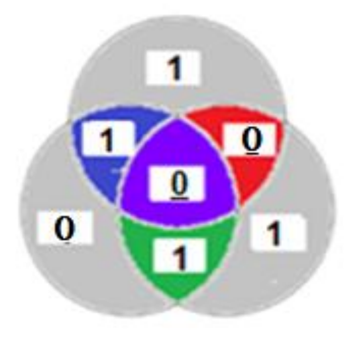


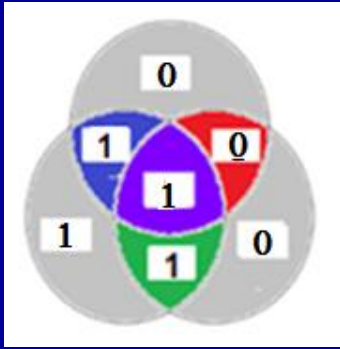
The next closest grid positions



Parity bits recalculated







ADDING PARITY BITS

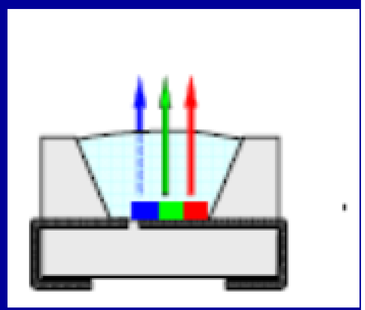
S= [1 1 1]

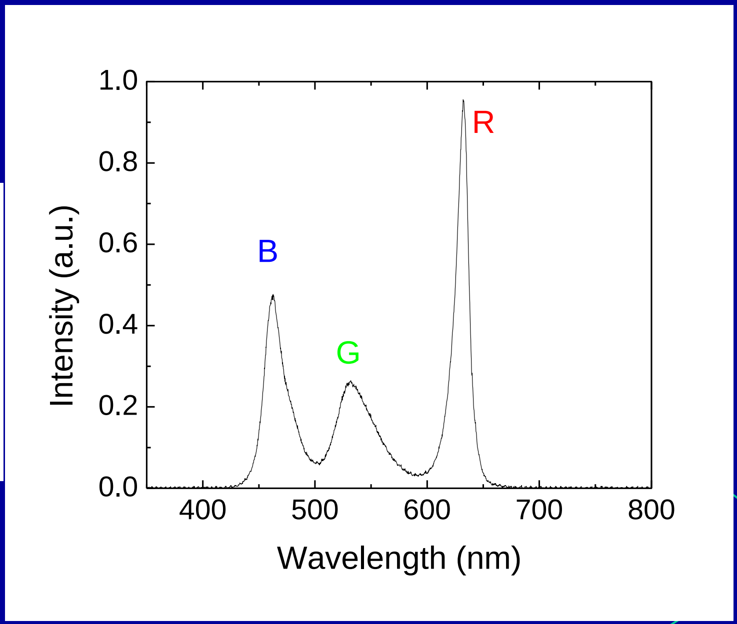
Syndrome linked to violet bit

SYSTEM DESIGN

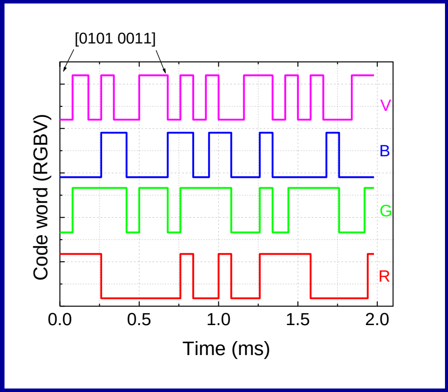
The system is a self-positioning system in which the measuring unit is mobile.
This unit receives the signals from several transmitters in known locations, and has the capability to compute its location based on the measured signals.

Transmitter



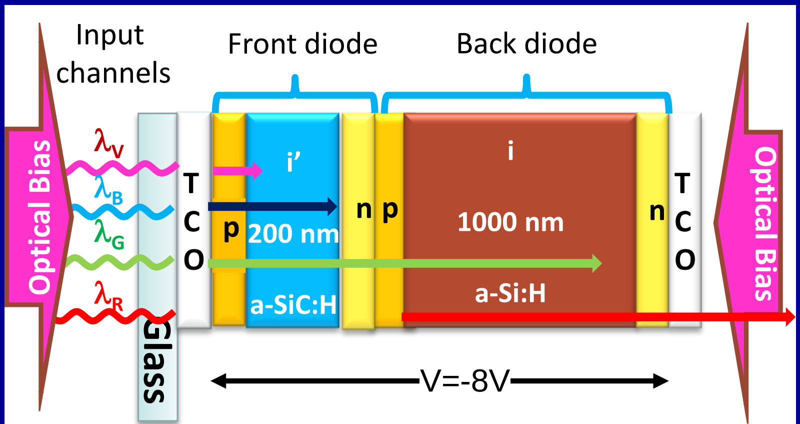


Red, Green and Blue white LED



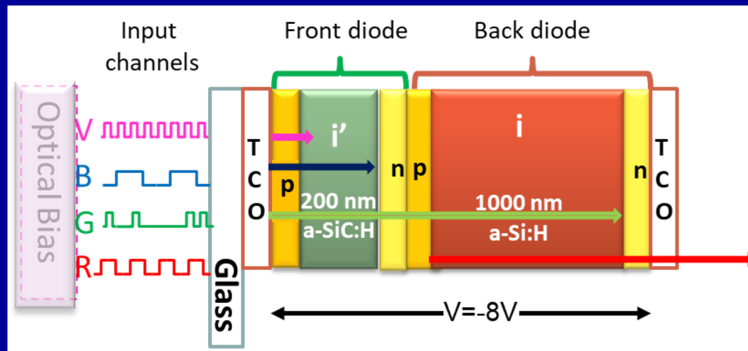
Receiver

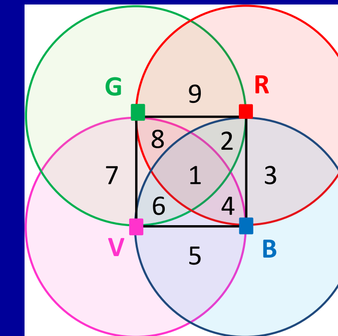
Representation communication
The structure of the frame
synchronization bits.ID´s,…

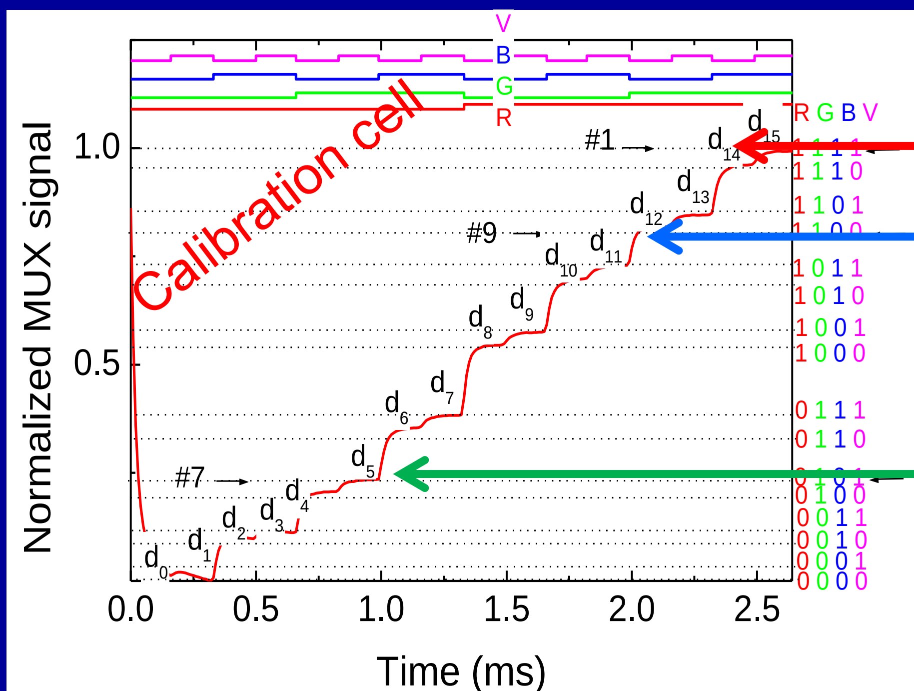


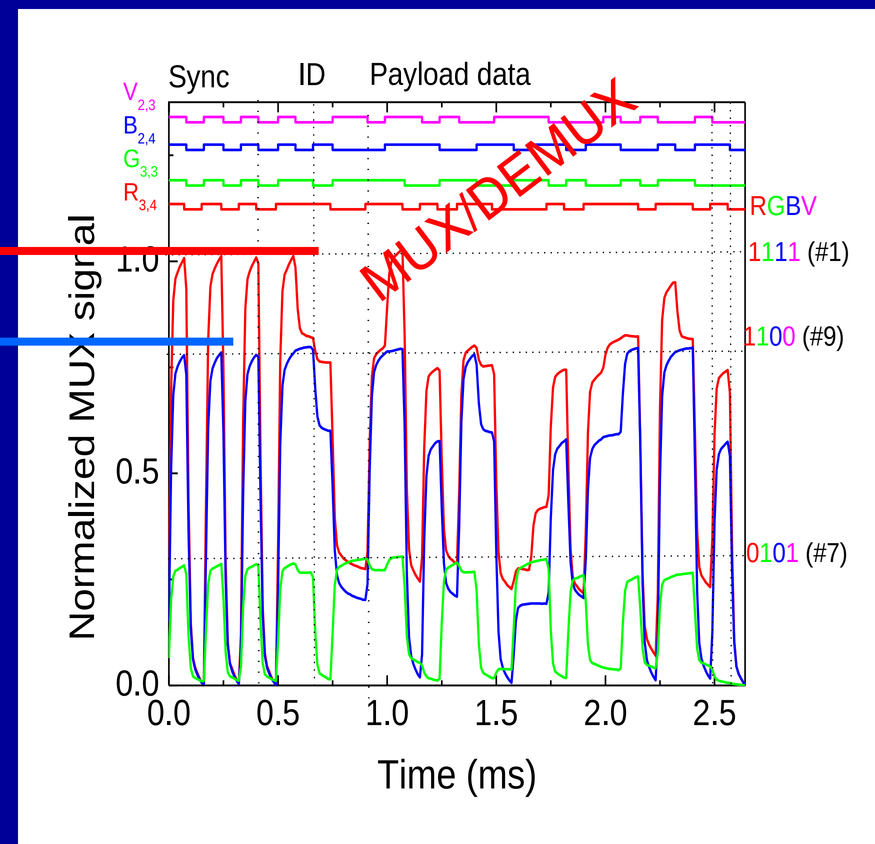
p-i'(a-SiC:H)-n/p-i(a-Si:H)-n heterostructure produced by PECVD.

