Experimental Verification of Theoretical Configuration Mixing in the Energy Levels of Er II Spectra via Isotope Shift Measurements Using a FTS

Balkrishna Keraba Ankush1, *, Mukul Narayan Deo2

1 Atomic and Molecular Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai, India
2 High Pressure and Synchrotron Radiation Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai, India

Email address: bkankush@barc.gov.in (B. K. Ankush)
* Corresponding author

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Abstract: We report the first detailed investigation on isotope shift, $\Delta \sigma^{166,170}$ measurements carried out in the spectrum of singly-ionized erbium (Er II/Er$^+$) recorded with a FTS. Isotope shift in 85 spectral lines were determined in the 350-590 nm wavelength region. The source was accomplished of mixture of highly enriched isotopes of $^{166}$Er: $^{170}$Er in 7:10 ratio respectively and the detector was a photomultiplier tube. These investigations have contributed significantly to the understanding of the 92 known energy levels of Er$^+$. Level isotope shift, $\Delta T^{166,170}$ values have been evaluated for 29 even- and 63 odd-parity energy levels for the first time. On the basis of the derived level isotope shifts the configuration mixing was estimated for altogether 92 involved levels and compared those with the theoretically predicted configuration mixings available in the literature and found that both the theoretical and experimental mixings have excellent agreement with each other.

Keywords: Isotope Shift, Configuration Mixing, Singly-Ionized Spectra, Fourier Transform Spectrometer, Hollow Cathode Lamp

1. Introduction

The comprehensive list of the energy levels of the singly-ionized erbium atom (Er II) was published by Martin et al. [1] taking aid from the unpublished extension of the Er II spectral analysis carried out by van Kleef TAM et al. [2]. Sugar et al. [3] have derived the ionization potential 11.93 eV (±0.08 eV) of Er$^+$ along with the other rare earth ions i.e. from La II to Lu II by means of semi empirical calculations. The analysis of lifetimes of 11 odd-parity levels and measurement of precise transition energies for several spectral lines of Er II were conducted in the reference [4]. Improved values of laboratory transition probabilities for 418 lines of Er II were presented and employed those values for the Er abundance measurement of the sun and five r-process-rich metal-poor stars [5]. Wyart et al. [6] have classified and extended both theoretically and experimentally the Er II spectra to interpret the known energy levels first parametrically using Cowan code and then the predictions of the unknown energy levels employed for the classification of the experimental hollow cathode FT spectra. Their detailed investigation of level configurations has shown that the levels of 4f$^{12}$6p were strongly mixed with 4f$^{11}$5d6s and 4f$^{11}$5d$^2$ configurations and provided the configuration mixing in percentages for most of the known even and odd levels. The hyperfine structure for 4f$^2$6s and 4f$^3$5d configurations of $^{167}$Er in 14 transitions of Er II were carried out with the collinear fast-beam laser and radio-frequency laser double-resonance spectroscopy techniques and reported the hf A- and B- coupling constants of various Er II levels for the$^{167}$Er isotope [7]. Isotope shift (IS) data in the spectral lines of Er II was very scarce in the literature. Wilets and Bradley [8] have reported IS in 67 spectral lines of Er and they argued that most of these lines belong to Er II spectrum. However only 6 of these lines falling at 4552.13 Å, 4820.75 Å, 5164.77 Å, 5485.93 Å, 5485.93 Å, 6066.80Å and 6076.44Å were classified as Er II
lines in NBS Tables [9]; and the remaining 61 lines belong to Er I spectrum as have claimed by [10]. Determination of the intrinsic quadrupole moment of $^{162}$Er was carried out in [11] using the IS data of the Er I and Er II lines. Pacheva et al. [12] have published only abstract where no details are given of the Er II lines in which they conducted IS measurements. IS in 9 lines along with the crossed-second-order effects of the Er II lines in which they conducted IS measurements.

The objectives of the present investigation were to obtain the IS data in as many spectral lines of Er II as possible in the first stage because so far IS data in only 9 lines have been reported earlier [13] and in the second stage to evaluate the IS of even- and odd- parity energy levels and use this data to designate the configurations to the known but unassigned levels as all the even- levels between 38400- 43400 cm$^{-1}$ and the odd- levels above 21000 cm$^{-1}$ have tentative configuration assignments and all the known 54 even levels above 43400 cm$^{-1}$ and 144 odd levels between 33000- 45000 cm$^{-1}$ have no configuration designations. The status of classification of these levels [1] has been summarized in Table 1. In the third stage compare the experimentally derived configuration mixing with the theoretically calculated configuration mixing available in the literature [6].

