# 練習実験報告

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May 24, 2024

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# Galvano Sepctrum

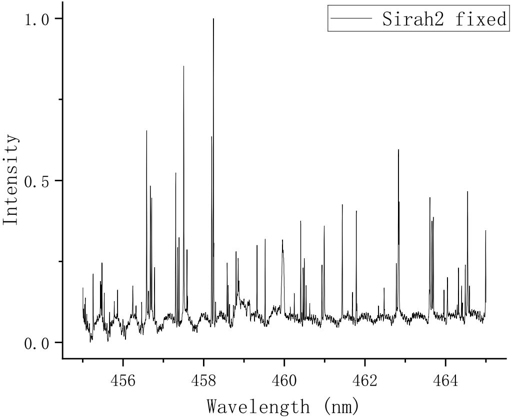


**Fig. 1:** Wavelen. correction

# Galvano Sepctrum

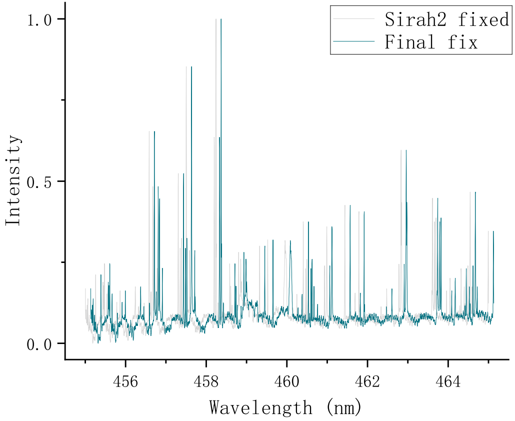


**Fig. 1:** Wavelen. correction

# Galvano Sepctrum

## Correction

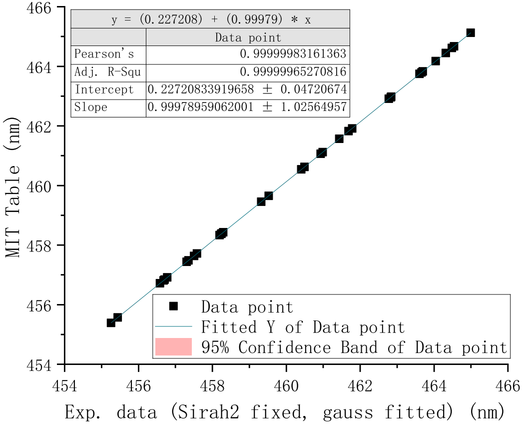


**Fig. 2:** Correction function

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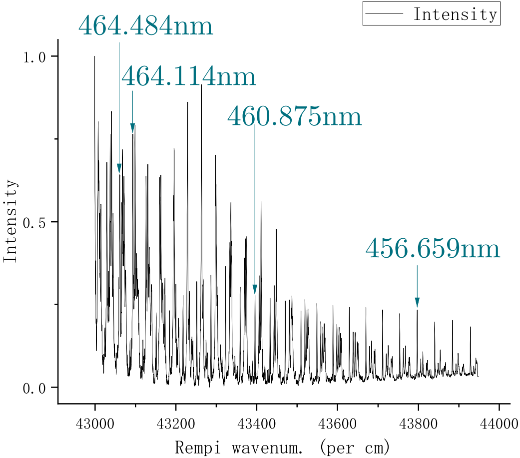
# Selected peaks



