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

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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 [1] taking aid from the unpublished extension of the Er II spectral analysis carried out by van Kleef TAM et al.[2].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 $4f^{12}6s$ and $4f^{12}5d$ 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 hfs 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, 6006.80Å 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 IS in the ground configuration $4f^{12}6s$ of Er II were measured [13] using enriched isotopes of $^{166}$Er and $^{170}$Er and computer- interfaced Fabry- Perot Spectrometer.

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 | $4f^{12}6s$ |
| | 23 | $4f^{12}5d$ |
| | 9 | $4f^{11}6s6p$ |
| | 8 | $4f^{11}6s6p$? |
| | 11 | $4f^{11}5d6p$? |
| | 54 | Unassigned |
| Odd (243 known levels) | 3 | $4f^{11}6s^2$ |
| | 28 | $4f^{11}5d6s$ |
| | 5 | $4f^{11}5d6s$ (?) |
| | 2 | $4f^{11}5d^2$ (?) |
| | 10 | $4f^{12}6p$ (?) |
| | 195 | Unassigned |

## 2. Experimental Techniques

IS, $\Delta\sigma^{166,170}$ were measured in the 67 lines falling in the 350-590 nm region of the Er II spectra with a Bomem DA8 Fourier Transform Spectrometer (FTS). The light detector was photo multiplier tube (PMT) and the source was liquid nitrogen cooled hollow cathode lamp (HCL). The source consisted of manmade mixture (7:10 ratio) of highly enriched isotopes $^{166}$Er (96.3%) and $^{170}$Er (98.0%) respectively in the oxide form. The sample weighing about 12- 15 mg was coated on the copper crucible as a thin layer of paste prepared using distilled water. The coated crucible was dried under the infrared lamp and later heated to red hot on the Bunsen flame before inserting it into the HCL. Ne was filled at 2.5 mbar as a buffer gas and the discharge was run at 45 mA DC between the anode and cu-cathode maintaining 2-3 mm gap. To get an acceptable signal to noise ratio, about 90 minute integration time (~50 scans co-added) was used to record the each set of data. The entrance aperture of the spectrometer adjusted to ~1 mm to give rise to the resolution of 0.02 cm$^{-1}$.

During the IS measurements we considered the different parameters like intensity, Full width at half maximum (FWHM), the center of gravity of each component. All IS data were converted to ($1.10^{-3}$ cm$^{-1}$= 30 MHz) MHz from wavenumber (cm$^{-1}$) scale. Er spectra encompass the Ne I and Ne II lines (FWHM 4500 MHz) in addition to Er I and Er II. IS $\Delta\sigma^{166,\,170}$ data in 660 Er I spectral lines has been already published in [14] in 2015. Er II lines exhibit 2000 MHz FWHM at 350 nm and 1500 MHz at 590 nm. The spectral positions were shifted to +0.200 cm$^{-1}$ towards shorter wavelength region and -0.05 cm$^{-1}$ shift observed towards the longer wavelength region. The accuracy of the IS measurements for all lines was (±0.003 cm$^{-1}$) ± 90 MHz. IS was said to be positive if the peak representing heavier isotope,$^{170}$Er appears on the higher frequency side and it was negative if it appears on the lower frequency side. The IS 0 MHz suggests that the peaks of both the isotopes $^{166}$Er and $^{170}$Er overlap one above another.

## 3. Results and Discussions

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- to 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 measurably 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].

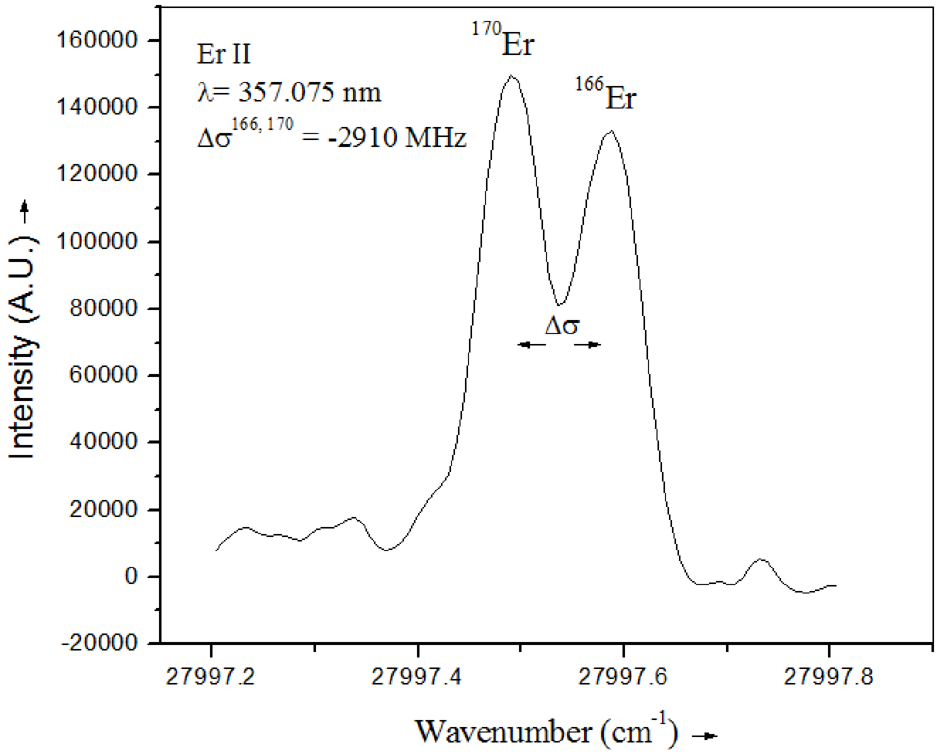


***Figure 1.*** *Er II FTS Spectrum, Wavelength, λ= 357.075 nm [Wavenumber, σ= 27997.304 cm$^{-1}$= 33129.912 cm$^{-1}$ (J=9/2) ΔT$^{166, 170}$ (81 MHz) – 5132.608 cm$^{-1}$ (J= 9/2) 4f$^{12}$6s ΔT$^{166, 170}$ (2991 MHz)]. This energy level classification compiled in Meggers et al. [9] was rejected by Wyart et al. [6]. The presently derived ΔT$^{166, 170}$ (81 MHz) for the level at 33129 cm$^{-1}$ can not be classified under any of the odd configurations listed in the Table 3. Thus experimentally measured IS, Δσ$^{166,170}$ = -2910 MHz data in this line does not suite with the existing classification [9] and supports its rejection. Light Source: Liquid nitrogen cooled HCL, Detector: PMT. a. u : Arbitrary units.*

