MEP 2005

ACETYLENE ($\lambda \approx 1.54$ µm)

Absorbing molecule $^{13}C_2H_2$, P(16) ($\nu_1+\nu_3$) transition

1. CIPM recommended values

The values f = 194 369 569 384 kHz
λ = 1 542 383 712.38 fm

- with a relative standard uncertainty of 2.6×10^{-11} apply to the radiation of a laser stabilized using the third harmonic detection technique to an external $^{13}C_2H_2$ cell within an enhancement cavity and subject to the following conditions:
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- C_2H_2-pressure (3 ± 2) Pa;
- frequency modulation width, peak-to-peak (1 ± 0.5) MHz[1];
- one-way intracavity beam power density of (25 ± 20) W cm^{-2}

2. Source data

Adopted value :	f = 194 369 569 384 (5) kHz	$u_c/y = 2.6 \times 10^{-11}$
	for which:	
	λ = 1 542 383 712.38 (4) fm	$u_c/y = 2.6 \times 10^{-11}$

calculated from

f / kHz	u_c/y	source data
194 369 569 384.875	1.4×10^{-11}	[1]
194 369 569 383.5	6.7×10^{-12}	[2]
194 369 569 386.4	5.7×10^{-12}	[3]
194 369 569 384	1.3×10^{-11}	[4]

In order to combine these measurements which were carried out with a variety of acetylene cell pressures, the values were converted to a common 3 Pa cell pressure by use of the pressure shift coefficients measured for each particular system, leading to the following values:

f / kHz	u_c/y	source data
194 369 569 384.6	1.4×10^{-11}	[1]
194 369 569 383.3	6.7×10^{-12}	[2]
194 369 569 385.5	5.7×10^{-12}	[3]
194 369 569 384	1.3×10^{-11}	[4]
Unweighted mean:	f = 194 369 569 384.3 kHz	

The recommended value by the CCL is the unweighted mean of these last four values, rounded to the nearest kHz. Given the good agreement between the different laboratories, the CCL decided to reduce the uncertainty from the 10

[1] For the specification of operating conditions, such as temperature, modulation width and laser power, the symbols ± refer to a tolerance, not an uncertainty.

kHz 2003 value to 5kHz (2.6 × 10^{-11}), which corresponds approximately to the quadrature sum of the quoted uncertainties, then rounded up.

3. Frequency intervals of the other transitions of the band related to the recommended value

Table 1 replaces that published in BIPM Com. Cons. Long., 2001, **10**, 177, and in Metrologia, 2003, **40**, 124.

- The notation for the transitions is that used in the source references. The values adopted for the frequency intervals were determined from the unweighted mean of the values given by three laboratories in references [1, 2, 3, 4], where available.
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- The uncertainties were determined from the square root of the quadrature sum of individual line uncertainties divided by the number of laboratories contributing and then rounded.
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- u_c represents the estimated combined standard uncertainty (1 σ).

Table 1

$\lambda \approx 1.54$ µm $^{13}C_2H_2$ ($\nu_1 + \nu_3$) band

J	f (P(J))- f (P(16)/kHz	u_c /kHz	J	f (R(J))- f (P(16)/kHz	u_c /kHz
31	–1 236 727 330	5	0	1 219 093 122	1
30	–1 149 564 562	4	1	1 284 956 011	1
29	–1 063 105 009	3	2	1 350 174 198	1
28	–977 244 288	3	3	1 414 736 584	1
27	–892 105 380	1	4	1 478 632 192	1
26	–807 638 070	1	5	1 541 851 517	1
25	–723 847 084	1	6	1 604 387 136	1
24	–640 721 967	1	7	1 666 233 736	1
23	–558 275 721	1	8	1 727 380 519	1
22	–476 502 654	1	9	1 787 844 397	1
21	–395 402 8867	1	10	1 847 604 826	1
20	–314 976 290	1	11	1 906 665 847	1
19	–235 222 731	1	12	1 965 025 956	1
18	–156 142 106	1	13	2 022 683 714	1
17	–77 734 397	1	14	2 079 635 680	1
16	0.0	—	15	2 135 883 116	1
15	77 063 007	1	16	2 191 421 970	1
14	153 451 226	1	17	2 246 250 502	1
13	229 165 964	1	18	2 300 366 567	1
12	304 206 524	1	19	2 353 767 928	1
11	378 572 272	1	20	2 406 452 321	1
10	452 257 032	1	21	2 458 417 492	1
9	525 279 212	1	22	2 509 661 432	1
8	597 619 759	1	23	2 560 176 324	1
7	669 287 337	1	24	2 609 973 044	1
6	740 285 116	1	25	2 659 039 015	1
5	810 618 380	1	26	2 707 376 844	1
4	880 294 498	1	27	2 754 934 187	1
3	949 322 304	1	28	2 801 831 908	2
2	1 017 710 757	1	29	2 847 963 516	2
1	1 085 467 073	1			

Frequency referenced to P(16) $\nu_1 + \nu_3$, $^{13}C_2H_2$: f = 194 369 569 384 kHz

Refs. [2, 3, 4, 5]

4. Absolute frequencies of transitions in other bands

Data were reported by only one laboratory. Consequently, the corresponding uncertainties were increased by a factor of three. In the following tables, the quoted uncertainty associated with each transition is the higher value of either the calculated uncertainty or the adopted uncertainty for the recommended transition P16 (5 kHz).