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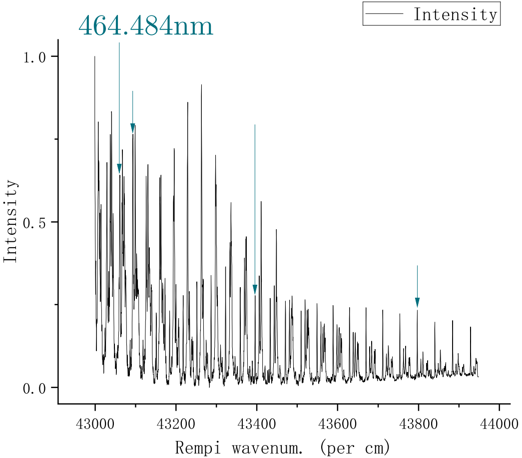
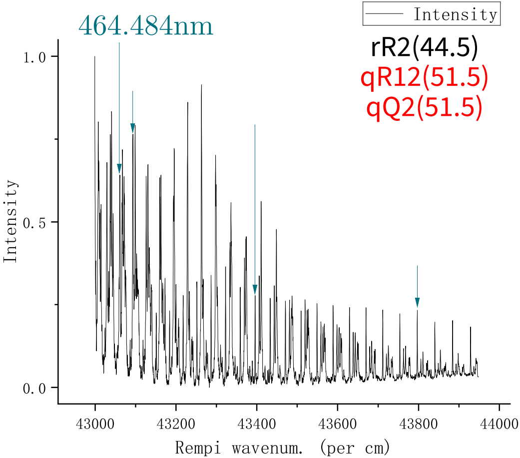
# Contents

# Peak 1



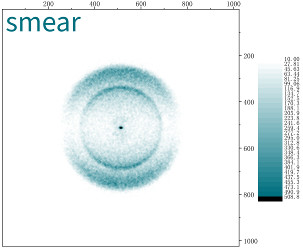
464.484nm
Intensity
1.0
0.5
0.0
Intensity
43000
43200
43400
43600
43800
44000
Rempi wavenum. (per cm)

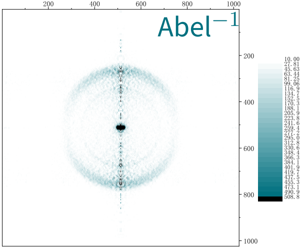
# Peak 1

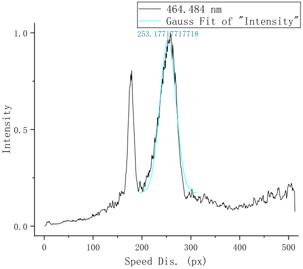


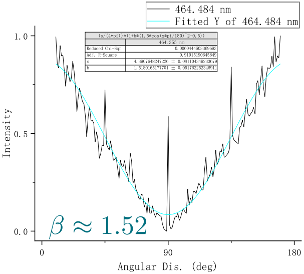
464.484nm
Intensity
rR2(44.5)
qR12(51.5)
qQ2(51.5)
1.0
0.5
0.0
Intensity
43000
43200
43400
43600
43800
44000
Rempi wavenum. (per cm)

# Peak 1

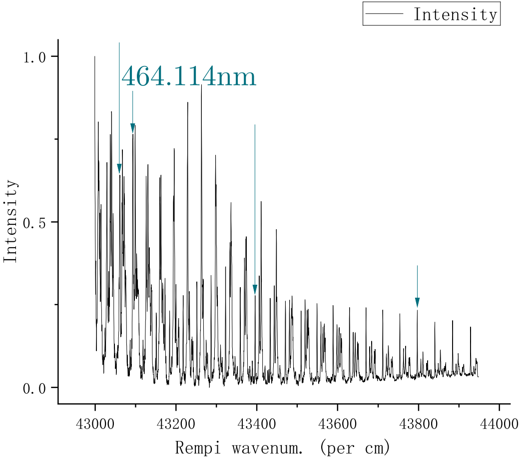

smear


$\text{Abel}^{-1}$


464.484 nm
Gauss Fit of "Intensity"
253.17717717718
Intensity
Speed Dis. (px)

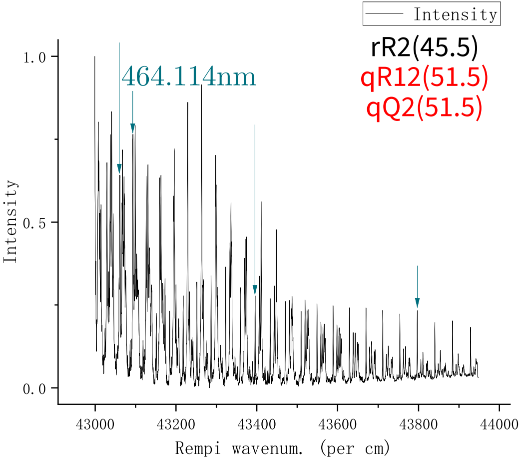

464.484 nm
Fitted Y of 464.484 nm
(s/(4*pi))*(1+b*(1.5*cos(x*pi/180)^2-0.5))
464.355 nm
Reduced Chi-Sqr 0.00604446033369693
Adj. R-Square 0.91915190645849
s 4.3907648247226 ± 0.081104349233679
b 1.5180165177701 ± 0.051762252346911
Intensity
Angular Dis. (deg)
$\beta \approx 1.52$