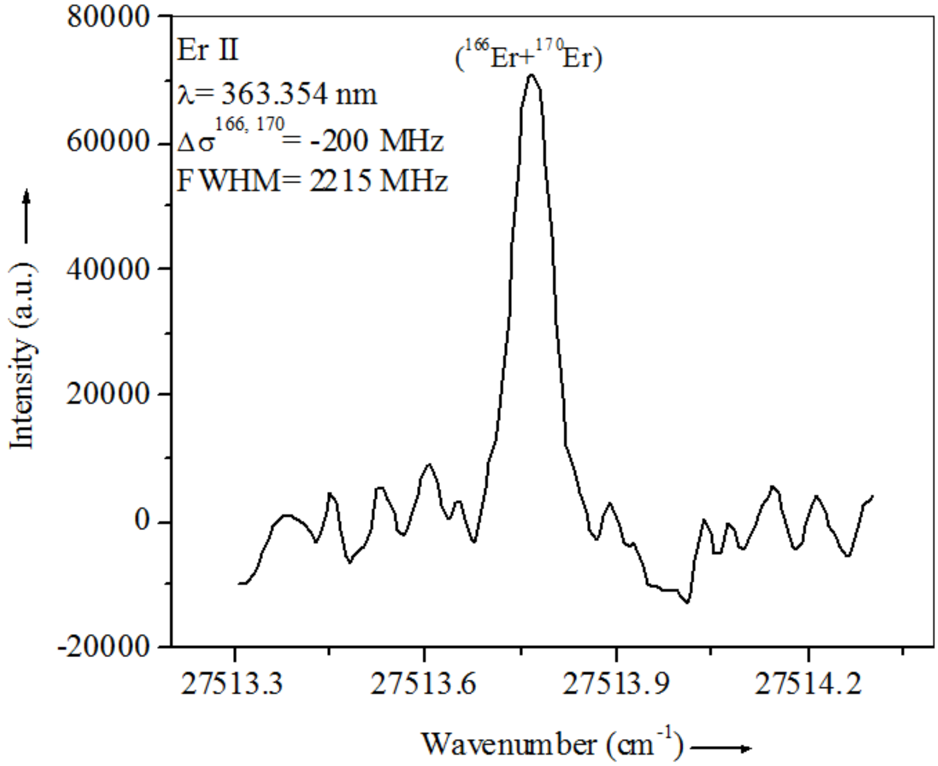


***Figure 2.*** *Er II FTS Spectrum, Wavelength, λ= 363.354 nm [Wavenumber, σ= 27513.555 cm$^{-1}$, Energy Level Classification, 27513.555 cm$^{-1}$ (J=13/2) ΔT$^{166, 170}$(2798 MHz) – 0.00 cm$^{-1}$ (J= 13/2) 4f$^{12}$6sΔT$^{166, 170}$(3000 MHz)]. The extracted IS, Δσ$^{166,170}$ = -200 MHz, Light Source: Liquid nitrogen cooled HCL, Detector: PMT.*

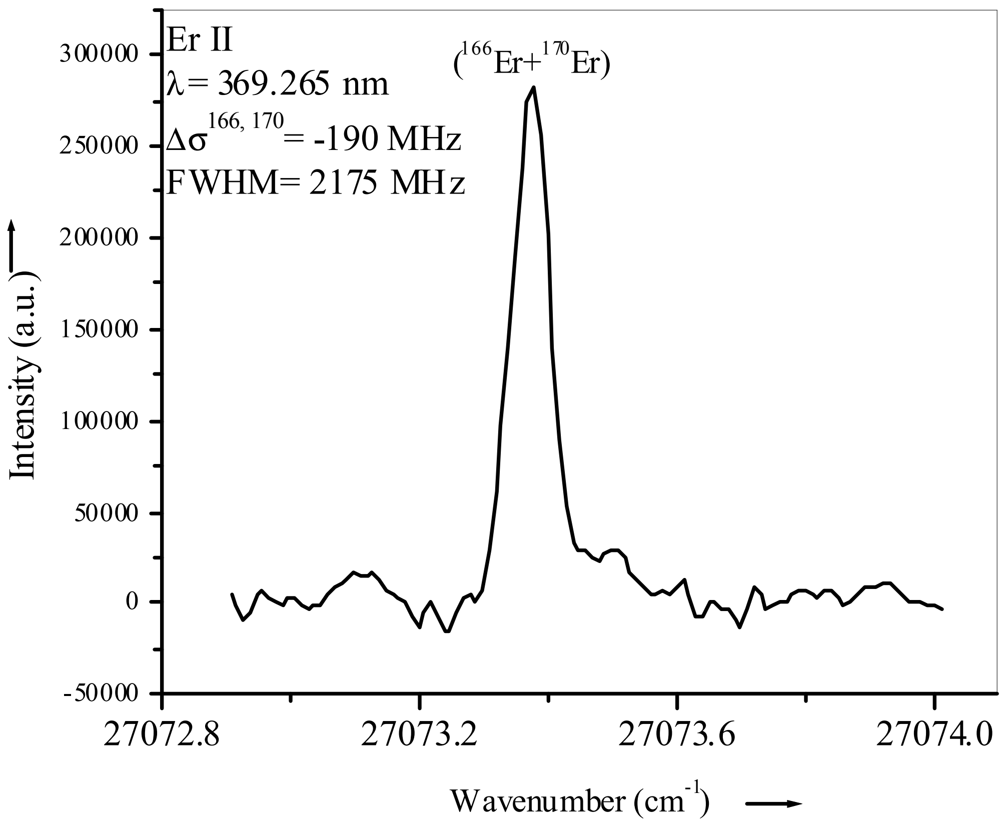


***Figure 3.*** *Er II FTS Spectrum, Wavelength, $\lambda$= 369.265 nm [Wavenumber, $\sigma$= 27073.11 cm$^{-1}$, Energy Level Classification, 27513 cm$^{-1}$ (J=13/2) $\Delta T^{166,170}$(2798 MHz) – 440 cm$^{-1}$ (J= 11/2) 4f$^{12}$6s$\Delta T^{166,170}$(2990 MHz)]. The extracted IS, $\Delta\sigma^{166,170}$ = -190 MHz, Light Source: Liquid nitrogen cooled HCL, Detector: PMT.*

