01

COMMUNICATION PAR LASER À GRANDE DISTANCE

CAYZAC Erhel 32242

PLAN

PRÉSENTATION DU PROJET

Enjeux et problématiques de la communication par laser

PREMIER PROTOTYPE

Blocages, limitations

AMÉLIORATION DU MODÈLE

Capteurs, codes correcteurs, vitesse d’émission

LIMITES, ÉTUDE THÉORIQUE

Analyse théorique du projet proposé

POURQUOI ?

- Haut débit de transmission
- Liaison sans fil sécurisée
- Lien analogique / numérique

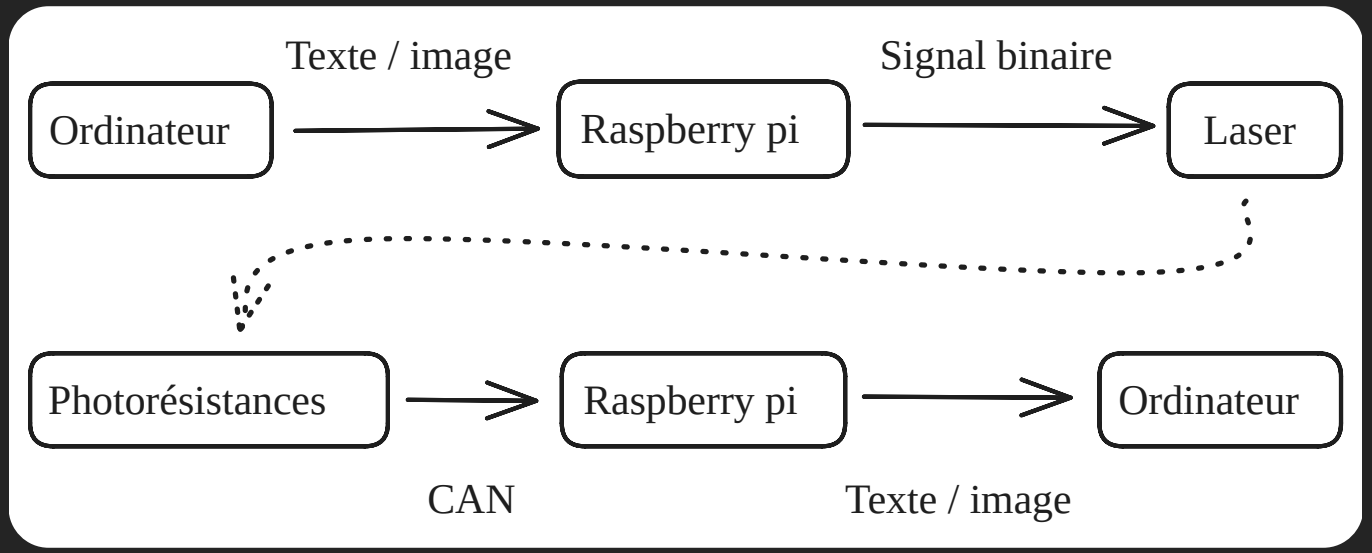
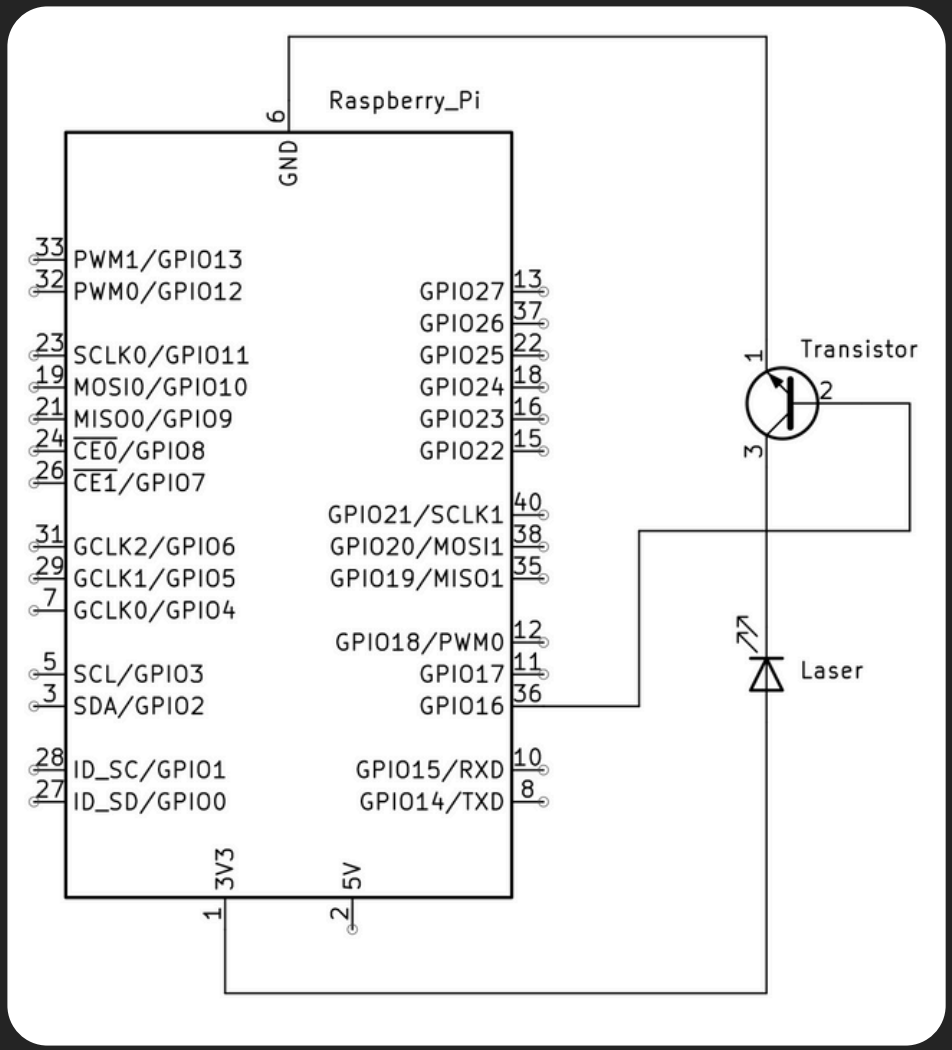


Schéma de principe

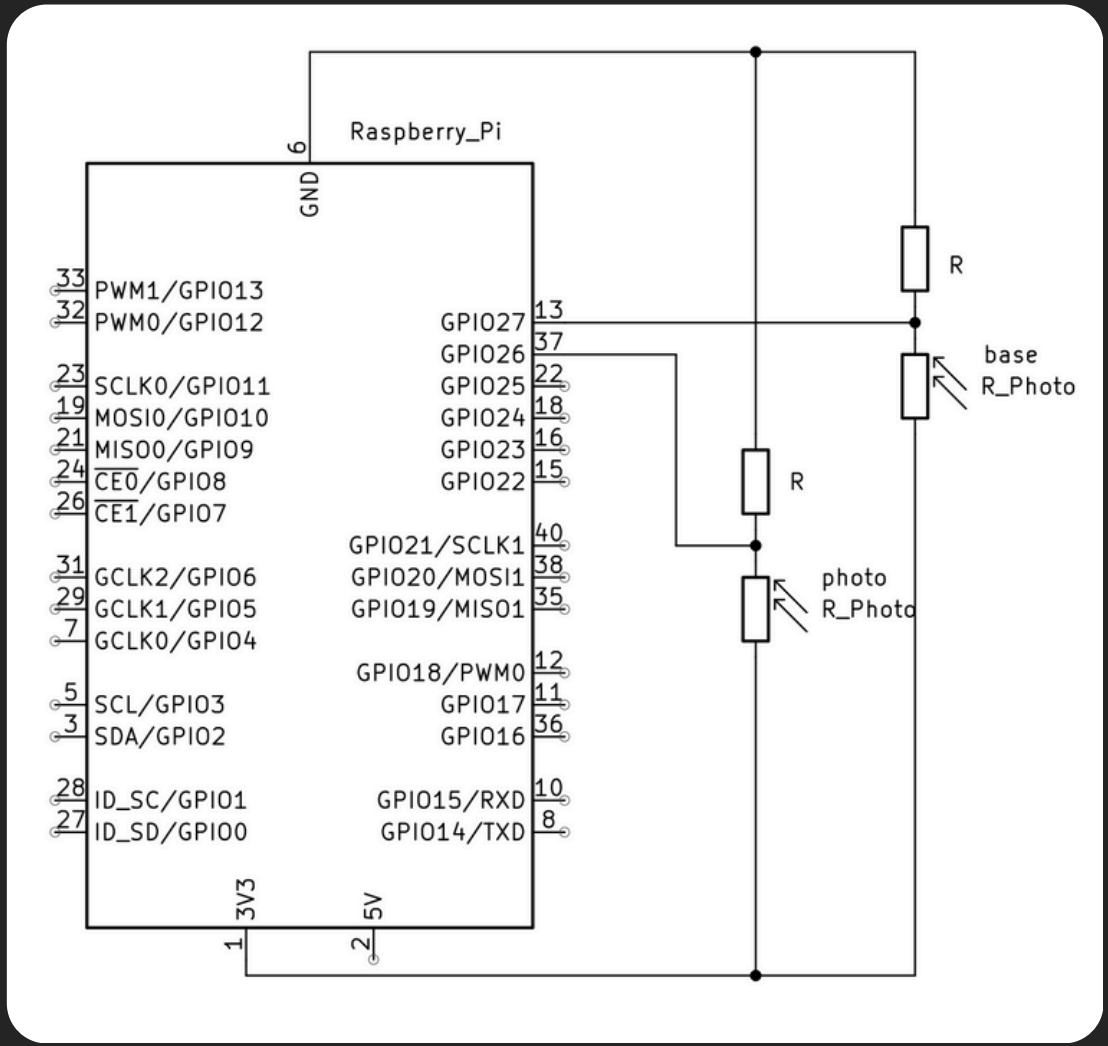
UN PREMIER PROTOTYPE

- Laser
- Photorésistances
- Traitement en direct
- Liaison type RS 232



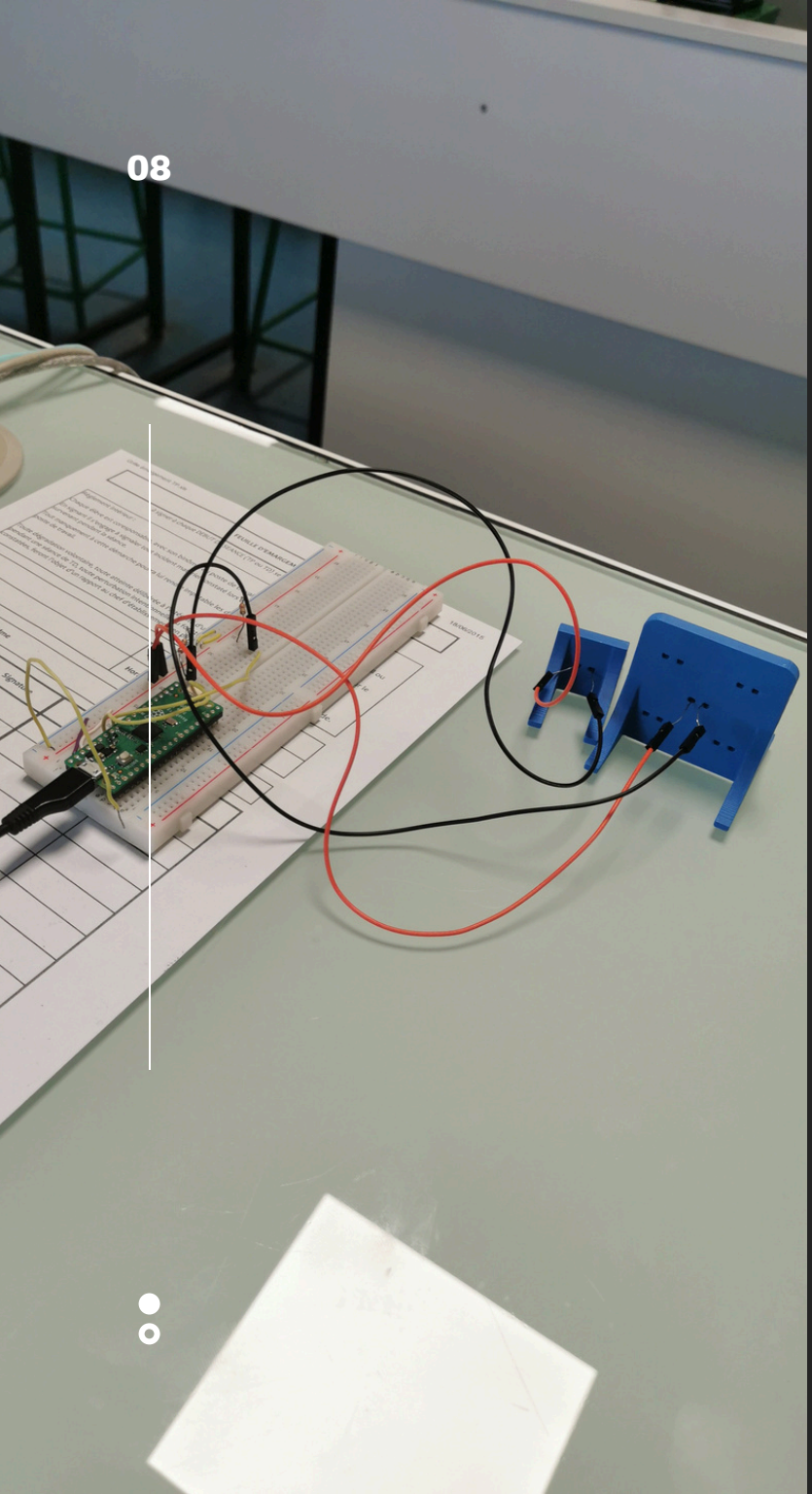
- Envoi de bits
- Transistor
- Laser 10mW, 532nm, classe III