# Peak 2



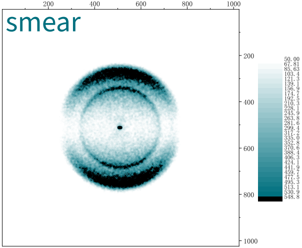
Intensity
464.114nm
1.0
0.5
0.0
Intensity
43000
43200
43400
43600
43800
44000
Rempi wavenum. (per cm)

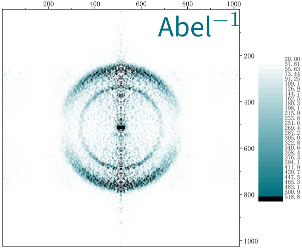
# Peak 2

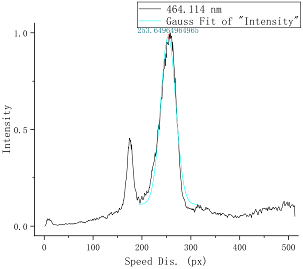


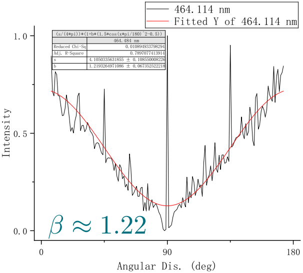
Intensity
rR2(45.5)
qR12(51.5)
qQ2(51.5)
464.114nm
1.0
0.5
0.0
Intensity
43000
43200
43400
43600
43800
44000
Rempi wavenum. (per cm)

# Peak 2

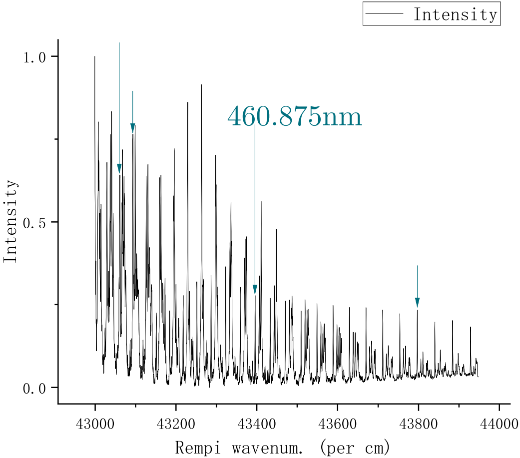

smear
200
400
600
800
1000


Abel$^{-1}$
200
400
600
800
1000


464.114 nm
Gauss Fit of "Intensity"
253.64964964965
Intensity
Speed Dis. (px)

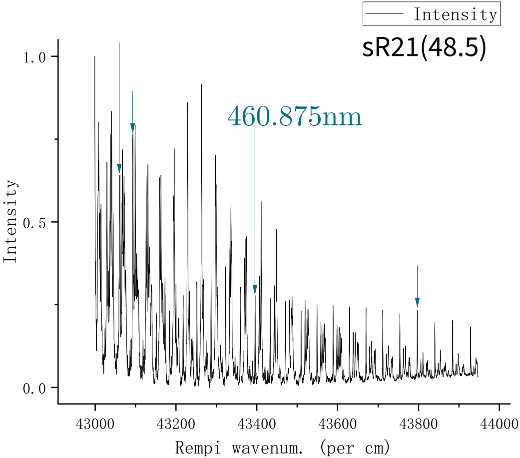

464.114 nm
Fitted Y of 464.114 nm
(s/(4*pi))*(1+b*(1.5*cos(x*pi/180)^2-0.5))
464.484 nm
Reduced Chi-Sq 0.010894933798294
Adj. R-Square 0.7897077413914
s 4.1050335631855 ± 0.108550008226
b 1.2193264971086 ± 0.067352522218
$\beta \approx 1.22$
Intensity
Angular Dis. (deg)