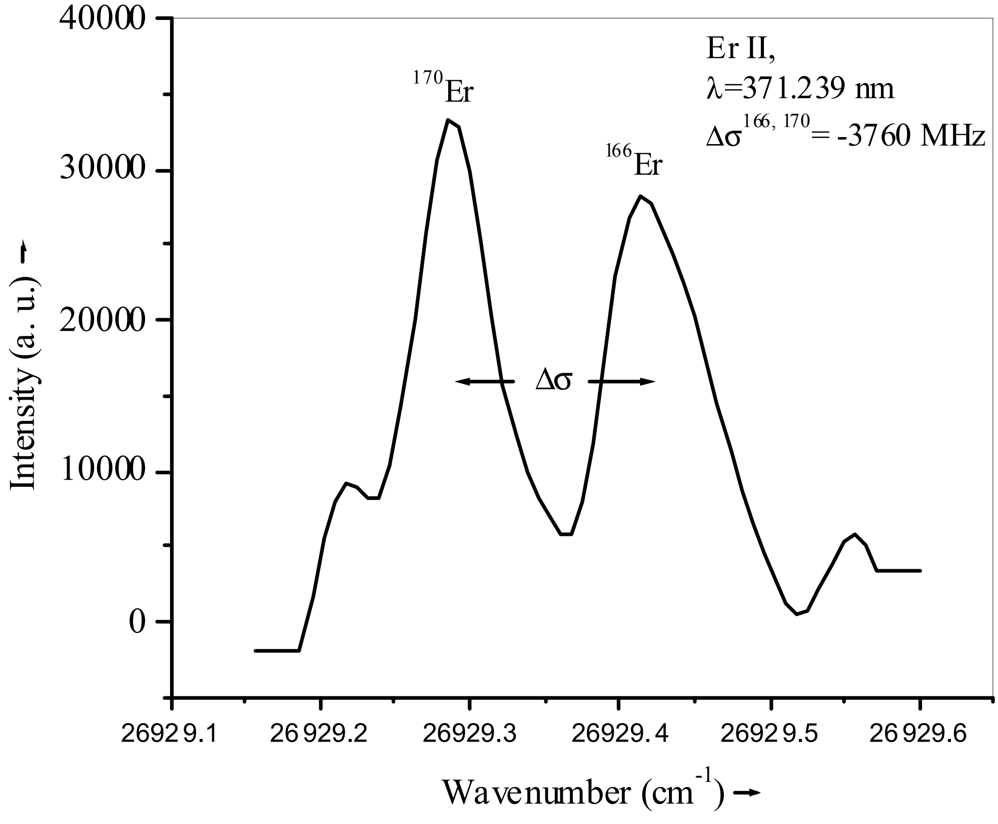


***Figure 4.*** *Er II FTS Spectrum, Wavelength, $\lambda$= 371.239 nm [Wavenumber, $\sigma$= 26929.246 cm$^{-1}$, Energy Level Classification, 33753 cm$^{-1}$ (J=13/2) $\Delta T^{166,170}$(2671 MHz) 4f$^{11}$6s6p – 6824 cm$^{-1}$ (J= 15/2)4f$^{11}$6s$^{2}\Delta T^{166,170}$(6430 MHz)]. The experimentally measured IS, $\Delta\sigma^{166,170}$ = -3760 MHz. Light Source: Liquid nitrogen cooled HCL, Detector: PMT.*

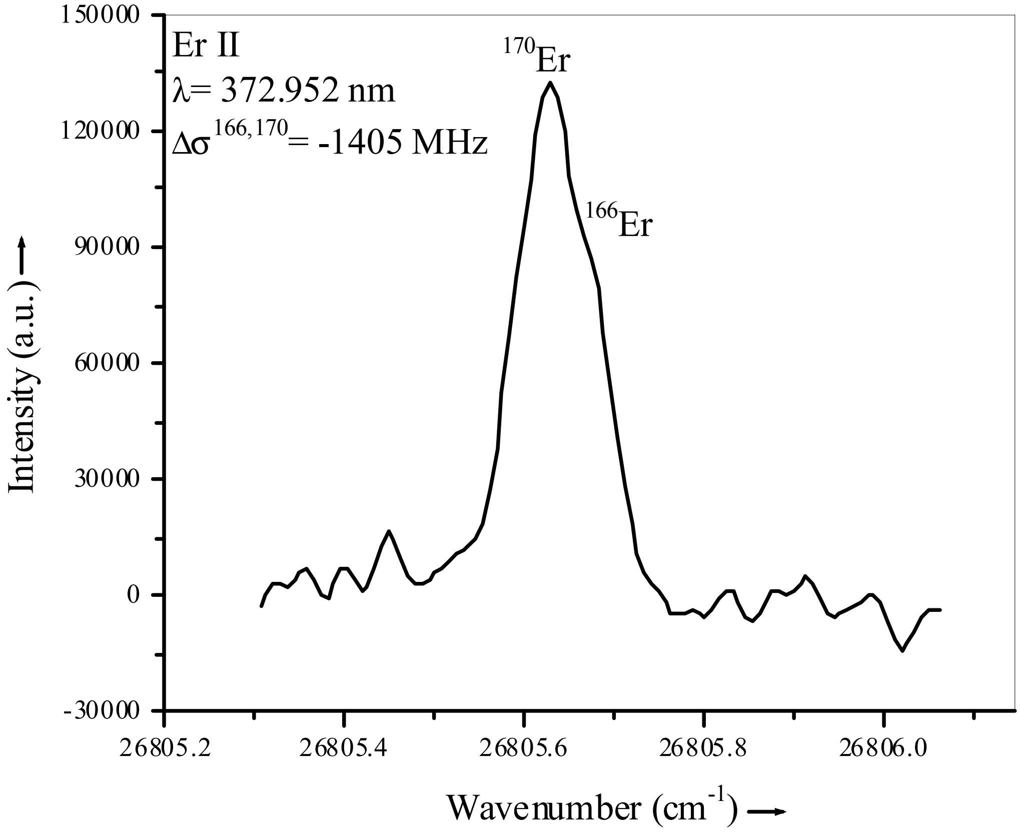


***Figure 5.*** *Er II FTS Spectrum, Wavelength, $\lambda$= 372.952 nm [Wavenumber, $\sigma$= 26805 cm$^{-1}$, Energy Level Classification, 26805 cm$^{-1}$ (J=11/2) $\Delta T^{166,170}$ (1595 MHz) – 0.00 cm$^{-1}$ (J= 13/2)4f$^{12}$6s $\Delta T^{166,170}$ (3000 MHz)]. The extracted IS, $\Delta\sigma^{166,170}$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

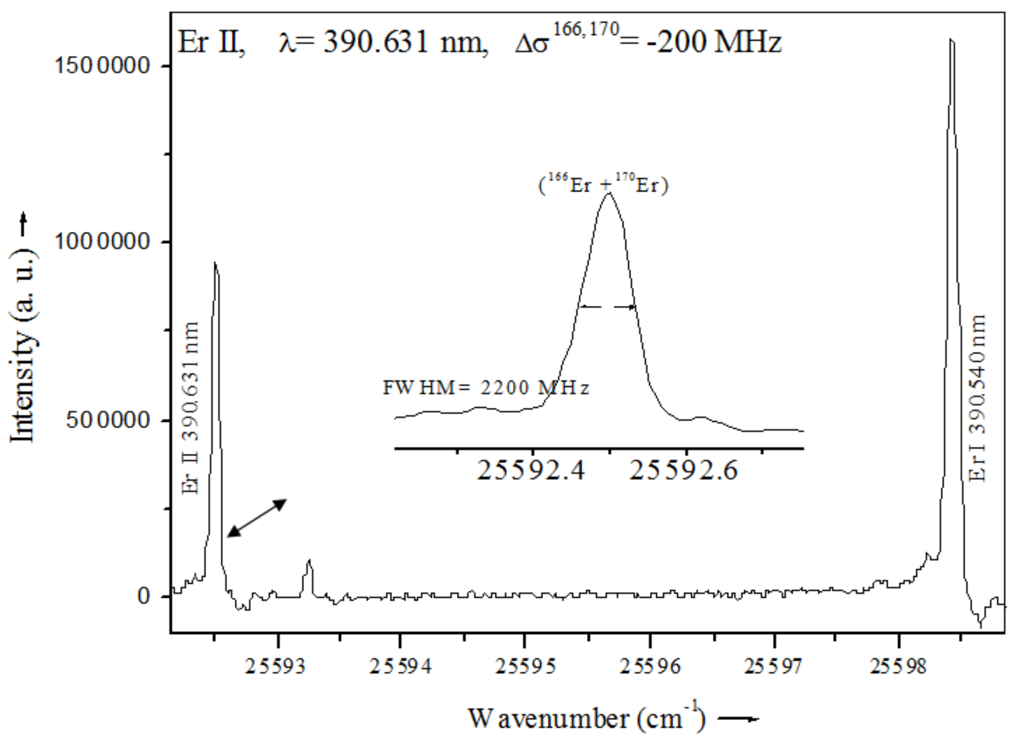


***Figure 6.*** *Er II FTS Spectrum, Wavelength, $\lambda$= 390.631 nm [Wavenumber, $\sigma$= 25592.343 cm$^{-1}$, energy level classification 25592 cm$^{-1}$ (J=11/2) 4f$^{12}$6p, $\Delta T^{166,170}$ (2798 MHz) – 0.00 cm$^{-1}$ (J= 13/2) 4f$^{12}$6s$\Delta T^{166,170}$ (3000 MHz)]. The extracted IS, $\Delta\sigma^{166,170}$= -200 MHz. Light Source: Liquid nitrogen cooled HCL, Detector: PMT.*

