# LÁSER DE ND:YAG
## CAVIDADES Y MODOS TRANSVERSALES

BERNARDO PIRONIO, TOMÁS MASTANTUONO, FACUNDO CAAMAÑO

# OBJETIVOS

1. ARMAR UN LASER UTILIZANDO DIFERENTES CAVIDADES RESONANTES
2. MEDICIÓN DE EFICIENCIA
3. ESTUDIO DE MODOS TEM (TRANSVERSO ELECTRO-MAGNÉTICO)

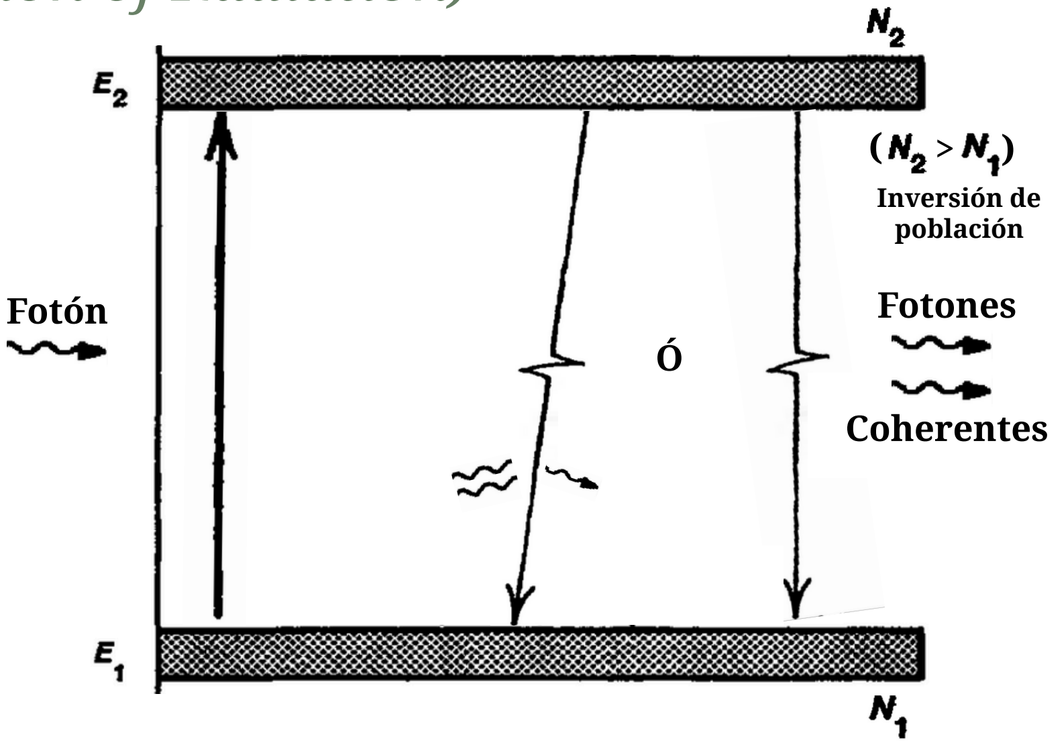
# LASER

*(Light Amplification by Stimulated Emission of Radiation)*

# L A S E R

*(Light Amplification by Stimulated Emission of Radiation)*

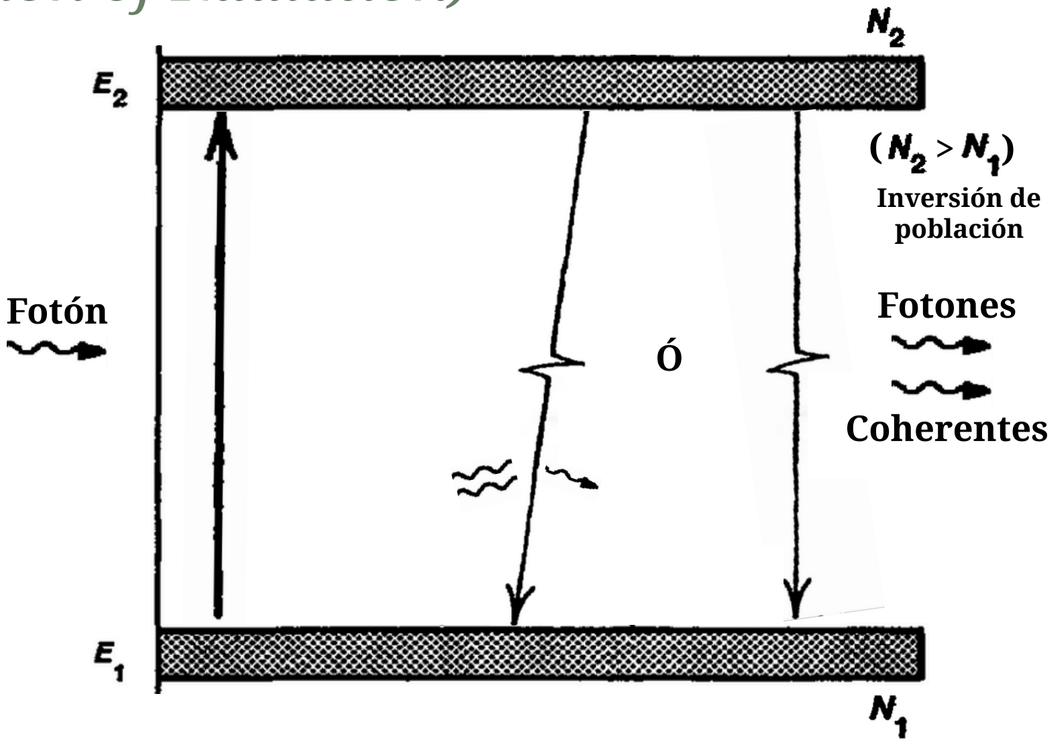
- Emisión estimulada ---> Inversión de población.



# LASER

*(Light Amplification by Stimulated Emission of Radiation)*

- Emisión estimulada ---> Inversión de población.
- 3 partes fundamentales:
  - Medio activo

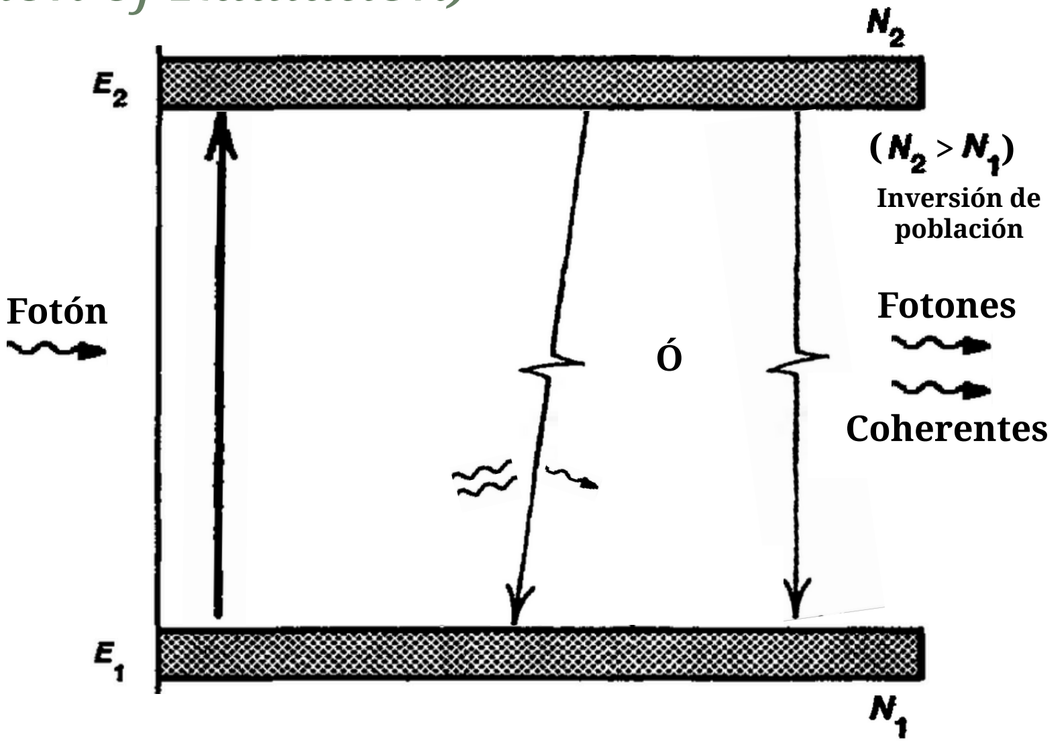


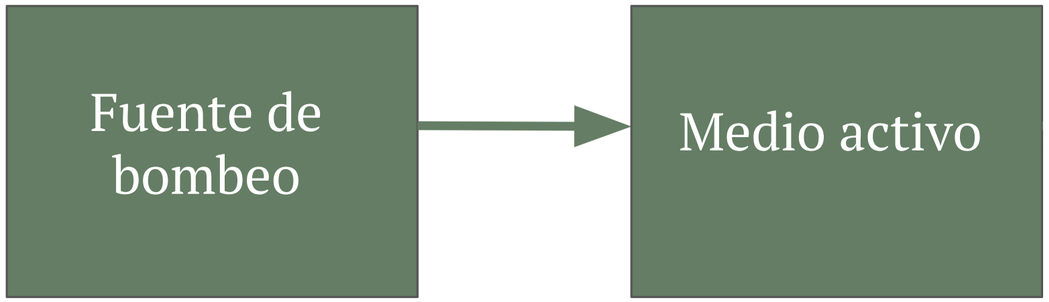

Medio activo

# LASER

*(Light Amplification by Stimulated Emission of Radiation)*

- Emisión estimulada ---> Inversión de población.
- 3 partes fundamentales:
  - Medio activo
  - Fuente de bombeo

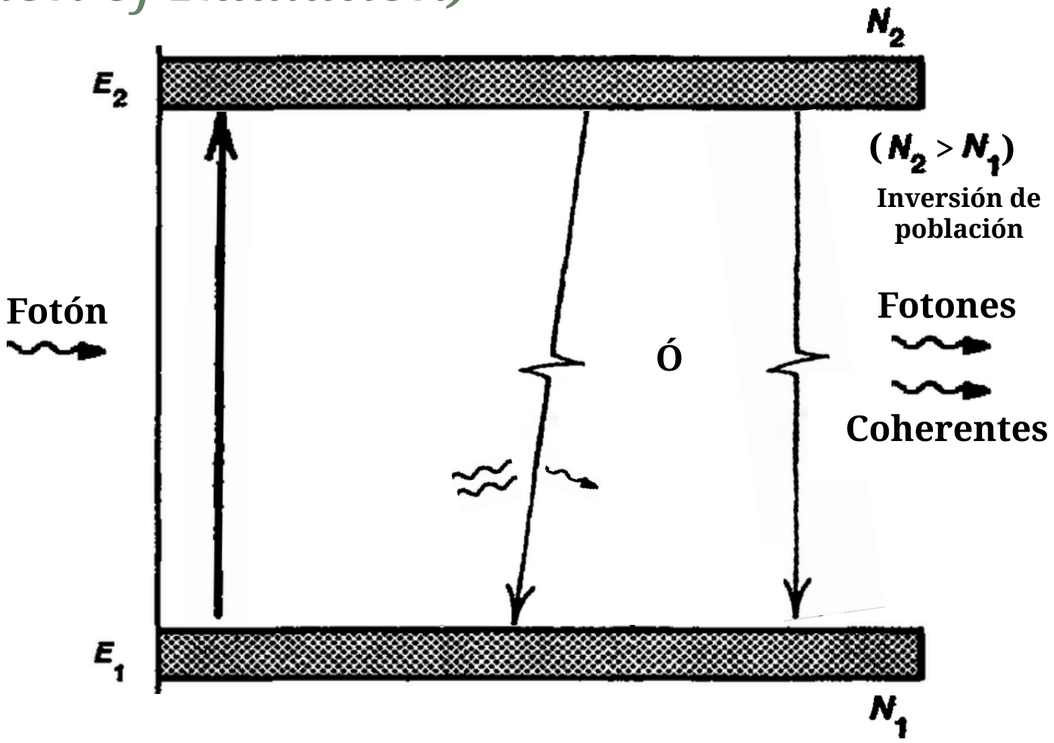


# LASER

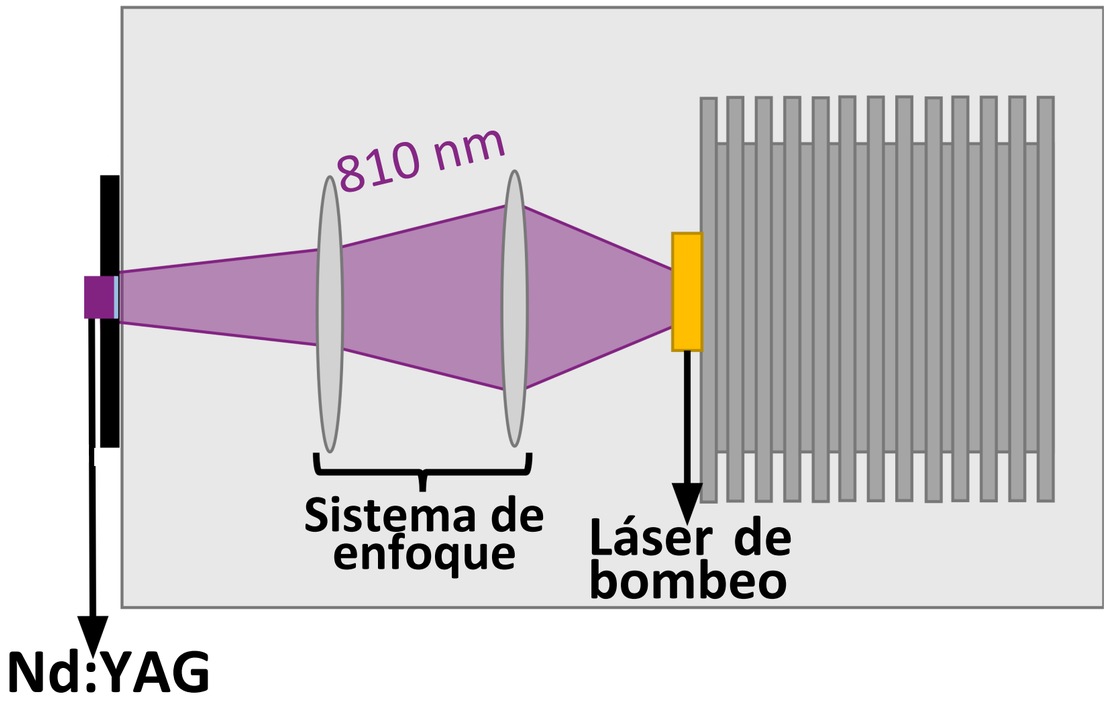
*(Light Amplification by Stimulated Emission of Radiation)*