# Peak 3



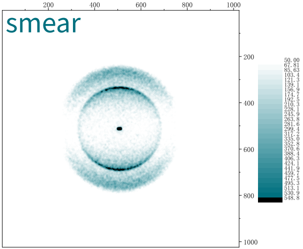
Intensity
460.875nm
1.0
0.5
0.0
Intensity
43000
43200
43400
43600
43800
44000
Rempi wavenum. (per cm)

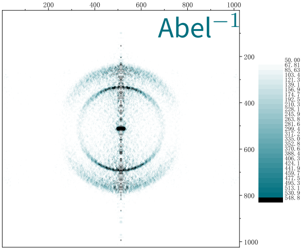
# Peak 3

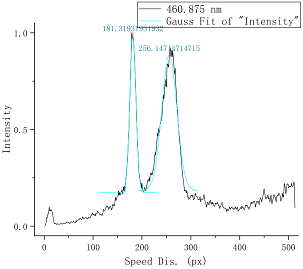


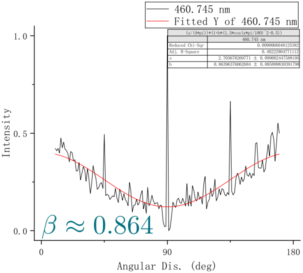
Intensity
sR21(48.5)
460.875nm
1.0
0.5
0.0
Intensity
43000
43200
43400
43600
43800
44000
Rempi wavenum. (per cm)

# Peak 3

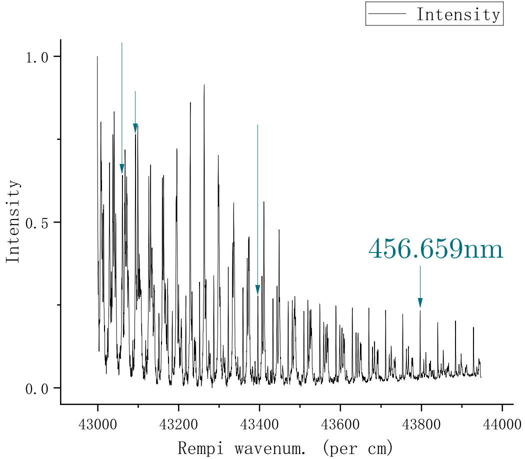

smear
200
400
600
800
1000



Abel$^{-1}$
200
400
600
800
1000



460.875 nm
Gauss Fit of "Intensity"
181.31931931932
256.14714714715
Intensity
Speed Dis. (px)

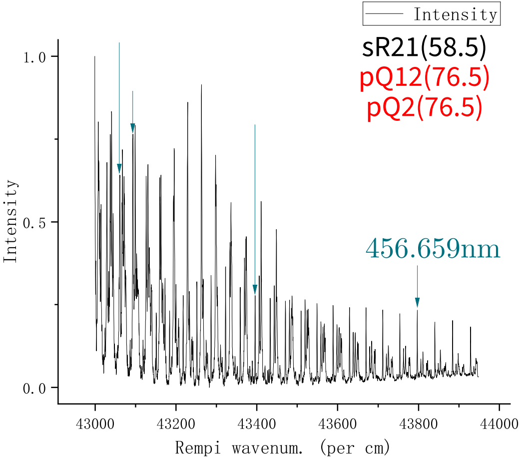


460.745 nm
Fitted Y of 460.745 nm
(s/(4*pi))*(1+b*(1.5*cos(x*pi/180)^2-0.5))
460.745 nm
Reduced Chi-Sqr 0.0090066048125382
Adj. R-Square 0.48222904771112
s 2.703678269771 ± 0.099002447588195
b 0.86396376062684 ± 0.085899830391798
Intensity
Angular Dis. (deg)
$\beta \approx 0.864$