MUX/DEMUX techniques





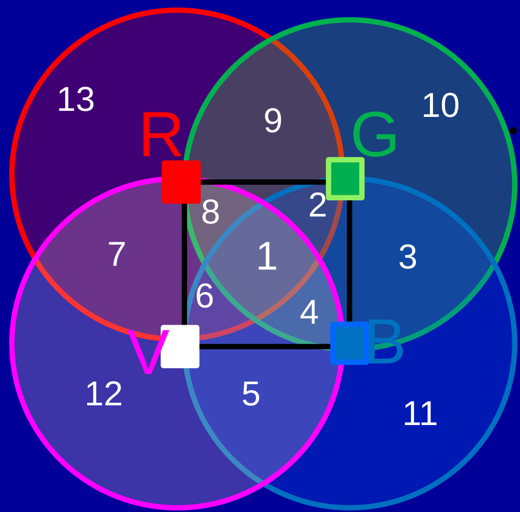




The output presents 2^4 ordered levels each one related with ***RGBV*** bit sequences

TOPOLOGY

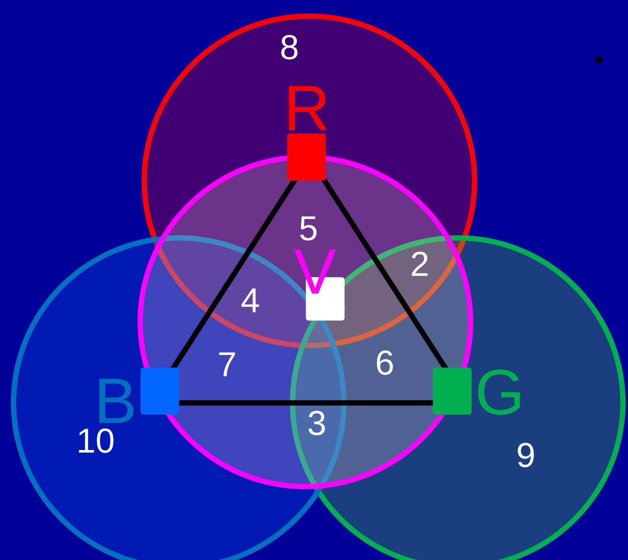
Square



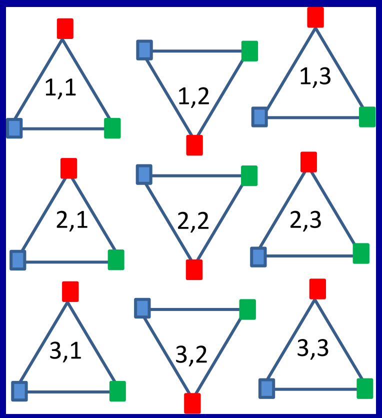
- Four modulated LEDs (RGBV) located at the corners of a square grid.

Region	1	2	3	4	5	6	7	8	9	10	11	12	13
Overlap	RGBV	RGB	GB	GBV	BV	RBV	RV	RGV	RG	G	B	V	R

Triangular



- Four modulated LEDs (RGBV), three of them (RGB-LED) are located at the vertices of an equilateral triangle and a fourth one (V) is located at its centroid.

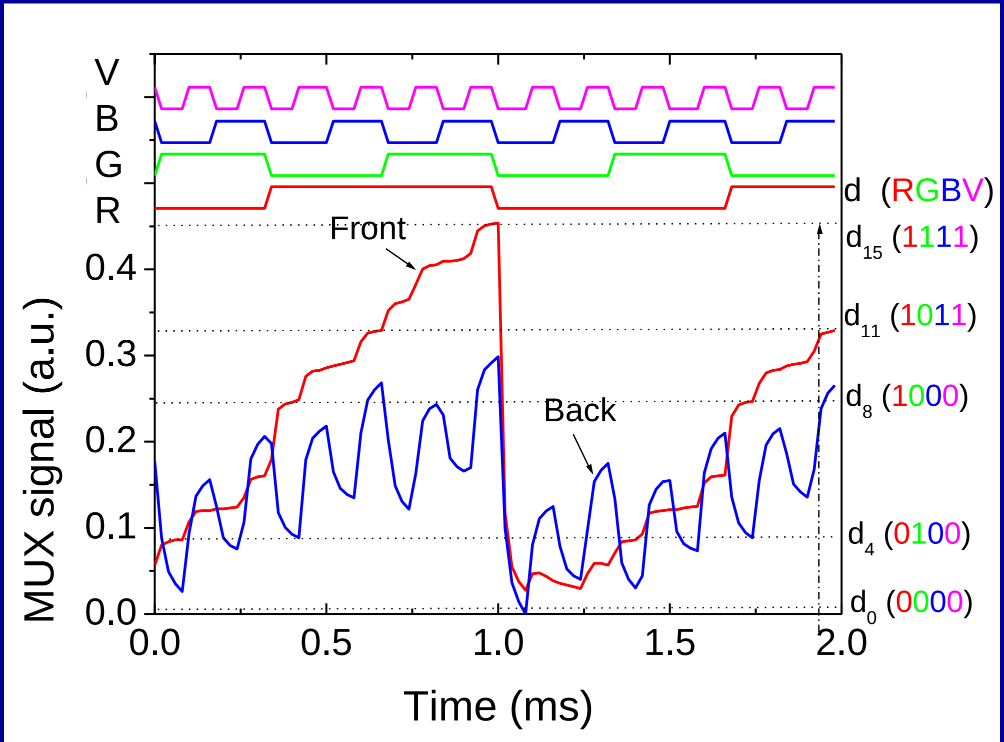


cluster

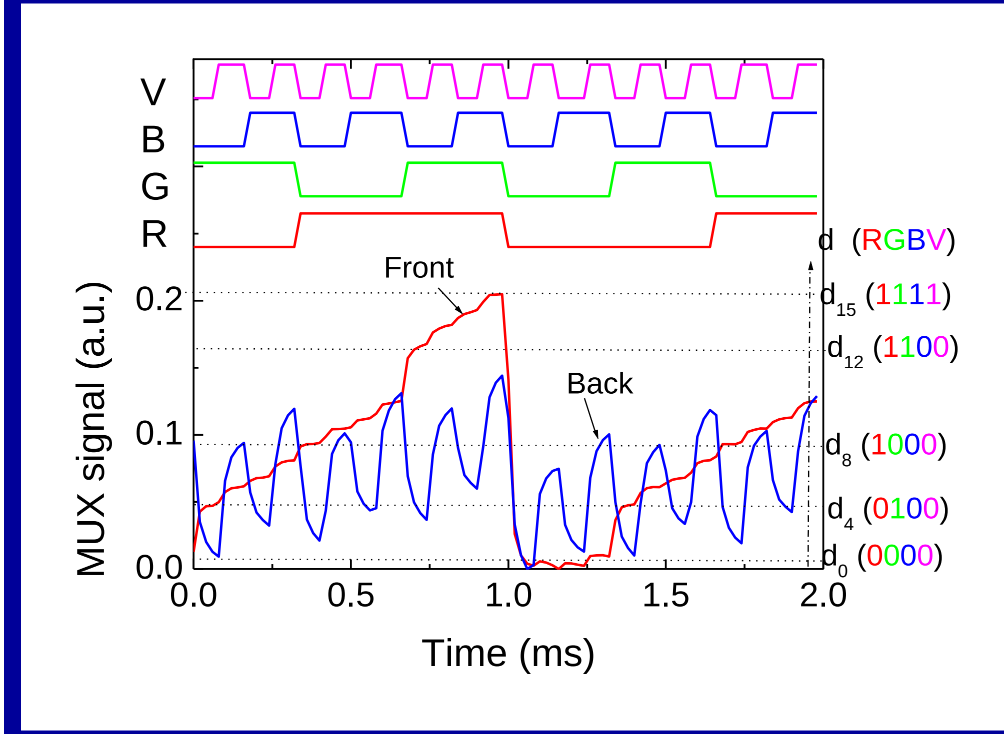
Region	1	2	3	4	5	6	7	8	9	10
Overlap	RGBV	RGV	GBV	RBV	RV	GV	RB	R	G	B