- Emisión estimulada ---> Inversión de población.
- 3 partes fundamentales:
  - Medio activo
  - Fuente de bombeo
  - Realimentación



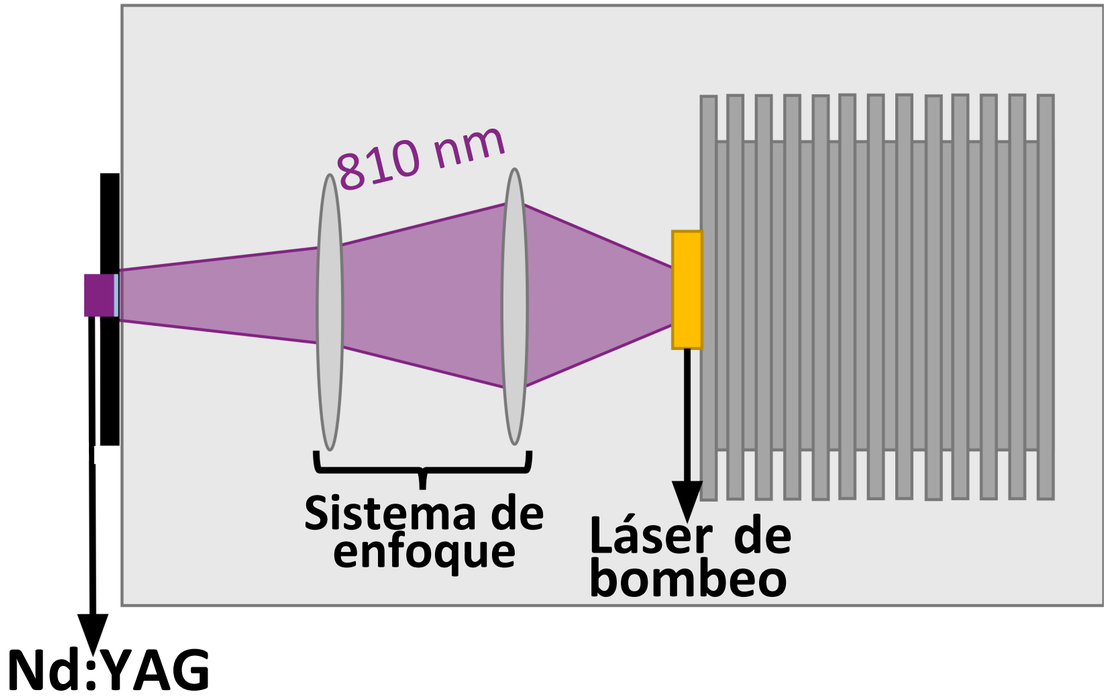

# MATERIALES UTILIZADOS

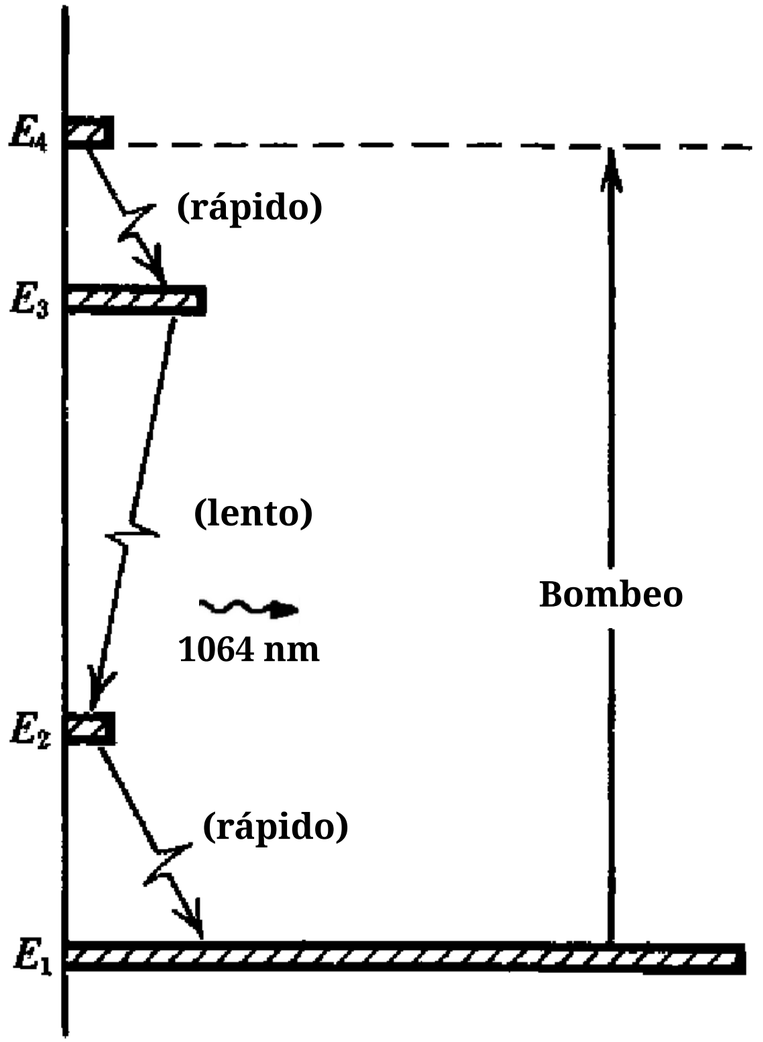
- Nd:YAG (grante de itrio y aluminio dopado con impurezas de neodimio).
- Láser de bombeo (con un sistema de enfoque).



# MATERIALES UTILIZADOS

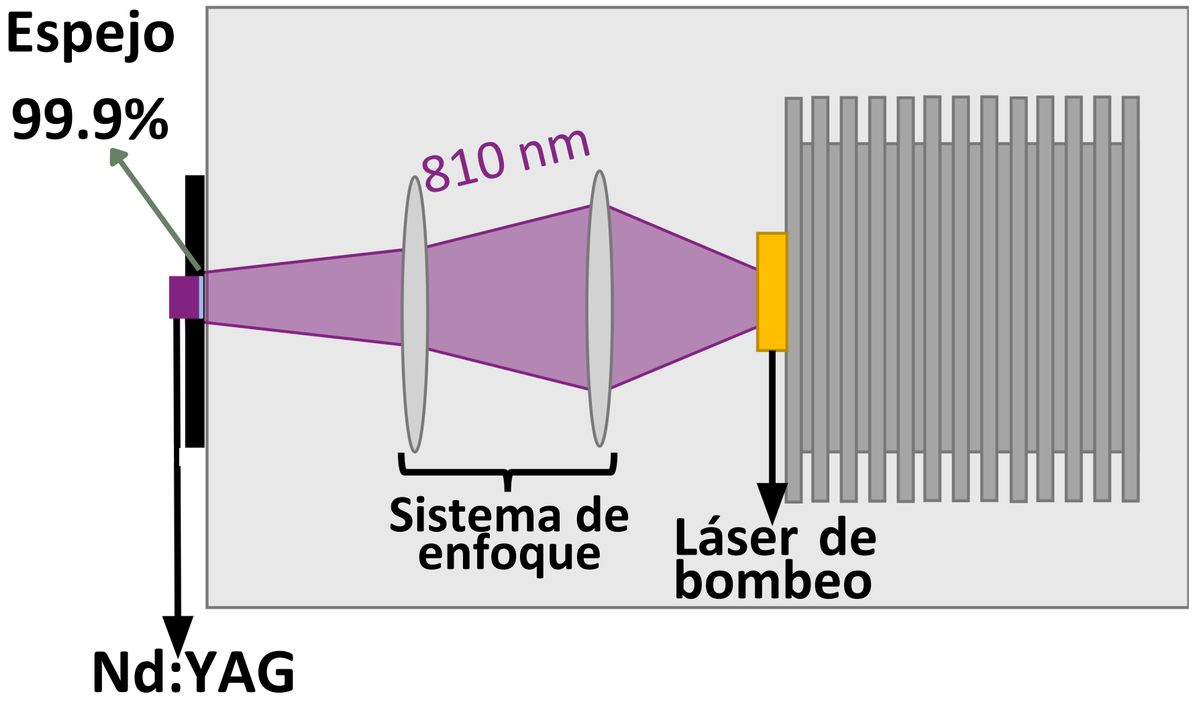
- Nd:YAG (grante de itrio y aluminio dopado con impurezas de neodimio).
- Láser de bombeo (con un sistema de enfoque).
- ¿Por qué Nd:YAG? ---> Niveles energéticos del neodimio, emisión estimulada fácil de lograr.