As can be seen from Table 1, about 50 percent of the known even- and 80 percent of the known odd- parity levels are without configuration assignments.

### Table 1. Status of configuration assignment to the known energy levels of Er II [1].

| Parity          | Energy Levels          | Configuration status [1] |
|-----------------|------------------------|--------------------------|
| Even (117 known levels) | 12: 4f$^2$6s |                        |
|                 | 23: 4f$^2$5d |                        |
|                 | 9: 4f$^4$6s6p |                        |
|                 | 8: 4f$^4$6s6p? |                        |
|                 | 11: 4f$^5$5d6p |                        |
|                 | 54: Unassigned |                        |
|                 | 3: 4f$^6$6s |                        |
|                 | 28: 4f$^5$5d6s |                        |
|                 | 5: 4f$^5$5d6s (?) |                        |
|                 | 2: 4f$^5$5d6p (?) |                        |
|                 | 10: 4f$^6$6p (?) |                        |
|                 | 195: Unassigned |                        |

2. Experimental Techniques

IS, $\Delta \sigma^{166,170}$ (MHz) data measured in the 85 lines of Er II are listed in Table 2. The magnitude of IS observed presently was in the range of -3842 to +1400MHz. As can be seen from Table 2, 54 transitions observed are from high odd- parity levels to low even- parity levels, whereas the 31 transitions observed are from high even- low odd- parity levels. 20 lines have exhibited positive IS and 60 lines have indicated negative IS whereas the remaining 5 spectral lines have shown no or 0 IS. The wavelengths of the spectral lines studied presently, their intensities and their relevant energy level classifications, are taken from Meggers et al. [9] and are presented in the column 1. The IS $\Delta \sigma^{166,170}$ (MHz) data of the lines studied were presented in the column 2 of the Table 2. IS in the chosen 7spectral lines at 357.075 nm, 363.354 nm, 369.265 nm, 371.239 nm, 372.952 nm, 390.631 nm, and at 590.208 nm of Er II recorded on FTS were exhibited in Figs. 1-7 respectively. The magnitude of IS as seen in Figures 1 and 4 is measureably large whereas it is too small to measure directly in Figures 2, 3, 5, 6 and 7 and had been extracted using profiles of single isotopes. Energy level classification (33129- 5132 cm$^{-1}$) listed by Meggers et al. [9] for the line at 357.075 was unfit (see Fig. 1) and conclusively rejected by Wyart et al. [6]. The IS value -2910 MHz presently measured in the line was not agreeing with the classification listed by Meggers et al. [9] hence we also support the rejection of the said classification. Wyart et al. [6] have provided energy level classifications for the three lines compiled as unclassified lines in [9] at 495.360 nm, 502.428 nm and at 521.826 nm. The present IS data derived in these lines support the recent classifications (see Table 2) calculated by Wyart et al. [6].
Figure 1. Er II FTS Spectrum, Wavelength, $\lambda = 357.075$ nm [Wavenumber, $\sigma = 27997.304$ cm$^{-1}$ = 33129.912 cm$^{-1}$ ($J=9/2$) $4f^{12}6s \Delta T^{166,170}$ (81 MHz) – 5132.608 cm$^{-1}$ ($J=9/2$) 4f$^{12}6s$ 4f$^{12}6s$ $\Delta T^{166,170}$ (2991 MHz)]. This energy level classification compiled in Meggers et al. [9] was rejected by Wyart et al. [6]. The presently derived $\Delta T^{166,170}$ (81 MHz) for the level at 33129 cm$^{-1}$ cannot be classified under any of the odd configurations listed in the Table 3. Thus experimentally measured IS, $\Delta \sigma^{166,170} = -2910$ MHz data in this line does not suit with the existing classification [9] and supports its rejection. Light Source: Liquid nitrogen cooled HCL, Detector: PMT. a. u.: Arbitrary units.