# Peak 4



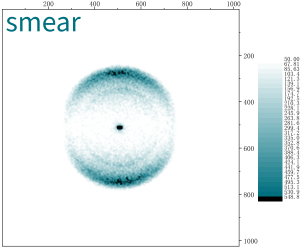
Intensity
1.0
0.5
0.0
Intensity
456.659nm
43000
43200
43400
43600
43800
44000
Rempi wavenum. (per cm)

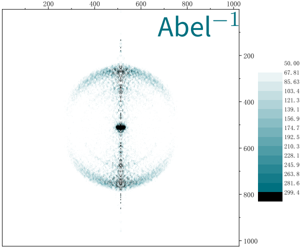
# Peak 4

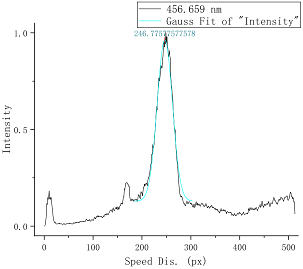


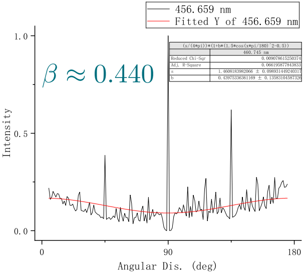
Intensity
sR21(58.5)
pQ12(76.5)
pQ2(76.5)
456.659nm
1.0
0.5
0.0
Intensity
43000
43200
43400
43600
43800
44000
Rempi wavenum. (per cm)

# Peak 4


smear


Abel$^{-1}$


456.659 nm
Gauss Fit of "Intensity"
246.77577577578
Intensity
Speed Dis. (px)


456.659 nm
Fitted Y of 456.659 nm
$\beta \approx 0.440$
(s/(4*pi))*(1+b*(1.5*cos(x*pi/180)^2-0.5))
460.745 nm
Reduced Chi-Sqr 0.009078615250374
Adj. R-Square 0.066195877843833
s 1.4608183982066 ± 0.098931449240317
b 0.43975336361169 ± 0.13583104587326
Intensity
Angular Dis. (deg)

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# Peak assignments

| | | | |
|---|---|---|---|
| 464.484nm $\approx 43058.49\text{cm}^{-1}$ | 464.114nm $\approx 43092.81\text{cm}^{-1}$ | 460.875nm $\approx 43395.69\text{cm}^{-1}$ | 456.659nm $\approx 43796.34\text{cm}^{-1}$ |
| px $= 253.177$ | px $= 253.650$ | px $= 181.319$ & $256.147$ | px $= 246.776$ |
| $rR2$ 44.5<br>$qR12$ 51.5<br>$qQ2$ 51.5 | $rR2$ 45.5<br>$qR12$ 51.5<br>$qQ2$ 51.5 | $sR21$ 48.5 | $sR21$ 58.5<br>$pQ12$ 76.5<br>$pP2$ 76.5 |

**Notice**

Colored assignments are mismatched, and will not be used to calculate.

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# Speed correction

## $y$ trans. energy of NO

| | $E_{\text{total}}$ | $E_{\text{bond}}(\text{O}-\text{NO})$[1] | $E_{\text{int.}}(\text{NO})$ |
|---|---|---|---|
| Peak 1<br>$464.484\text{nm}$ | $43\,058.49\text{cm}^{-1}$ | | $\Delta E_v(1 \to 0) + E(J = 44)$ |
| Peak 2<br>$464.114\text{nm}$ | $43\,092.81\text{cm}^{-1}$ | | $\Delta E_v(1 \to 0) + E(J = 45)$ |
| Peak 3<br>$460.875\text{nm}$ | $43\,395.69\text{cm}^{-1}$ | $25\,128.57\text{cm}^{-1}$ | $\Delta E_v(1 \to 0) + E(J = 48)$ |
| Peak 4<br>$456.659\text{nm}$ | $43\,796.34\text{cm}^{-1}$ | | $\Delta E_v(1 \to 0) + E(J = 58)$ |

[1] Rémy Jost et al. *The Journal of Chemical Physics* **105**.3 (July 1996).