Decoding algorithm

Square topology

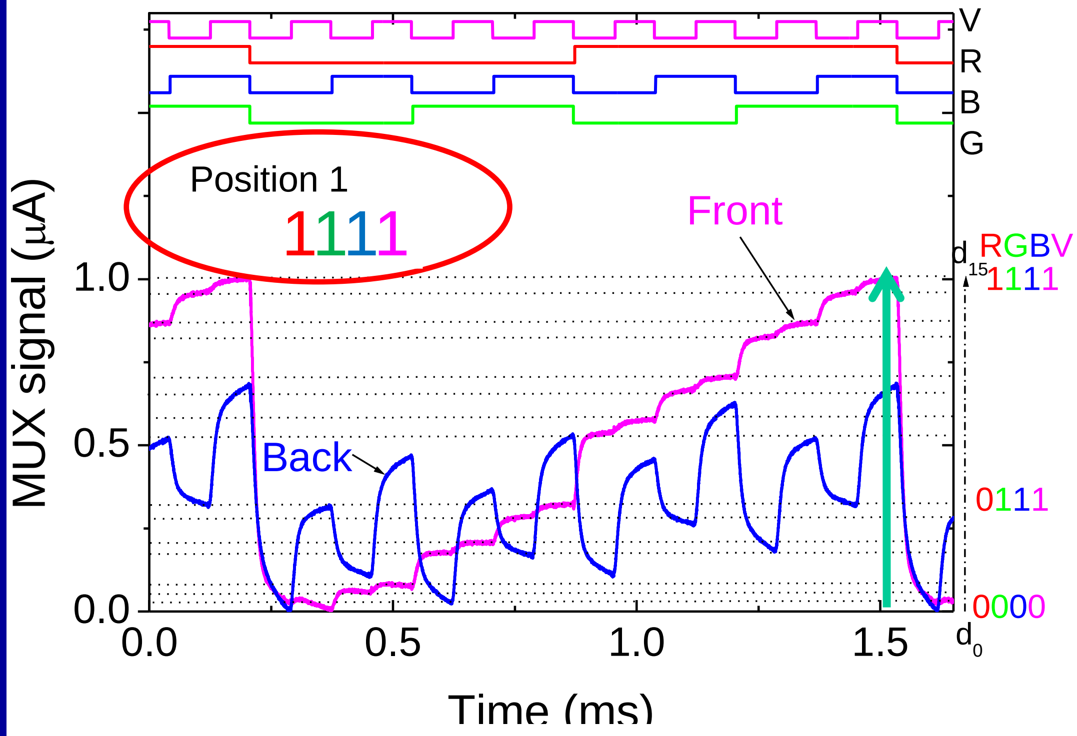


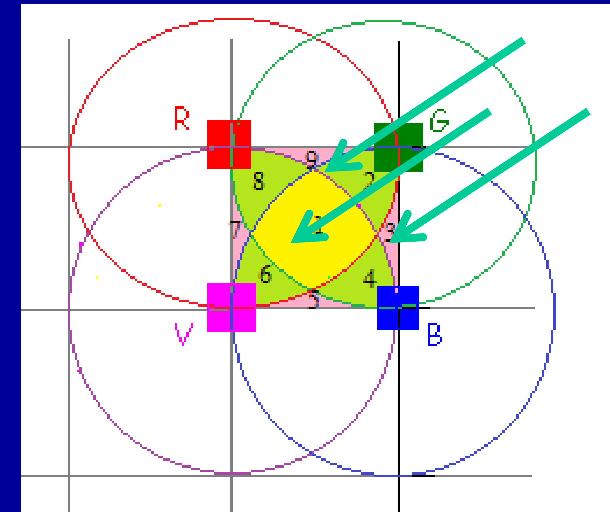
Triangular topology

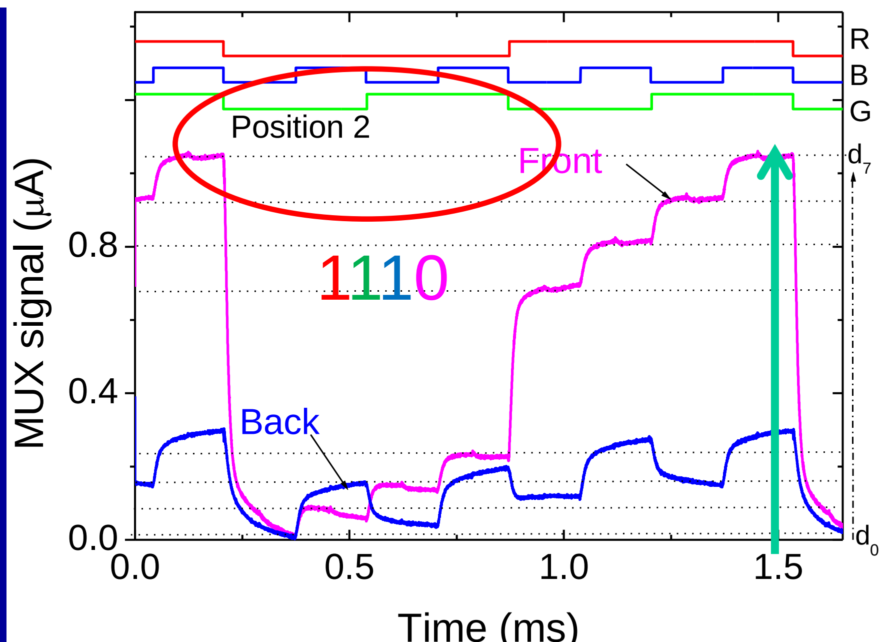


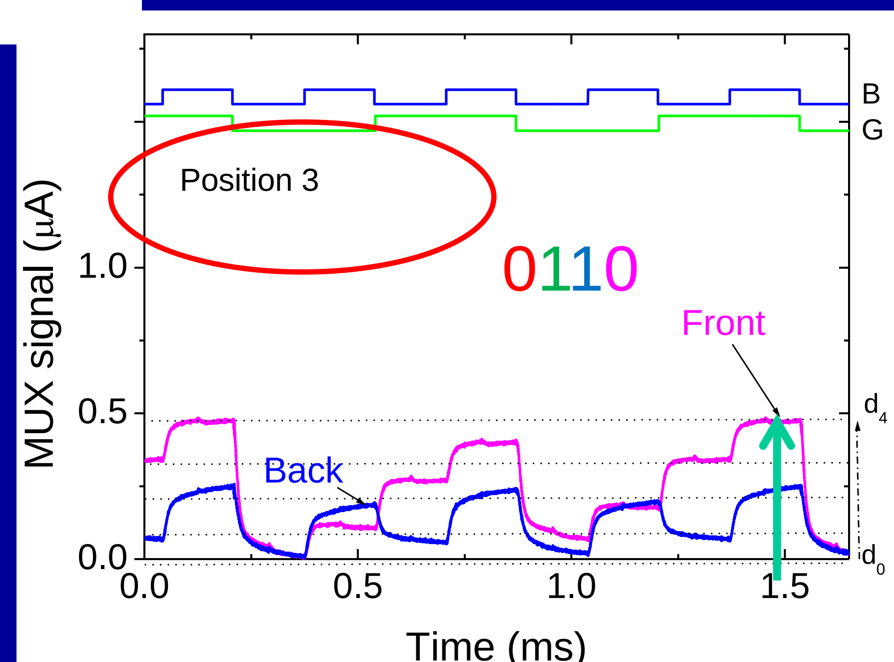
- 2^n ordered levels pondered by their optical gains are detected and correspond to all the possible combinations of the *on/off* states.
- The background acts as selector that chooses one or more of the 2^n sublevels, with *n* the number of transmitted channels, and their *n*-bit binary code .
- By assigning each output level to a n digit binary code the signal can be decoded. A maximum transmission rate capability of 30 Kbps was achieved.