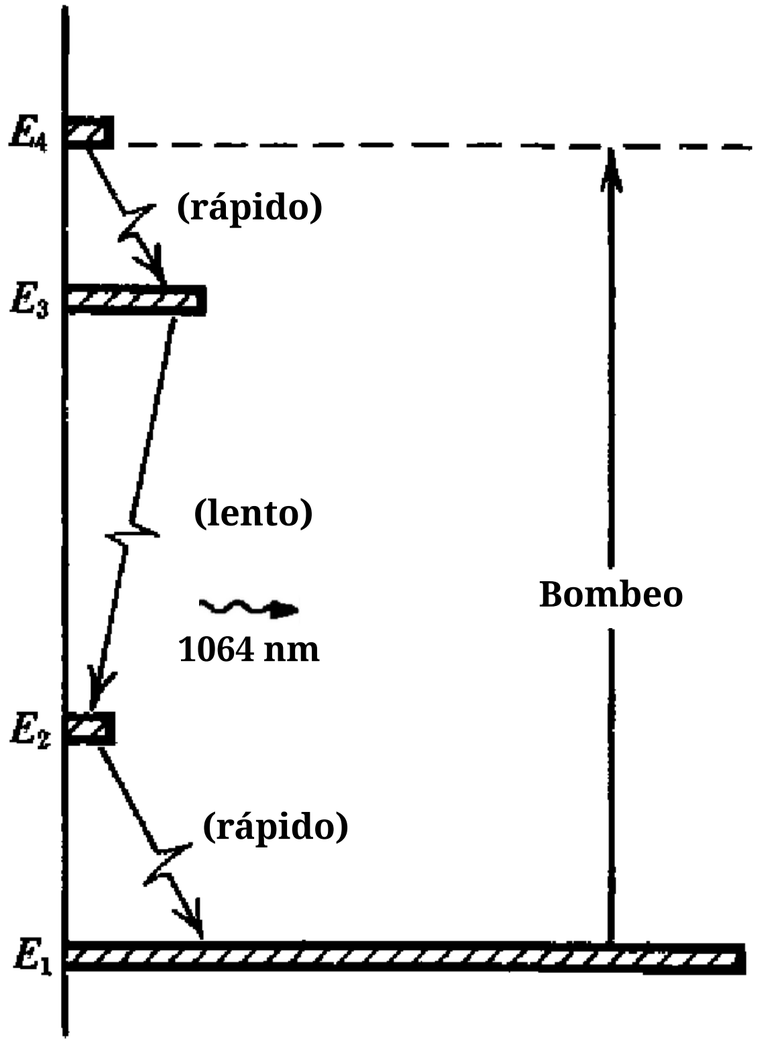


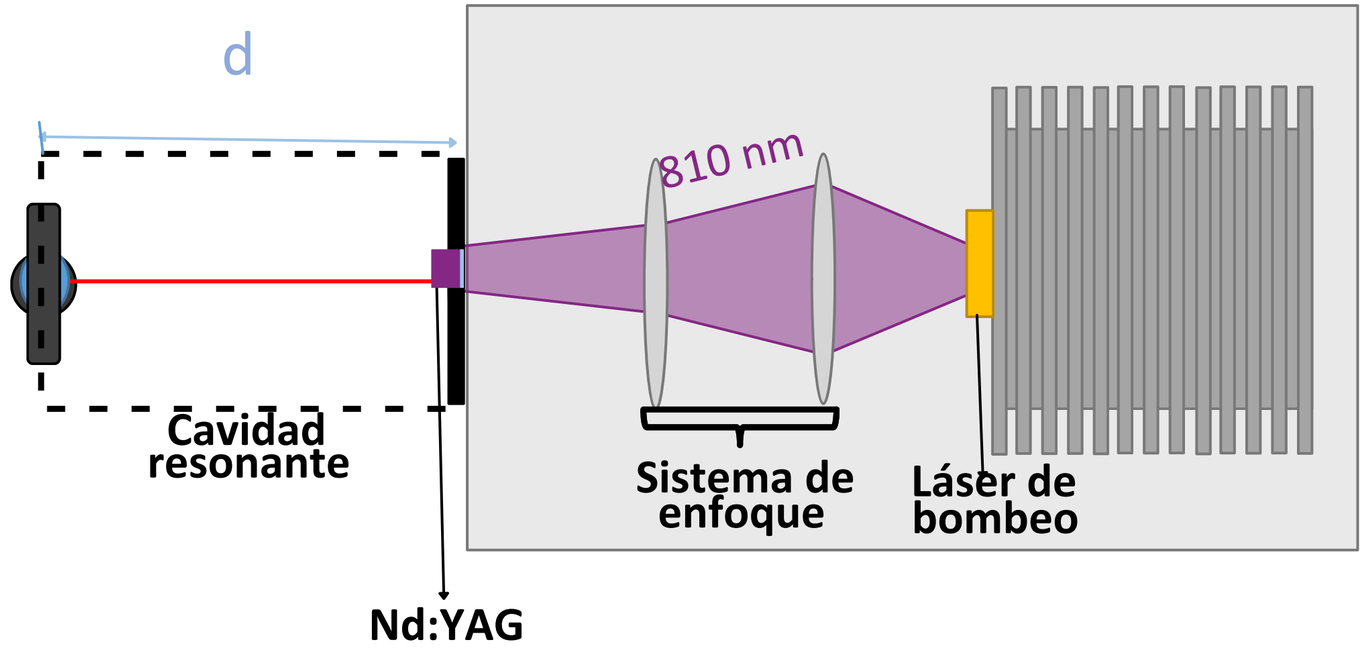
# MATERIALES UTILIZADOS

- Nd:YAG (grante de itrio y aluminio dopado con impurezas de neodimio).
- Láser de bombeo (con un sistema de enfoque).
- ¿Por qué Nd:YAG? ---> Niveles energéticos del neodimio, emisión estimulada fácil de lograr.
- Realimentación ---> Cavidades estables