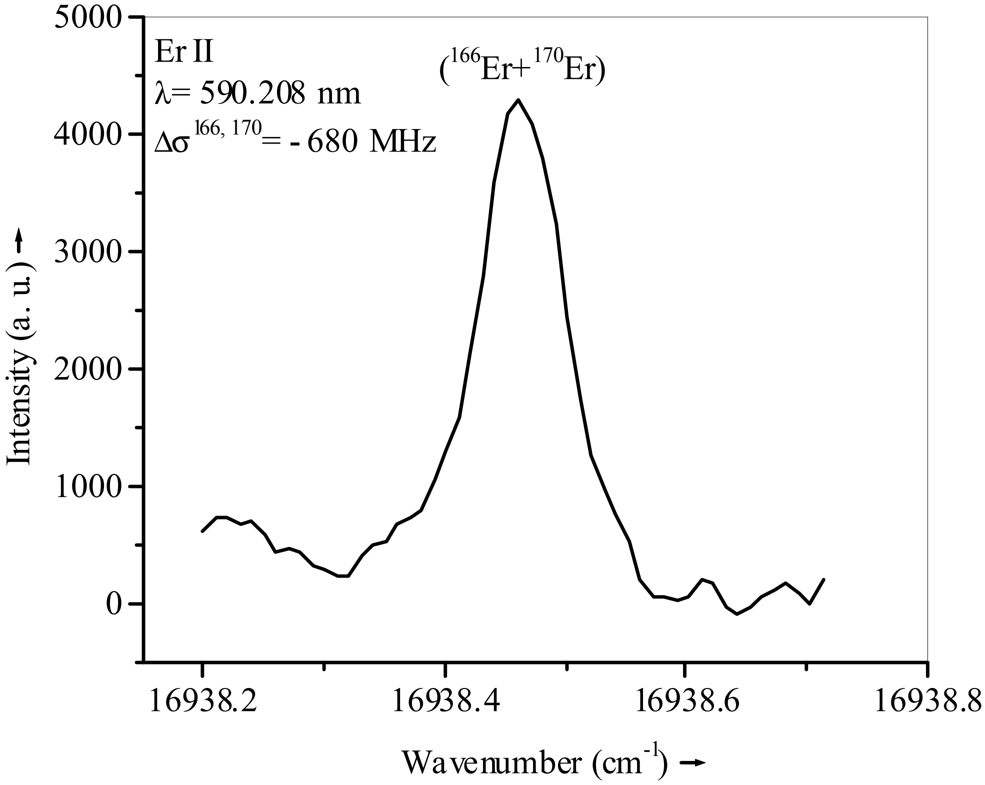


***Figure 7.*** *Er II FTS Spectrum, Wavelength, $\lambda$= 590.208 nm [Wavenumber, $\sigma$= 16938.483 cm$^{-1}$, energy level classification 17378.917cm$^{-1}$(J=13/2) 4f$^{11}$5d6s $\Delta T^{166, 170}$ (2311 MHz) – 440.434 cm$^{-1}$ (J= 11/2) 4f$^{12}$6s $\Delta T^{166, 170}$ (2990 MHz)]. The extracted $\Delta\sigma^{166,170}$ = -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].*

| λ (nm) | Intensity (a. u.) | Odd (cm$^{-1}$) | LIS, $\Delta T^{166,170}$ MHz | Even (cm$^{-1}$) | LIS, $\Delta T^{166,170}$ (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 | 450 | 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 |
| 379.706 | 560 | 26769 | 2332 | 440 | 2990 | -660 |

| λ (nm) | Intensity (a. u.) | Odd (cm$^{-1}$) | LIS, $\Delta T^{166,170}$ MHz | Even (cm$^{-1}$) | LIS, $\Delta T^{166,170}$ (MHz) | IS, $\Delta\sigma^{166,170}$ (MHz) |
|---|---|---|---|---|---|---|
| 383.048 | 3600 | 26098 | 1595 | 0 | 3000 | -1410 |
| 383.926 | 950 | 16948 | 5876 | 42987 | 2255 | -3620 |
| 384.831 | 80 | 31381 | 3020 | 5403 | 2990 | 0 |
| 388.061 | 1500 | 30894 | 1781 | 5132 | 2991 | -1210 |
| 388.289 | 1200 | 32896 | 1639 | 7149 | 2991 | -1350 |
| 389.061 | 400 | 36738 | 1208 | 11042 | 2991 | -1785 |
| 389.623 | 5200 | 26098 | 1595 | 440 | 2990 | -1400 |
| 390.276 | 810 | 32811 | 1493 | 7195 | 2990 | -1500 |
| 390.384 | 50 | 17378 | 2311 | 42987 | 2255 | 0 |
| 390.631 | 11000 | 25592 | 2798 | 0 | 3000 | -200 |
| 391.242 | 140 | 11309 | 2399 | 36861 | 2680 | +280 |
| 392.188 | 280 | 30894 | 1781 | 5403 | 2990 | -1210 |
| 393.225 | 810 | 32619 | 2268 | 7195 | 2990 | -725 |
| 393.863 | 2100 | 25382 | 2141 | 0 | 3000 | -860 |
| 393.892 | 85 | 17842 | 2188 | 43223 | 2289 | -100 |
| 397.472 | 1400 | 25592 | 2798 | 440 | 2990 | -190 |
| 400.916 | 280 | 24935 | 2184 | 0 | 3000 | -825 |
| 401.557 | 350 | 30028 | 2060 | 5132 | 2991 | -930 |
| 404.624 | 270 | 31902 | 2083 | 7195 | 2990 | -910 |
| 404.949 | 200 | 24687 | 2378 | 0 | 3000 | -625 |
| 405.547 | 940 | 29783 | 1793 | 5132 | 2991 | -1200 |
| 405.978 | 690 | 30028 | 2060 | 5403 | 2990 | -930 |
| 408.124 | 550 | 24935 | 2184 | 440 | 2990 | -825 |
| 409.464 | 140 | 24415 | 2345 | 0 | 3000 | -655 |
| 410.398 | 60 | 29492 | 2089 | 5132 | 2991 | -900 |
| 414.291 | 550 | 29263 | 1446 | 5132 | 2991 | -1551 |
| 427.648 | 140 | 12815 | 2395 | 36192 | 2678 | +285 |
| 430.160 | 320 | 23241 | 2233 | 0 | 3000 | -770 |
| 430.381 | 60 | 28361 | 2132 | 5132 | 2991 | -860 |
| 433.900 | 50 | 14280 | 2400 | 37321 | 2677 | +275 |
| 438.470 | 300 | 23241 | 2233 | 440 | 2990 | -760 |
| 441.961 | 570 | 13572 | 2400 | 36192 | 2678 | +280 |
| 445.924 | 100 | 22859 | 2375 | 440 | 2990 | -625 |
| 450.075 | 200 | 14649 | 2400 | 36861 | 2680 | +280 |
| 467.562 | 570 | 10667 | 2399 | 32048 | 2688 | +290 |
| 467.906 | 150 | 12388 | 2400 | 33753 | 2671 | +165 |
| 473.159 | 85 | 15732 | 2400 | 36861 | 2680 | +280 |
| 475.965 | 170 | 21004 | 2261 | 0 | 3000 | -740 |
| 476.264 | 60 | 16643 | 2375 | 37634 | 2682 | +310 |
| 482.035 | 190 | 11309 | 2399 | 32048 | 2688 | +290 |
| 483.115 | 85 | 13060 | 2408 | 33753 | 2671 | +265 |
| 485.164 | 30 | 17063 | 2798 | 37669 | 2626 | -175 |
| 487.209 | 150 | 13027 | 2400 | 33547 | 2682 | +280 |
| 487.248 | 30 | 20517 | 2362 | 0 | 3000 | -640 |
| 490.008 | 210 | 12815 | 2395 | 33217 | 2609 | +215 |
| 493.411 | 210 | 23973 | 926 | 44235 | 2058 | +1135 |
| 495.360$^{B}$ | 45 | 24053 | 880 | 44235 | 2058 | +1180 |
| 500.038 | 90 | 19992 | 2175 | 0 | 3000 | -825 |
| 502.428$^{B}$ | 45 | 20319 | 2368 | 40217 | 2677 | +310 |
| 502.891 | 120 | 20319 | 2368 | 440 | 2990 | -625 |
| 504.205 | 210 | 13719 | 2392 | 33547 | 2682 | +290 |
| 518.890 | 160 | 14280 | 2400 | 33547 | 2682 | +280 |
| 521.826$^{B}$ | 30 | 28016 | 852 | 47174 | 2253 | +1400 |
| 525.593 | 140 | 13027 | 2400 | 32048 | 2688 | +290 |
| 590.208 | 27 | 17378 | 2311 | 440 | 2990 | -680 |