POSITIONING MUX/DEMUX SIGNALS



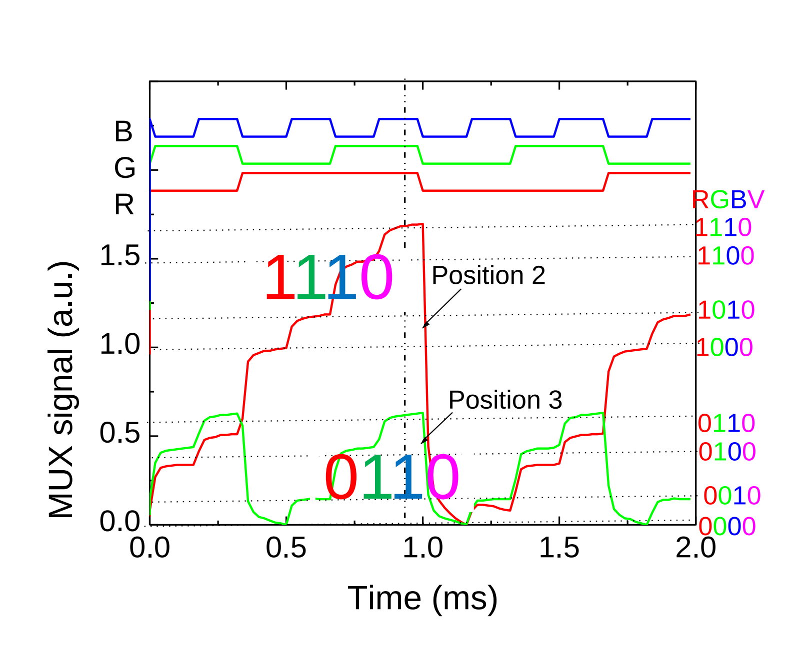


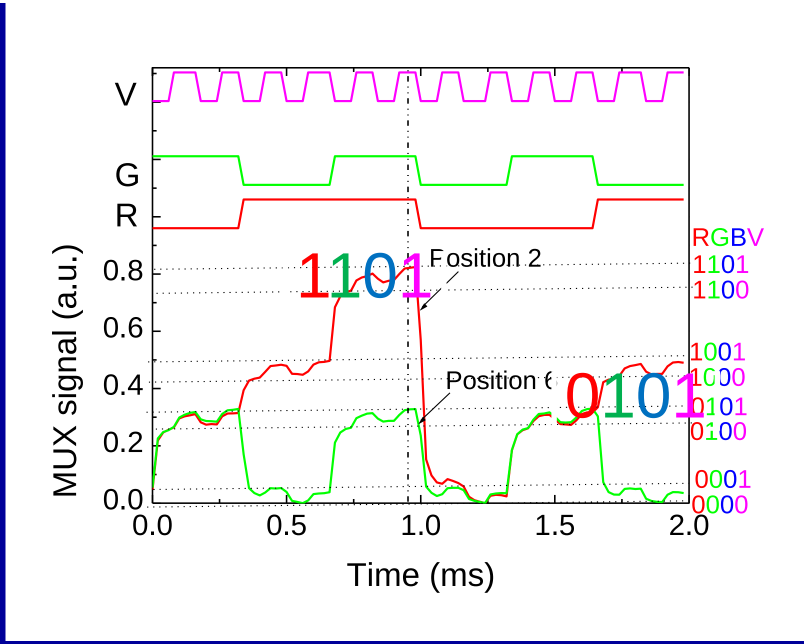




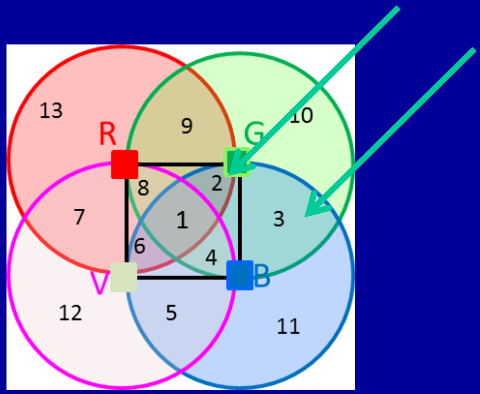
- Looking to the different levels, we have ascribed a binary code of 4 bits (RGBV) to each position, where 1 means that the channel is received and 0 that is absent .

POSITIONING

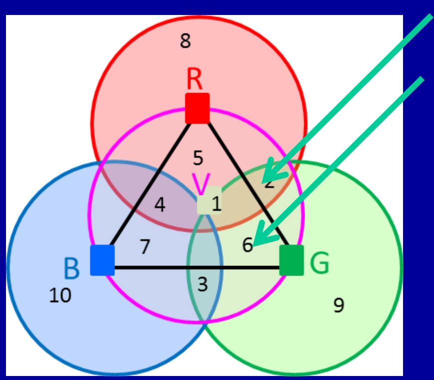




Square topology

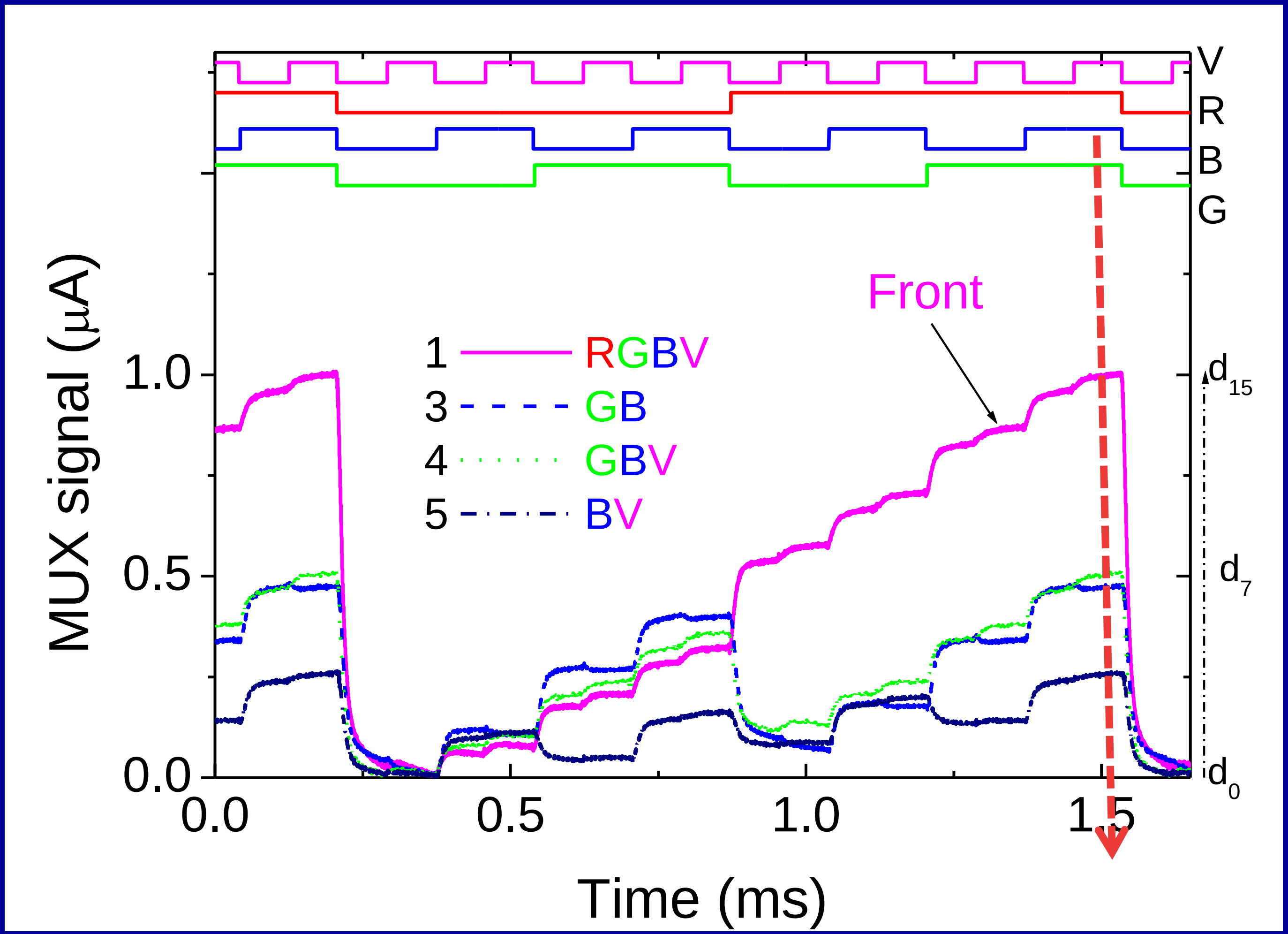


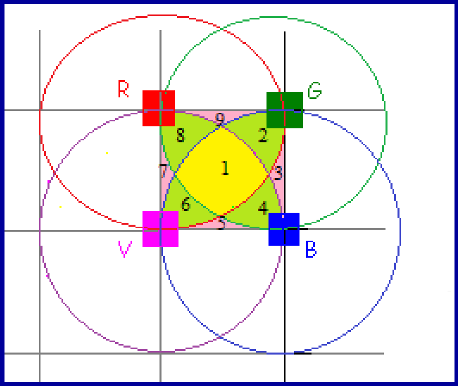
Triangular topology

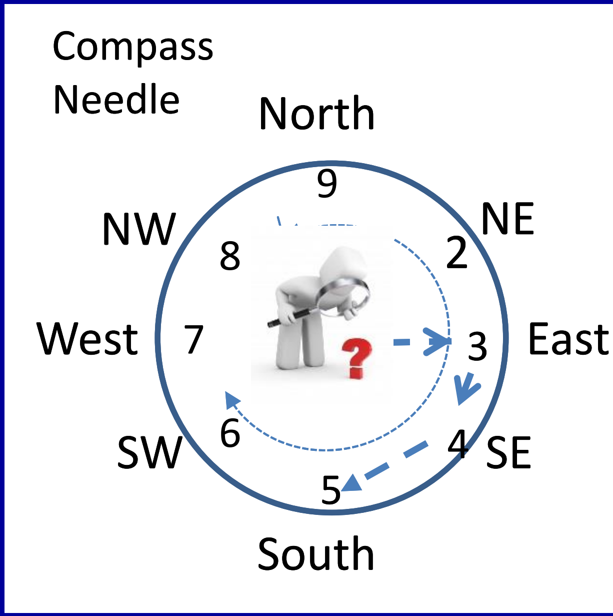


Nearest regions	1	2	3	4	5	6	7	8	9	10	11	12	13
Code position (Square topology)	1111	1110	0110	0111	0011	1011	1001	1101	1100	0100	0010	0001	1000
Code position (Triangular topology)	1111	1101	0111	1011	1001	0101	1010	1000	0100	0010	-	-	-