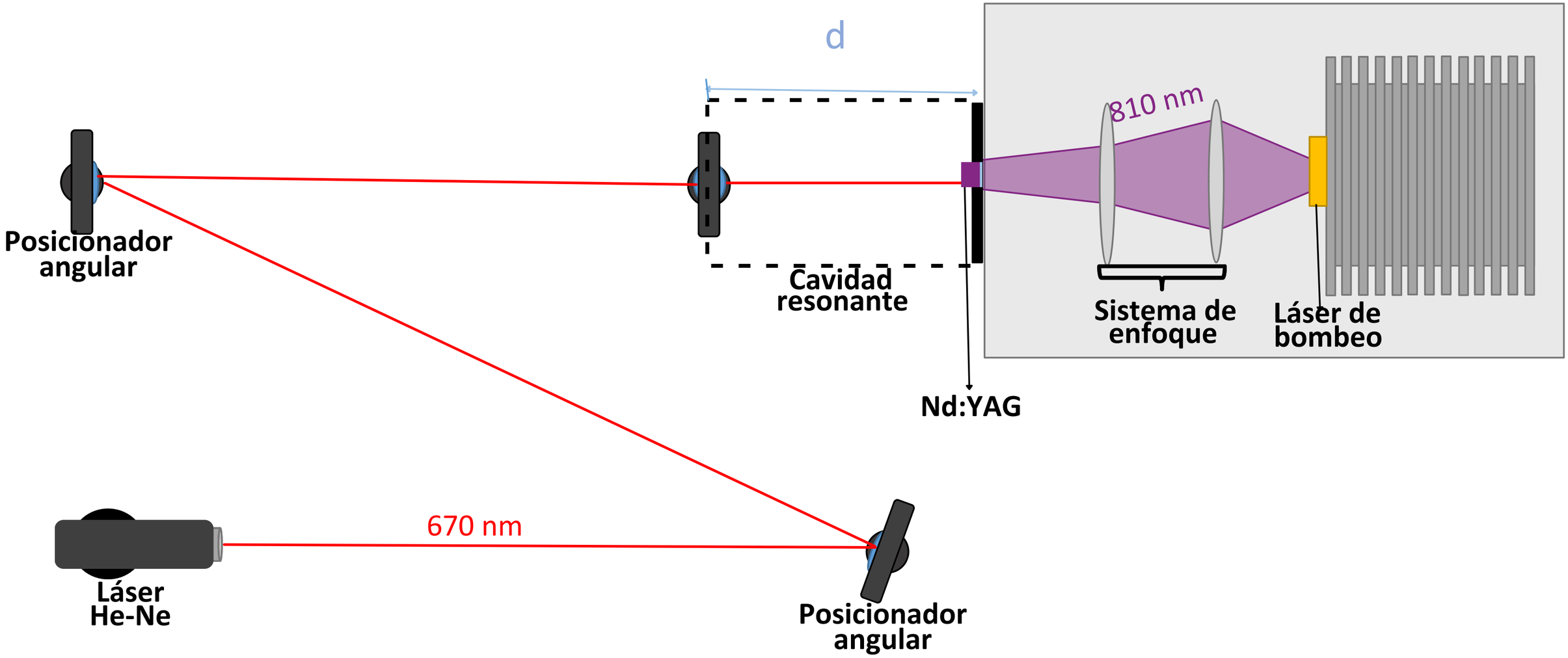


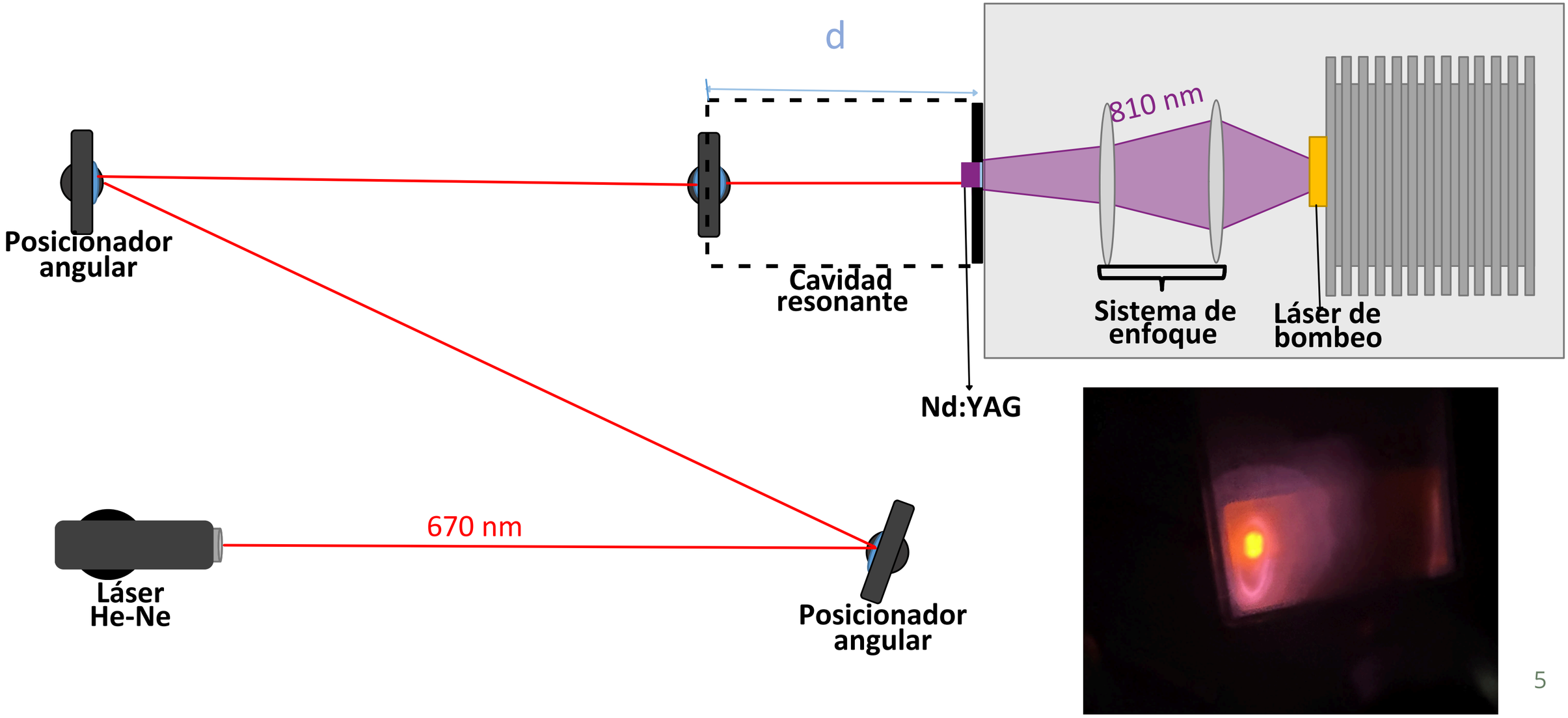
# CAVIDAD LINEAL



# CAVIDAD LINEAL

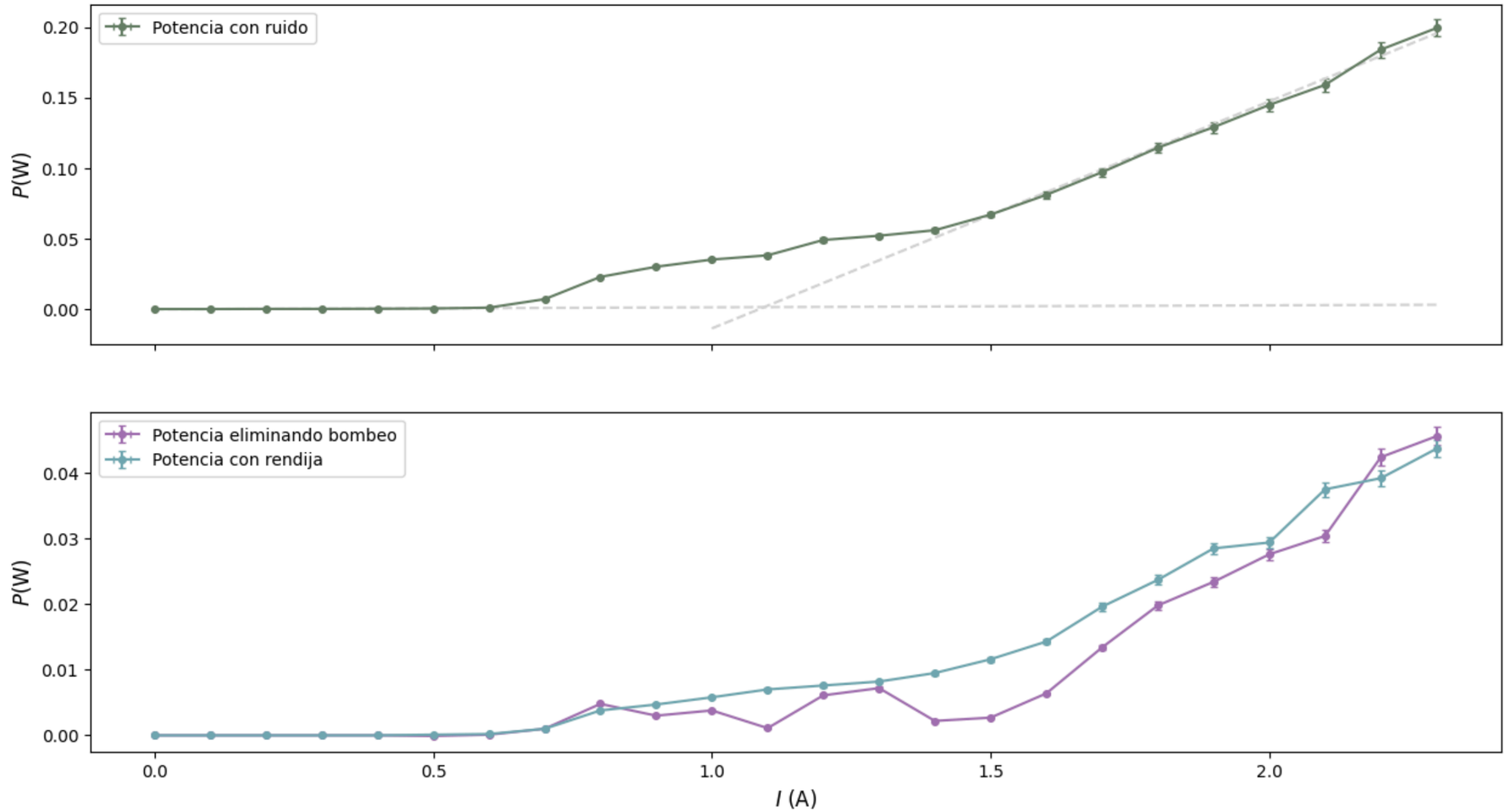


# CAVIDAD LINEAL

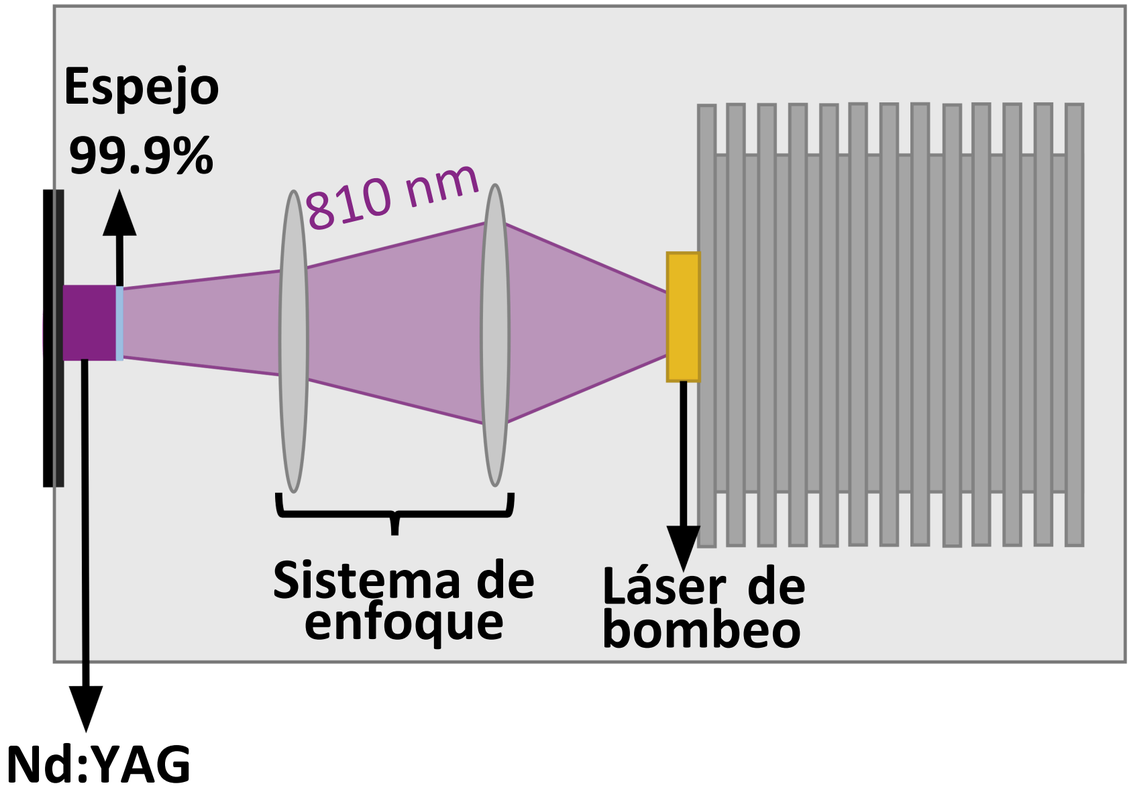


# EFICIENCIA

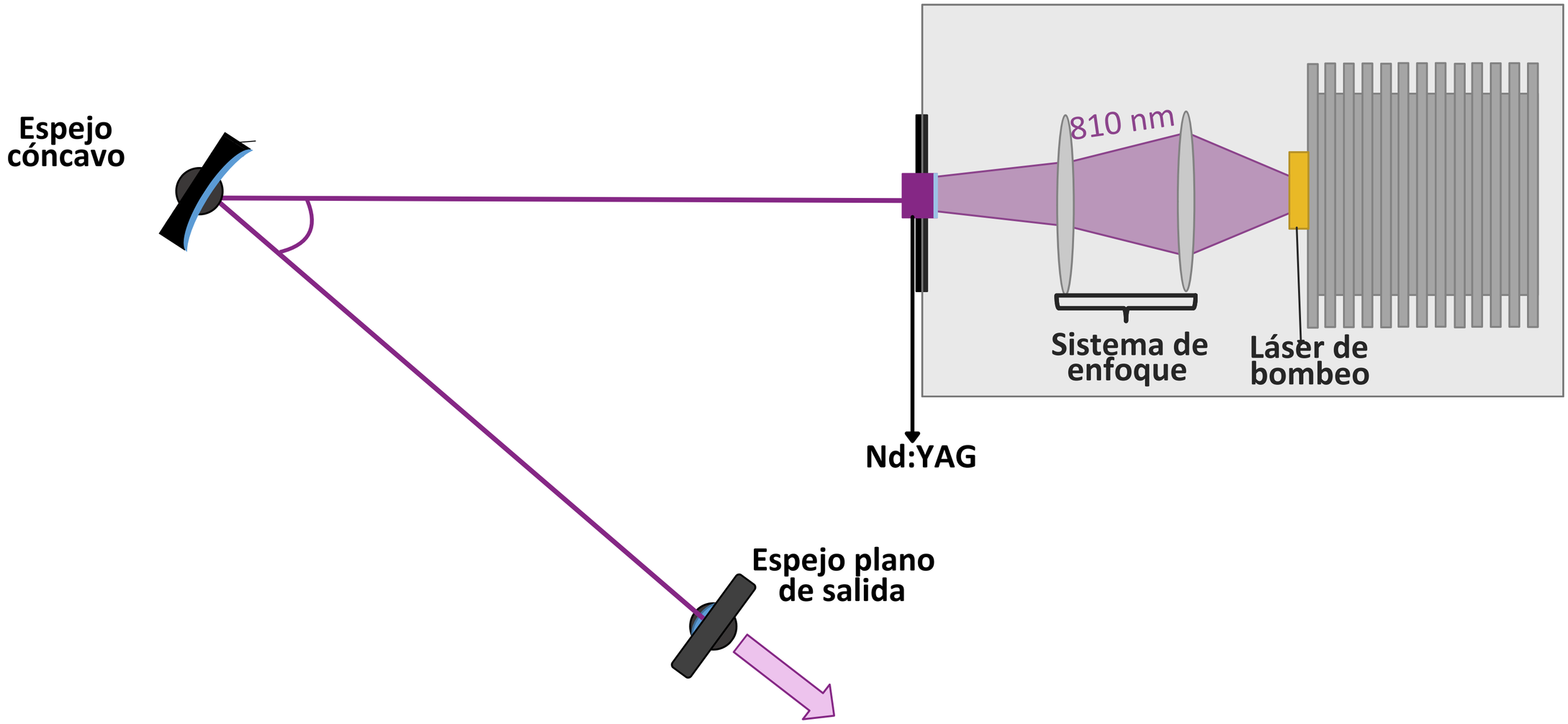
- Potencia en funcion de la corriente medida a  1064 nm
- Potencia eliminando el bombeo
- Potencia tapando el bombreo con una rendija



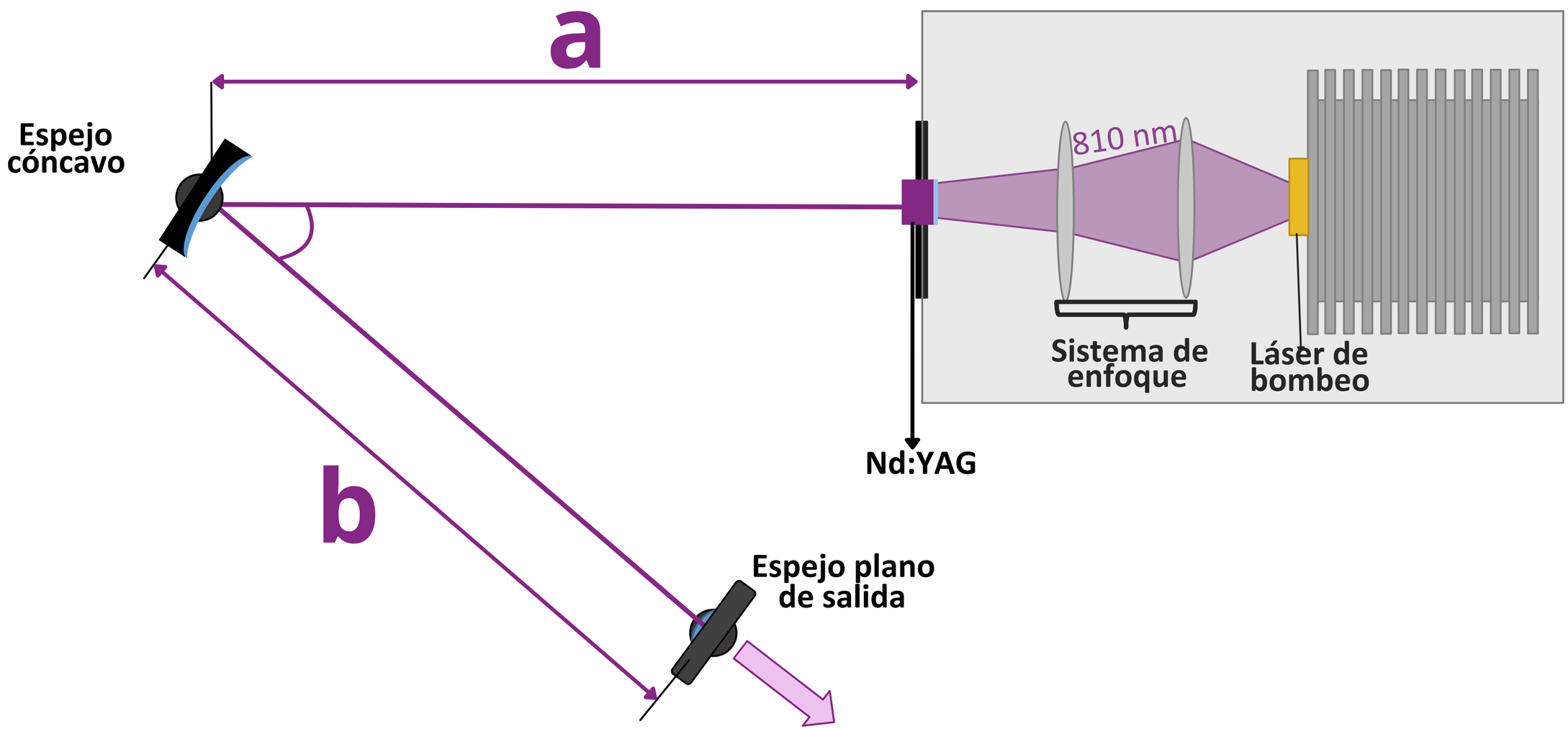
# CAVIDAD EN V



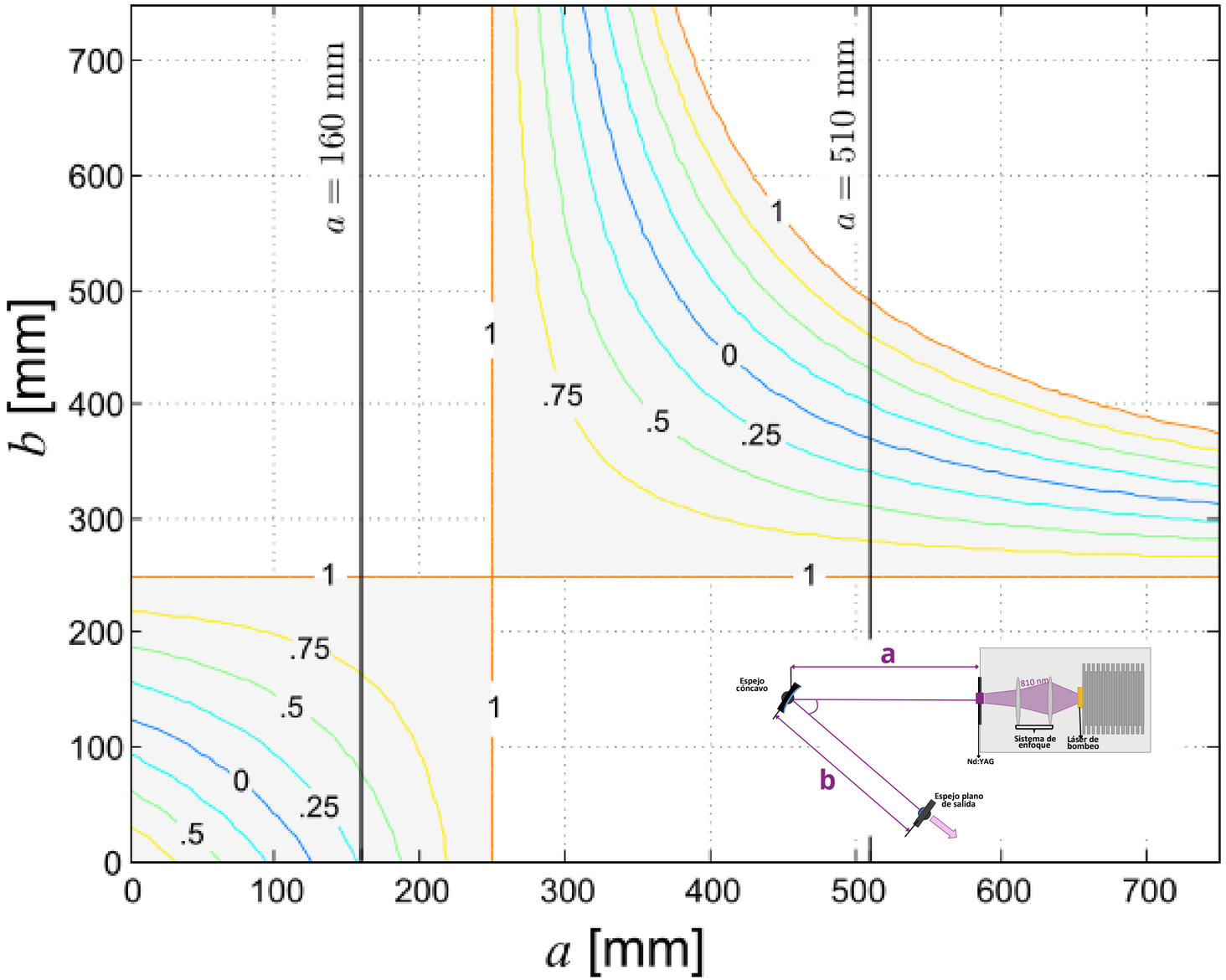
# CAVIDAD EN V


Espejo
cóncavo
810 nm
Sistema de
enfoque
Láser de
bombeo
Nd:YAG
Espejo plano
de salida