### *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 ≥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 (*Ψ*) results from mixing of 'n' number of configurations, the LIS, ΔT equals the sum of LIS, $\Delta T_i$ of individual configurations, multiplied by square of weight $C_i$ of the configurations in *Ψ*,

$$\Delta T = \sum_{i=1}^{n} C_i^2 \Delta T \quad \text{with} \quad \Sigma C_i^2 = 1 \qquad (1)$$

We evaluated the hypothetical ΔT 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 ($4f^{12}6s+4f^{12}5d+4f^{11}6s6p+4f^{11}5d6p$) whereas the odd levels have of the type ($4f^{11}6s^2+4f^{11}5d6s+4f^{12}6p+4f^{11}5d^2$) 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 $4f^{12}6s^2$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] ΔT ($4f^{12}6s^2$)/ ΔT ($4f^{12}6s$) = 1.6. Some of the screening ratios derived presently for the even and odd configurations of Er II are summarized here;

ΔT ($4f^{12}6s^2$)/ ΔT ($4f^{12}6s$) = 1.6, ΔT ($4f^{11}6s6p$)/ ΔT ($4f^{12}6s$) = 0.9, ΔT ($4f^{11}6s5d$]/ ΔT ($4f^{12}6s$) = 0.8, ΔT ($4f^{12}6s$)/ ΔT ($4f^{12}6p$) = 5.0, and ΔT ($4f^{11}6s^2$)/ ΔT ($4f^{12}6s$) = 2.2

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

| Even Configuration | $\Delta T^{166,\,170}$ (MHz) | Odd Configuration | $\Delta T^{166,\,170}$ (MHz) |
|---|---|---|---|
| $4f^{12}6s^2$ | 4800 | $4f^{11}6s^2$ | 6600 |
| $4f^{12}6s$ | 3000 | $4f^{11}6s5d$ | 2400 |
| $4f^{12}5d$ | 0 | $4f^{11}5d^2$ | 850 |
| $4f^{11}6s6p$ | 2700 | $4f^{12}6p$ | 600 |
| $4f^{11}5d6p$ | 2250 | | |

LIS of pure configurations of Er II derived using the above mentioned screening ratios and these were listed in the Table 3. 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 ΔT 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 ΔTs. All the 29 even parity energy levels exhibit configuration mixings of the type ($4f^{12}6s$ + $4f^{12}5d$+ $4f^{11}$ 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.

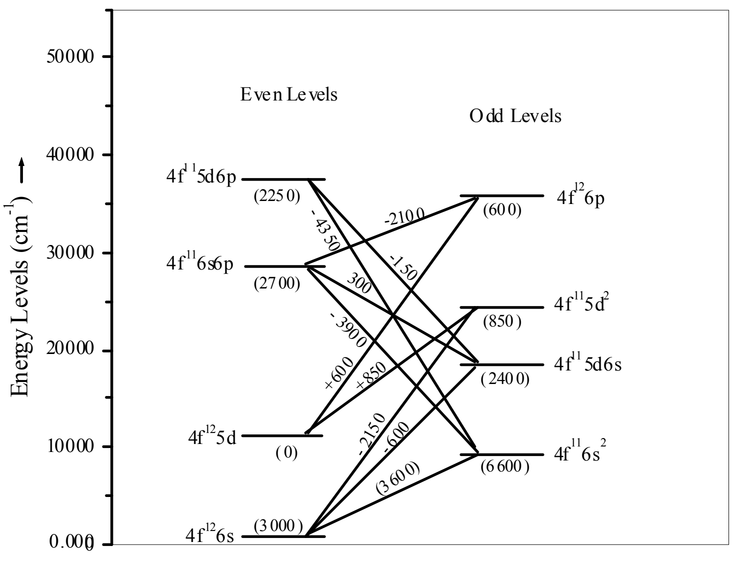


***Figure 8.*** *Partial energy level scheme, Horizontal lines represent energy levels, vertical lines represent the transitions, values across the transitions represent IS, $\Delta\sigma^{166,170}$ (MHz), values in the parenthesis represent LIS, $\Delta T^{166,170}$ (MHz) of the pure configuration.*