Figure 2. Er II FTS Spectrum, Wavelength, $\lambda = 363.354$ nm [Wavenumber, $\sigma = 27513.555$ cm$^{-1}$, Energy Level Classification, 27513.555 cm$^{-1}$ ($J=13/2$) $4f^{12}6s \Delta T^{166,170}$ (2798 MHz) – 0.00 cm$^{-1}$ ($J=13/2$) $4f^{12}6s$ $\Delta T^{166,170}$ (3000 MHz)]. The extracted IS, $\Delta \sigma^{166,170} = -200$ MHz, Light Source: Liquid nitrogen cooled HCL, Detector: PMT.
Figure 3. Er II FTS Spectrum, Wavelength, $\lambda = 369.265$ nm [Wavenumber, $\sigma = 27073.11$ cm$^{-1}$, Energy Level Classification, $27513$ cm$^{-1}$ ($J=13/2$), $\Delta T_{166,170} = 2798$ MHz] - $440$ cm$^{-1}$ ($J=11/2$) $4f^66s6p$ - $6824$ cm$^{-1}$ ($J=15/2$) $4f^66s2$. The extracted IS, $\Delta \sigma_{166,170} = -190$ MHz. Light Source: Liquid nitrogen cooled HCL, Detector: PMT.

Figure 4. Er II FTS Spectrum, Wavelength, $\lambda = 371.239$ nm [Wavenumber, $\sigma = 26929.11$ cm$^{-1}$, Energy Level Classification, $33753$ cm$^{-1}$ ($J=13/2$), $\Delta T_{166,170} = 2798$ MHz] - $440$ cm$^{-1}$ ($J=11/2$) $4f^66s6p$ - $6824$ cm$^{-1}$ ($J=15/2$) $4f^66s2$. The experimentally measured IS, $\Delta \sigma_{166,170} = -3760$ MHz. Light Source: Liquid nitrogen cooled HCL, Detector: PMT.
**Figure 5.** Er II FTS Spectrum, Wavelength, $\lambda = 372.952$ nm [Wavenumber, $\sigma = 26805$ cm$^{-1}$, Energy Level Classification, $26805$ cm$^{-1}$ ($J=11/2$) $4f^{12}6s^2$ $\Delta T^{166,170}$ (1595 MHz) – 0.00 cm$^{-1}$ ($J=13/2$) $4f^{12}6p$ $\Delta T^{166,170}$ (3000 MHz)]. The extracted IS, $\Delta \sigma^{166,170} = -1405$ MHz. Light Source: Liquid nitrogen cooled HCL, Detector: PMT.

**Figure 6.** Er II FTS Spectrum, Wavelength, $\lambda = 390.631$ nm [Wavenumber, $\sigma = 25592$ cm$^{-1}$, Energy Level Classification, $25592$ cm$^{-1}$ ($J=11/2$) $4f^{12}6p$ $\Delta T^{166,170}$ (2798 MHz) – 0.00 cm$^{-1}$ ($J=13/2$) $4f^{12}6s$ $\Delta T^{166,170}$ (3000 MHz)]. The extracted IS, $\Delta \sigma^{166,170} = -200$ MHz. Light Source: Liquid nitrogen cooled HCL, Detector: PMT.
Figure 7. Er II FTS Spectrum, Wavelength, $\lambda = 590.208$ nm [Wavenumber, $\sigma = 16938.483$ cm$^{-1}$, energy level classification $17378.917$ cm$^{-1}$ (J=13/2) $4f^{11}5d6s$ $\Delta T_{166,170}$ (2311 MHz) – $440.434$ cm$^{-1}$ (J= 11/2) $4f^{12}6s$ $\Delta T_{166,170}$ (2990 MHz)]. The extracted $\Delta \sigma_{166,170} = -680$ MHz. Light Source: Liquid nitrogen cooled HCL, Detector: PMT.

Table 2. List of IS, $\Delta \sigma_{166,170}$ (MHz) data in the spectral lines of the Er II in the wavelength region of 350-590 nm. a. u.: Arbitrary units. The wavelengths and the energy level classifications are referred from Meggers et al. [9]. A: Wyart et al. [6] have rejected the energy level classification provided (in the parenthesis) by Meggers et al. [9]. B: Energy level classification of this line has been taken from Wyart et al. [6] since this line was unclassified in [9].