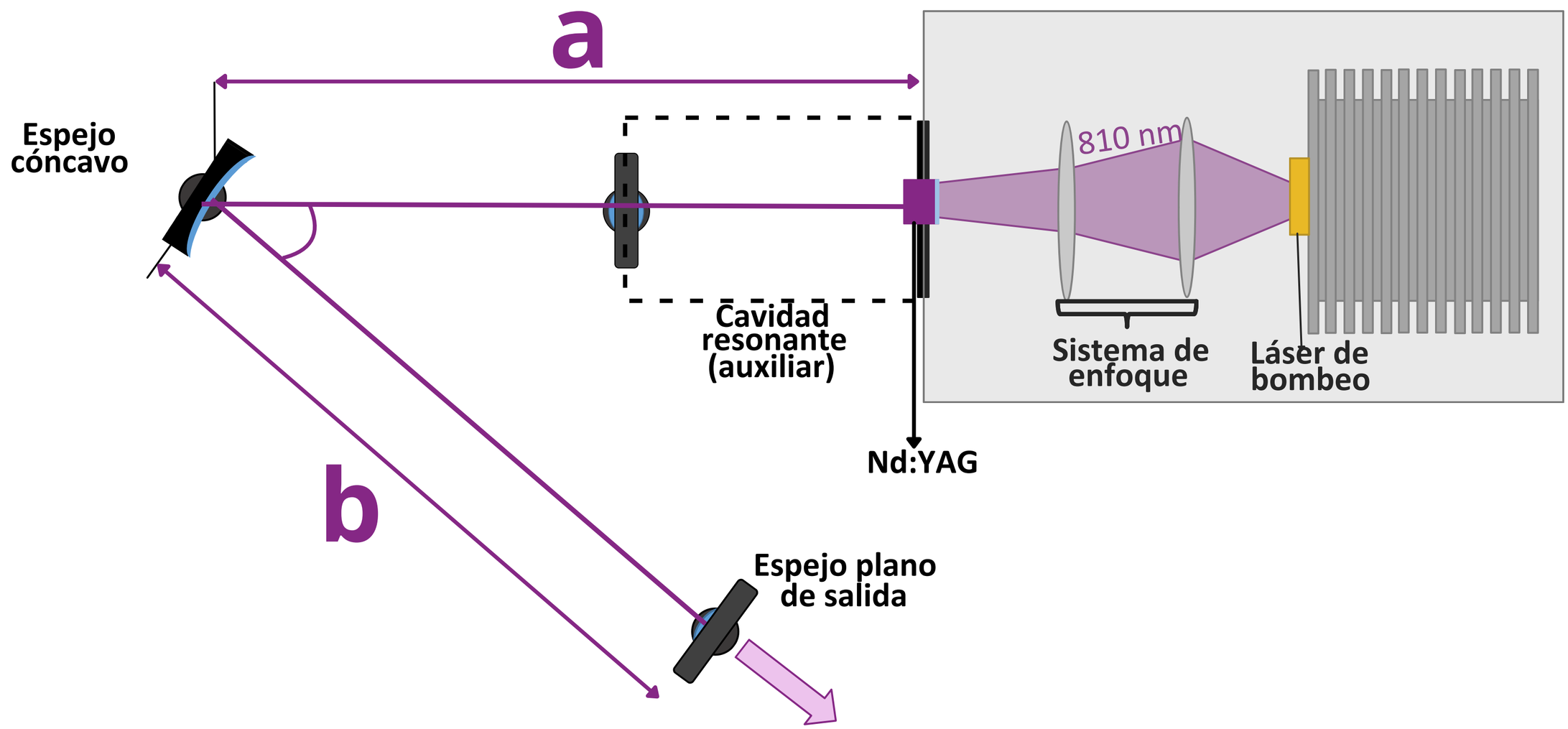
# CAVIDAD EN V


a
Espejo
cóncavo
810 nm
Sistema de
enfoque
Láser de
bombeo
Nd:YAG
b
Espejo plano
de salida

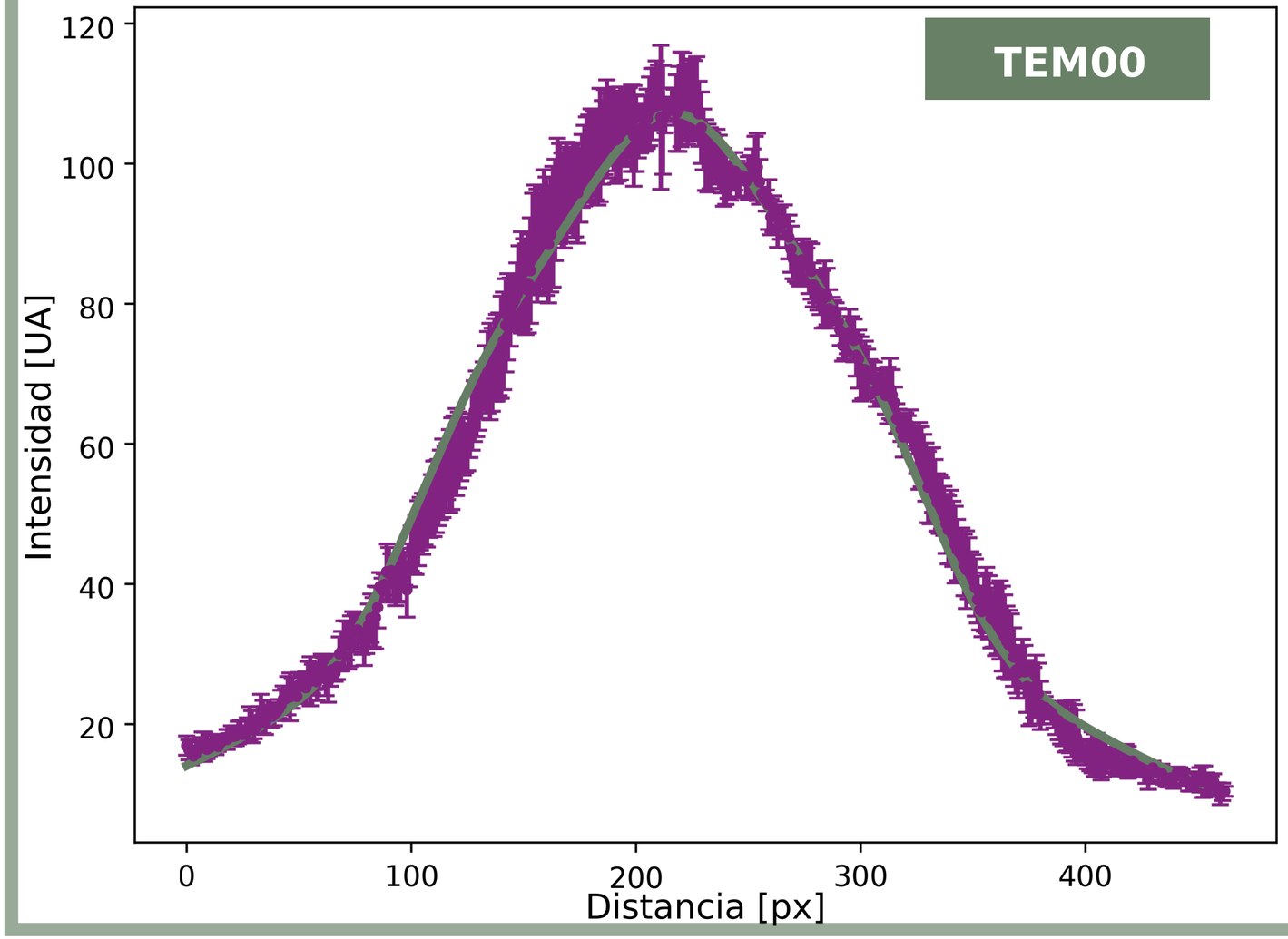
# CAVIDAD EN V


$a = 160$ mm
$a = 510$ mm
$b$ [mm]
$a$ [mm]
0
100
200
300
400
500
600
700
1
.75
.5
0
.25
a
b
Espejo cóncavo
Espejo plano de salida
810 nm
Sistema de enfoque
Láser de bombeo
Nd:YAG

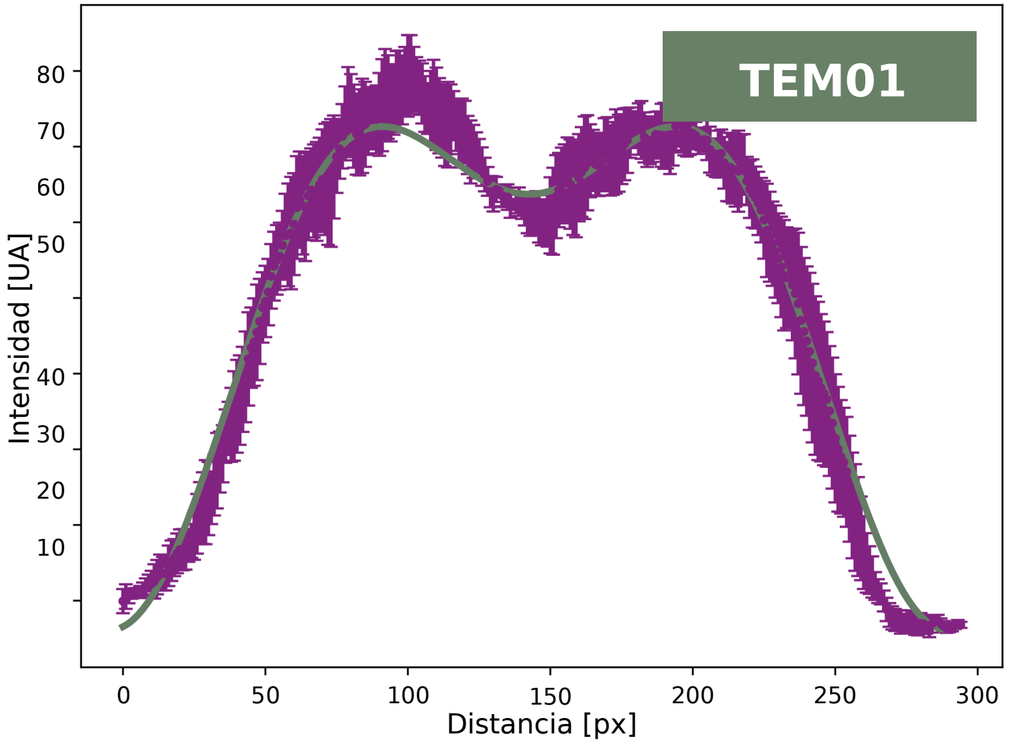
# CAVIDAD EN V

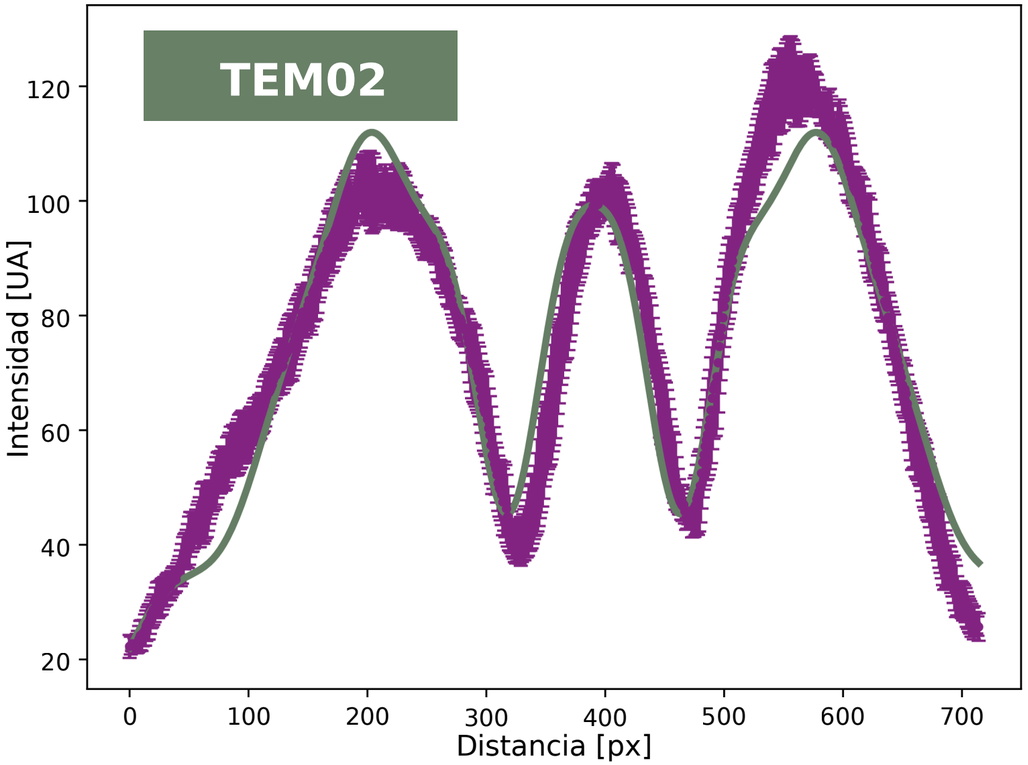

a
Espejo
cóncavo
Cavidad
resonante
(auxiliar)
Nd:YAG
810 nm
Sistema de
enfoque
Láser de
bombeo
b
Espejo plano
de salida