Table 2

$\lambda \approx 1.54$ µm $^{13}C_2H_2$ ($\nu_1 + \nu_3 + \nu_4 + \nu_5$) band

J	f (P(J))/kHz	u_c /kHz	J	f (R(J))/kHz	u_c /kHz
22	194 307 400 767	5	0	195 984 590 791	5
21	194 387 420 760	7	1	196 050 630 476	6
20	194 466 700 977	5	2	196 116 121 548	5
19	194 545 255 871	14	3	196 181 059 390	5
18	194 623 100 111	8	4	196 245 438 197	5
17	194 700 248 978	5	5	196 309 250 959	5
16	194 776 717 968	5	6	196 372 489 471	5
15	194 852 522 485	8	7	196 435 144 317	6
14	194 927 677 581	5	8	196 497 204 895	5
13	195 002 197 738	5	9	196 558 659 425	7
12	195 076 096 694	5	10	196 619 494 998	5
11	195 149 387 300	5	11	196 679 697 623	7
10	195 222 081 409	5	12	196 739 252 313	5
9	195 294 189 794	5	13	196 798 143 195	5
8	195 365 722 096	5	14	196 856 353 650	5
7	195 436 686 781	5	15	196 913 866 494	5
6	195 507 091 120	11	16	196 970 664 190	5
5	195 576 941 187	10	17	197 026 729 110	9
4	195 646 241 847	7	18	197 082 043 836	9
3	195 714 996 769	5	19	197 136 591 576	9
2	195 783 208 426	5	20	197 190 355 743	9
1	195 850 878 107	13			

Refs. [3]

Table 3

$\lambda \approx 1.54$ µm $^{12}C_2H_2$ ($\nu_1 + \nu_3$) band

J	f (P(J))/kHz	u_c /kHz	J	f (R(J))/kHz	u_c /kHz
31	194 018 374 094	13	0	196 627 647 488	10
30	194 111 459 729	21	1	196 696 652 920	10
29	194 203 815 943	10	2	196 764 884 471	10
28	194 295 440 627	10	3	196 832 341 013	10
27	194 386 332 293	11	4	196 899 021 431	10
26	194 476 488 873	10	5	196 964 924 628	10
25	194 565 910 200	11	6	197 030 049 518	10
24	194 654 593 139	11	7	197 094 395 033	10
23	194 742 536 730	10	8	197 157 960 121	10
22	194 829 739 425	10	9	197 220 743 737	10
21	194 916 199 708	11			
20	195 001 916 082	11			
19	195 086 887 071	10			
18	195 171 111 214	11			
17	195 254 587 071	11			

16	195 337 313 215	10
15	195 419 288 239	10
14	195 500 510 748	10
13	195 580 979 371	10
12	195 660 692 745	11
11	195 739 649 525	10
10	195 817 848 382	11
9	195 895 288 002	10
8	195 971 967 086	10
7	196 047 884 350	10
6	196 123 038 521	11
5	196 197 428 346	10
4	196 271 052 582	10
3	196 343 910 001	13
2	196 415 999 399	10
1	196 487 319 567	10

Refs. [6]

5. References

[1] Balling P., Fischer M., Kubina Ph., Holzwarth R., Absolute Frequency Measurement of Wavelength Standard at 1542 nm: Acetylene-Stabilized DFB Laser, *Opt. Express*, **13** (23), pp. 9196-9201, 2005.

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[3] Edwards C. S., Margolis H. S., Barwood G. P., Lea S. N., Gill P., Rowley W. R. C., High-Accuracy Frequency Atlas of $^{13}C_2H_2$ in the 1.5 µm Region, *Appl. Phys. B*, **80**, pp. 977-83, 2005.

[4] Czajkowski A., Bernard J. E., Madej A. A., Windeler R. S., Absolute Frequency Measurement of Acetylene Transitions in the Region of 1540 nm, *Appl. Phys. B*, **79**, pp. 45-50, 2004.

[5] Madej A. A., Bernard J. E., Alcock A. J., Czajkowski A., Chepurov S., Accurate Absolute Frequencies of the $\nu_1 + \nu_3$ Band of $^{13}C_2H_2$ Determined Using an Infrared Mode-Locked Cr:YAG Laser Frequency Comb, *J. Opt. Soc. Am. B*, **23** (4), pp. 741-49, 2006.

[6] Edwards C. S., Barwood G. P., Margolis H. S., Gill P., Rowley W. R. C., High-precision frequency measurements of the $\nu_1 + \nu_3$ combination band of $^{12}C_2H_2$ in the 1.5 µm region, *J. Mol. Spectr.*, **234**, pp. 143-8, 2005.