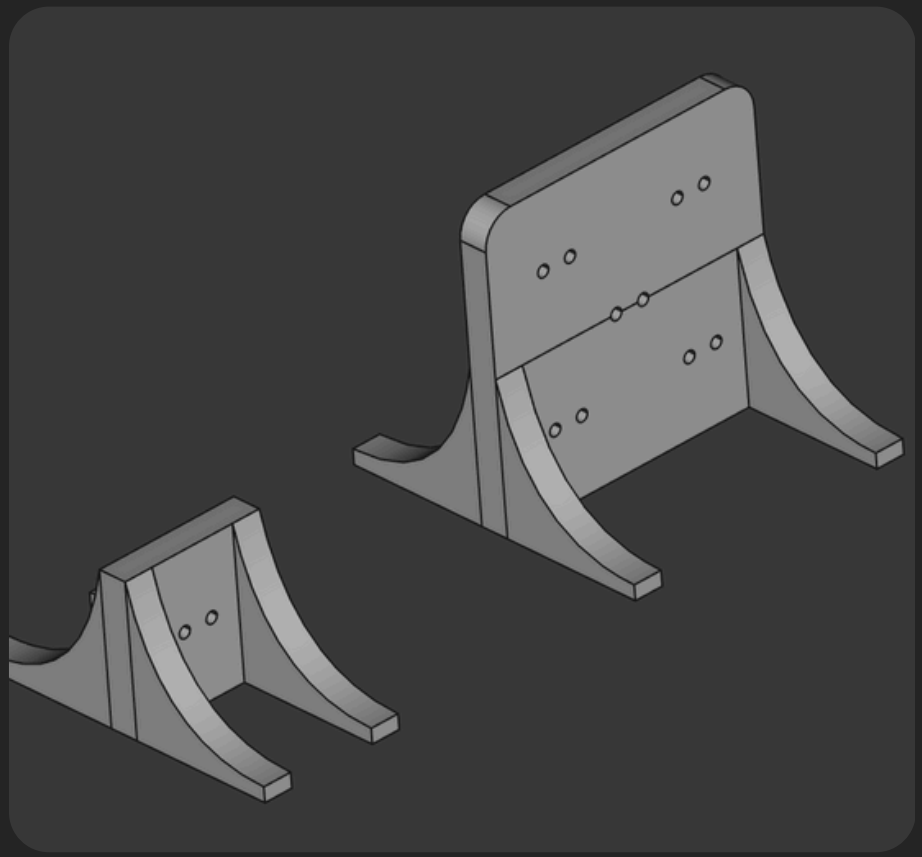
Schéma électrique émission



- Diviseurs de tension
- CAN
- Comparaison
- Seuil

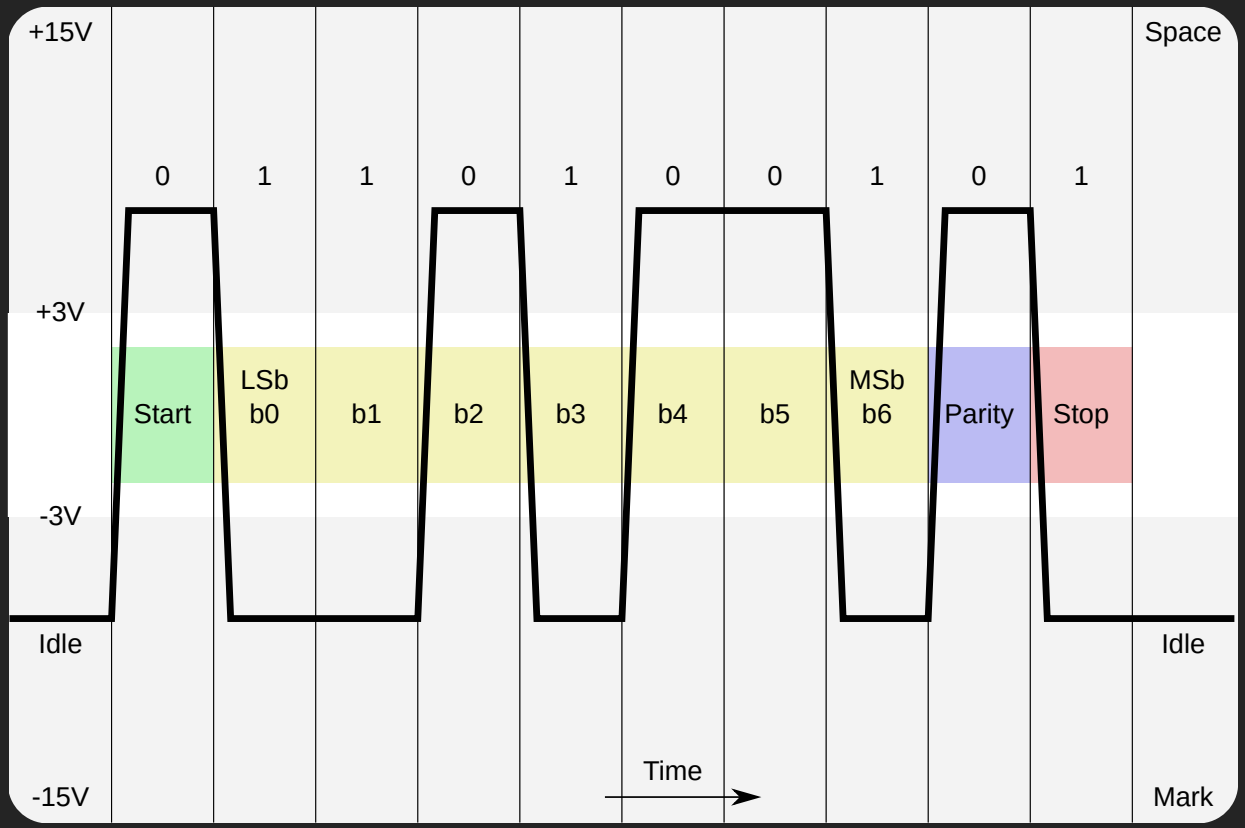
Schéma électrique réception





Réception

- Création de supports pour les photorésistances



Exemple liaison RS232 (start / stop)

PREMIÈRES LIMITATIONS

- Non adaptabilité (seuil)
- Non linéarité (photorésistances)
- Manque de fiabilité (lenteur Raspberry)

SECOND PROTOTYPE

- Phototransistors
- Traitement différé
- Seuil variable
- Gestion des erreurs

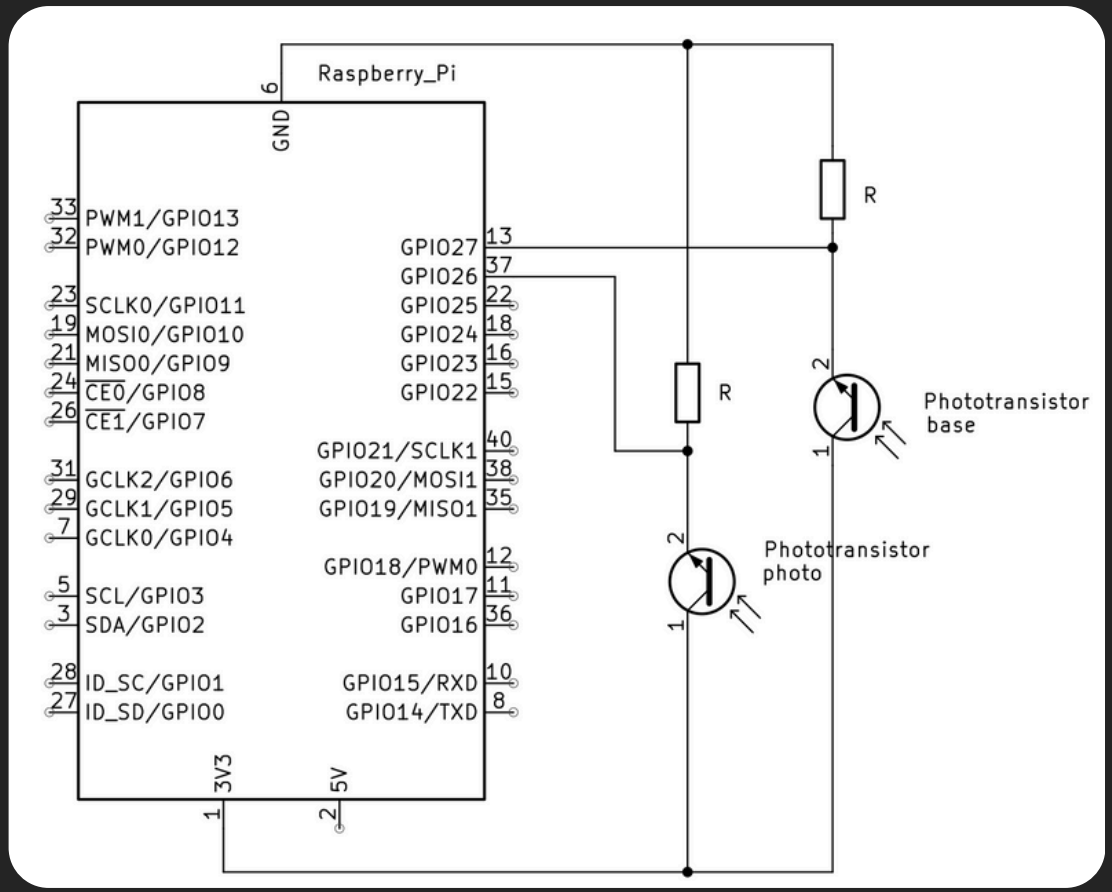
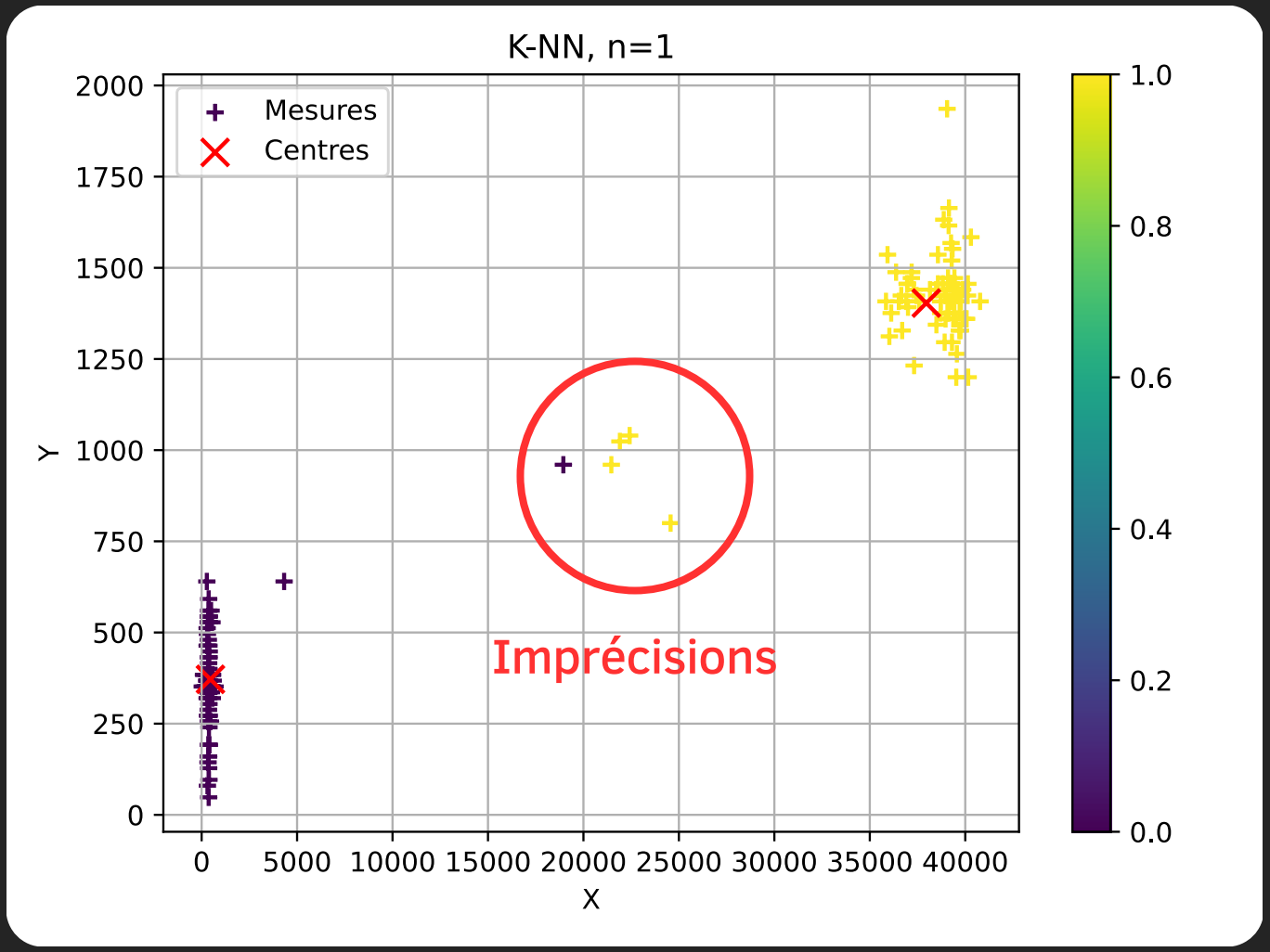