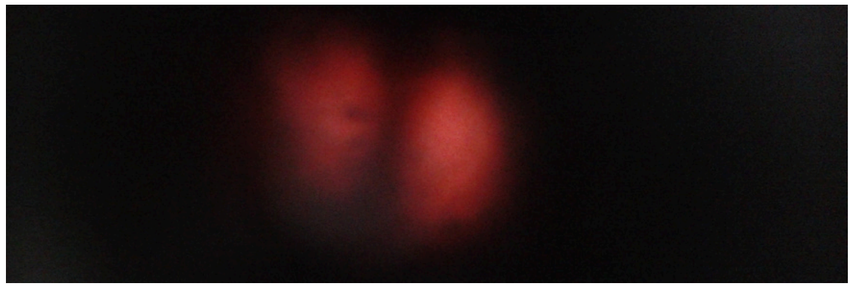
# MODOS

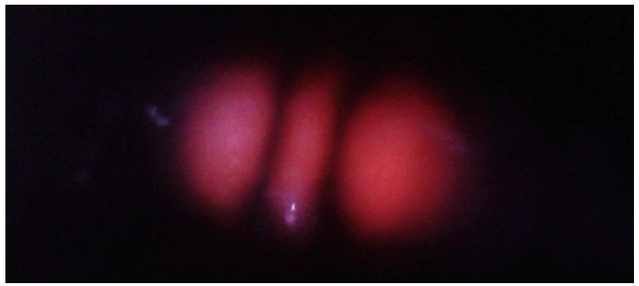

TEM00
Intensidad [UA]
120
100
80
60
40
20
0
100
200
300
400
Distancia [px]

# MODOS

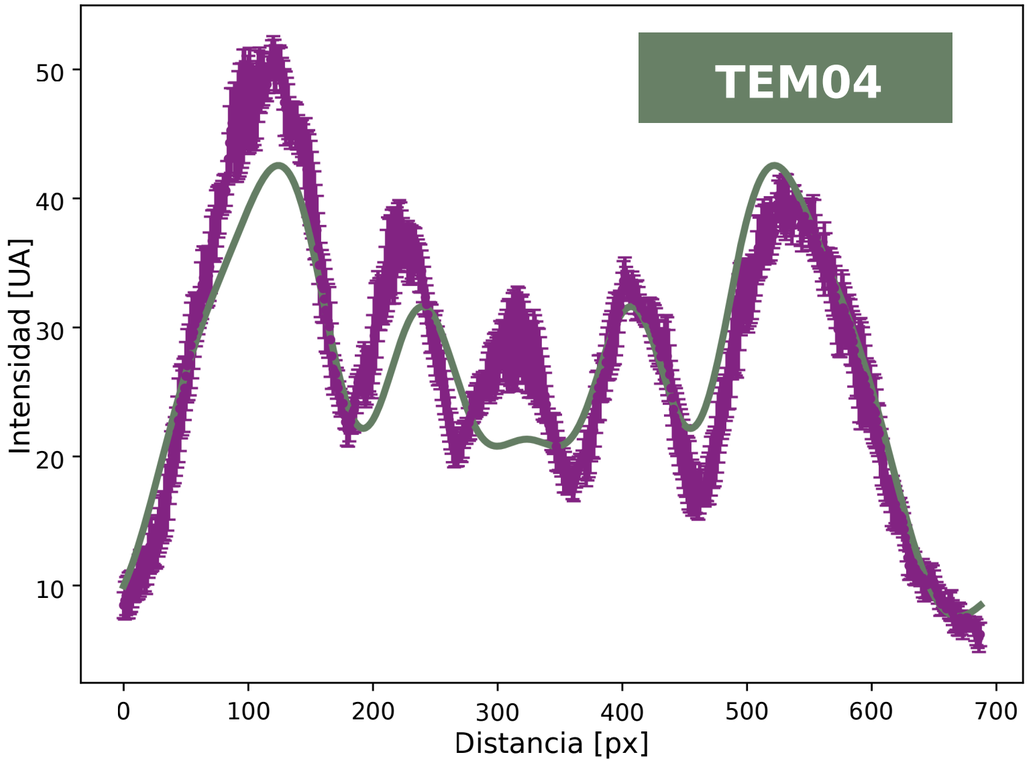

TEM01
Intensidad [UA]
Distancia [px]
10
20
30
40
50
60
70
80
0
50
100
150
200
250
300

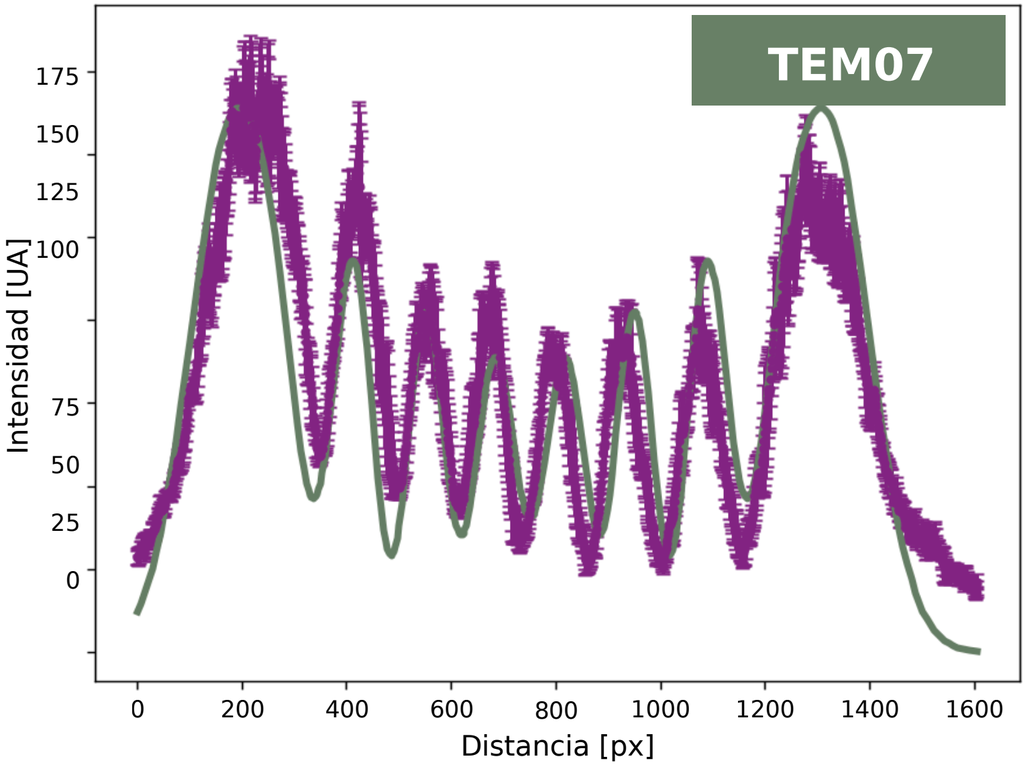

TEM02
Intensidad [UA]
Distancia [px]
20
40
60
80
100
120
0
100
200
300
400
500
600
700

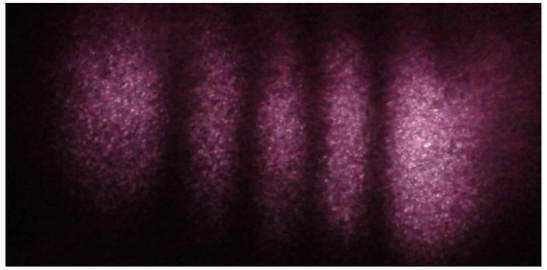


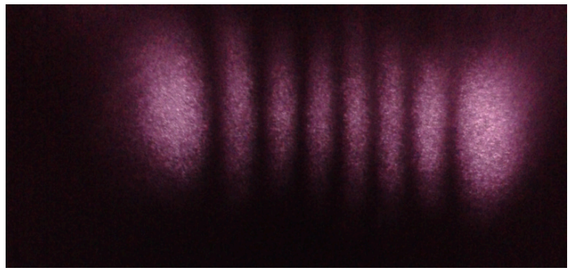


# MODOS


TEM04
Intensidad [UA]
Distancia [px]
10
20
30
40
50
0
100
200
300
400
500
600
700


TEM07
Intensidad [UA]
Distancia [px]
0
25
50
75
100
125
150
175
0
200
400
600
800
1000
1200
1400
1600





# RESUMEN

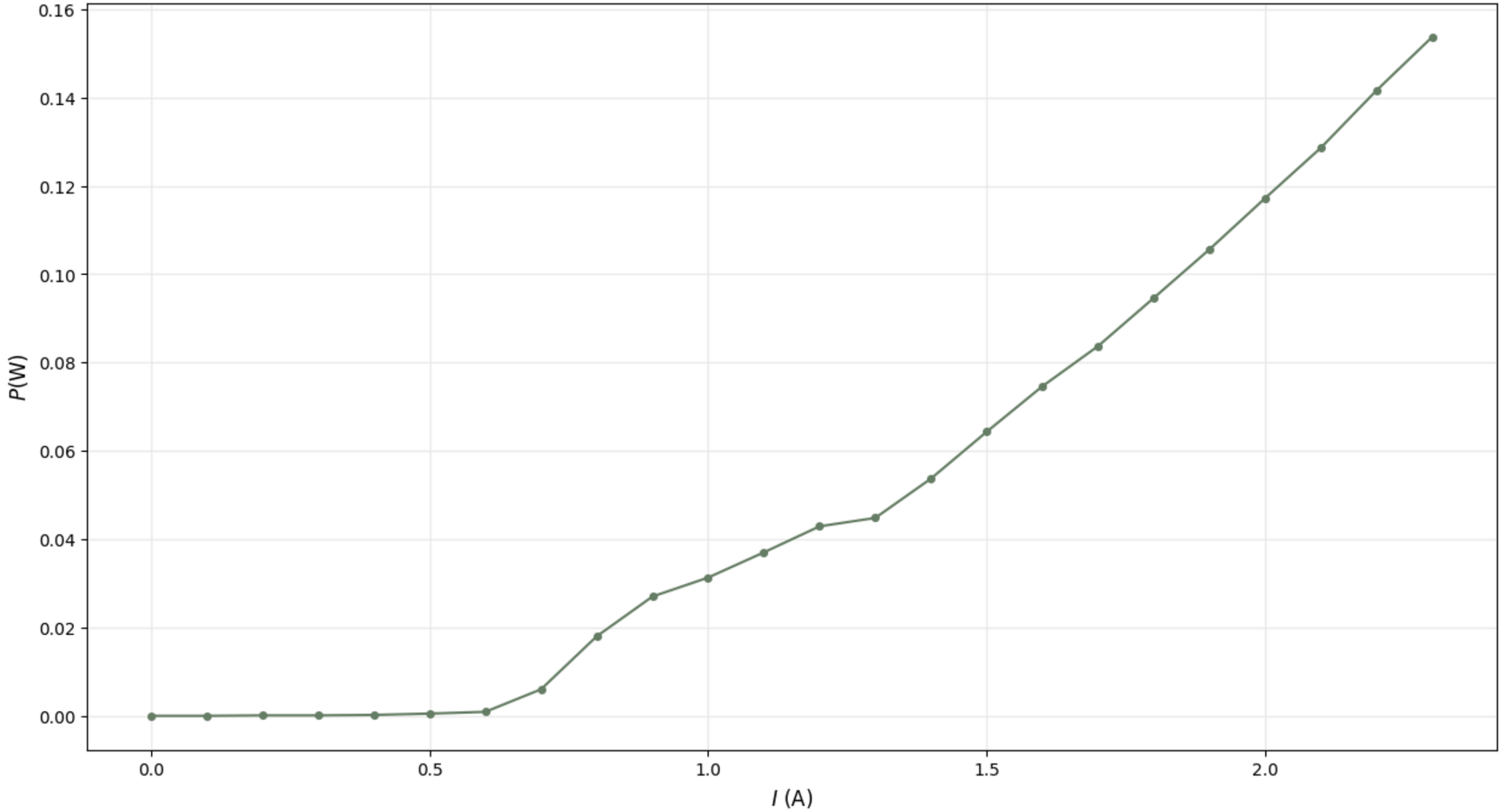
1. LOGRAMOS LASEAR CON LA CAVIDAD LINEAL Y MEDIR LA EFICIENCIA
2. NO LO LOGRAMOS CON LA CAVIDAD EN V
   - LIMPIAR ESPEJOS Y CRISTAL
   - USAR CAMARA DE INFRARROJO
3. PUDIMOS ESTUDIAR LOS MODOS CON DATOS DE GRUPOS ANTERIORES

# MUCHAS GRACIAS

¿PREGUNTAS?