# Speed correction

## $y$ trans. energy of NO

| | $E_{\text{total}}$ | $E_{\text{bond}}(\mathrm{O{-}NO})^2$ | $E_{\text{int.}}(\mathrm{NO})$ |
|---|---|---|---|
| Peak 1<br>$464.484\mathrm{nm}$ | $43\,058.49\mathrm{cm}^{-1}$ | | $2341.932\,775\,0\mathrm{cm}^{-1} + E(J = 44)$ |
| Peak 2<br>$464.114\mathrm{nm}$ | $43\,092.81\mathrm{cm}^{-1}$ | | $2341.932\,775\,0\mathrm{cm}^{-1} + E(J = 45)$ |
| Peak 3<br>$460.875\mathrm{nm}$ | $43\,395.69\mathrm{cm}^{-1}$ | $25\,128.57\mathrm{cm}^{-1}$ | $2341.932\,775\,0\mathrm{cm}^{-1} + E(J = 48)$ |
| Peak 4<br>$456.659\mathrm{nm}$ | $43\,796.34\mathrm{cm}^{-1}$ | | $2341.932\,775\,0\mathrm{cm}^{-1} + E(J = 58)$ |

[2] Rémy Jost et al. *The Journal of Chemical Physics* **105**.3 (July 1996).
[3] J. Danielak et al. *Journal of Molecular Spectroscopy* **181**.2 (1997), pp. 394–402.

# Speed correction

## $y$ trans. energy of NO

| | $E_{\text{total}}$ | $E_{\text{bond}}(\mathrm{O{-}NO})$[2] | $E_{\text{int.}}(\mathrm{NO})$ |
|---|---|---|---|
| Peak 1<br>$464.484\mathrm{nm}$ | $43\,058.49\mathrm{cm}^{-1}$ | | $2341.932\,775\,0\mathrm{cm}^{-1} + E(J=44)$ |
| Peak 2<br>$464.114\mathrm{nm}$ | $43\,092.81\mathrm{cm}^{-1}$ | | $2341.932\,775\,0\mathrm{cm}^{-1} + E(J=45)$ |
| Peak 3<br>$460.875\mathrm{nm}$ | $43\,395.69\mathrm{cm}^{-1}$ | $25\,128.57\mathrm{cm}^{-1}$ | $2341.932\,775\,0\mathrm{cm}^{-1} + E(J=48)$ |
| Peak 4<br>$456.659\mathrm{nm}$ | $43\,796.34\mathrm{cm}^{-1}$ | | $2341.932\,775\,0\mathrm{cm}^{-1} + E(J=58)$ |

**Vib. energy level**[3]

$$E_v = \omega_e\left(v+\tfrac{1}{2}\right) - \omega_e x_e\left(v+\tfrac{1}{2}\right)^2 + \omega_e y_e\left(v+\tfrac{1}{2}\right)^3.$$

[2] Rémy Jost et al. *The Journal of Chemical Physics* **105**.3 (July 1996).

[3] J. Danielak et al. *Journal of Molecular Spectroscopy* **181**.2 (1997), pp. 394–402.

# Speed correction

## $y$ trans. energy of NO

| | $E_{\text{total}}$ | $E_{\text{bond}}(\mathrm{O{-}NO})$[4] | $E_{\text{int.}}(\mathrm{NO})$ |
|---|---|---|---|
| Peak 1 $464.484\mathrm{nm}$ | $43\,058.49\mathrm{cm}^{-1}$ | $25\,128.57\mathrm{cm}^{-1}$ | $5814.033\mathrm{cm}^{-1}$ |
| Peak 2 $464.114\mathrm{nm}$ | $43\,092.81\mathrm{cm}^{-1}$ | | $5965.969\mathrm{cm}^{-1}$ |
| Peak 3 $460.875\mathrm{nm}$ | $43\,395.69\mathrm{cm}^{-1}$ | | $6239.696\mathrm{cm}^{-1}$ |
| Peak 4 $456.659\mathrm{nm}$ | $43\,796.34\mathrm{cm}^{-1}$ | | $8004.278\mathrm{cm}^{-1}$ |

[4] Rémy Jost et al. *The Journal of Chemical Physics* **105**.3 (July 1996).