Schéma électrique réception



Tri des bits, convergence rapide (30m)

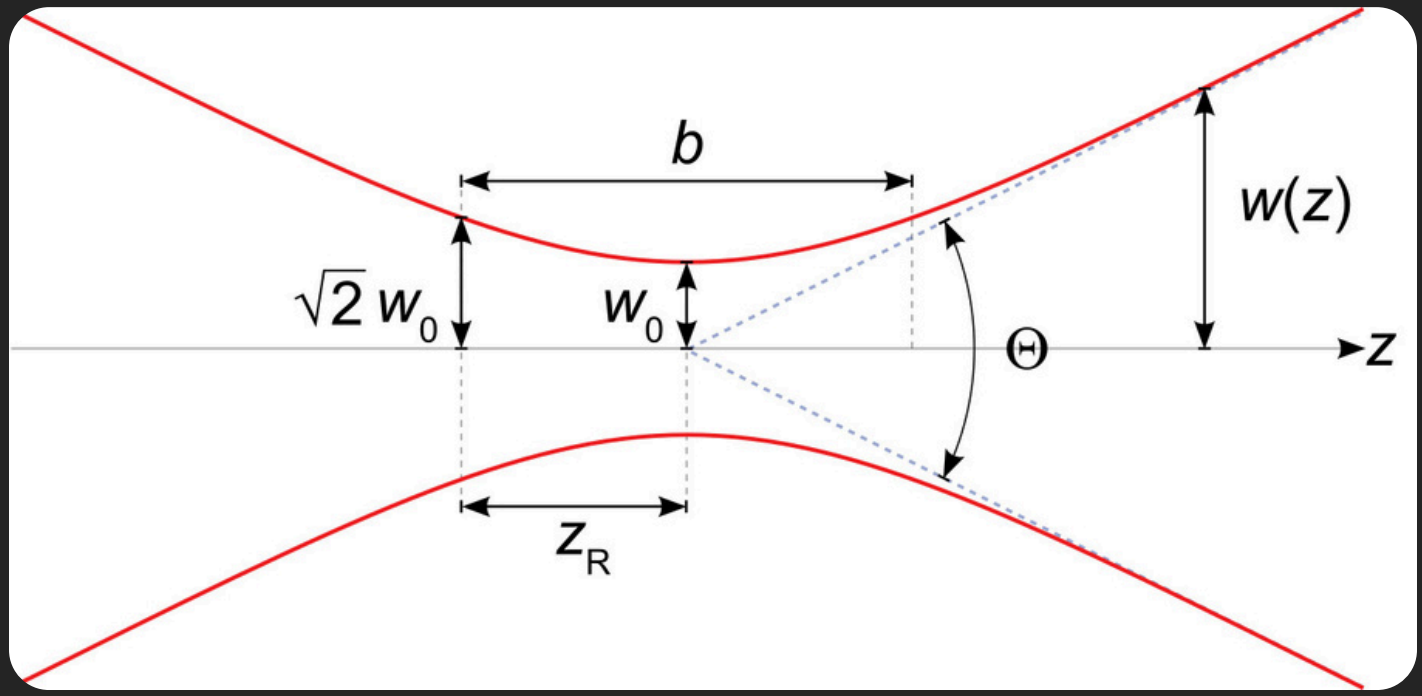
Correction de Hamming

- Ajout de bits
- Vérification de la cohérence

DIODE LASER

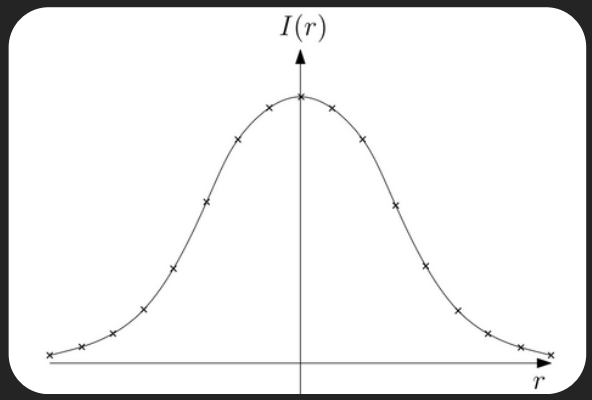
Modèle du faisceau gaussien

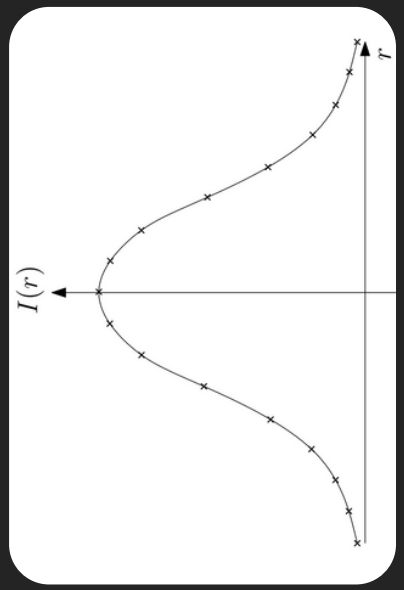
$$w : z \longmapsto w_0 \sqrt{1 + \left(\frac{z}{z_r}\right)^2}$$

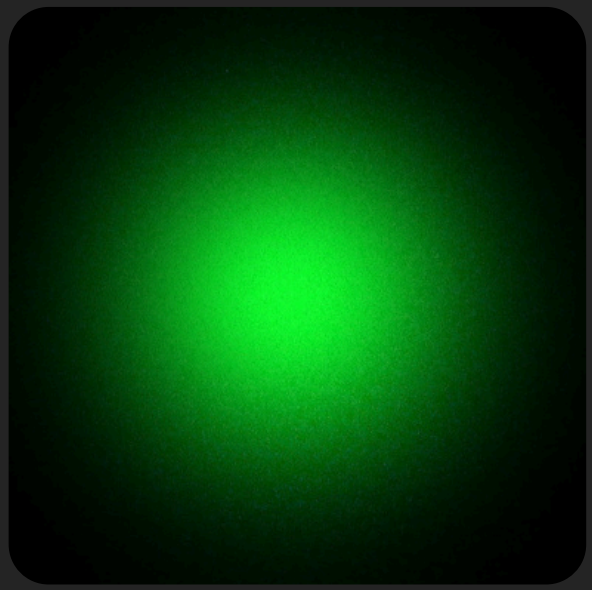


Divergence et longueur de Rayleigh

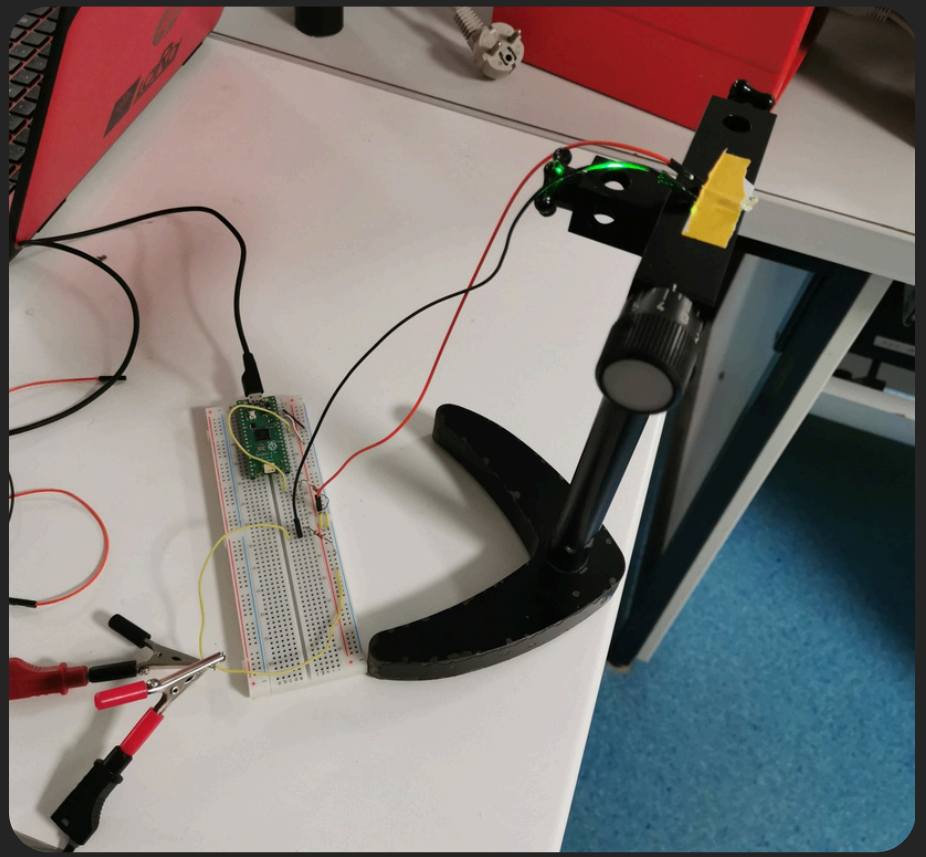
$$I : (z, r) \longmapsto I_0 \frac{w_0^2}{w^2(z)} \cdot \exp\left(\frac{-2r^2}{w^2(z)}\right)$$