***Table 4.** The LIS, $\Delta T^{166, 170}$(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** | **$4f^{12}6s$** | **$4f^{12}5d$** | **$4f^{11}6s6p$** | **$4f^{11}5d6p$** | **$\Delta T_{FTS}$** | **$\Delta T_{Sharing\ rule}$** | **$4f^{12}6s$** | **$4f^{12}5d$** | **$4f^{11}6s6p$** | **$4f^{11}5d6p$** |
| 0.000 | $4f^{12}6s$ | 13/2 | 98.85 | 0.01 | 0.01 | 1.13 | 3000 | 2991.195 | 98.85 | 0.01 | 0.01 | 1.13 |
| 440.434 | $4f^{12}6s$ | 11/2 | 98.81 | 0.02 | 0.01 | 1.15 | 2990 | 2990.445 | 98.81 | 0.02 | 0.01 | 1.15 |
| 5132.608 | $4f^{12}6s$ | 9/2 | 98.82 | 0.01 | 0.02 | 1.15 | 2991 | 2991.015 | 98.82 | 0.01 | 0.02 | 1.15 |
| 5403.688 | $4f^{12}6s$ | 7/2 | 98.80 | 0.03 | 0.02 | 1.15 | 2990 | 2990.415 | 98.80 | 0.03 | 0.02 | 1.15 |
| 7149.630 | $4f^{12}6s$ | 11/2 | 98.83 | 0.02 | 0.01 | 1.14 | 2991 | 2990.82 | 98.83 | 0.02 | 0.01 | 1.14 |
| 7195.355 | $4f^{12}6s$ | 9/2 | 98.82 | 0.02 | 0.01 | 1.15 | 2990 | 2990.745 | 98.82 | 0.02 | 0.01 | 1.15 |
| 10893.936 | $4f^{12}6s$ | 7/2 | 98.81 | 0.02 | 0.02 | 1.15 | 2991 | 2990.715 | 98.81 | 0.02 | 0.02 | 1.15 |
| 11042.640 | $4f^{12}6s$ | 9/2 | 98.81 | 0.03 | 0.02 | 1.15 | 2991 | 2990.715 | 98.81 | 0.03 | 0.02 | 1.15 |
| 12587.998 | $4f^{12}6s$ | 7/2 | 98.78 | 0.03 | 0.03 | 1.17 | 2991 | 2990.535 | 98.78 | 0.03 | 0.03 | 1.17 |
| 12600.093 | $4f^{12}6s$ | 5/2 | 98.79 | 0.02 | 0.03 | 1.16 | 2991 | 2990.61 | 98.79 | 0.02 | 0.03 | 1.16 |
| 32048.749 | $4f^{11}6s6p$ | 15/2 | 0.00 | 0.00 | 97.49 | 2.51 | 2688 | 2688.705 | 0.00 | 0.00 | 97.49 | 2.51 |
| 33217.200 | $4f^{11}6s6p$ | 17/2 | 0.06 | 0.00 | 95.61 | 4.39 | 2682 | 2682.045 | 0.06 | 0.00 | 95.61 | 4.39 |
| 33547.268 | $4f^{11}6s6p$ | 15/2 | 0.00 | 0.00 | 95.97 | 4.03 | 2682 | 2681.865 | 0.00 | 0.00 | 95.97 | 4.03 |
| 33753.920 | $4f^{11}6s6p$ | 13/2 | 0.01 | 0.08 | 93.96 | 5.96 | 2671 | 2671.32 | 0.01 | 0.08 | 93.96 | 5.96 |
| 36192.206 | $4f^{11}6s6p$ | 19/2 | 0.00 | 0.00 | 95.33 | 4.67 | 2678 | 2678.985 | 0.00 | 0.00 | 95.33 | 4.67 |
| 36861.561 | $4f^{11}6s6p$ | 17/2 | 0.00 | 0.00 | 95.63 | 4.37 | 2680 | 2680.335 | 0.00 | 0.00 | 95.63 | 4.37 |
| 37321.029 | $4f^{11}6s6p$ | 15/2 | 0.00 | 0.01 | 94.95 | 5.04 | 2677 | 2677.05 | 0.00 | 0.01 | 94.95 | 5.04 |
| 37634.115 | $4f^{11}6s6p$ | 13/2 | 0.00 | 0.05 | 96.21 | 3.73 | 2682 | 2681.595 | 0.00 | 0.05 | 96.21 | 3.73 |
| 37669.535 | $4f^{11}6s6p$ | 11/2 | 0.01 | 1.94 | 93.31 | 4.74 | 2626 | 2626.02 | 0.01 | 1.94 | 93.31 | 4.74 |
| 38438.391 | $4f^{11}5d6p$? | 11/2 | 0.00 | 0.00 | 1.37 | 98.63 | 2256 | 2256.165 | 0.00 | 0.00 | 1.37 | 98.63 |
| 39994.031 | $4f^{11}6s6p$? | 15/2 | 0.00 | 0.00 | 70.99 | 29.01 | 2569 | 2569.455 | 0.00 | 0.00 | 70.99 | 29.01 |
| 40217.711[a] | | 11/2 | 0.00 | 0.05 | 95.13 | 4.82 | 2677 | 2676.96 | 0.00 | 0.05 | 95.13 | 4.82 |
| 40447.910 | $4f^{11}5d6p$? | 19/2 | 0.00 | 0.00 | 0.26 | 99.74 | 2251 | 2251.17 | 0.00 | 0.00 | 0.26 | 99.74 |
| 42987.453 | $4f^{11}5d6p$? | 11/2 | 0.00 | 0.01 | 1.29 | 98.68 | 2255 | 2255.13 | 0.00 | 0.01 | 1.29 | 98.68 |
| 43223.145 | $4f^{11}5d6p$? | 15/2 | 0.00 | 0.01 | 4.31 | 96.58 | 2289 | 2289.42 | 0.00 | 0.01 | 4.31 | 96.58 |
| 43413.717 | $4f^{11}5d6p$? | 19/2 | 0.00 | 0.00 | 1.32 | 98.68 | 2256 | 2255.94 | 0.00 | 0.00 | 1.32 | 98.68 |
| 43977.651 | | 19/2 | 0.00 | 0.00 | 0.18 | 99.82 | 2251 | 2251.17 | 0.00 | 0.00 | 0.18 | 99.82 |
| 44235.276 | | 17/2 | 0.00 | 0.00 | 8.54 | 91.45 | 2058 | 2058.71 | 0.00 | 0.00 | 8.54 | 91.45 |
| 47174.273 | | 17/2 | 0.00 | 0.01 | 0.67 | 99.20 | 2253 | 2253.42 | 0.00 | 0.01 | 0.67 | 99.20 |