[5] J. Danielak et al. *Journal of Molecular Spectroscopy* **181**.2 (1997), pp. 394–402.

[6] Colin M. Western. *Journal of Quantitative Spectroscopy and Radiative Transfer* **186** (2017), pp. 221–242.

# Speed correction

## $y$ trans. energy of NO

| | $E_{\text{total}}$ | $E_{\text{bond}}(\mathrm{O-NO})$[4] | $E_{\text{int.}}(\mathrm{NO})$ |
|---|---|---|---|
| Peak 1 $464.484\,\mathrm{nm}$ | $43\,058.49\,\mathrm{cm}^{-1}$ | | $5814.033\,\mathrm{cm}^{-1}$ |
| Peak 2 $464.114\,\mathrm{nm}$ | $43\,092.81\,\mathrm{cm}^{-1}$ | $25\,128.57\,\mathrm{cm}^{-1}$ | $5965.969\,\mathrm{cm}^{-1}$ |
| Peak 3 $460.875\,\mathrm{nm}$ | $43\,395.69\,\mathrm{cm}^{-1}$ | | $6239.696\,\mathrm{cm}^{-1}$ |
| Peak 4 $456.659\,\mathrm{nm}$ | $43\,796.34\,\mathrm{cm}^{-1}$ | | $8004.278\,\mathrm{cm}^{-1}$ |

**Rot. energy level**[5]

Simulated data generated by PGOPHER[6].

[4] Rémy Jost et al. *The Journal of Chemical Physics* **105**.3 (July 1996).

[5] J. Danielak et al. *Journal of Molecular Spectroscopy* **181**.2 (1997), pp. 394–402.

[6] Colin M. Western. *Journal of Quantitative Spectroscopy and Radiative Transfer* **186** (2017), pp. 221–242.

# Speed correction

## $y$ trans. energy of NO

| $E_{\text{int.}}(\mathrm{O})$ [7] | $E_{\text{trans}}(\text{total}) \approx 2.875464 E_{\text{trans}}(\mathrm{NO})$ $= E_{\text{total}} - E_{\text{bond}}(\mathrm{O{-}NO}) - E_{\text{int.}}(\mathrm{O}) - E_{\text{int.}}(\mathrm{NO})$ | $E_{\text{trans}}(\mathrm{NO})$ $= \frac{1}{2} m(\mathrm{NO}) v^2(\mathrm{NO})$ |
|---|---|---|
| $^3P_2$ $(0\mathrm{cm}^{-1})$ | $11081.356\mathrm{cm}^{-1}$ | $4375.588\mathrm{cm}^{-1}$ |
| | $10964.609\mathrm{cm}^{-1}$ | $4334.685\mathrm{cm}^{-1}$ |
| | $10794.143\mathrm{cm}^{-1}$ | $4344.824\mathrm{cm}^{-1}$ |
| | $9398.766\mathrm{cm}^{-1}$ | $3870.489\mathrm{cm}^{-1}$ |
| $^3P_1$ $(158.625\mathrm{cm}^{-1})$ | $10922.731\mathrm{cm}^{-1}$ | $4320.423\mathrm{cm}^{-1}$ |
| | $10805.984\mathrm{cm}^{-1}$ | $4279.520\mathrm{cm}^{-1}$ |
| | $10635.518\mathrm{cm}^{-1}$ | $4289.659\mathrm{cm}^{-1}$ |
| | $9240.141\mathrm{cm}^{-1}$ | $3815.324\mathrm{cm}^{-1}$ |
| $^3P_0$ $(226.977\mathrm{cm}^{-1})$ | $10854.379\mathrm{cm}^{-1}$ | $4296.653\mathrm{cm}^{-1}$ |
| | $10737.632\mathrm{cm}^{-1}$ | $4255.749\mathrm{cm}^{-1}$ |
| | $10567.166\mathrm{cm}^{-1}$ | $4265.888\mathrm{cm}^{-1}$ |
| | $9171.789\mathrm{cm}^{-1}$ | $3791.553\mathrm{cm}^{-1}$ |

[7] Charlotte Emma Moore and Jean W. Gallagher. “Tables of spectra of hydrogen, carbon, nitrogen, and oxygen atoms and ions”. 1993.