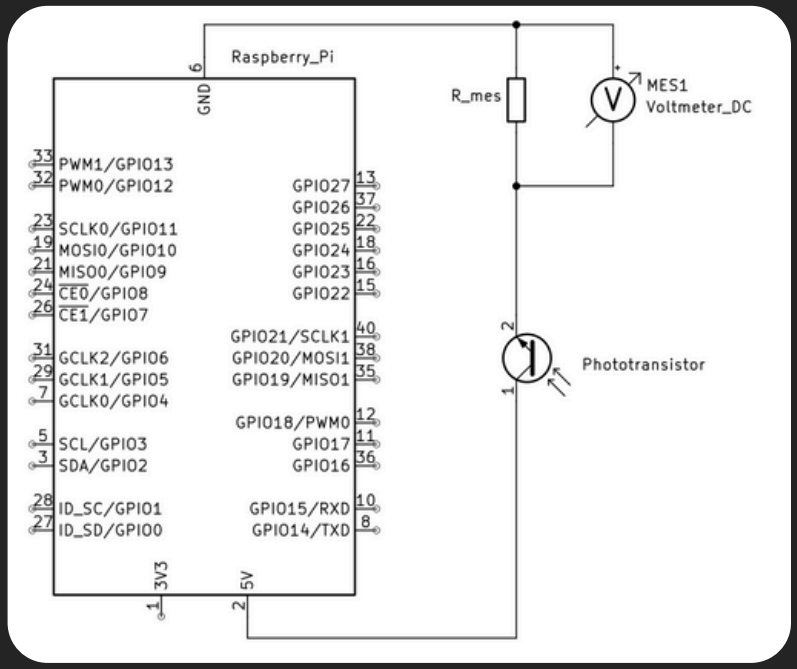


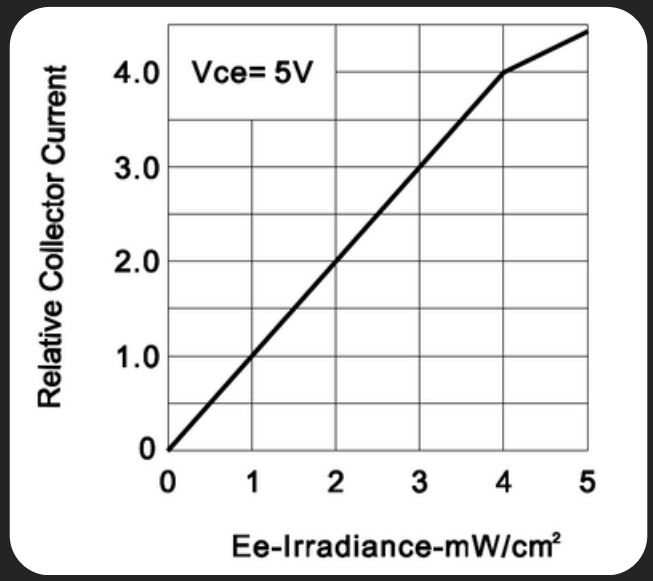
Faisceau Gaussien



Étude du faisceau

- Distance z fixée
- Tension aux borne d’une résistance

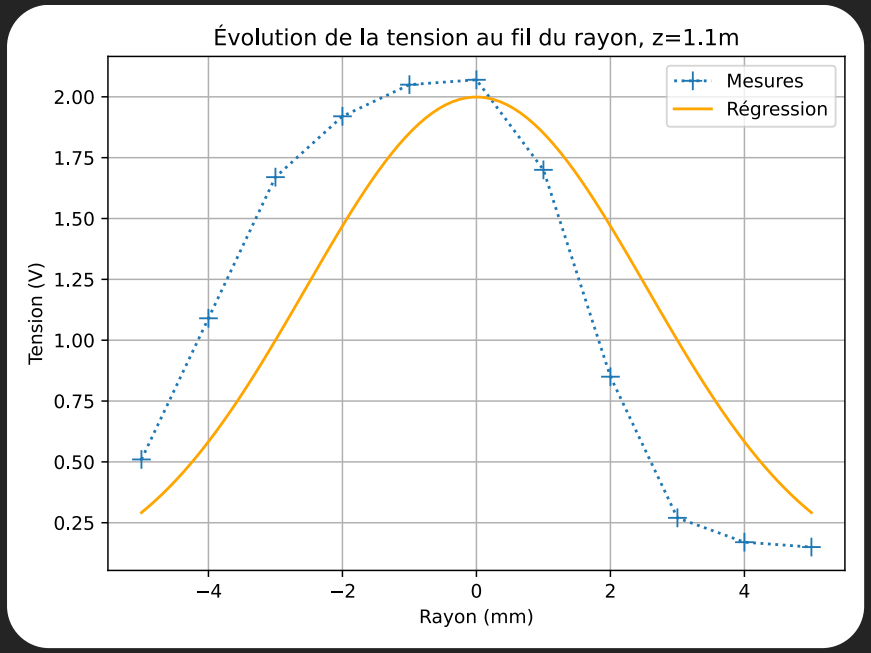


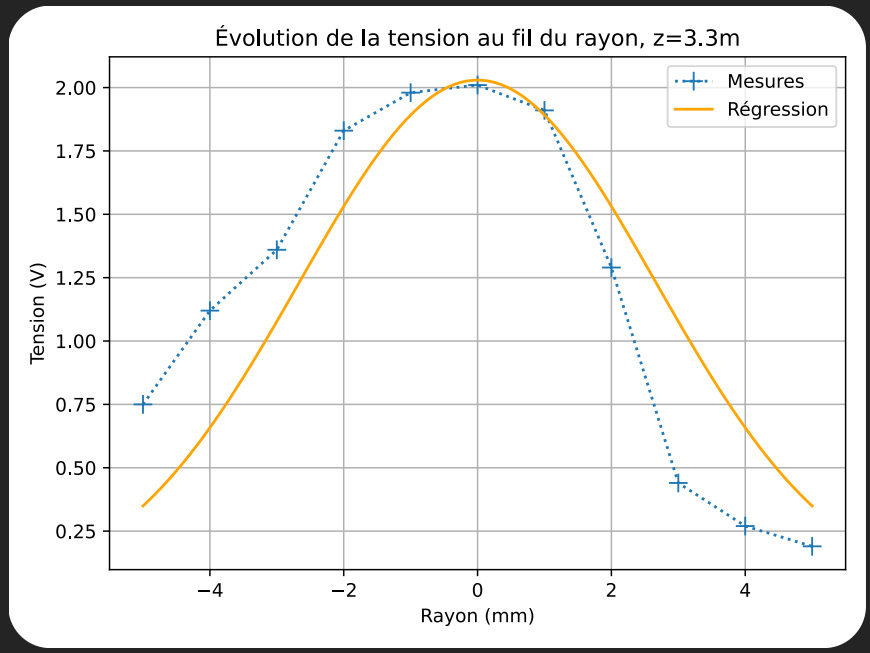


$$i = k_{capt} \cdot I$$

$$U = Rk_{capt} \cdot I$$

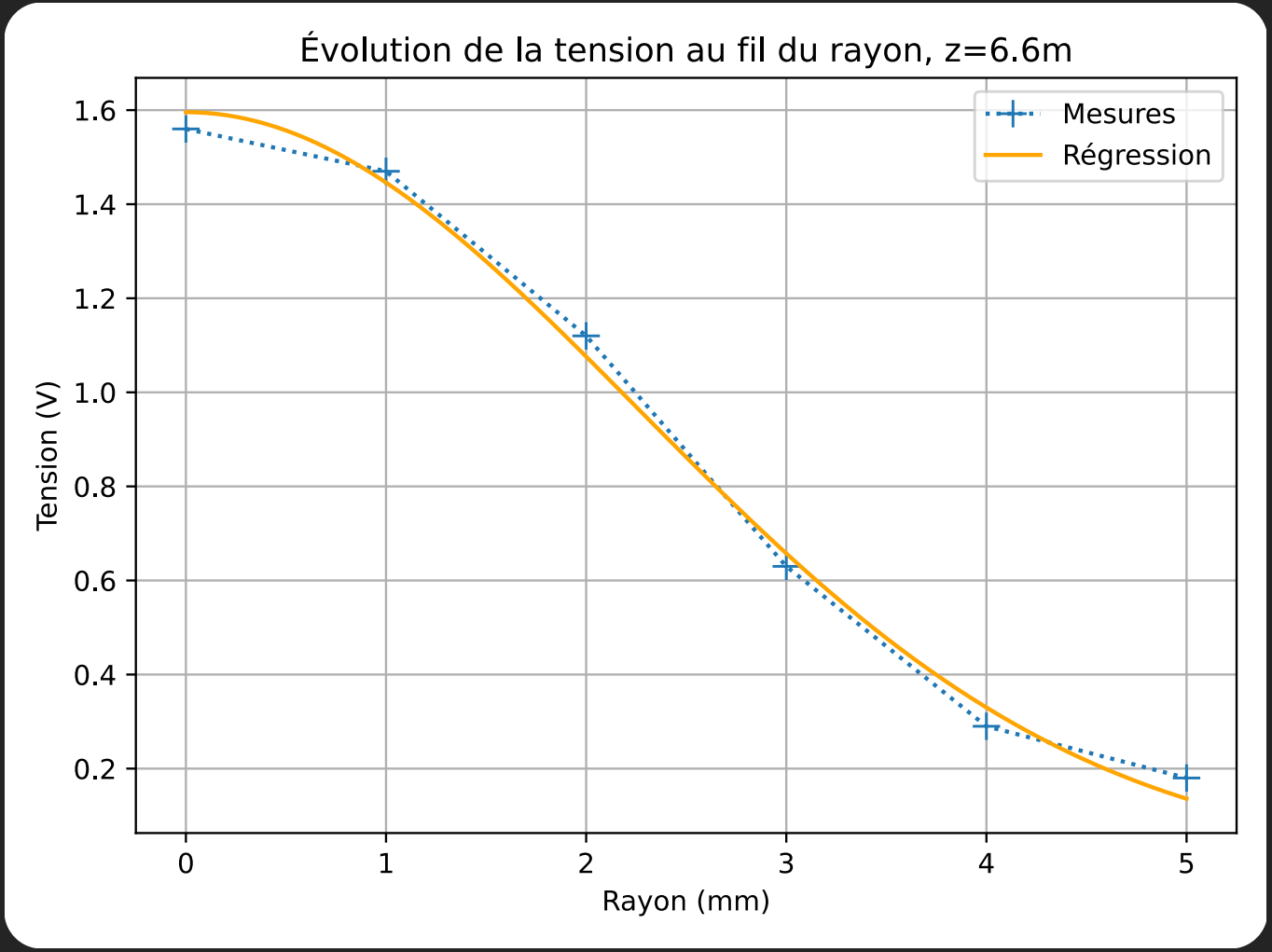
Protocole



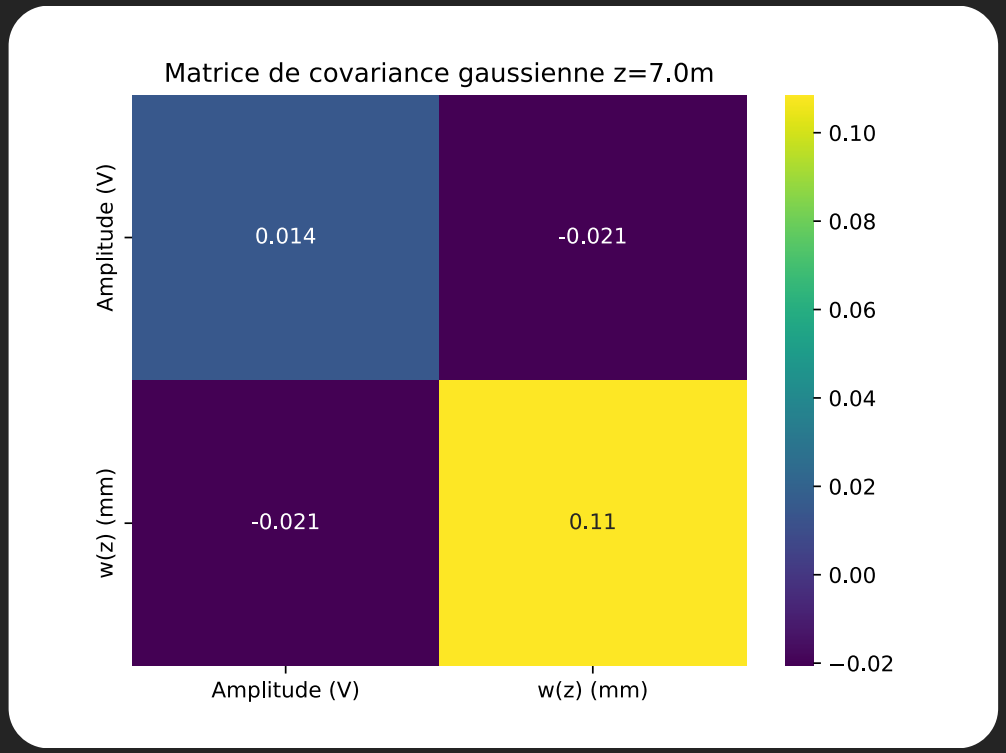


$$U(z,r) = A(z) \cdot \exp\left(\frac{-2r^2}{B^2(z)}\right)$$

Première approche



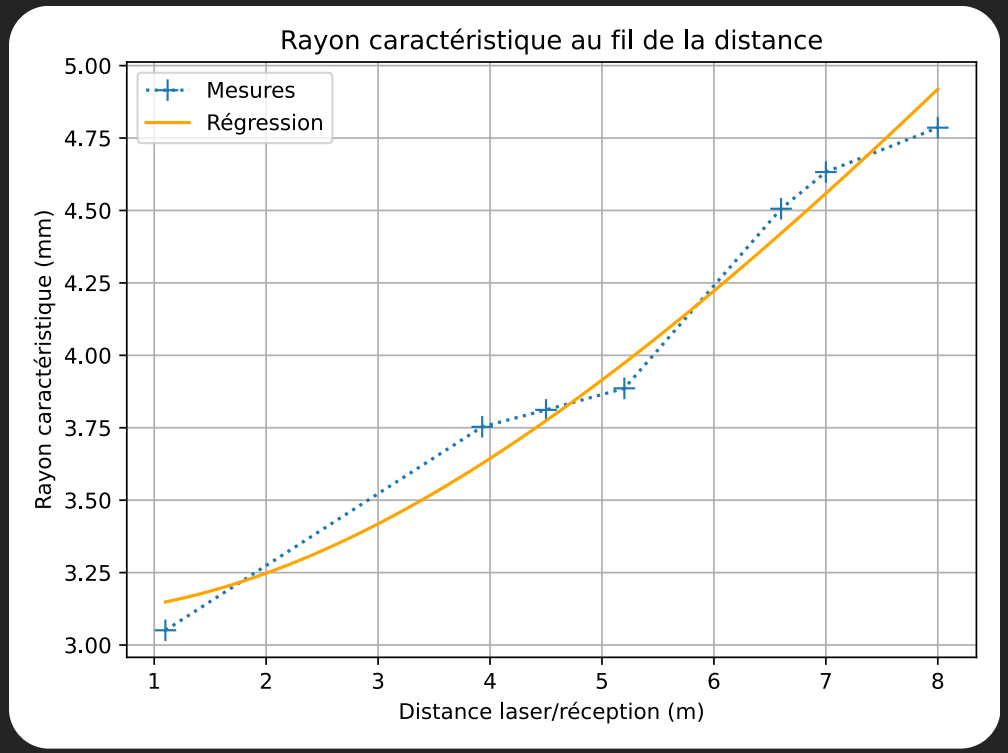
Seconde approche



- $\sigma(A) \sim 10^{-1}\mathrm{V}$
- $\sigma(B) \sim 10^{-1}\mathrm{mm}$
- $\mathrm{cov}(A, B) < 0$

$$A = \frac{cste}{B^2}$$

Matrice de covariance (pire cas)