***Table 5.** The list of the odd parity energy levels of Er II and their LIS, $\Delta T^{166, 170}$ values in MHz. A: This is newly calculated level taken from [6]. B: The unassigned level at 32811.006 $cm^{-1}$ 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** | **$4f^{11}6s^2$** | **$4f^{11}5d6s$** | **$4f^{12}6p$** | **$4f^{11}5d^2$** | **$\Delta T_{FTS}$** | **$\Delta T_{Sharing\ rule}$** | **$4f^{11}6s^2$** | **$4f^{11}5d6s$** | **$4f^{12}6p$** | **$4f^{11}5d^2$** |
| 6824.774 | $4f^{11}6s^2$ | 15/2 | 97.04 | 0.04 | 0.00 | 2.91 | 6430 | 6430.335 | 97.04 | 0.04 | 0.00 | 2.91 |
| 10667.165 | $4f^{11}5d6s$ | 13/2 | 0.00 | 99.97 | 0.00 | 0.02 | 2399 | 2399.45 | 0.00 | 99.97 | 0.00 | 0.02 |
| 11309.180 | $4f^{11}5d6s$ | 15/2 | 0.01 | 99.91 | 0.00 | 0.08 | 2399 | 2400.62 | 0.01 | 99.91 | 0.00 | 0.08 |
| 12388.090 | $4f^{11}5d6s$ | 11/2 | 0.01 | 99.78 | 0.03 | 1.18 | 2400 | 2405.59 | 0.01 | 99.78 | 0.03 | 1.18 |
| 12815.043 | $4f^{11}5d6s$ | 19/2 | 0.00 | 99.61 | 0.00 | 0.39 | 2395 | 2393.955 | 0.00 | 99.61 | 0.00 | 0.39 |
| 13027.927 | $4f^{11}5d6s$ | 17/2 | 0.00 | 99.99 | 0.00 | 0.01 | 2400 | 2399.845 | 0.00 | 99.99 | 0.00 | 0.01 |
| 13060.693 | $4f^{11}5d6s$ | 13/2 | 0.79 | 97.58 | 0.04 | 1.60 | 2408 | 2407.90 | 0.79 | 97.58 | 0.04 | 1.60 |
| 13338.777 | $4f^{11}6s^2$ | 13/2 | 96.26 | 0.84 | 0.00 | 2.90 | 6376 | 6397.97 | 96.26 | 0.84 | 0.00 | 2.90 |
| 13572.118 | $4f^{11}5d6s$ | 21/2 | 0.00 | 100.00 | 0.00 | 0.00 | 2400 | 2400.00 | 0.00 | 100.00 | 0.00 | 0.00 |
| 13719.562 | $4f^{11}5d6s$ | 17/2 | 0.00 | 99.46 | 0.00 | 0.54 | 2392 | 2391.63 | 0.00 | 99.46 | 0.00 | 0.54 |
| 14280.723 | $4f^{11}5d6s$ | 15/2 | 0.00 | 99.44 | 0.03 | 0.53 | 2400 | 2391.245 | 0.00 | 99.44 | 0.03 | 0.53 |
| 14649.277 | $4f^{11}5d6s$ | 19/2 | 0.00 | 99.98 | 0.00 | 0.02 | 2400 | 2399.69 | 0.00 | 99.98 | 0.00 | 0.02 |
| 15732.917 | $4f^{11}5d6s$ | 17/2 | 0.00 | 99.90 | 0.00 | 0.10 | 2400 | 2398.45 | 0.00 | 99.90 | 0.00 | 0.10 |
| 16643.237 | $4f^{11}5d6s$ | 13/2 | 0.00 | 97.89 | 0.98 | 1.13 | 2375 | 2364.845 | 0.00 | 97.89 | 0.98 | 1.13 |
| 16935.811 | $4f^{11}5d6s$ | 19/2 | 0.00 | 88.99 | 0.00 | 11.01 | 2229 | 2229.345 | 0.00 | 88.99 | 0.00 | 11.01 |
| 16948.197 | $4f^{11}6s^2$ | 11/2 | 84.30 | 12.86 | 0.08 | 2.75 | 5876 | 5896.295 | 84.30 | 12.86 | 0.08 | 2.75 |
| 17063.709 | $4f^{11}5d6s$ | 11/2 | 10.74 | 86.03 | 0.35 | 2.88 | 2798 | 2800.14 | 10.74 | 86.03 | 0.35 | 2.88 |
| 17378.917 | $4f^{11}5d6s$ | 13/2 | 0.02 | 94.26 | 0.51 | 5.21 | 2311 | 2310.905 | 0.02 | 94.26 | 0.51 | 5.21 |
| 17842.664 | $4f^{11}5d6s$ | 17/2 | 0.00 | 86.34 | 0.00 | 13.66 | 2188 | 2188.27 | 0.00 | 86.34 | 0.00 | 13.66 |
| 19992.895 | $4f^{11}5d6s$ | 11/2 | 0.20 | 89.45 | 1.60 | 8.74 | 2175 | 2243.89 | 0.20 | 89.45 | 1.60 | 8.74 |
| 20319.934 | $4f^{11}5d6s$ | 13/2 | 0.00 | 98.11 | 1.04 | 0.85 | 2368 | 2368.105 | 0.00 | 98.11 | 1.04 | 0.85 |
| 20517.717 | - | 15/2 | 0.01 | 97.68 | 0.88 | 1.43 | 2362 | 2362.415 | 0.01 | 97.68 | 0.88 | 1.43 |
| 21004.060 | $4f^{11}5d6s$ | 13/2 | 0.00 | 91.70 | 4.00 | 4.30 | 2261 | 2261.35 | 0.00 | 91.70 | 4.00 | 4.30 |
| 22859.510 | $4f^{11}5d6s$? | 13/2 | 0.00 | 98.49 | 0.42 | 1.09 | 2375 | 2375.545 | 0.00 | 98.49 | 0.42 | 1.09 |
| 23240.649 | - | 11/2 | 0.06 | 89.74 | 4.55 | 5.65 | 2233 | 2233.045 | 0.06 | 89.74 | 4.55 | 5.65 |