| $\lambda$ (nm) | Intensity (a. u.) | Odd (cm$^{-1}$) | LIS, $\Delta \sigma_{166,170}$ (MHz) | Even (cm$^{-1}$) | LIS, $\Delta \sigma_{166,170}$ (MHz) | IS, $\Delta \sigma_{166,170}$ (MHz) |
|---------------|------------------|----------------|-------------------------------|----------------|-------------------------------|-------------------------------|
| 349.910       | 6700             | 29011          | 1071                          | 440            | 2990                          | -1920                         |
| 352.491       | 610              | 28361          | 2132                          | 0              | 3000                          | -870                          |
| 355.990       | 1000             | 28082          | 2051                          | 0              | 3000                          | -950                          |
| 357.075$^a$   | 920              | (33129)        | 83                            | (5132)         | 2991                          | -2910                         |
| 358.052       | 1000             | 28361          | 2132                          | 440            | 2990                          | -850                          |
| 359.983       | 1000             | 10667          | 2399                          | 38438          | 2256                          | -145                          |
| 361.656       | 3100             | 27642          | 2159                          | 0              | 3000                          | -840                          |
| 361.892       | 510              | 33028          | 1711                          | 5403           | 2990                          | -1280                         |
| 363.354       | 1000             | 27513          | 2798                          | 0              | 3000                          | -200                          |
| 363.716       | 270              | 32619          | 2268                          | 5132           | 2991                          | -725                          |
| 364.594       | 900              | 13027          | 2400                          | 40447          | 2251                          | 0                             |
| 365.287       | 500              | 34563          | 904                           | 7195           | 2990                          | -2090                         |
| 368.270       | 500              | 34341          | 1990                          | 7195           | 2990                          | -1000                         |
| 368.428       | 380              | 32267          | 1902                          | 5132           | 2991                          | -1090                         |
| 369.265       | 7900             | 27513          | 2798                          | 440            | 2990                          | -190                          |
| 369.625       | 450              | 34196          | 2382                          | 7149           | 2991                          | -610                          |
| 369.692       | 160              | 16935          | 2229                          | 43977          | 2251                          | 0                             |
| 371.239       | 520              | 6824           | 6430                          | 33753          | 2671                          | -3760                         |
| 372.364       | 65               | 39447          | 1775                          | 12600          | 2991                          | -1215                         |
| 372.952       | 1300             | 26805          | 1595                          | 0              | 3000                          | -1405                         |
| 373.126       | 1300             | 33988          | 1854                          | 7195           | 2990                          | -1135                         |
| 373.458       | 270              | 26769          | 2332                          | 0              | 3000                          | -670                          |
| 374.110       | 340              | 6824           | 6430                          | 33547          | 2682                          | -3750                         |
| 374.264       | 900              | 31844          | 1641                          | 5132           | 2991                          | -1350                         |
| 374.571       | 55               | 39277          | 2048                          | 12587          | 2991                          | -950                          |
| 375.054       | 190              | 13338          | 6374                          | 39994          | 2569                          | -3805                         |
| 377.566       | 230              | 16935          | 2229                          | 43413          | 2256                          | 0                             |
| 378.447       | 310              | 33565          | 2093                          | 7149           | 2991                          | -900                          |
| 378.684       | 1800             | 26399          | 2338                          | 0              | 3000                          | -660                          |
| 379.076       | 560              | 26769          | 2332                          | 440            | 2990                          | -660                          |
3.1. Electron Configurations and Their Screening Ratios

Transition IS defined as the difference between the energies of upper and lower energy levels (LIS) of two different isotopes. IS in a line consists mainly of mass shifts (MS) and field isotope shifts (FIS) or field shift (FS). MS further divided into the normal mass shift (NMS) and specific mass shifts (SMS). MS dominates in lighter elements whereas FS dominates in the high Z elements with mass number, \( A \geq 100 \). FS is observed due to the change in \( ns \) and in small extent in \( np \) electron densities at the nucleus or simply due to change in size and shape of the nuclei [15]. FS varies according to number of \( ns \) electrons present in the configuration and hence helps in identifying the definite configuration if LIS data is available for that energy level. However \( np \) and \( nd \) electrons screen the \( ns \)-electron in the given configuration thus amount of screening is different for different configurations. It has been observed that the
screening ratios of ns- electron densities for different configurations are proportional to the ratios of respective LIS of the pure configurations [16]. The task of identifying the configuration for the particular high lying level becomes theoretically difficult because of the favorable chances of configuration mixing. The configuration mixing takes place between two or more configurations of the close lying energy levels provided these energy levels have same parity and the same J. The LIS, \( \Delta T_{166,170} \) (MHz) were estimated using the well-known “Sharing Rule” (see eq. 1) according to which a state whose wave function \( \Psi \) results from mixing of ‘n’ number of configurations, the LIS, \( \Delta T \) equals the sum of LIS, \( \Delta T_i \) of individual configurations, multiplied by square of weight \( C_i \) of the configurations in \( \Psi \).