- $w_0 = 3,1\text{mm}, \quad \sigma(w_0) \simeq 0,1\text{mm}$
- $z_r = 6,5\text{m}, \quad \sigma(z_r) \simeq 0,4\text{m}$

$$z_r = \frac{\pi w_0^2}{\lambda}$$

$$z_r = 56\text{m}$$

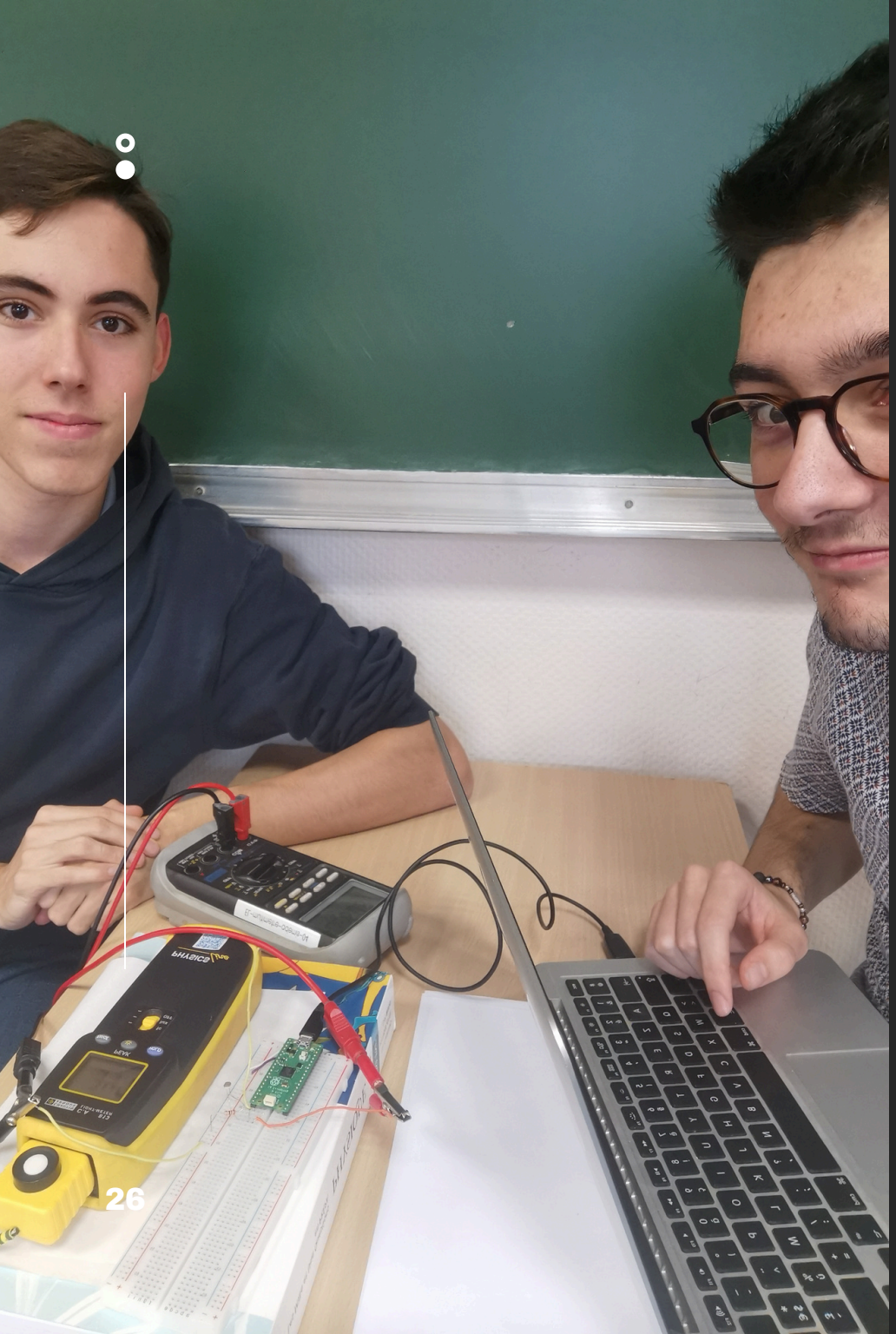
Distance de Rayleigh

CONCLUSION

- Système fonctionnel
- Adaptation à la luminosité
- Correction des erreurs
- Débit peu élevé (Python)

PHOTORÉSISTANCE

- Facile d’utilisation
- Non linéaire



Tracé de la caractéristique

PROTOCOLE :

- Pont diviseur de tension
- Éclairement constant

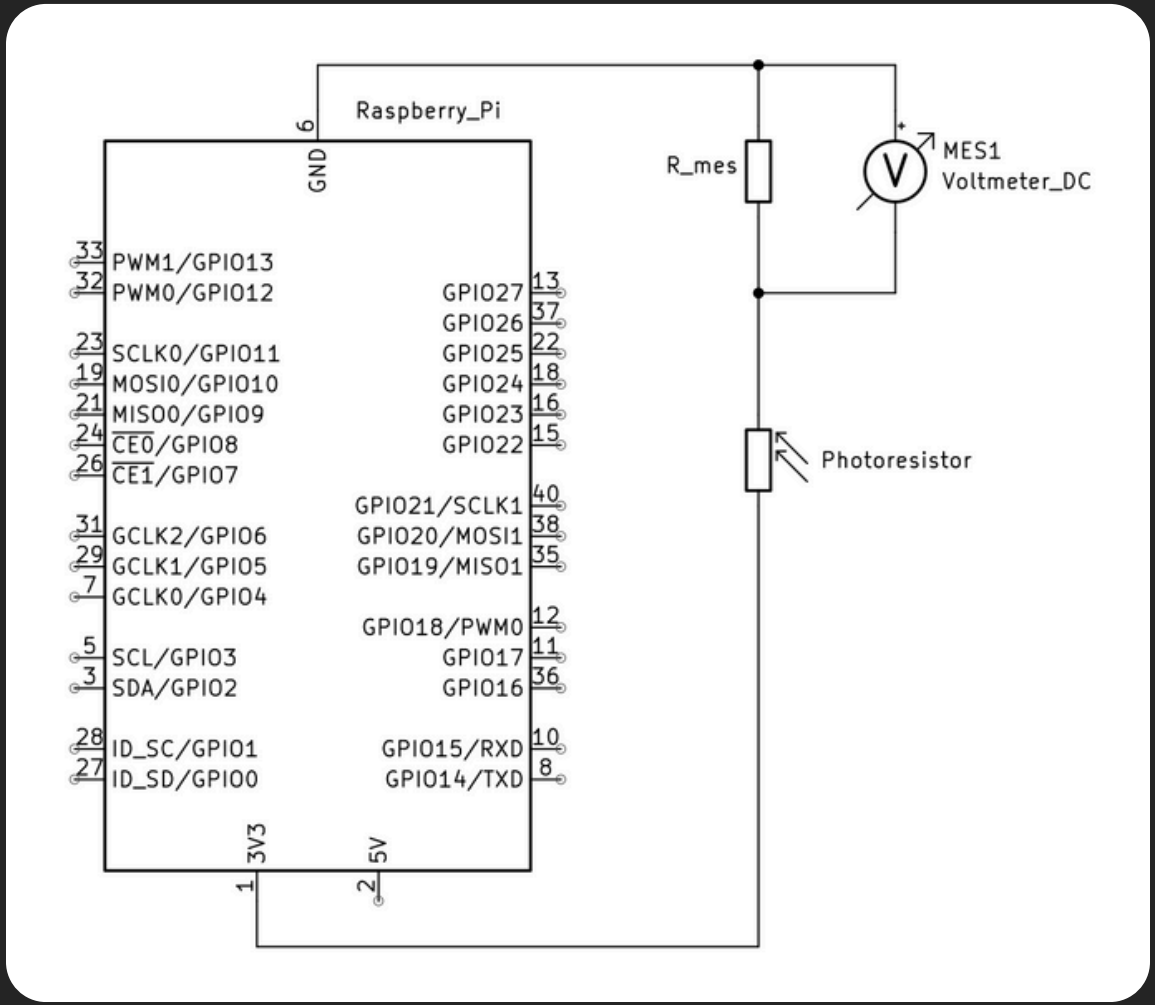
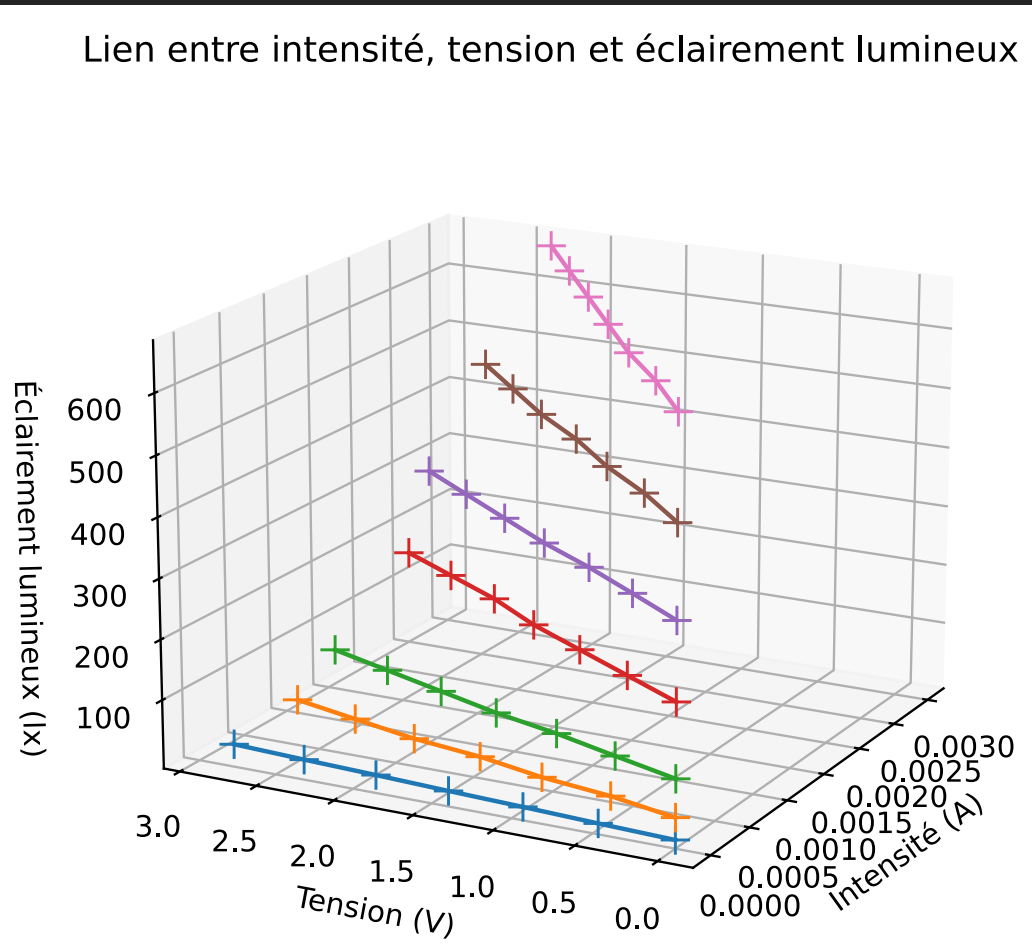
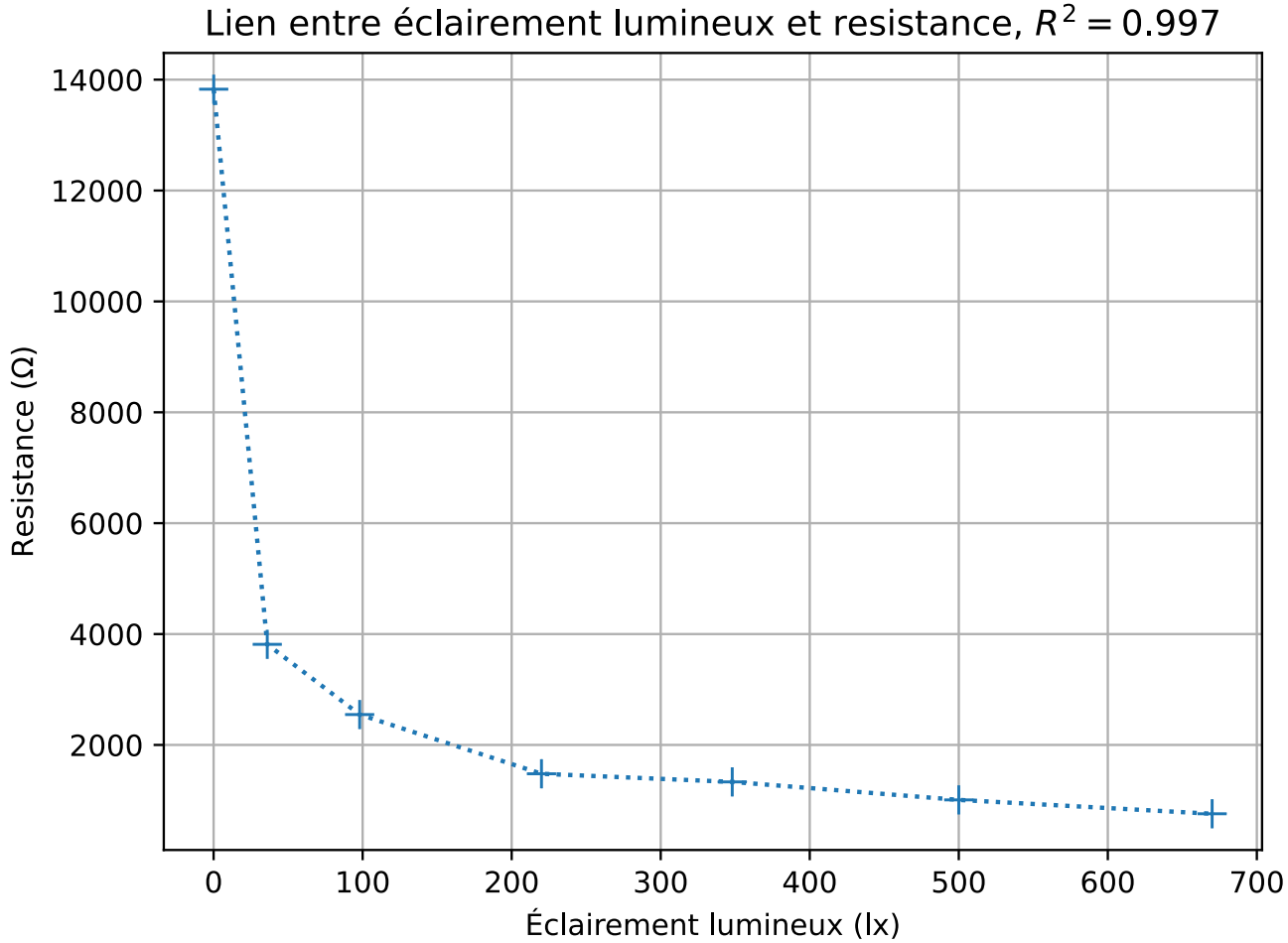


