MEP 2005

RUBIDIUM ($\lambda \approx 778$ nm)

Absorbing atom ^{85}Rb, $5S_{1/2}$ ($F_g = 3$) – $5D_{5/2}$ ($F_e = 5$) two-photon transition

1. CIPM recommended values

The values f = 385 285 142 375 kHz
λ = 778 105 421.23 fm
with a relative standard uncertainty of 1.3×10^{-11} apply to the radiation of a laser stabilized to the centre of the two-photon transition. The values apply to a rubidium cell at a temperature below 100 °C and are corrected to zero laser power.

2. Source data

Adopted value :	f = 385 285 142 375 (5) kHz	$u_c/y = 1.3 \times 10^{-11}$
	for which:	
	λ = 778 105 421.23 (1) fm	$u_c/y = 1.3 \times 10^{-11}$

calculated from

f / kHz	u_c/y	source data
385 285 142 378.3	5.2×10^{-12}	[1]
385 285 142 373.8	3.4×10^{-12}	[2]
385 285 142 372.3	1.4×10^{-11}	1.10-1
Weighted mean:	f = 385 285 142 375.0 kHz	

applies to the single-photon laser frequency of the two-photon transition. The CCL decided to attribute a standard uncertainty of 5 kHz, corresponding to a relative standard uncertainty of 1.3×10^{-11}.[1]

1.10-1 Bernard et al. [4] gives

$f\{^{87}\mathrm{Rb}, 5S_{1/2}(F_g = 2) - 5D_{5/2}(F_e = 4)\}/2 =$ 385 284 566 370.4 kHz $\qquad u_c/y = 5.2 \times 10^{-12}$.

From [5] cited in Table 4,

$f\{^{87}\mathrm{Rb}, 5S_{1/2}(F_g = 2) - 5D_{5/2}(F_e = 4)\}/2 - f\{^{85}\mathrm{Rb}, 5S_{1/2}(F_g = 3) - 5D_{5/2}(F_e = 5)\}/2 =$ -576 002 kHz $\quad u_c/y = 1.3 \times 10^{-11}$,

one obtains

$f\{^{85}\mathrm{Rb}, 5S_{1/2}(F_g = 3) - 5D_{5/2}(F_e = 5)\}/2 =$ 385 285 142 371.40 $\qquad u_c/y = 1.4 \times 10^{-11}$.

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[1] A recent measurement made after the CCL 2001 has confirmed one of the data [3].

3. Absolute frequency of the other transitions related to those adopted as recommended and frequency intervals between transitions and hyperfine components

These tables replace those published in BIPM Com. Cons. Long., 2001, **10**, 174-176 and Metrologia, 2003, **40**, 123-124.

The notation for the transitions and the components is that used in the source references. The values adopted for the frequency intervals are the weighted means of the values given in the references.

For the uncertainties, account has been taken of:

- the uncertainties given by the authors;
- the spread in the different determinations of a single component;
- the effect of any perturbing components;
- the difference between the calculated and the measured values.

In the tables, u_c represents the estimated combined standard uncertainty (1 σ).
When a two-photon transition is listed, the listed frequency indicates the one-photon laser frequency.

Table 1

$\lambda \approx 778$ nm ^{85}Rb $5S_{1/2} - 5D_{3/2}$ two-photon transition

$F_g - F_e$	$[f\,(5S_{1/2}\,(F_g) - 5D_{3/2}\,(F_e))/2 - f_{ref}]$/kHz	u_c/kHz
3–1	−44 462 655	7
3–2	−44 459 151	7
3–3	−44 453 175	7
3–4	−44 443 871	7
2–1	−42 944 789	7
2–2	−42 941 283	7
2–3	−42 935 308	7
2–4	−42 926 004	7

Frequency referenced to $(5S_{1/2}\,(F_g=3) - 5D_{5/2}\,(F_e=5))/2$ {^{85}Rb}: f_{ref} = 385 285 142 375 kHz [6]

Ref. [7]

Table 2

$\lambda \approx 778$ nm ^{85}Rb $5S_{1/2} - 5D_{5/2}$ two-photon transition

$F_g - F_e$	$[f(5S_{1/2}(F_g) - 5D_{5/2}(F_e))/2 - f_{ref}]$/kHz	u_c/kHz
3–5	0	—
3–4	4 718	9
3–3	9 228	9
3–2	13 031	9
3–1	15 771	14
2–4	1 522 595	9
2–3	1 527 094	9
2–2	1 530 887	9
2–1	1 533 631	11
2–0	1 535 084	26