NAVIGATION DATA BITS

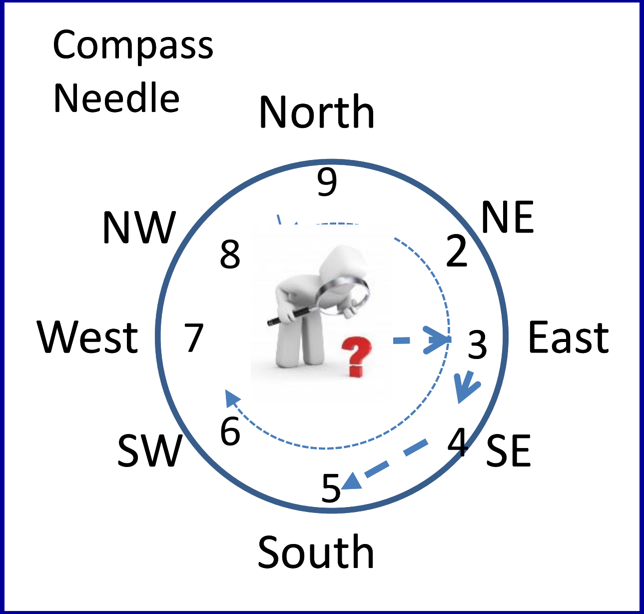




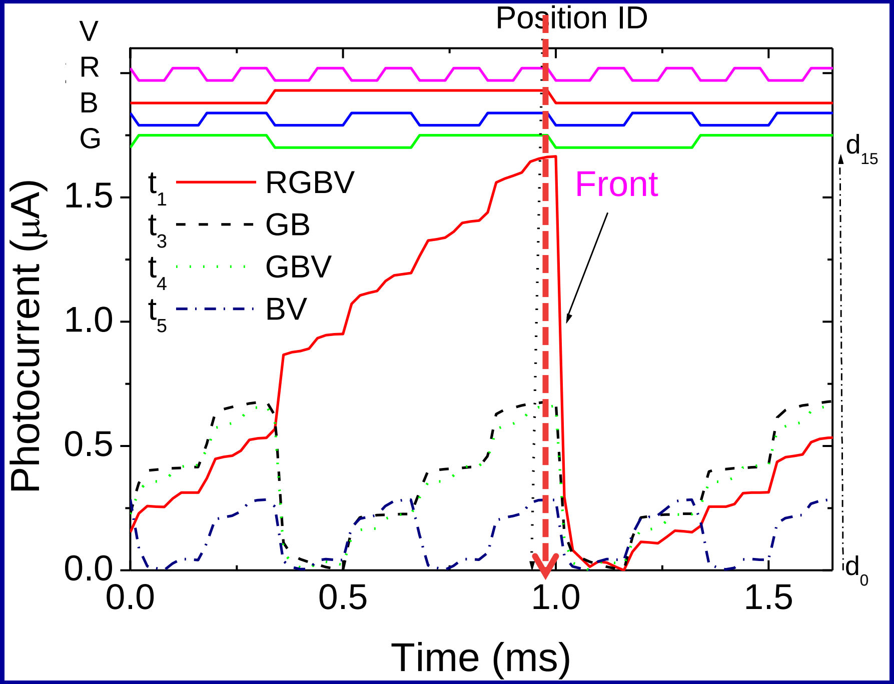


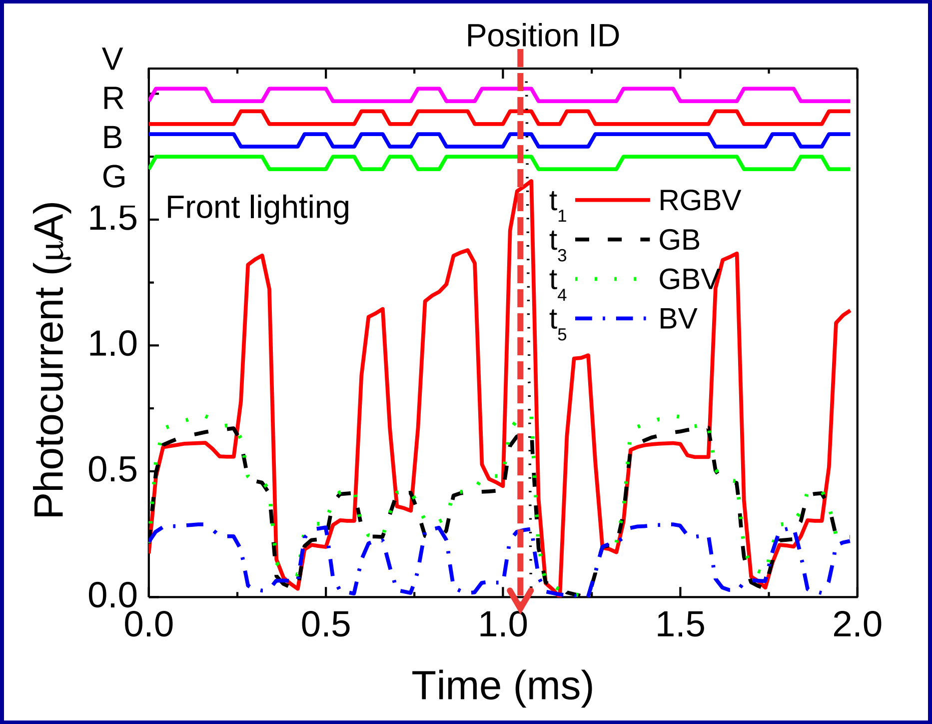
For each transition between an initial location and a final one, two code words are generated, the initial (*i*) and the final (*f*). If the receiver stays under the same region they should be the same, if it moves away they are different.

NAVIGATION DATA BITS

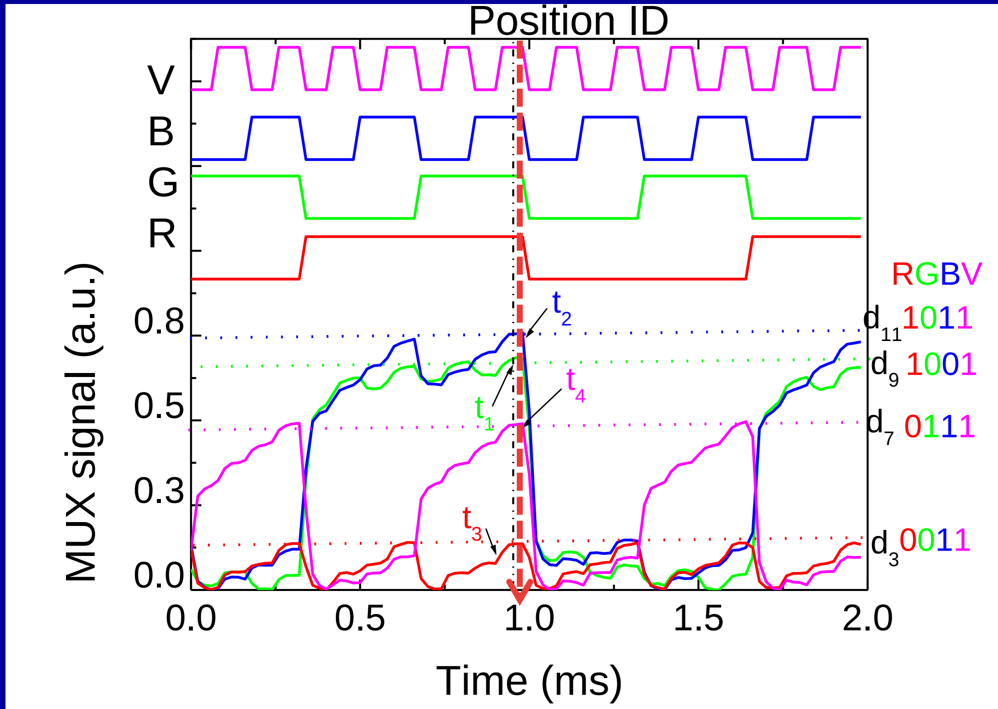


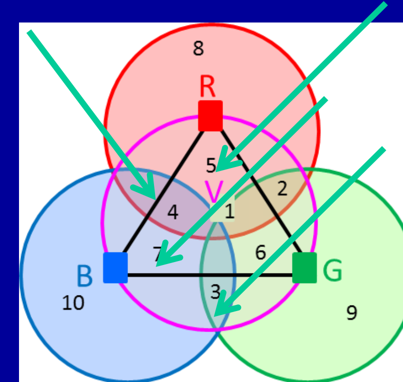
- At each regions the MUX signals present different pattern that after decoding give information about the mobile navigation and received information along the time.
- The device's position (ID position) during the receiving process will be given by the highest detected level (vertical dot line in the figures), *i. e,* the level where all the *n* (n=1, 2, 3, 4) channels are simultaneously on.





NAVIGATION DATA BITS





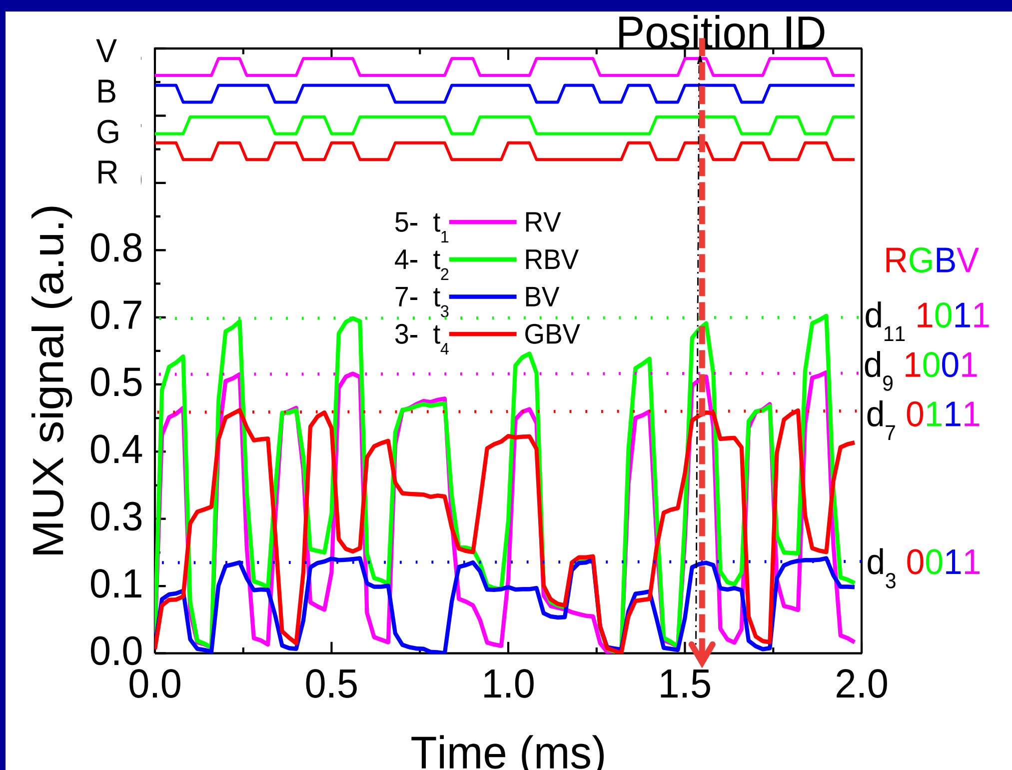
[1001]

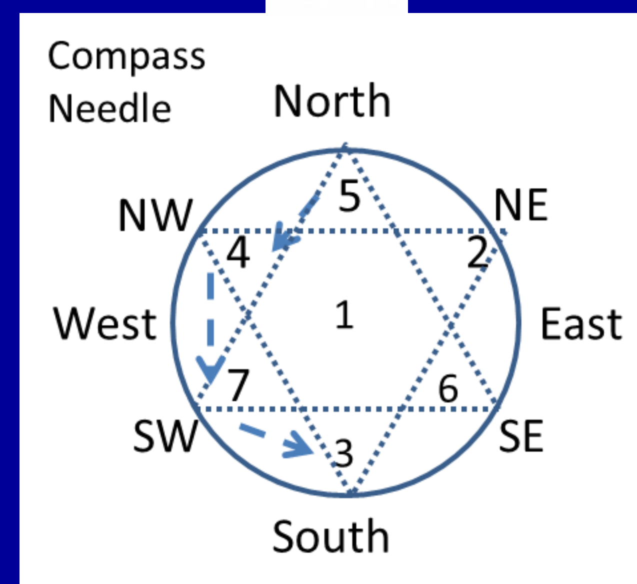
[1011]

[0011]

[0111]

For each transition between an initial location and a final one, two code words are generated, the initial (*i*) and the final (*f*). If the receiver stays under the same region they should be the same, if it moves away they are different.