\[
\Delta T = \sum_{i=1}^{n} C_i^2 \Delta T_i \quad \text{with} \quad \sum C_i^2 = 1 \tag{1}
\]

We evaluated the hypothetical \( \Delta T \) values for the even and odd energy levels with the aid of various percentage compositions of different configurations. The even levels have configuration mixing of the type \((4f^{12}6s^{2}+4f^{11}5d+4f^{11}6s6p+4f^{11}5d6p)\) whereas the odd levels have of the type \((4f^{11}6s^{2}+4f^{11}5d6s+4f^{11}6p+4f^{11}5d^{2})\) as has been provided in Wyart et al. [6].

The LIS of different even and odd levels of Er II were derived using the transition arrays, the different screening ratios published in reference [16] and the LIS, \( \Delta T_{166,170} \) 4800 MHz (0.160 cm\(^{-1}\)) of the ground state level of 4f\(^{11}\)6s\(^2\) configuration of Er I [14]. LIS \( \Delta T_{166,170} \) 3000 MHz (0.100 cm\(^{-1}\)) in the ground state level of 4f\(^{12}\)6s configuration was calculated using the empirical screening ratio provided in [16] \( \Delta T \) \( (4f^{11}6s^{2})/ \Delta T \) \( (4f^{12}6s) = 1.6 \) of the screening ratios derived presently for the even and odd configurations of Er II are summarized here;

\[\Delta T \] \((4f^{11}6s^{2})/ \Delta T \) \((4f^{11}6s) = 1.6, \Delta T \] \((4f^{11}6s6p)/ \Delta T \] \((4f^{11}6s) = 0.9, \Delta T \] \((4f^{11}6s6d)/ \Delta T \] \((4f^{11}6s) = 0.8, \Delta T \] \((4f^{11}6s)/ \Delta T \] \((4f^{11}6p) = 5.0, \Delta T \] \((4f^{11}6s)/ \Delta T \] \((4f^{11}6p) = 2.2 \]

LIS of pure configurations of Er II derived using the above mentioned screening ratios and these were listed in the Table 3.

| Even Configuration | \( \Delta T_{166,170} \) (MHz) | Odd Configuration | \( \Delta T_{166,170} \) (MHz) |
|--------------------|-----------------|------------------|-----------------|
| \( 4f^{11}5d6p \) | 2250            | \( 4f^{11}5d6p \) | 6600            |
| \( 4f^{11}6p \)  | 3000            | \( 4f^{11}6s5d \) | 2400            |
| \( 4f^{11}5d \)  | 0              | \( 4f^{11}5d^{2} \) | 850             |
| \( 4f^{11}6s6p \) | 2700            | \( 4f^{11}6p \)  | 600             |
| \( 4f^{11}5d6p \) | 2250            |                  |                 |

Table 3. Pure Even and odd configurations with their expected LIS, \( \Delta T_{166,170} \) (MHz) of Er II.

Fig. 4 depicts the partial energy level diagram for the Er II spectrum encompassing the different types of transitions, IS \( \Delta \sigma_{166,170} \) (MHz) data, different configurations, and their LIS, \( \Delta T_{166,170} \) (MHz). LIS data was derived with the accuracy of ± 0.003 cm\(^{-1}\) (±90 MHz) accordingly for 29 even and 63 odd levels and presented in Table 4 and 5.

3.1.1. Even Parity Energy Levels and Their Configuration Mixing

Column 1 and 2 in the Table 4 exhibit the previous status of configuration assignment whereas column 3 shows the present experimental LIS, \( \Delta T_{166,170} \) data and the configuration mixing suggested by us. We have derived the hypothetical LIS \( \Delta T \) values for the energy levels encountered in the present studies using the different possible configuration mixings and listed those along with the experimentally derived LIS \( \Delta T \)s. All the 29 even parity energy levels exhibit configuration mixings of the type \((4f^{11}6s + 4f^{11}5d + 4f^{11}6s6p + 4f^{11}5d6p)\) of the different configurations. As seen in the Table, the experimental LIS values and LIS values derived using ‘Sharing rule’ do not wonder much from each other. Thus the theoretically predicted configuration mixings for all even levels as reported in [6] were confirmed experimentally.