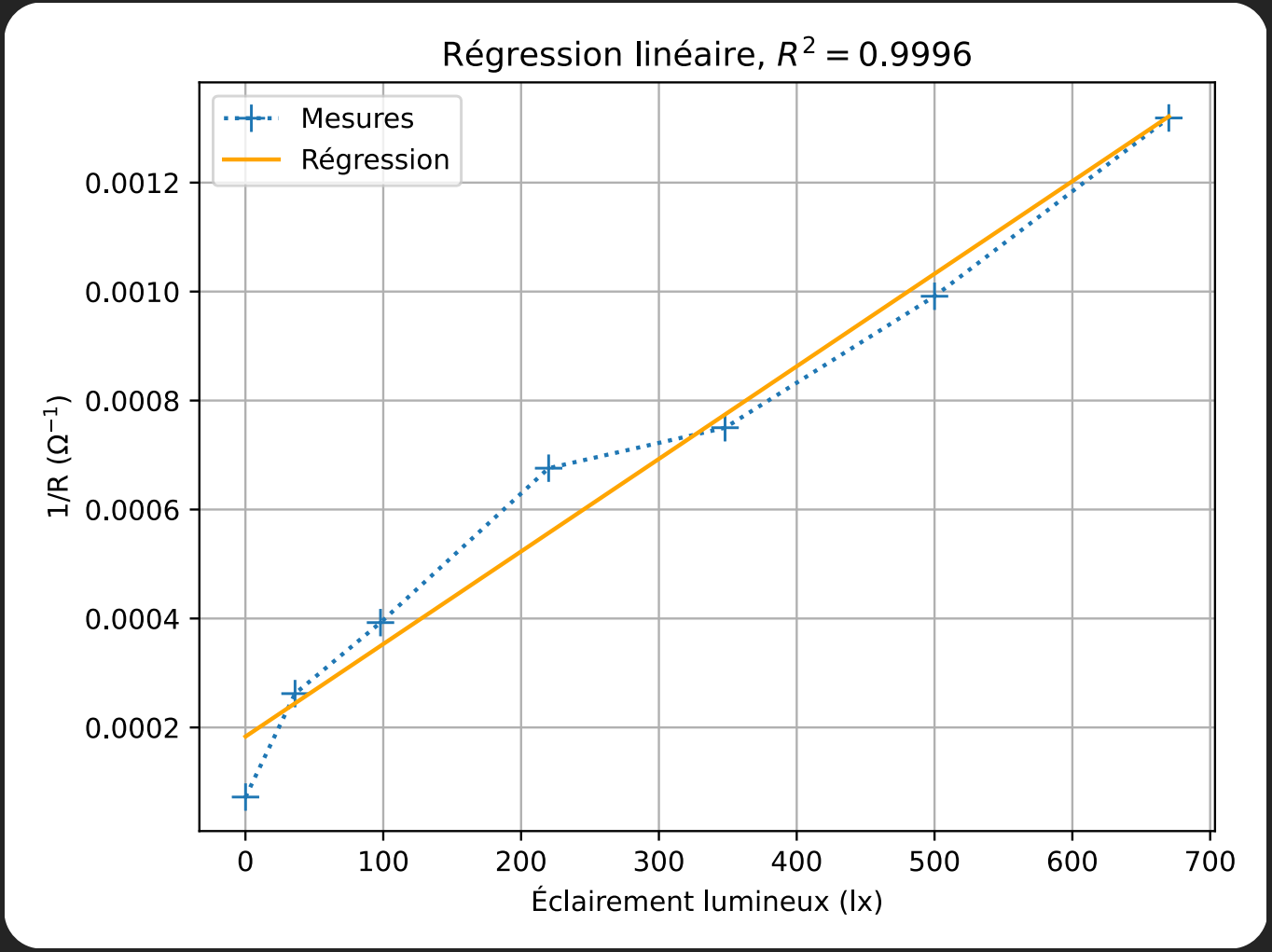
Schéma électrique



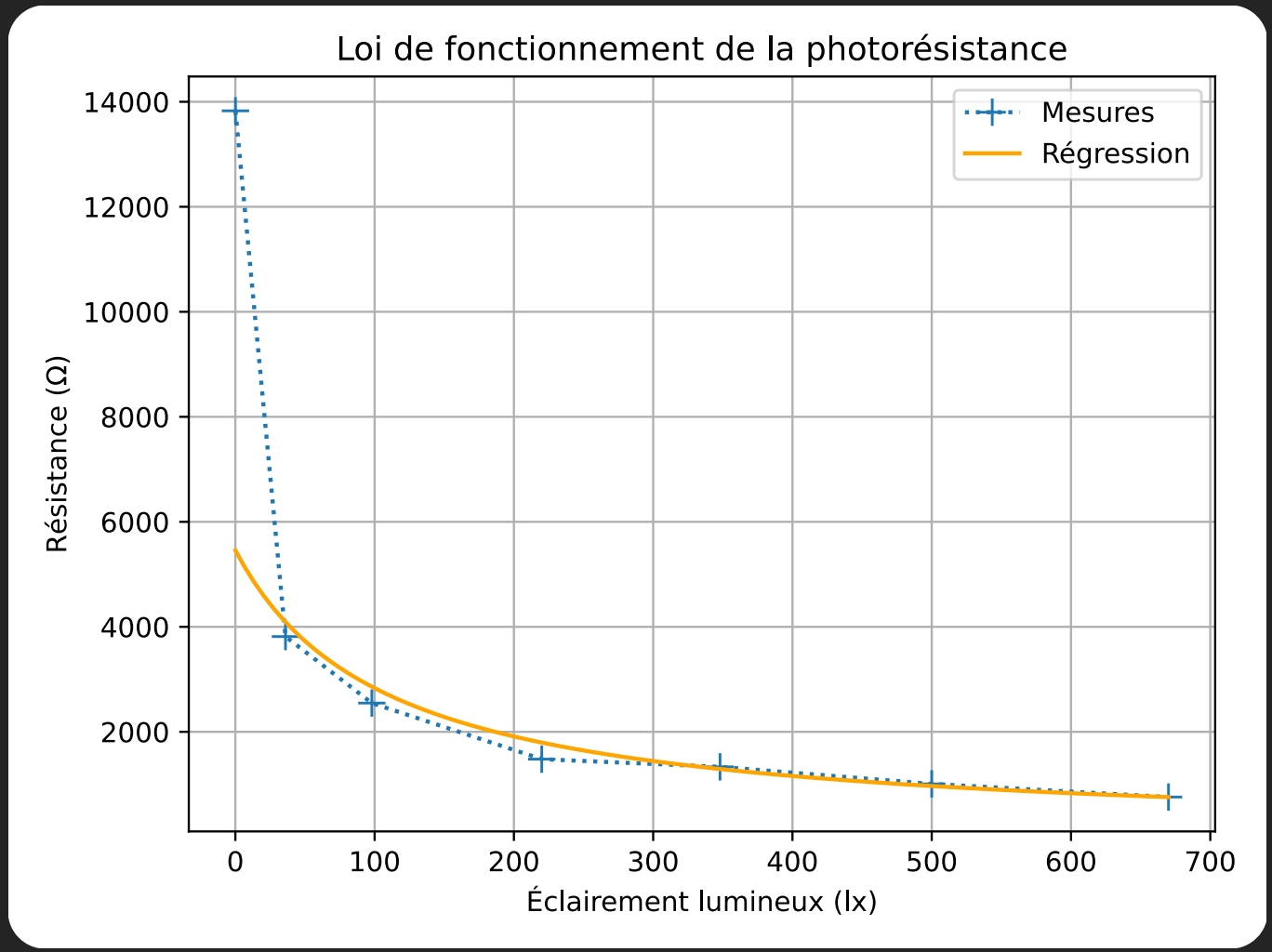
Données brutes



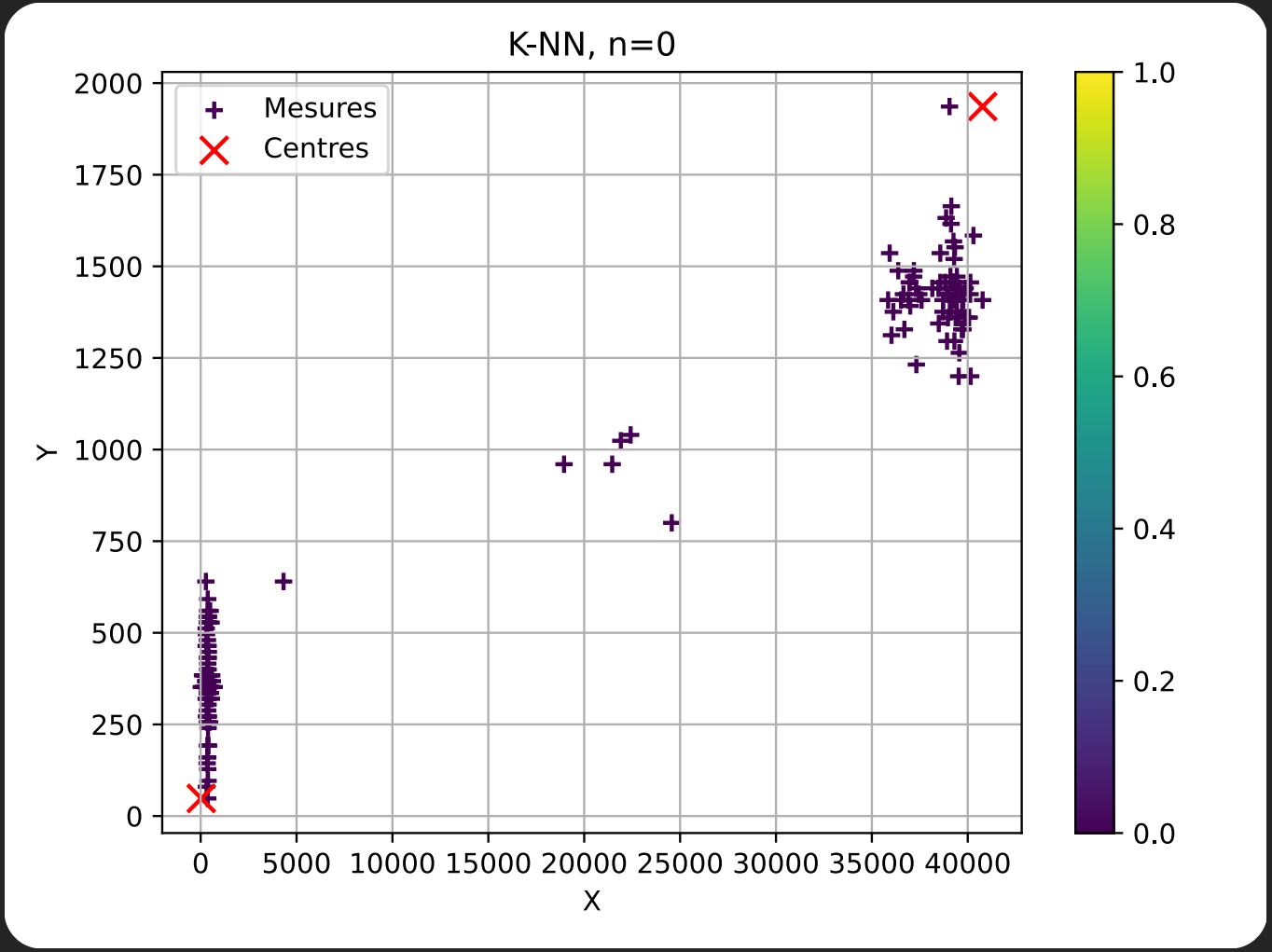
Régressions linéaires



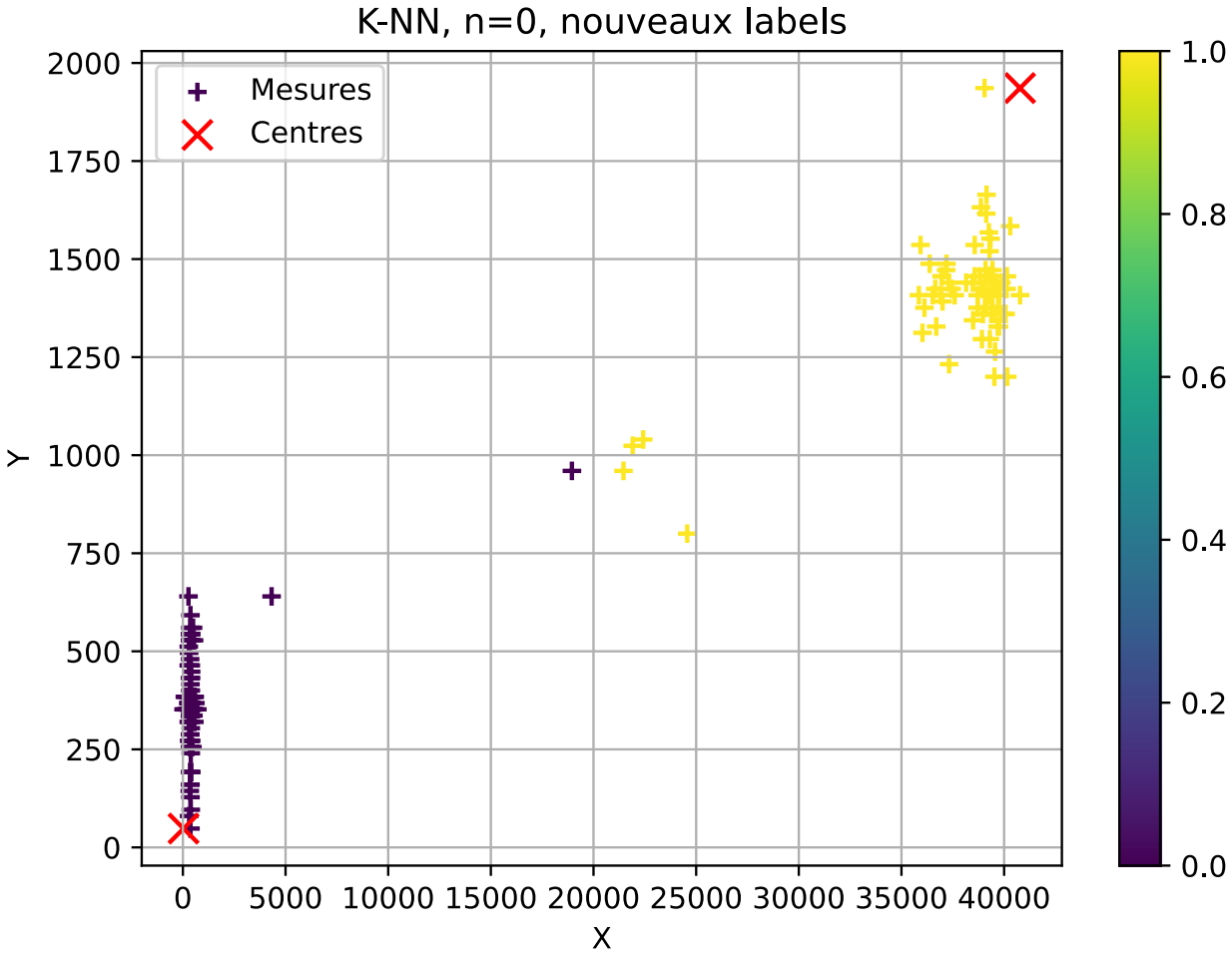
Fonction inverse + régression linéaire



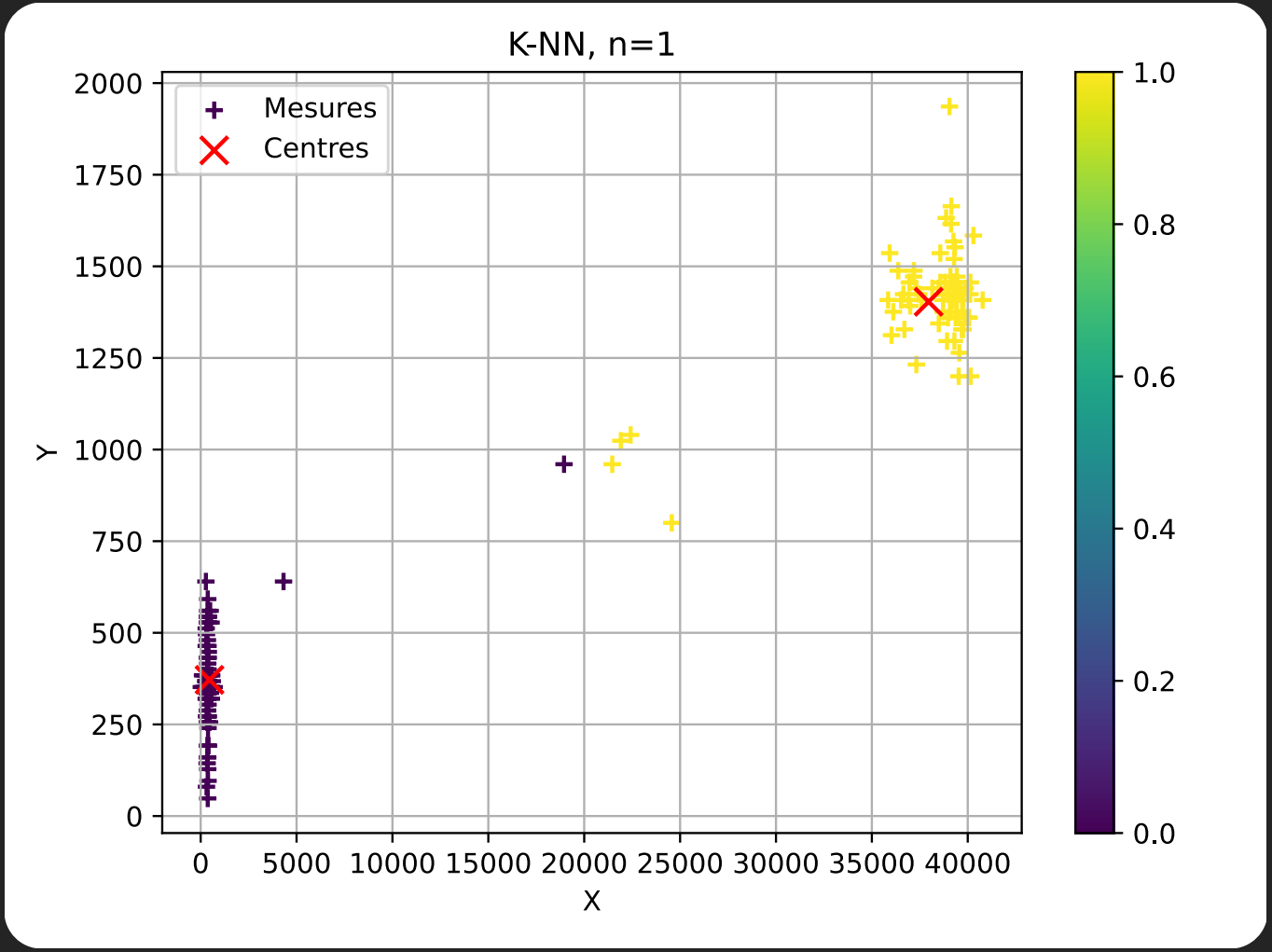
Transformée inverse



Annexe : KNN, 30m, 1



Annexe : KNN, 30m, 2



Annexe : KNN, 30m, 3

```python
def format_bis(entier, nb_bits):
    """
    Convertit un entier en binaire sur un nombre fixe de bits.

    Args:
        entier (int): L'entier à convertir.
        nb_bits (int): Le nombre de bits pour la représentation binaire.

    Returns:
        str: La représentation binaire de l'entier sur le nombre de bits spécifié.
    """
    # Convertit l'entier en binaire
    binaire = ""
    while entier > 0:
        binaire = str(entier % 2) + binaire
        entier //= 2

    # Ajoute des zéros de remplissage si nécessaire
    while len(binaire) < nb_bits:
        binaire = "0" + binaire

    # Tronque la chaîne si elle est trop longue
    if len(binaire) > nb_bits:
        binaire = binaire[-nb_bits:]

    return binaire

led = Pin('LED', Pin.OUT)
laser = Pin(16, Pin.OUT)
```

Annexe : Émission, 1

```python
alphabet = {'a':1,'b':2,'c':3,'d':4,'e':5,'f':6,'g':7,'h':8,'i':9,'j':10,'k':11,'l':12,
            'm':13,'n':14,'o':15,'p':16,'q':17,'r':18,'s':19,'t':20,'u':21,'v':22,'w':23,
            'x':24,'y':25,'z':26,' ':27,',':28,'.':29,'!':30,'?':31,"'":32}

# Inversion du dictionnaire pour obtenir une correspondance valeur -> lettre
tebahpla = {i: j for j, i in alphabet.items()}

def text_to_binary(message): #Entrée : str
    # Stocker le résultat
    binary_message = ""
    # Parcourir chaque caractère
    for c in message:
        if c in alphabet:
            # On attribue une valeur au cractère
            value = alphabet[c]
            # Convertir la valeur en binaire sur 5 bits
            binary_c = format_bis(value, 5)
            binary_message += binary_c
        else:
            print("Caractère '{c}' non supporté dans l'alphabet personnalisé.")
    return binary_message
```

Annexe : Émission, 2

```python
def hamming_encode(str):
    reverse_str=str[::-1]
    n=len(str)
    k = 0
    while (2 ** k) < (n + k + 1): #Calcul du nombre k de bits de contrôle
        k += 1
    result = [0 for u in range (n+k)]
    i = 0
    for x in range(1,n+k+1): #Ajoute les bits d'informations aux bons emplacements
        if x & (x-1) != 0: #Vérifie si x n'est pas une puissance de 2, & est l'opérateur ET logique qui compare en binaire x et x-1.
            #L'idée avec x et x-1 est que si x est une puissance de 2, son binaire ne possède qu'un 1, x-1 inverse alors tous les bits.
            #Donc aucun des bits ne sera commun à x et x-1 donc "l'indicatrice" & ne s'allume jamais et on a 0.
            result[x-1]=reverse_str[i]
            i+=1
    bits_1=[]
    bin_bits_1=[]
    for x in range(n+k):
        if result[x] == '1':
            bits_1.append(x+1) #stock la position de tous les bits valant 1
    for x in bits_1:
        bin_bits_1.append(format_bis(x,k))
    parity=[0 for i in range(k)]
    for x in bin_bits_1:
        for i in range(len(x)):
            parity[i]+=int(x[::-1][i]) #Calcule la parité de chaque bit de contrôle
    for u in range(len(parity)):
        if parity[u]%2==1:
            result[(2**u)-1]='1' #Ajuste la valeur du bit de contrôle selon sa parité
    final=''
    for y in result[::-1]:
        final+=y
    return(final)
```