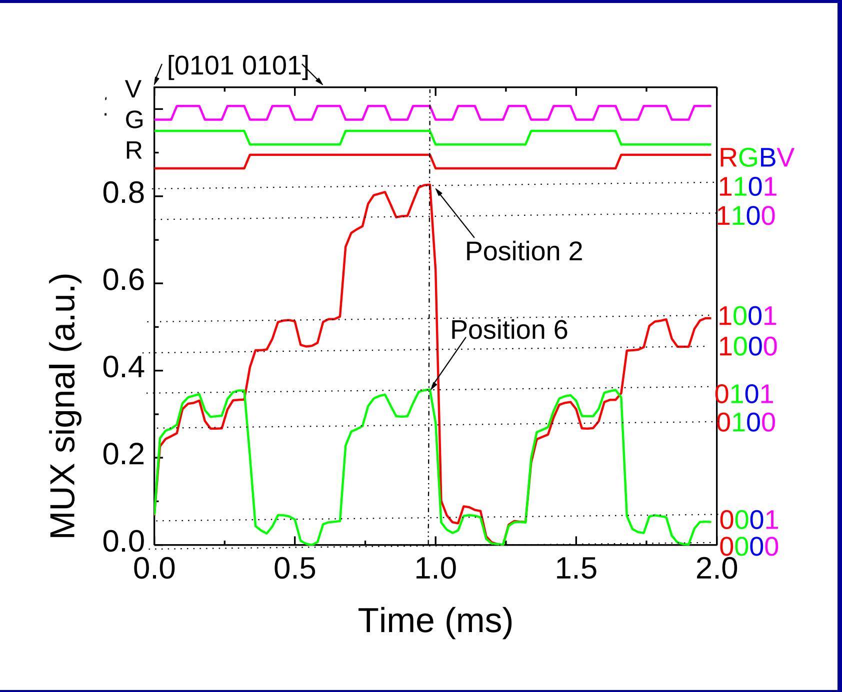




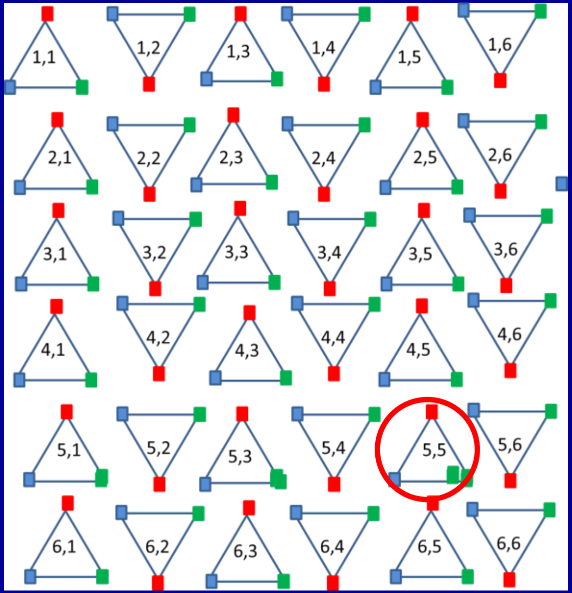
Cell location in the cluster and for each cell

I. Macro-grained information

The Violet LED sends triangular cell ID.



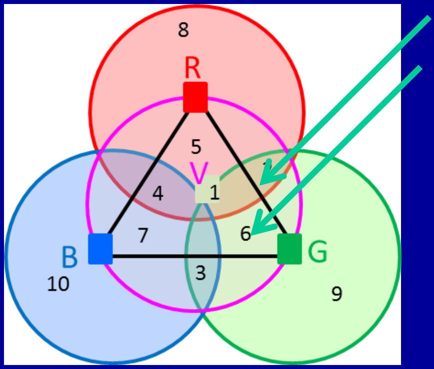
In case of the cell being part of a cluster composed by *nxm* triangular cells, the ID from the cell located at row 5: column 5:, will be [0101 0101],
Triangular cell's IDs can be encoded as sub-region using **a binary representation** for decimal number.



Channel state localization

II. Fine-grained localization

The 4-bit code that corresponds to the ID position inside the unit cell is: Position 2 [1101] and Position 6 [0101]..

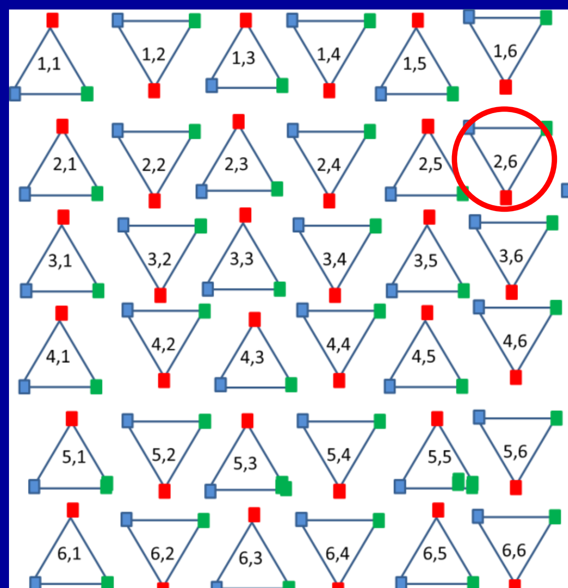


Cell location in the cluster and for each cell

I. Macro-grained information

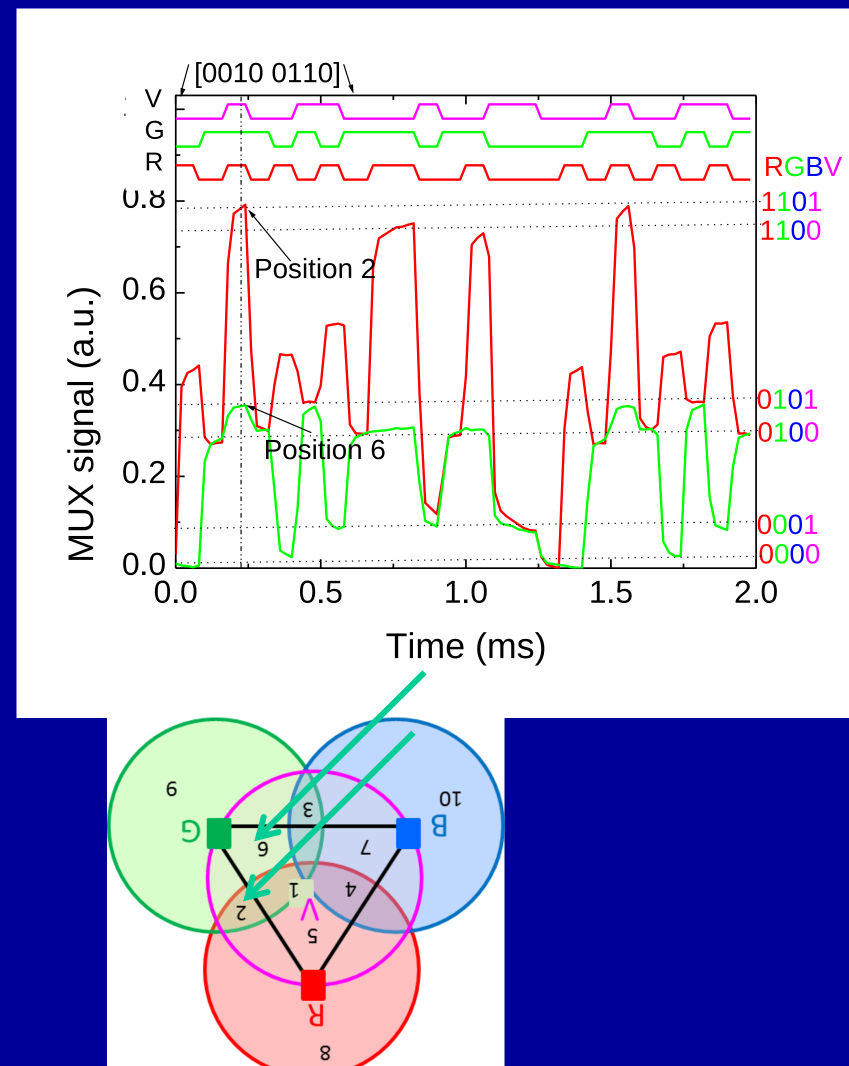
The Violet LED sends triangular cell ID

In case of the cell being part of a cluster composed by *nxm* triangular cells, the ID from the cell located at row 2: column 6:, will be [0010 0110],
Triangular cell's IDs can be encoded as sub-region using a binary representation for decimal number.