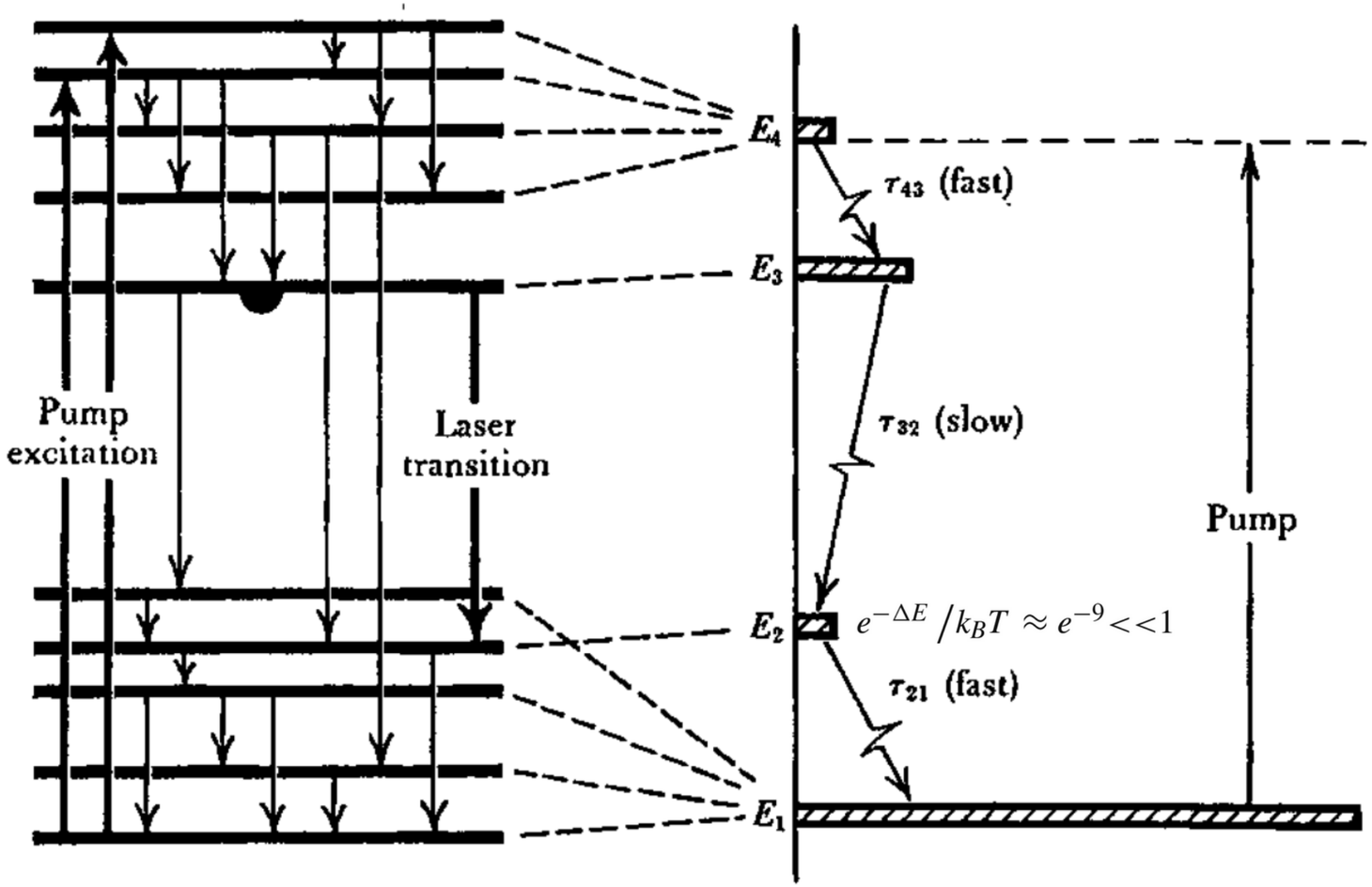
# APENDICE

## CON OTRO MEDIDOR DE POTENCIA



# APENDICE

## NIVELES DEL NEODIMIO




Fuente: Anthony E. Siegman, *Lasers*, University Science Books, 1986

# APENDICE

## CAMPO DEL HAZ Y POLINOMIOS DE HERMITE

$$U_{pq}(x,y) = H_q\left(\frac{\sqrt{2}x}{w}\right) H_p\left(\frac{\sqrt{2}y}{w}\right) e^{-(x^2+y^2)/w^2} \longrightarrow I_{pq} = |U_{pq}|^2$$

$$H_m(u) = (-1)^m e^{u^2} \frac{d^m(e^{-u^2})}{du^m}$$

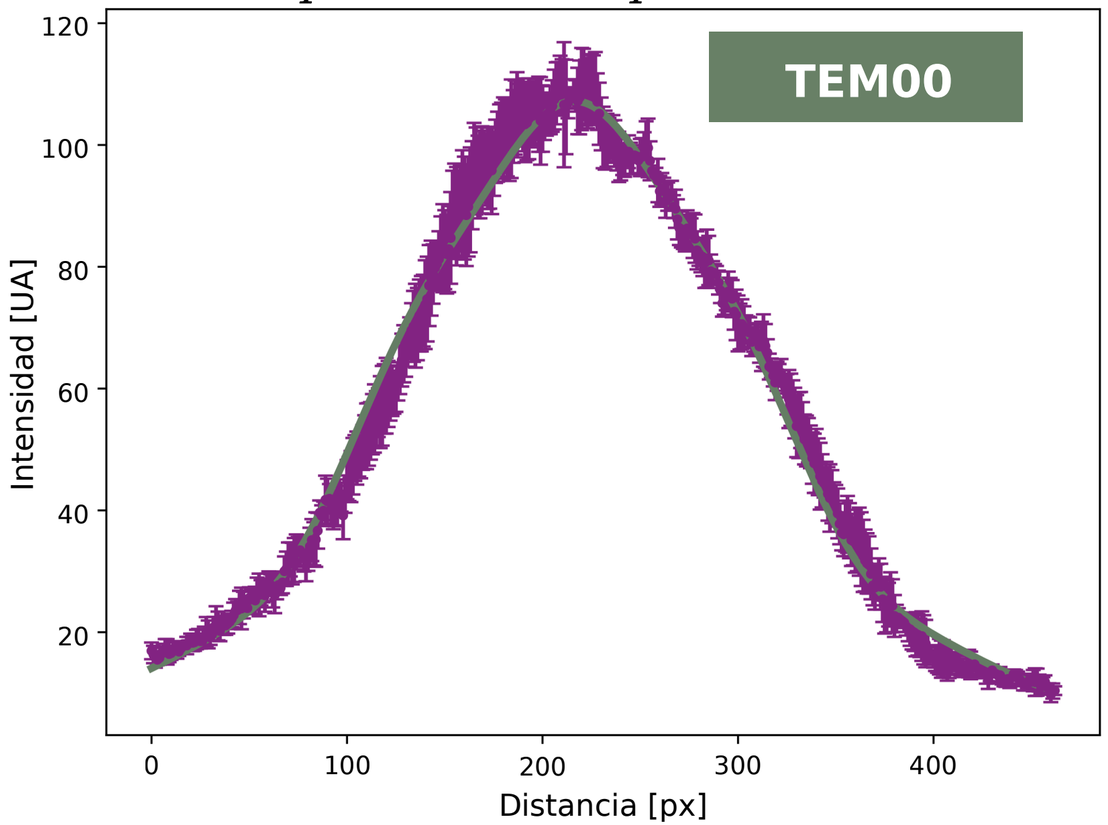
**POLINOMIOS DE HERMITE**

Fuente: Laser Fundamentals, Second Edition

# APENDICE

## AJUSTES MODOS TEM

$$I = \sum_{q=0}^{10} a_q I_q = \sum_{q=0}^{10} a_q |U_{0q}|^2$$

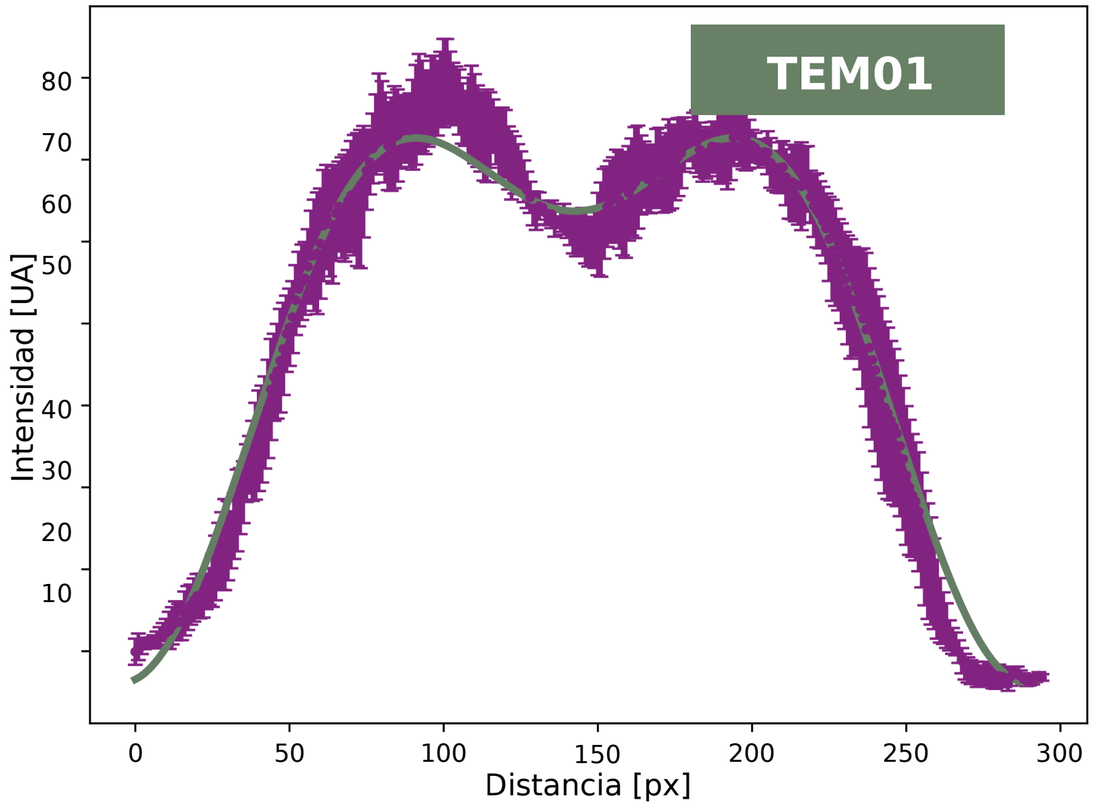



$$a_0 = 98.9 \pm 10.4$$
$$a_1 = 1.18e^{-9} \pm 12.7$$
$$a_2 = 3.16e^{-9} \pm 4.5$$
$$a_3 = 0.1 \pm 3.9$$
$$a_4 = 1.1e^{-9} \pm 2.0$$
$$a_5 = 7.7e^{-9} \pm 0.3$$
$$a_6 = 1.6e^{-5} \pm 0.7$$
$$a_7 = 3.4e^{-9} \pm 1.4$$
$$a_8 = 1.8e^{-6} \pm 3.9$$
$$a_9 = 9.6e^{-8} \pm 5.5$$
$$a_{10} = 3.2e^{-9} \pm 7.2e^{-8}$$