![Figure 8](image-url)
Table 4. The LIS, ΔT/ΔT_{exp} (MHz) derived in the even-parity levels of Er II. a: The new level referred from [6].

| [1] | Configuration mixing (%) [6] | Present work ← (MHz) → ← Configuration mixing (%) → |
|-----|-----------------------------|-----------------------------------------------|
| Level (cm⁻¹) | configuration | J | 4f⁴5s⁴ | 4f⁴5s⁵d | 4f⁴6p⁶s | 4f⁴5s⁵d⁶p | ΔT_{exp} | ΔT_{therm} | 4f⁴5s⁴ | 4f⁴5s⁵d | 4f⁴6p⁶s | 4f⁴5s⁵d⁶p |
| 0.000 | 4f⁴5s⁴ | 13/2 | 98.85 | 0.01 | 0.01 | 1.13 | 3000 | 2991.195 | 98.85 | 0.01 | 0.01 | 1.13 |
| 1.000 | 4f⁴5s⁴ | 11/2 | 98.81 | 0.08 | 0.11 | 1.5 | 2990 | 2990.445 | 98.81 | 0.02 | 0.01 | 1.15 |
| 2.000 | 4f⁴5s⁴ | 11/2 | 98.82 | 0.01 | 0.02 | 1.15 | 2991 | 2991.015 | 98.82 | 0.01 | 0.02 | 1.15 |
| 3.000 | 4f⁴5s⁴ | 7/2 | 98.80 | 0.03 | 0.03 | 1.15 | 2990 | 2990.415 | 98.80 | 0.03 | 0.02 | 1.15 |
| 4.000 | 4f⁴5s⁴ | 11/2 | 98.83 | 0.02 | 0.01 | 1.14 | 2991 | 2990.82 | 98.83 | 0.02 | 0.01 | 1.14 |
| 5.000 | 4f⁴5s⁴ | 7/2 | 98.82 | 0.02 | 0.01 | 1.15 | 2990 | 2990.745 | 98.82 | 0.02 | 0.01 | 1.15 |
| 6.000 | 4f⁴5s⁴ | 7/2 | 98.81 | 0.03 | 0.02 | 1.15 | 2991 | 2990.715 | 98.81 | 0.02 | 0.02 | 1.15 |
| 7.000 | 4f⁴5s⁴ | 7/2 | 98.80 | 0.03 | 0.03 | 1.17 | 2991 | 2990.535 | 98.78 | 0.03 | 0.03 | 1.17 |
| 8.000 | 4f⁴5s⁴ | 5/2 | 98.79 | 0.02 | 0.03 | 1.16 | 2991 | 2990.61 | 98.79 | 0.02 | 0.03 | 1.16 |

Table 5. The list of the odd parity energy levels of Er II and their LIS, ΔT/ΔT_{exp} (MHz) values in MHz. A: This is newly calculated level taken from [6]. B: The unassigned level at 32811.066 cm⁻¹ tabulated in [1] was revised to 32810.980 cm⁻¹ in reference [6].