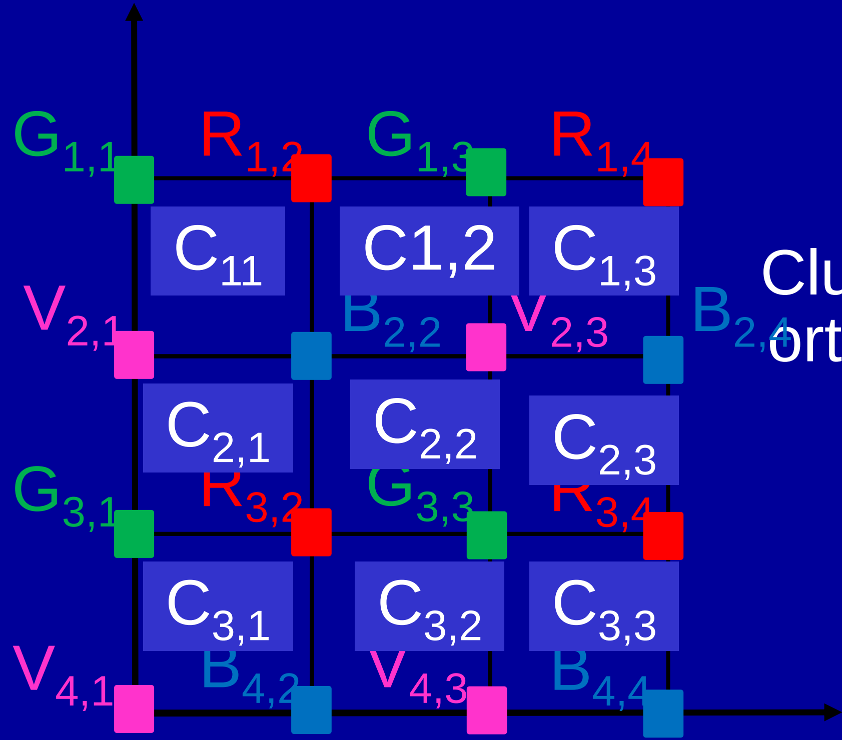


II. Fine-grained localization

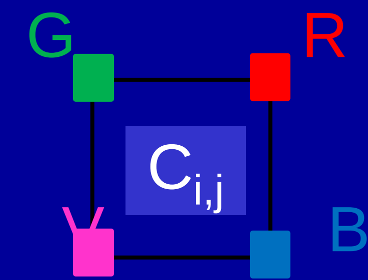
The unit cell is different, but the 4-bit code that corresponds to the ID position inside the unit cell is the same: Position 2 [1101] and Position 6 [0101] but the unit cell is different.



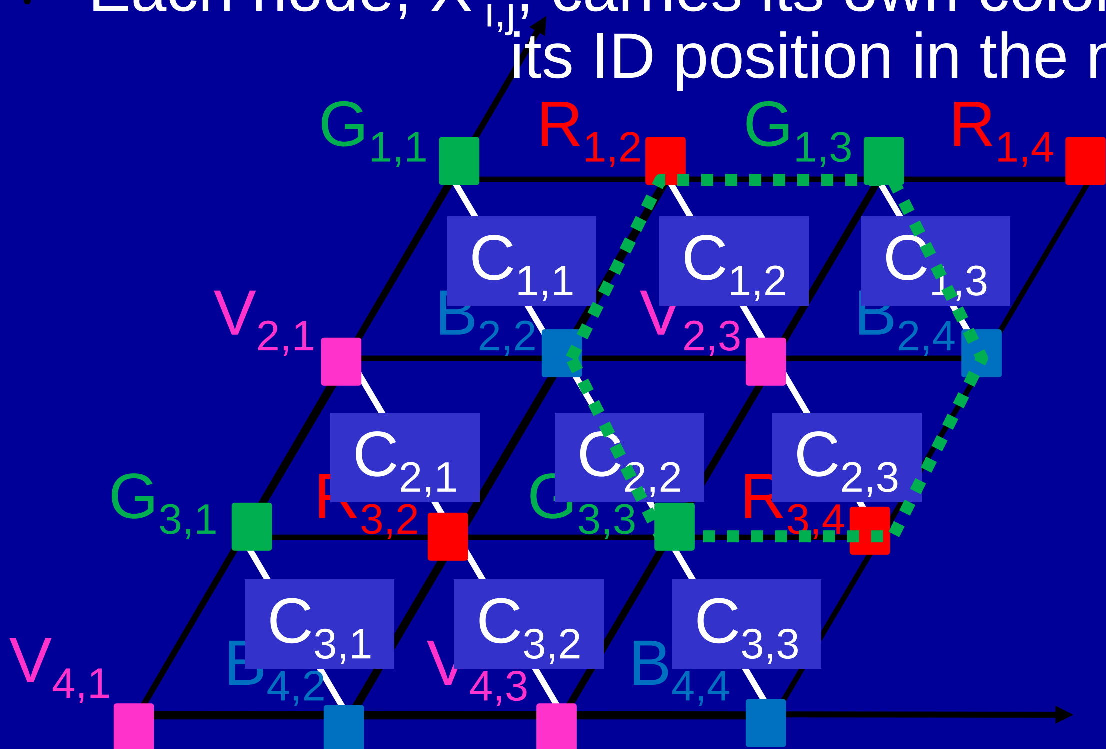
CELLULAR TOPOLOGY

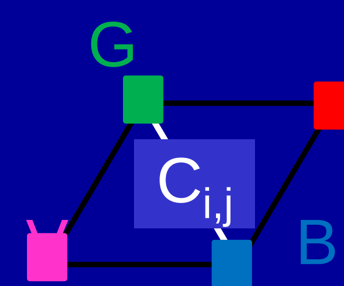


Clusters of cell in an orthogonal topology (square).



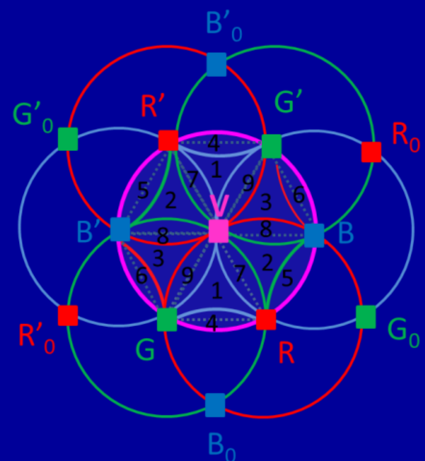
Each node, $X_{i,j}$, carries its own color, X, (RGBV) as well as its ID position in the network.

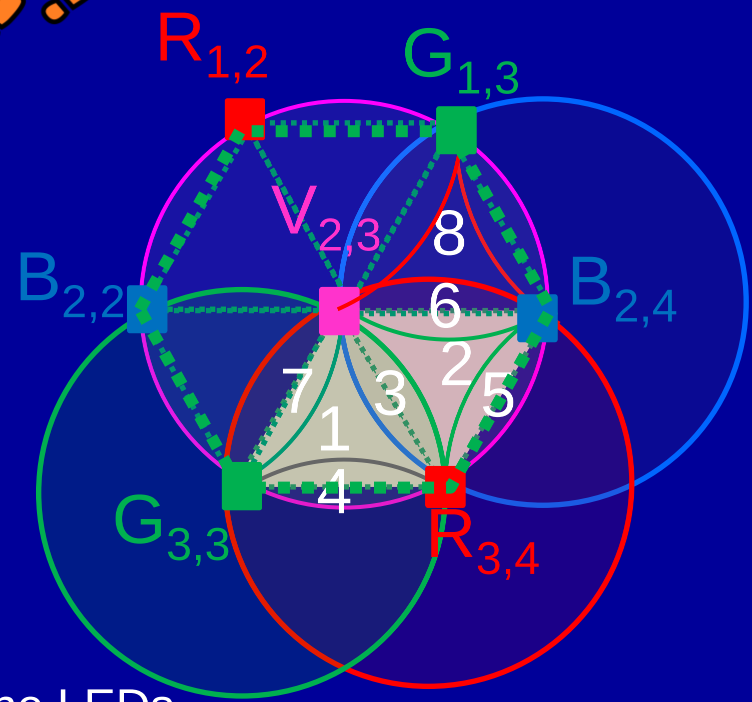




Cluster of cells in no-orthogonal topology (diamond).