# APENDICE

## AJUSTES MODOS TEM

$$I = \sum_{q=0}^{10} a_q I_q = \sum_{q=0}^{10} a_q |U_{0q}|^2$$

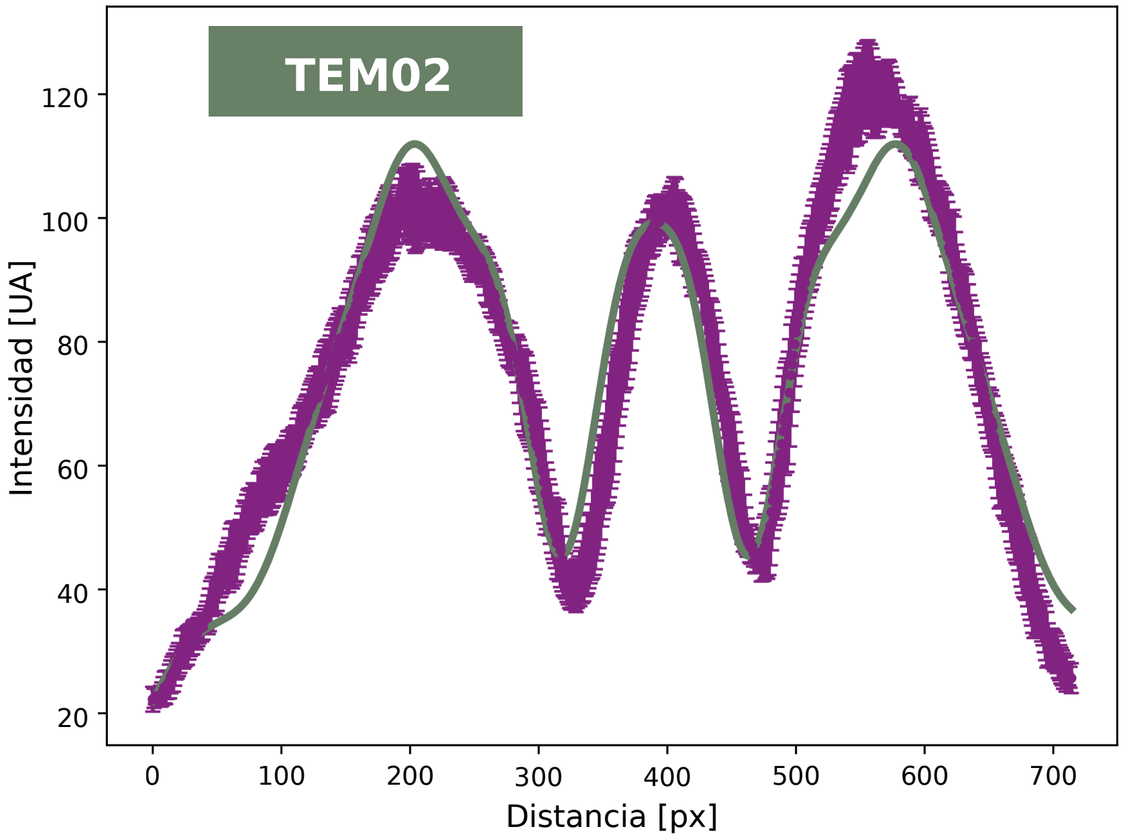



$$a_0 = 1.0e^{-13} \pm 40.3$$
$$a_1 = 7.0e^{-14} \pm 79.0$$
$$a_2 = 15.4 \pm 110.3$$
$$a_3 = 2.9e^{-12} \pm 212.8$$
$$a_4 = 2.5e^{-16} \pm 11.3$$
$$a_5 = 0.0 \pm 25.2$$
$$a_6 = 4.1e^{-14} \pm 4.0$$
$$a_7 = 0.0 \pm 0.1$$
$$a_8 = 8.0e^{-12} \pm 2.6$$
$$a_9 = 1.2e^{-11} \pm 6.1$$
$$a_{10} = 2.1e^{-9} \pm 1.3e^{-5}$$

# APENDICE

## AJUSTES MODOS TEM

$$I = \sum_{q=0}^{10} a_q I_q = \sum_{q=0}^{10} a_q |U_{0q}|^2$$

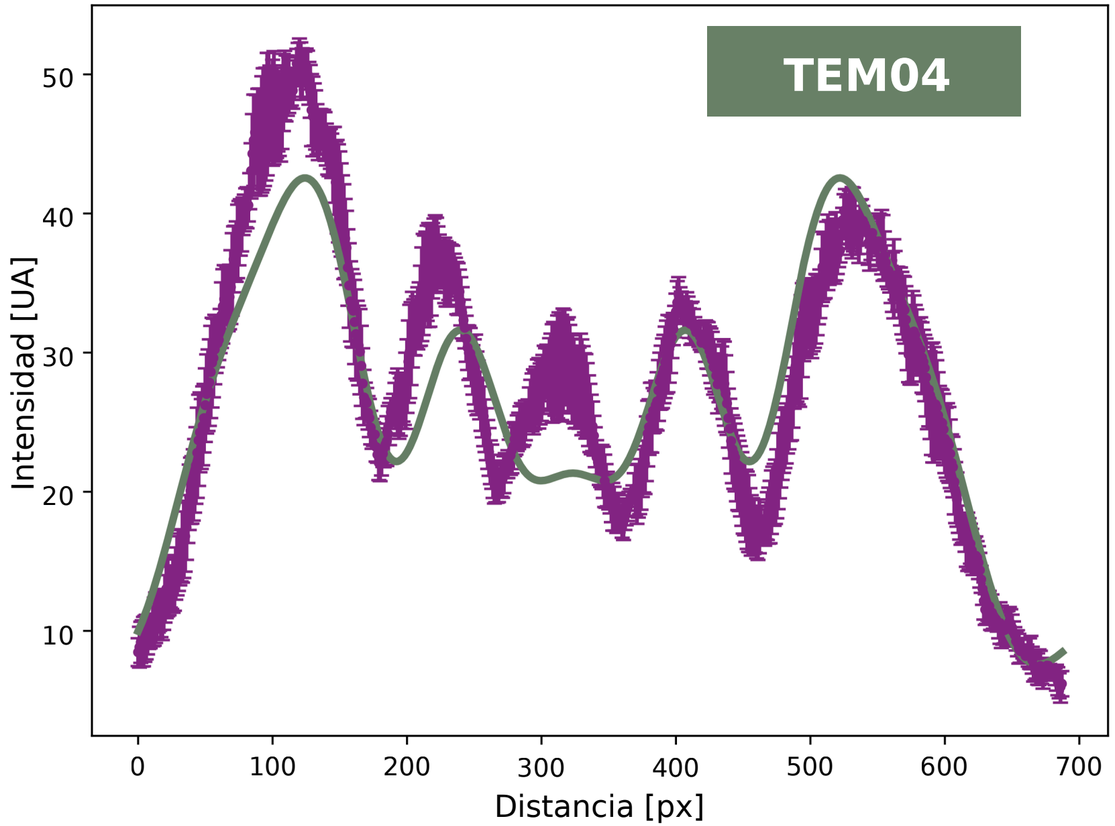



$$a_0 = 17.7 \pm 0.1$$
$$a_1 = 1.2e^{-19} \pm 0.4$$
$$a_2 = 13.9 \pm 0.2$$
$$a_3 = 1.0 \pm 0.4$$
$$a_4 = 0.1 \pm 0.1$$
$$a_5 = 0.0 \pm 5.9$$
$$a_6 = 0.0 \pm 3.5e^{-5}$$
$$a_7 = 4.3e^{-5} \pm 2.6e^{-6}$$
$$a_8 = 8.6e^{-7} \pm 1.6e^{-7}$$
$$a_9 = 1.3e^{-7} \pm 8.8e^{-9}$$
$$a_{10} = 1.3e^{-30} \pm 5.3e^{-10}$$

# APENDICE

## AJUSTES MODOS TEM

$$I = \sum_{q=0}^{10} a_q I_q = \sum_{q=0}^{10} a_q |U_{0q}|^2$$

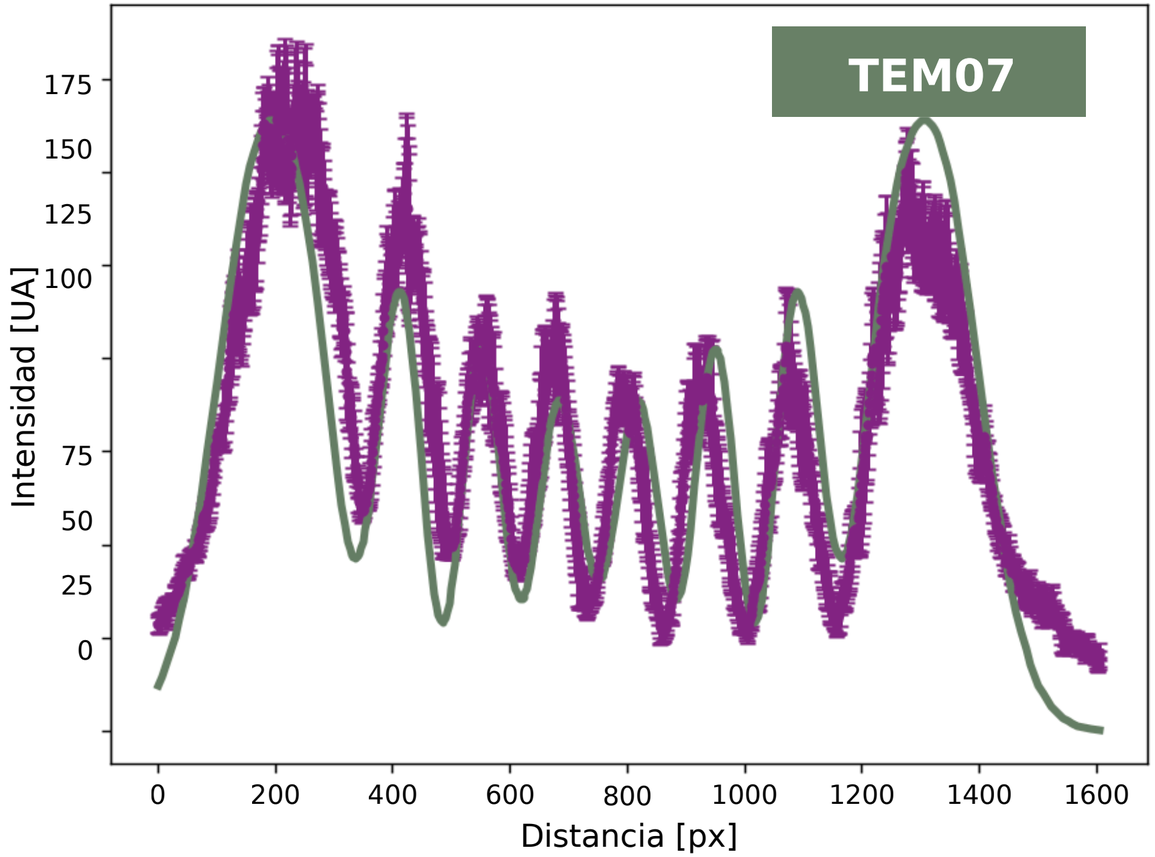



$$a_0 = 2.1 \pm 0.7$$
$$a_1 = 7.9 \pm 0.5$$
$$a_2 = 3.2 \pm 0.2$$
$$a_3 = 0.7 \pm 10.0$$
$$a_4 = 3.7e^{-33} \pm 3.1$$
$$a_5 = 4.8e^{-27} \pm 7.1$$
$$a_6 = 0.0 \pm 4.2e^{-5}$$
$$a_7 = 1.3e^{-31} \pm 3.0e^{-6}$$
$$a_8 = 1.5e^{-6} \pm 6.0e^{-7}$$
$$a_9 = 1.0e^{-34} \pm 4.1e^{-8}$$
$$a_{10} = 6.6e^{-27} \pm 1.3e^{-9}$$

# APENDICE

## AJUSTES MODOS TEM

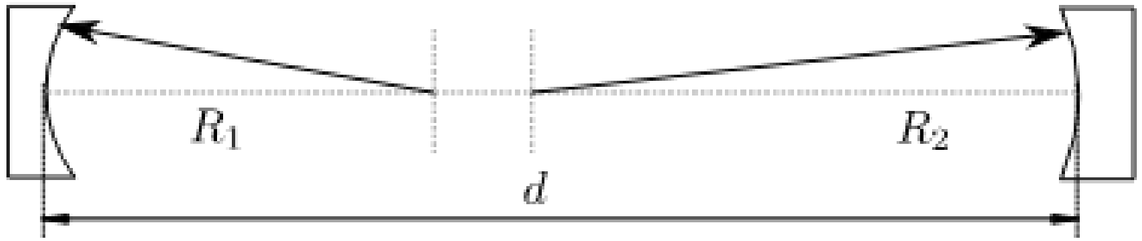
$$I = \sum_{q=0}^{10} a_q I_q = \sum_{q=0}^{10} a_q |U_{0q}|^2$$




$$a_0 = 1.6e^{-12} \pm 2.5$$
$$a_1 = 5.4e^{-9} \pm 1.6$$
$$a_2 = 1.1e^{-9} \pm 0.4$$
$$a_3 = 2.8e^{-9} \pm 0.1$$
$$a_4 = 0.0 \pm 3.2$$
$$a_5 = 0.0 \pm 0.3$$
$$a_6 = 2.6e^{-14} \pm 8.5$$
$$a_7 = 0.0 \pm 1.0e^{-5}$$
$$a_8 = 6.3e^{-6} \pm 8.3e^{-7}$$
$$a_9 = 3.4e^{-7} \pm 3.3e^{-8}$$
$$a_{10} = 1.9e^{-8} \pm 2.3e^{-9}$$

# APENDICE

## CONDICIÓN DE ESTABILIDAD




$$0 \leq g_1 g_2 \leq 1 \longrightarrow g_i = 1 - \frac{d}{R_i}$$