| [1] | Configuration mixing (%) [6] | Present work ← (MHz) → ← Configuration mixing (%) → |
|-----|-----------------------------|-----------------------------------------------|
| Level (cm⁻¹) | configuration | J | 4f⁴5s⁴ | 4f⁴5s⁵d | 4f⁴6p⁶s | 4f⁴5s⁵d⁶p | ΔT_{exp} | ΔT_{therm} | 4f⁴5s⁴ | 4f⁴5s⁵d | 4f⁴6p⁶s | 4f⁴5s⁵d⁶p |
| 32810.980 | 4f⁴6p⁶s | 15/2 | 0.00 | 0.00 | 97.49 | 2.51 | 2688 | 2688.705 | 0.00 | 0.00 | 97.49 | 2.51 |
| 32810.980 | 4f⁴6p⁶s | 17/2 | 0.06 | 0.00 | 95.61 | 4.39 | 2682 | 2682.045 | 0.06 | 0.00 | 95.61 | 4.39 |
| 32810.980 | 4f⁴6p⁶s | 15/2 | 0.00 | 0.00 | 95.97 | 4.03 | 2682 | 2681.865 | 0.00 | 0.00 | 95.97 | 4.03 |
| 32810.980 | 4f⁴6p⁶s | 13/2 | 0.01 | 0.08 | 93.96 | 5.96 | 2671 | 2671.32 | 0.01 | 0.08 | 93.96 | 5.96 |
| 32810.980 | 4f⁴6p⁶s | 19/2 | 0.00 | 0.01 | 95.33 | 4.67 | 2678 | 2678.985 | 0.00 | 0.01 | 95.33 | 4.67 |
| 32810.980 | 4f⁴6p⁶s | 17/2 | 0.00 | 0.00 | 95.63 | 4.37 | 2680 | 2680.335 | 0.00 | 0.00 | 95.63 | 4.37 |
| 32810.980 | 4f⁴6p⁶s | 15/2 | 0.00 | 0.01 | 94.95 | 5.04 | 2677 | 2677.05 | 0.00 | 0.01 | 94.95 | 5.04 |
| 32810.980 | 4f⁴6p⁶s | 13/2 | 0.00 | 0.00 | 96.21 | 3.73 | 2682 | 2681.595 | 0.00 | 0.05 | 96.21 | 3.73 |
| 32810.980 | 4f⁴6p⁶s | 11/2 | 0.00 | 0.01 | 93.31 | 4.74 | 2626 | 2626.02 | 0.01 | 0.01 | 93.31 | 4.74 |
| 32810.980 | 4f⁴6p⁶s | 17/2 | 0.00 | 0.00 | 95.15 | 4.82 | 2677 | 2676.96 | 0.00 | 0.05 | 95.15 | 4.82 |
| 32810.980 | 4f⁴6p⁶s | 15/2 | 0.06 | 0.00 | 99.74 | 8.63 | 2600 | 2600.15 | 0.00 | 0.06 | 99.74 | 8.63 |
| 32810.980 | 4f⁴6p⁶s | 11/2 | 0.00 | 0.01 | 92.99 | 6.40 | 2569 | 2569.04 | 0.00 | 0.01 | 92.99 | 6.40 |
| 32810.980 | 4f⁴6p⁶s | 12/2 | 0.00 | 0.00 | 99.98 | 8.22 | 2564 | 2563.98 | 0.00 | 0.00 | 99.98 | 8.22 |
| 32810.980 | 4f⁴6p⁶s | 11/2 | 0.00 | 0.00 | 93.31 | 4.74 | 2626 | 2626.02 | 0.01 | 0.01 | 93.31 | 4.74 |
| 32810.980 | 4f⁴6p⁶s | 17/2 | 0.00 | 0.00 | 95.15 | 4.82 | 2677 | 2676.96 | 0.00 | 0.05 | 95.15 | 4.82 |
3.1.2. Odd Parity Energy Levels and Their Configuration Mixing

All the 63 odd levels involved in the present experiment have configuration mixing of the type \(4f^66s^2\) [1] have average LIS 2000 MHz suggests that these levels should belong to the dominant 4f\(^{15}\)6d\(^5\) configuration [6].

4. Conclusion

The high resolution Er II spectra recorded using the mixture of highly enriched \(^{166}\)Er and \(^{170}\)Er isotopes (7:10 ratio) in the liquid nitrogen cooled HCL. This first detailed investigation of IS, \(\Delta\sigma\) (ratio) in the 85 spectral lines of Er were conducted using a FTS. The measurements have contributed significantly to the acquaintance of the known even and odd energy levels of Er. The main features of this work could be summarized as, the present IS data in 85 lines has enabled us to evaluate LIS, \(\Delta\sigma\) values for 29 even and 63 odd parity energy levels for the first time. The theoretically predicted configuration mixings found in the excellent agreement with the experimentally derived mixings. 4 odd levels tentatively assigned to 4f\(^{16}\)6p configuration were revised to 4f\(^{15}\)6d\(^5\) configuration.
configuration. 9 even levels of $4f^{11}6s6p$ and 19 odd levels of $4f^{11}5d6s$ configuration were confirmed whereas 24 unassigned odd levels designated dominantly to the $4f^{11}5d6s$ configuration.

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