Annexe : Émission, 3

```
def emission(binary,f):
    binary2="1"+str(binary)+"1"
    for x in binary2:
        if x == "1":
            laser.high()
            sleep(1/f)
            laser.low()
        else:
            sleep(1/f)

def text_to_light(message,f):
    return(emission(text_to_binary(message),f))

def text_to_light_hamming(message,f):
    return(emission(hamming_encode(text_to_binary(message)),f))
```

Annexe : Émission, 4

```
photo = ADC(Pin(26))
base = ADC(Pin(27))
switch = Pin(0, Pin.IN)

f_emit = 7
bit_duration = 3
f_recep = f_emit*bit_duration

data = []

while switch.value() == 0:
    pass

while switch.value() == 1:
    data.append([photo.read_u16(), base.read_u16()])
    sleep(1/f_recep)
```

```
centers = [[min(point[0] for point in data), min(point[1] for point in data)],[max(point[0] for point in data), max(point[1] for point in data)]]

centers, labels = knn.k_means(data, centers, n = 100)
bits = error_detection.clean_signal(labels, bit_duration)
bits = convertors.list_to_str(bits)

### sans hamming
message = convertors.binary_to_text(bits)

### avec hamming
hamminged_message = hamming.hamming_decode(bits)

message = convertors.binary_to_text(hamminged_message)
print(message)
```

Annexe : Réception, 1

```python
from math import sqrt

def distance(p1, p2):
    return sqrt((p1[0] - p2[0]) ** 2 + (p1[1] - p2[1]) ** 2)

def k_means(data, centers, n=100):
    n_points = len(data)
    n_clusters = len(centers)

    labels = [0]*n_points

    for _ in range(n):
        # update labels
        new_labels = []
        for i in range(n_points):
            # compute all distances, attribute new centers
            distances = [distance(data[i], center) for center in centers]
            new_labels.append(distances.index(min(distances)))

        # update clusters
        new_centers = []
        for k in range(n_clusters):
            cluster_points = [data[i] for i in range(n_points) if new_labels[i] == k]
            if cluster_points != []: # for not empty clusters
                mean_x = sum(point[0] for point in cluster_points) / len(cluster_points)
                mean_y = sum(point[1] for point in cluster_points) / len(cluster_points)
                new_centers.append([mean_x, mean_y])

            else: # for empty clusters
                new_centers.append(centers[k])

        # check for convergence
        if new_centers == centers:
            break
        centers = new_centers
        labels = new_labels

    return centers, labels
```

Annexe : Réception, 2

```python
def clean_signal(bits, bit_duration):
    output = rmv_first_zeros(bits, bit_duration)
    output = filtering(output, bit_duration)
    output = rmv_last_zeros(output)

    output = output[1:-1]

    print("clean_signal")
    print(output)

    return output

def rmv_first_zeros(bits, bit_duration):
    init = True

    while init :
        while bits[0] == 0:
            bits.pop(0)

        mean = round(sum(bits[:bit_duration])/bit_duration)

        if mean == 1:
            init = False

        else:
            bits.pop(0)

    return bits
```

Annexe : Réception, 3

```python
def filtering(bits, bit_duration):
    n = len(bits)
    groups = [bits[i:i+bit_duration] for i in range(0, n, bit_duration)]
    output = []

    for group in groups:
        mean = round(sum(group)/bit_duration)
        output.append(mean)

    return output

def fintering2(bits, bit_duration):
    n = len(bits)
    groups = [bits[i:i+bit_duration] for i in range(0, n, bit_duration)]
    output = []

    for group in groups:
        mean = round(sum(group[1:-1])/(bit_duration-2))
        output.append(mean)

    return output

def rmv_last_zeros(bits):
    while bits[-1] == 0:
      bits.pop(-1)

    return bits
```

Annexe : Réception, 4

```python
def hamming_decode(stri:str)->str:
    reverse_str=list(stri[::-1])
    n=len(stri)
    k = 0
    while (2 ** k) < (n + 1): #Cherche le nombre de bits de contrôle
        k += 1
    result=[]
    bits_1=[]
    bin_bits_1=[]
    for x in range(n):
        if reverse_str[x] == '1':
            bits_1.append(x+1) #stock la position de tous les bits valant 1
    for x in bits_1:
        bin_bits_1.append(format_bis(x,k))
    parity=[0 for i in range(k)]
    for x in bin_bits_1:
        for i in range(len(x)):
            parity[i]+=int(x[::-1][i]) #Calcule la parité de chaque bit de contrôle
    ok=0 #Tant que ok=0, aucune erreur détectée
    bit_error = 0
    for u in range(len(parity)):
        if parity[u]%2==1:
            ok+=1
            bit_error+=2**u
            index_bit_error=bit_error-1
    if ok == 0:
        print("Aucune erreur détectée")
    else:
        print("Erreur détectée au bit",bit_error)
        reverse_str[index_bit_error] = '0' if reverse_str[index_bit_error] == '1' else '1'
    for u in range(n):
        if u+1 & u != 0:
            result.append(reverse_str[u])
    final=''
    for y in result[::-1]:
        final+=y
    return final
```

Annexe : Réception, 5

```python
def list_to_str(list:list) -> str:
    output = ""
    for i in list :
        output += str(i)
    return output


def binary_to_text(binary_message, tebahpla:dict=tebahpla) -> str:
    """Convert a "01" string to a string of ASCII characters."""

    if type(binary_message) != str:
        binary_message = list_to_str(binary_message)

    message = ""

    # parse the binary string into groups of 5 bits
    for i in range(0, len(binary_message), 5):
        bit = binary_message[i:i+5]

        # convert the 5 bits to an integer, convert the integer to a character
        try :
            message += tebahpla[int(bit, 2)]

        # if wrong char
        except KeyError:
            message += "*"

    return message
```

Annexe : Réception, 6

```python
def gauss(x, A, B):
        y = A*np.exp(-2*x**2/(B**2))
        return y

def div(x,A,B):
        y = A*np.sqrt(1+(x/B)**2)
        return y

def get_r_v(z):
    global cur
    cur.execute(f'SELECT data.Radius, data.Voltage FROM data WHERE data.distance = {z} AND data.radius >= {0} ORDER BY data.Radius')
    rows = cur.fetchall()
    r = np.array([row[0] for row in rows])
    v = np.array([row[1] for row in rows])
    return np.array(r),np.array(v)
```

```python
conn = sqlite3.connect('V2/data2.db')
cur = conn.cursor()

z_list = cur.execute('SELECT DISTINCT data.distance FROM data ORDER BY data.distance').fetchall()
z_list = [z[0] for z in z_list]
W_list = []
```

Annexe : Caractéristique laser, 1

```python
for z in z_list:
    R,V = get_r_v_(z)
    parameters,covariance = curve_fit(gauss, R, V)
    fit_A = parameters[0]
    fit_B = parameters[1]

    W_list.append(fit_B)

    fit_r = np.linspace(min(R), max(R), 100)
    fit_v = gauss(fit_r, fit_A, fit_B)

    plt.figure(f'Matrice de covariance gaussienne z={z}m')
    plt.title(f'Matrice de covariance gaussienne z={z}m')
    sns.heatmap(covariance, annot=True, xticklabels=['Amplitude (V)', 'w(z) (mm)'], yticklabels=['Amplitude (V)', 'w(z) (mm)'], cmap='viridis')
    plt.figure(f'Tension au fil du rayon (z={z})')
    plt.plot(R,V, marker='+', linestyle='dotted', markersize=10, label='Mesures')
    plt.plot(fit_r, fit_v, color='orange', label='Régression')
    plt.grid()
    plt.xlabel('Rayon (mm)')
    plt.ylabel('Tension (V)')
    plt.title(f'Évolution de la tension au fil du rayon, z={z}m')
    plt.tight_layout()
    plt.legend()
```

Annexe : Caractéristique laser, 2

```python
z_list, W_list = np.array(z_list),np.array(W_list)

parameters,covariance = curve_fit(div, z_list, W_list)
fit_A = parameters[0]
fit_B = parameters[1]

plt.figure('Matrice de covariance rayon caractéristique')
plt.title('Matrice de covariance rayon caractéristique')
sns.heatmap(covariance, annot=True, xticklabels=[r'${W_0}$ (mm)', r'${z_r}$ (m)'], yticklabels=[r'${W_0}$ (mm)', r'${z_r}$ (m)'], cmap='viridis')

print(f'W0 = {fit_A}, zr = {fit_B}')

fit_z = np.linspace(min(z_list), max(z_list), 100)
fit_w = div(fit_z, fit_A, fit_B)

plt.figure('Rayon caractéristique distance')
plt.plot(z_list, W_list, marker='+', linestyle='dotted', markersize=10, label='Mesures')
plt.plot(fit_z, fit_w, color='orange', label='Régression')
plt.xlabel('Distance laser/réception (m)')
plt.ylabel('Rayon caractéristique (mm)')
plt.title('Rayon caractéristique au fil de la distance')
plt.legend()
plt.tight_layout()
plt.grid()
plt.show()
```

Annexe : Caractéristique laser, 3

```python
R_mes = 215

I_global = []
U_photo_global = []
i_mes_global = []
E = np.array([0,0.49,0.98,1.47,1.96,2.45,2.94])

def store(I,U_R):
    U_photo = E - U_R
    i_mes = U_R / R_mes

    I_global.append(I)
    U_photo_global.append(U_photo)
    i_mes_global.append(i_mes)

I_global = np.array(I_global)
U_photo_global = np.array(U_photo_global)
i_mes_global = np.array(i_mes_global)
```

```python
fig = plt.figure('Données brutes')
ax = fig.add_subplot(projection='3d')

for i in range(len(I_global)) :
    ax.plot(i_mes_global[i],U_photo_global[i], I_global[i], marker = '+', markersize=10)

plt.title('Lien entre intensité, tension et éclairement lumineux')
ax.set_xlabel('Intensité (A)')
ax.set_ylabel('Tension (V)')
ax.set_zlabel('Éclairement lumineux (lx)')
plt.tight_layout()
ax.grid()
```

```python
R = []
R_square = []

for i in range(len(I_global)) :
    vec = np.polyfit(i_mes_global[i], U_photo_global[i],1)
    R.append(vec[0])
    U_reg = i_mes_global[i]*vec[0]
    err_quadratique = np.sum((U_photo_global[i] - U_reg)**2)
    ecart_type = np.sum((U_photo_global[i] - np.mean(U_photo_global[i]))**2)
    R_square.append(1-err_quadratique/ecart_type)

R = np.array(R)

min_R_square = min(R_square)
min_R_square = round(min_R_square,3)

fig = plt.figure('Régression linéaire 1')

plt.plot(I_global,R, marker='+', linestyle='dotted', markersize=10)
plt.title(r'Lien entre éclairement lumineux et resistance, $R^2 = $' + str(min_R_square))
plt.xlabel('Éclairement lumineux (lx)')
plt.ylabel(r'Resistance ($\Omega$)')
plt.tight_layout()
plt.grid()
```

Annexe : Caractéristique photorésistance, 1

```
new_R = 1/R

vec = np.polyfit(I_global,new_R,1)
I_lin = np.linspace(min(I_global),max(I_global),100)
reg = vec[0]*I_lin + vec[1]

err_quadratique = np.sum((U_photo_global[i] - U_reg)**2)
ecart_type = np.sum((U_photo_global[i] - np.mean(U_photo_global[i]))**2)

R_square = (1-err_quadratique/ecart_type)
R_square = round(R_square,4)

fig = plt.figure('Régression linéaire 2')
plt.plot(I_global,new_R, marker='+', linestyle='dotted', markersize=10, label='Mesures')
plt.plot(I_lin,reg, color='orange', label='Régression')
plt.title(r'Régression linéaire, $R^2 = $' + str(R_square))
plt.xlabel('Éclairement lumineux (lx)')
plt.ylabel(r'1/R ($\Omega^{-1}$)')
plt.legend()
plt.tight_layout()
plt.grid()
```

```
R_reg = 1/reg

fig = plt.figure('Loi fonctionnement photorésistance')
plt.plot(I_global,R, marker='+', linestyle='dotted', markersize=10, label='Mesures')
plt.plot(I_lin,R_reg, color='orange', label='Régression')
plt.title('Loi de fonctionnement de la photorésistance')
plt.xlabel('Éclairement lumineux (lx)')
plt.ylabel(r'Résistance ($\Omega$)')
plt.legend()
plt.tight_layout()
plt.grid()
plt.show()
```

Annexe : Caractéristique photorésistance, 2