Frequency referenced to $(5S_{1/2}(F_g=3) - 5D_{5/2}(F_e=5))/2$ {^{85}Rb}: f_{ref} = 385 285 142 375 kHz [6]

Ref. [5*, 7]

Table 3

$\lambda \approx 778$ nm ^{85}Rb $5S_{1/2} - 5D_{3/2}$ two-photon transition

$F_g - F_e$	$[f(5S_{1/2}(F_g) - 5D_{3/2}(F_e))/2 - f_{ref}]$/kHz	u_c/kHz
2–0	–45 047 389	7
2–1	–45 040 639	7
2–2	–45 026 674	7
2–3	–45 004 563	7
1–1	–41 623 297	7
1–2	–41 609 335	7
1–3	–41 587 223	7

Frequency referenced to $(5S_{1/2}(F_g=3) - 5D_{5/2}(F_e=5))/2$ {^{85}Rb}: f_{ref} = 385 285 142 375 kHz [6]

Ref. [7]

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[*] Improved interval measurements are available for certain components and can be used provided appropriate consideration to uncertainties is made.

Table 4

$\lambda \approx 778$ nm ^{85}Rb $5S_{1/2} - 5D_{5/2}$ two-photon transition

$F_g - F_e$	$[f(5S_{1/2}(F_g) - 5D_{5/2}(F_e))/2 - f_{ref}]$/kHz	u_c/kHz
2–4	–576 001	9
2–3	–561 589	9
2–2	–550 112	9
2–1	–542 142	9
1–3	2 855 755	9
1–2	2 867 233	9
1–1	2 875 200	9

Frequency referenced to $(5S_{1/2}(F_g{=}3) - 5D_{5/2}(F_e{=}5))/2$ {^{85}Rb}: f_{ref} = 385 285 142 375 kHz [6]

Ref. [5*, 7]

4. Absolute frequency of other transitions

- Absorbing atom ^{87}Rb, $5S_{1/2}$ ($F_g = 2$) – $7S_{1/2}$ ($F_e = 2$) two-photon transition

The values f = 394 397 384 460 kHz
λ = 760 127 906.05 fm
with a relative standard uncertainty of 1.7×10^{-10} apply to the single-photon laser frequency of the two-photon transition.

Adopted value : f = 394 397 384 460 (67) kHz $u_c/y = 1.7 \times 10^{-10}$

for which:

λ = 760 127 906.05 (.13) fm $u_c/y = 1.7 \times 10^{-10}$

After [Refs 8, 9]

- Absorbing atom ^{87}Rb, $5S_{1/2}$ ($F_g = 1$) – $7S_{1/2}$ ($F_e = 1$) two-photon transition

The values f = 394 400 482 100 kHz
λ = 760 121 936.0 fm
with a relative standard uncertainty of 4.5×10^{-10} apply to the single-photon laser frequency of the two-photon transition.

Adopted value : f = 394 400 482 100 (180) kHz $u_c/y = 4.5 \times 10^{-10}$

for which:

λ = 760 121 936.0 (.34) fm $u_c/y = 4.5 \times 10^{-10}$

After [Refs 8, 9]

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[*] Improved interval measurements are available for certain components and can be used provided appropriate consideration to uncertainties is made.

5. References

[1] Touahri D., Acef O., Clairon A., Zondy J.-J., Felder R., Hilico L., de Beauvoir B., Biraben F., Nez F., Frequency measurement of the $5S_{1/2}$ (F=3) – $5D_{1/2}$ (F=5) two-photon transition in rubidium, *Opt. Commun.*, 1997, **133**, 471-478.

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[6] Recommendation M1 (*BIPM Com. Cons. Déf. Mètre*, 10th meeting, 2001) adopted by the Comité International des Poids et Mesures at its 91th Meeting as Recommendation 1 (CI-2002).

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[8] Marian A., Stowe M. C., Lawall J. R., Felinto D., Ye J., United Time-Frequency Spectroscopy for Dynamics and Global Structure, *Sciencexpress*, 1126/1-10, 2004.

[9] Marian A., Stowe M. C., Felinto D., Ye J., Direct Frequency Comb Measurements of Absolute Optical Frequencies and Population Transfer Dynamics, *Phys. Rev. Lett.*, **95**, 023001/1-4, 2005.