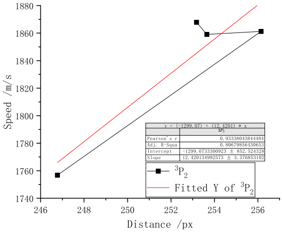
# Speed correction

## $y$ Trans. speed of NO

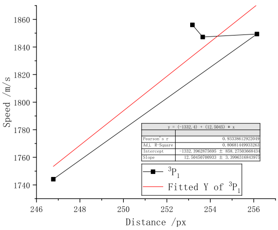
| $E_{\text{int.}}(\mathrm{O})$ | $v(\mathrm{NO}) = \sqrt{\frac{2E_{\text{trans}}(\mathrm{NO})}{m(\mathrm{NO})}}$ | $\Delta y$ |
|---|---|---|
| $^3P_2$ (0cm$^{-1}$) | $1867.845\,\mathrm{m\,s^{-1}}$ | 253.177 |
| | $1859.094\,\mathrm{m\,s^{-1}}$ | 253.650 |
| | $1861.267\,\mathrm{m\,s^{-1}}$ | 256.147 |
| | $1756.732\,\mathrm{m\,s^{-1}}$ | 246.776 |
| $^3P_1$ (158.625cm$^{-1}$) | $1856.033\,\mathrm{m\,s^{-1}}$ | 253.177 |
| | $1847.226\,\mathrm{m\,s^{-1}}$ | 253.650 |
| | $1849.413\,\mathrm{m\,s^{-1}}$ | 256.148 |
| | $1744.168\,\mathrm{m\,s^{-1}}$ | 246.776 |
| $^3P_0$ (226.977cm$^{-1}$) | $1850.920\,\mathrm{m\,s^{-1}}$ | 253.177 |
| | $1842.089\,\mathrm{m\,s^{-1}}$ | 253.650 |
| | $1844.282\,\mathrm{m\,s^{-1}}$ | 256.147 |
| | $1738.726\,\mathrm{m\,s^{-1}}$ | 246.776 |

# Speed correction

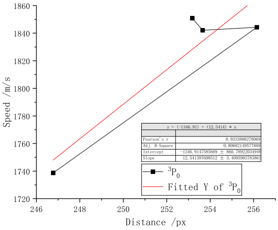
## $y$ Trans. speed of NO




$12.42\,\mathrm{m\,s^{-1}}$/px @ $^3P_2$



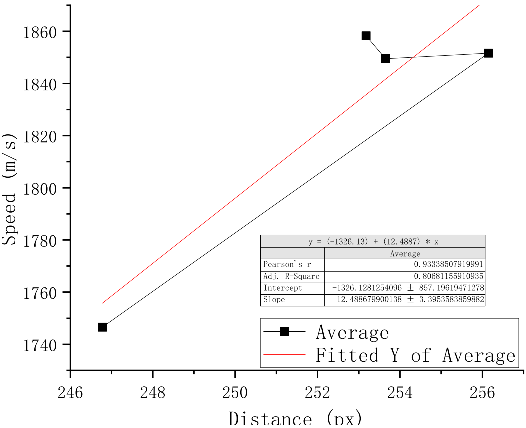

$12.54\,\mathrm{m\,s^{-1}}$/px @ $^3P_1$




$12.50\,\mathrm{m\,s^{-1}}$/px @ $^3P_0$

# Speed correction

## $y$ Trans. speed of NO




$12.49\,\mathrm{m\,s^{-1}}$/px @ Average

# Reference


[1] J. Danielak et al. *Journal of Molecular Spectroscopy* **181**.2 (1997), pp. 394–402.

[2] Rémy Jost et al. *The Journal of Chemical Physics* **105**.3 (July 1996).

[3] Charlotte Emma Moore and Jean W. Gallagher. “Tables of spectra of hydrogen, carbon, nitrogen, and oxygen atoms and ions”. 1993.

[4] Colin M. Western. *Journal of Quantitative Spectroscopy and Radiative Transfer* **186** (2017), pp. 221–242.