| [1] | | | Configuration mixing (%) [6] | | | | Present work ← ( MHz ) → ← Configuration mixing (%) → | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Level ($cm^{-1}$) | Configuration | J | $4f^{11}6s^2$ | $4f^{11}5d6s$ | $4f^{12}6p$ | $4f^{11}5d^2$ | $\Delta T_{FTS}$ | $\Delta T_{Sharing\ rule}$ | $4f^{11}6s^2$ | $4f^{11}5d6s$ | $4f^{12}6p$ | $4f^{11}5d^2$ |
| 23973.877 | - | 15/2 | 0.00 | 4.93 | 0.05 | 95.01 | 926 | 926.205 | 0.00 | 4.93 | 0.05 | 95.01 |
| 24053.520 | - | 17/2 | 0.00 | 1.92 | 0.00 | 98.08 | 880 | 879.76 | 0.00 | 1.92 | 0.00 | 98.08 |
| 24415.265 | - | 11/2 | 0.01 | 95.97 | 0.75 | 3.27 | 2345 | 2336.235 | 0.01 | 95.97 | 0.75 | 3.27 |
| 24687.523 | - | 11/2 | 0.02 | 98.67 | 1.13 | 0.18 | 2378 | 2377.71 | 0.02 | 98.67 | 1.13 | 0.18 |
| 24935.855 | - | 13/2 | 0.01 | 86.44 | 2.63 | 10.91 | 2184 | 2183.735 | 0.01 | 86.44 | 2.63 | 10.91 |
| 25382.379 | - | 11/2 | 0.37 | 84.37 | 12.55 | 2.71 | 2141 | 2147.635 | 0.37 | 84.37 | 12.55 | 2.71 |
| 25592.343 | $4f^{12}6p$? | 11/2 | 0.92 | 40.35 | 46.15 | 12.58 | 2798 | 2800.14 | 0.92 | 40.35 | 46.15 | 12.58 |
| 26098.957 | $4f^{12}6p$? | 13/2 | 0.01 | 54.98 | 43.06 | 1.95 | 1595 | 1595.115 | 0.01 | 54.98 | 43.06 | 1.95 |
| 26399.775 | - | 11/2 | 2.89 | 86.63 | 8.02 | 2.46 | 2338 | 2338.89 | 2.89 | 86.63 | 8.02 | 2.46 |
| 26769.141 | - | 13/2 | 0.00 | 95.96 | 2.29 | 1.75 | 2332 | 2331.655 | 0.00 | 95.96 | 2.29 | 1.75 |
| 26805.448 | - | 11/2 | 0.16 | 6.38 | 9.23 | 84.23 | 1595 | 1595.115 | 0.16 | 6.38 | 9.23 | 84.23 |
| 27513.555 | - | 13/2 | 0.00 | 54.95 | 40.56 | 4.48 | 2798 | 2800.14 | 10.74 | 86.03 | 0.35 | 2.88 |
| 27642.658 | - | 11/2 | 0.26 | 85.25 | 11.07 | 3.42 | 2159 | 2158.65 | 0.26 | 85.25 | 11.07 | 3.42 |
| 28016.137[A] | - | 19/2 | 0.00 | 0.12 | 0.00 | 99.88 | 852 | 851.86 | 0.00 | 0.12 | 0.00 | 99.88 |
| 28082.701 | - | 13/2 | 0.00 | 78.65 | 7.19 | 14.16 | 2051 | 2051.10 | 0.00 | 78.65 | 7.19 | 14.16 |
| 28361.286 | - | 11/2 | 0.31 | 83.08 | 9.27 | 7.35 | 2132 | 2132.475 | 0.31 | 83.08 | 9.27 | 7.35 |
| 29011.015 | $4f^{12}6p$? | 9/2 | 0.01 | 24.21 | 61.99 | 13.80 | 1071 | 1070.94 | 0.01 | 24.21 | 61.99 | 13.80 |
| 29263.402 | - | 7/2 | 0.10 | 40.58 | 15.66 | 43.66 | 1446 | 1445.59 | 0.10 | 40.58 | 15.66 | 43.66 |
| 29492.329 | $4f^{12}6p$? | 11/2 | 0.10 | 81.70 | 13.35 | 4.86 | 2089 | 2082.87 | 0.10 | 81.70 | 13.35 | 4.86 |
| 29783.733 | - | 9/2 | 0.26 | 62.86 | 18.47 | 18.41 | 1793 | 1793.105 | 0.26 | 62.86 | 18.47 | 18.41 |
| 30028.618 | - | 9/2 | 0.12 | 79.79 | 13.32 | 6.76 | 2060 | 2060.20 | 0.12 | 79.79 | 13.31 | 6.76 |
| 30894.447 | $4f^{12}6p$? | 7/2 | 0.02 | 64.74 | 29.44 | 5.80 | 1781 | 1781.02 | 0.02 | 64.74 | 29.44 | 5.80 |
| 31381.779 | - | 9/2 | 19.85 | 67.39 | 5.25 | 7.51 | 3020 | 3022.795 | 19.85 | 67.39 | 5.25 | 7.51 |
| 31844.124 | - | 9/2 | 0.92 | 53.52 | 36.10 | 9.46 | 1641 | 1642.21 | 0.92 | 53.52 | 36.10 | 9.46 |
| 31902.682 | - | 7/2 | 0.01 | 81.26 | 10.74 | 7.99 | 2083 | 2083.255 | 0.01 | 81.26 | 10.74 | 7.99 |
| 32267.246 | - | 9/2 | 0.06 | 69.91 | 13.89 | 16.14 | 1902 | 1902.33 | 0.06 | 69.91 | 13.89 | 16.14 |
| 32618.753 | - | 11/2 | 3.15 | 81.47 | 9.87 | 5.50 | 2268 | 2269.15 | 3.15 | 81.47 | 9.87 | 5.50 |
| 32811.006[B] | - | 11/2 | 0.01 | 45.34 | 24.01 | 30.63 | 1493 | 1493.475 | 0.01 | 45.34 | 24.01 | 30.63 |
| 32896.371 | $4f^{12}6p$? | 9/2 | 0.41 | 54.03 | 26.06 | 19.50 | 1639 | 1645.89 | 0.41 | 54.03 | 26.06 | 19.50 |
| 33028.394 | - | 9/2 | 1.03 | 57.60 | 29.03 | 12.35 | 1711 | 1729.536 | 1.03 | 57.60 | 29.03 | 12.35 |
| 33565.895 | - | 9/2 | 0.09 | 81.79 | 11.79 | 6.33 | 2093 | 2093.445 | 0.09 | 81.79 | 11.79 | 6.33 |
| 33988.301 | - | 11/2 | 2.47 | 59.18 | 22.01 | 16.33 | 1854 | 1854.205 | 2.47 | 59.18 | 22.01 | 16.33 |
| 34196.355 | - | 9/2 | 23.25 | 15.36 | 14.76 | 46.62 | 2382 | 2387.91 | 23.25 | 15.36 | 14.76 | 46.62 |
| 34341.611 | - | 11/2 | 0.11 | 77.15 | 13.14 | 9.60 | 1990 | 2019.30 | 0.11 | 77.15 | 13.14 | 9.60 |
| 34563.257 | - | 11/2 | 0.19 | 4.65 | 6.92 | 88.25 | 905 | 915.785 | 0.19 | 4.65 | 6.92 | 88.25 |
| 36738.247 | - | 7/2 | 0.12 | 29.61 | 43.32 | 26.95 | 1208 | 1207.555 | 0.12 | 29.61 | 43.32 | 26.95 |
| 39277.605 | - | 7/2 | 0.50 | 77.96 | 15.44 | 6.10 | 2048 | 2048.53 | 0.50 | 77.96 | 15.44 | 6.10 |
| 39447.909 | - | 5/2 | 3.76 | 50.43 | 28.89 | 16.92 | 1775 | 1775.62 | 3.76 | 50.43 | 28.89 | 16.92 |

### *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 ($4f^{11}6s^2$+$4f^{11}5d6s$+$4f^{12}6p$+$4f^{11}5d^2$) [6]. A multiplet $^4I^0$ consisted of 3 low odd levels of $4f^{11}6s^2$ configuration lying at 6824 $cm^{-1}$, 13338 $cm^{-1}$ and 16948 $cm^{-1}$ [1] listed in Table 5 exhibit LIS 6430, 6376 and 5896 MHz and thus confirmed having dominant 96% $4f^{11}6s^2$ configuration as quoted in the reference [6].11 levels of $4f^{11}5d6s$ configuration lying at 11309 – 20319 $cm^{-1}$ and one level at 22859 $cm^{-1}$ tentatively assigned to $4f^{11}5d6s$ configuration [1] have been confirmed on the basis of LIS value ~ 2400 MHz. The LIS 1071 MHz observed in the level at 29011 $cm^{-1}$ confirms the tentative $4f^{12}6P$ configuration. The 4 levels falling at 26098, 29492, 30894, and 32896 $cm^{-1}$ were previously assigned tentatively to $4f^{12}6p$ configuration [1] exhibit LIS 1595, 2089, 1781 and 1639 MHz respectively and found belonging to the dominant $4f^{11}5d6s$ configuration [6]. 7 unassigned levels falling between 23973- 34563 $cm^{-1}$listed in Table 5 can be assigned to dominant $4f^{11}5d^2$configuration. 24 unassigned levels including the level at 32811.008 $cm^{-1}$ (in reference [6] it was revised to 32810.980 $cm^{-1}$) falling in the energy range of 20517- 39447 $cm^{-1}$[1] have average LIS 2000 MHz suggests that these levels should belong to the dominant $4f^{11}5d6s$ 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, $\Delta\sigma^{166,170}$ 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, $\Delta T^{166,170}$ 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 $4f^{12}6p$ configuration were revised to $4f^{11}5d6s$ configuration. 7 unassigned levels assigned to dominant $4f^{11}5d^2$

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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