Footprint regions



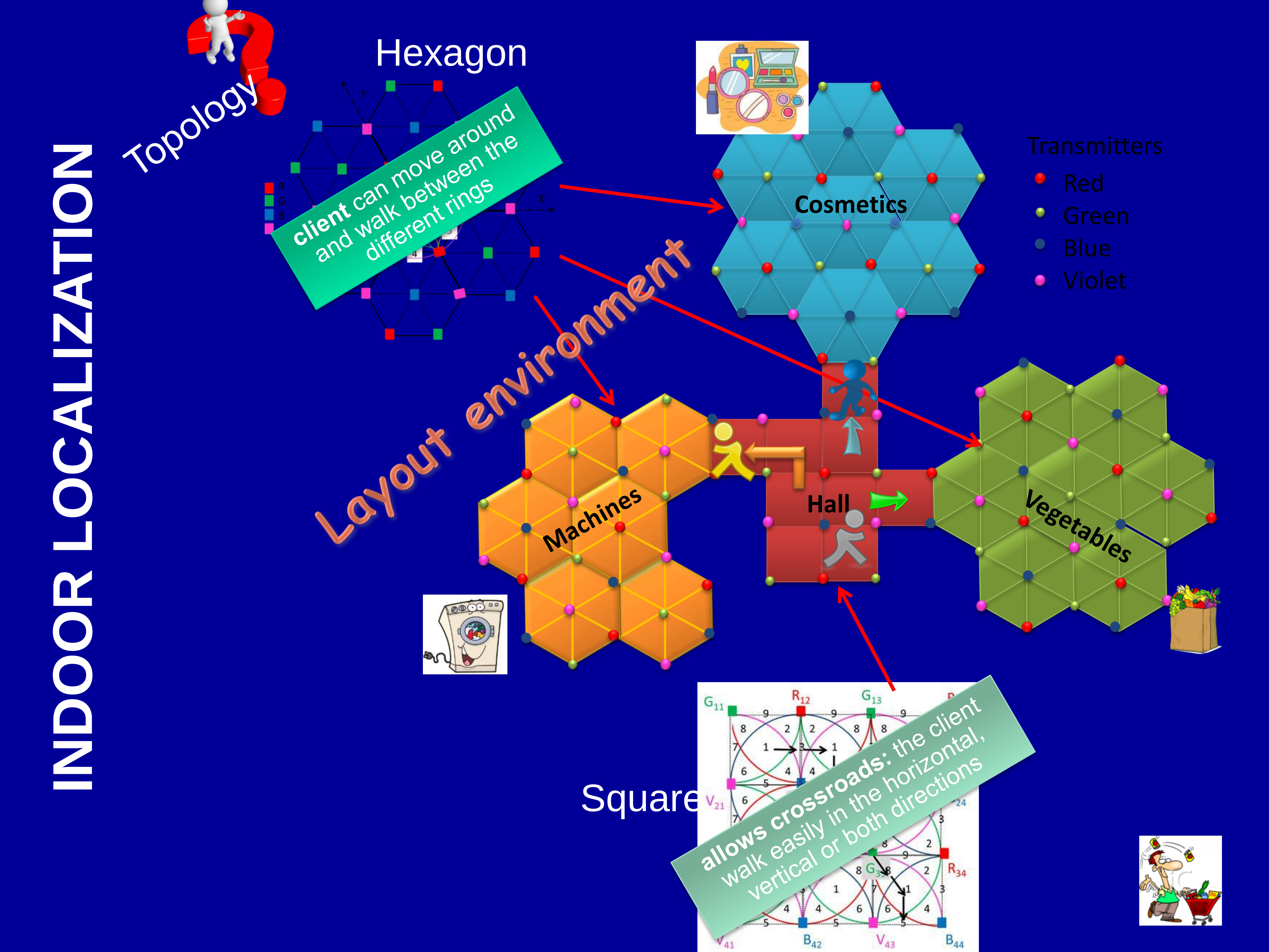


Four-code assignment for the LEDs

Hexagon topology

Diamond

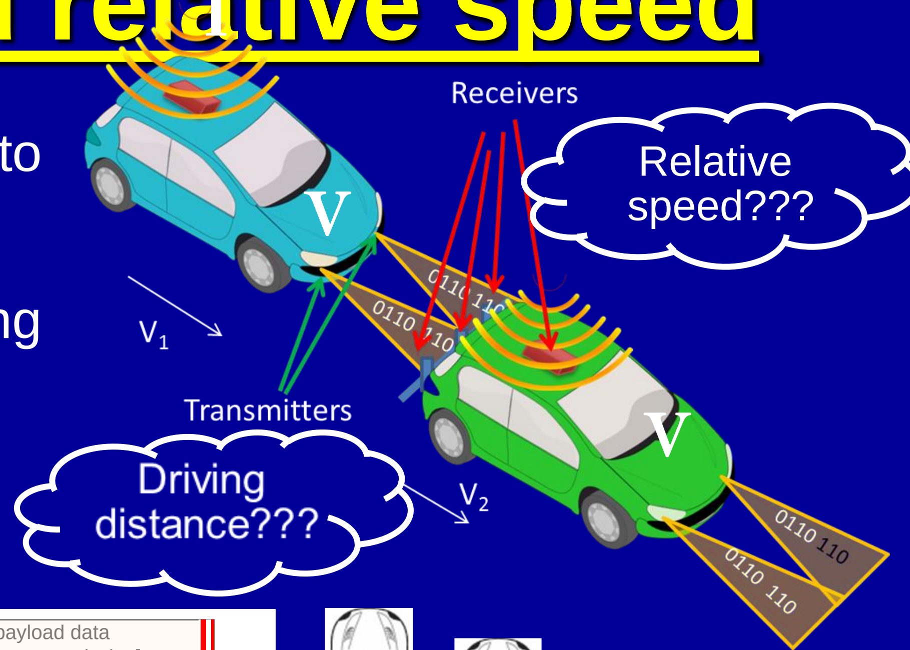
- Four modulated LEDs (RGBV) located at the corners of a diamond grid.


INDOOR LOCALIZATION
Topology
Hexagon
client can move around and walk between the different rings
Layout environment
Cosmetics
Transmitters
Red
Green
Blue
Violet
Machines
Hall
Vegetables
Square
allows crossroads: the client walk easily in the horizontal, vertical or both directions

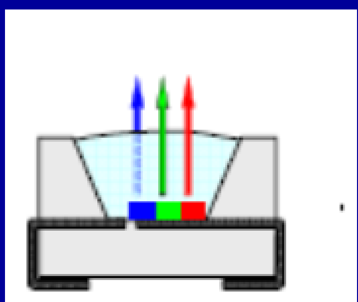
Driving distance and relative speed

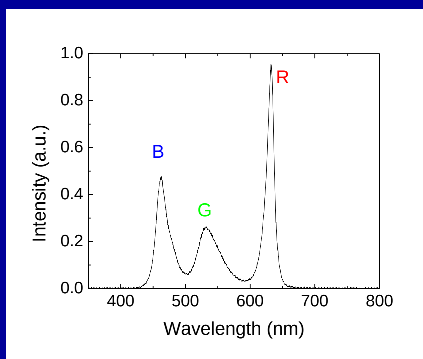
The street lamp (transmitter) sends a message to the SiC receiver, located at the rooftop.

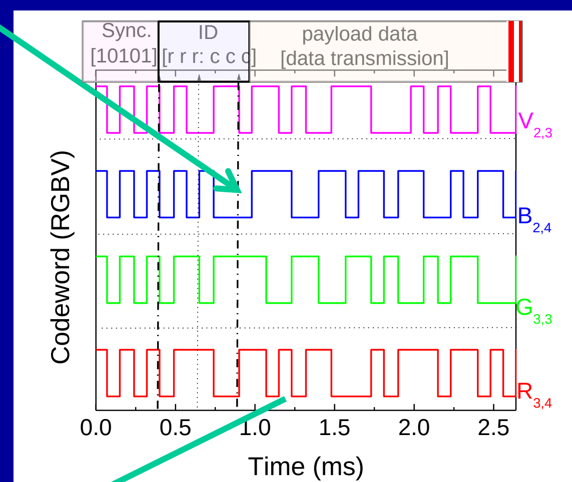
The information is resent to a leader vehicle, using the headlights as transmitters, .

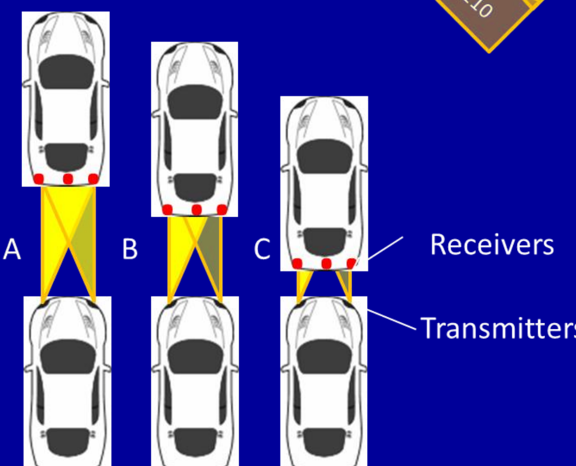


Transmitter RGB-LED

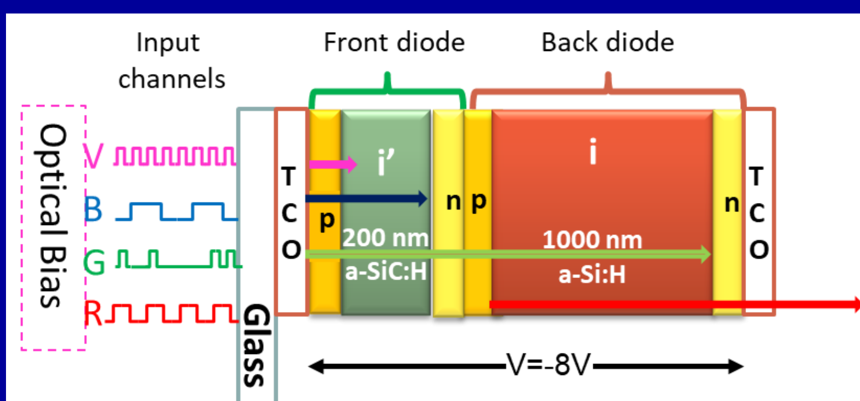








Receiver SiC pinpin



Representation of the I2V2V communication (working principle for the prototype)

The structure of the frame is a classical one

Safety, Warning or Braking Distance

1. Three sensors (L, M, W) receive the same or
2. different message

Conclusions

- Code and parity MUX/DEMUX signals and syndrome generators were designed and analyzed.
- Syndrome navigator helps the receiver to determine the position of a mobile target but also to infer the travel direction

- A square, triangular, diamond, hexagonal topologies were considered for the unit cell. Calibration cell was tested to determine the position

- Macro-grained information and Fine-grained indoor localization was tested to determine the position.

- Results showed that is possible not only to determine the position of a mobile target inside the unit cell but also in the cluster, celular or layout environment and to infer the travel direction along the time.

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