MEP 2003

METHANE ($\lambda \approx 3.39$ µm)

Absorbing molecule CH_4, $F_2^{(2)}$ component, P(7) ν_3 transition

1 CIPM recommended values

1.1 The values f = 88 376 181 600.18 kHz
λ = 3 392 231 397.327 fm

with a relative standard uncertainty of 3×10^{-12} apply to the radiation of a He-Ne laser stabilized to the central component, (7-6) transition, of the resolved hyperfine-structure triplet. The values correspond to the mean frequency of the two recoil-split components for molecules which are effectively stationary, i.e. the values are corrected for second-order Doppler shift.

1.2 The values f = 88 376 181 600.5 kHz
λ = 3 392 231 397.31 fm

with a relative standard uncertainty of 2.3×10^{-11} apply to the radiation of a He-Ne laser stabilized to the centre of the unresolved hyperfine-structure of a methane cell, within or external to the laser, held at room temperature and subject to the following conditions:

- methane pressure ≤ 3 Pa;
- mean one-way intracavity surface power density (i.e., the output power density divided by the transmittance of the output mirror) ≤ 10^4 W m^{-2};
- radius of wavefront curvature ≥ 1 m;
- inequality of power between counter-propagating waves ≤ 5 %;
- servo-referenced to a detector placed at the output facing the laser tube.

2. Source data

2.1 Resolved hyperfine structure

Adopted value : f = 88 376 181 600.18 (27) kHz $u_c/y = 3 \times 10^{-12}$
for which:
λ = 3392 231 397.327 (10) fm $u_c/y = 3 \times 10^{-12}$

calculated from

x / kHz	Laser	Frequency chain	Year	source data
600.29	LPI	PTB	1991	[1]
599.9	LPI	VNIIFTRI	1985-1986	[2]
600.11	LPI	VNIIFTRI	1989-1992	[2]
600.18	PTB	VNIIFTRI	1989	[2]
600.16	PTB	PTB	1992	[3]
600.44	ILP	ILP	1988-1991	[4]

Unweighted mean : f = 88 376 181 600.18 kHz

where $f = (88\ 376\ 181\ 000 + x)$ kHz.

Other available values having uncertainties larger than 200 Hz have not been used. The relative standard uncertainty of one measurement was estimated to be 2.9×10^{-12} using the maximum deviation from the mean and rounded to 3×10^{-12}.

2.2 Unresolved hyperfine structure

Adopted value : f = 88 376 181 600.5 (2.0) kHz $u_c/y = 2.3 \times 10^{-11}$

for which

λ = 3392 231 397.31 (8) fm $u_c/y = 2.3 \times 10^{-11}$

calculated from

x / kHz	Frequency source	Frequency chain	Year	source data
600.9	Stationary device	ILP	1983	[4-7]
601.48	Portable laser 2	NRC	1985	[8, 9]
599.33	Portable laser 3	NRC	1986-1991	[8, 9]
596.82	Portable laser 1	AIST	1988-1990	[9]
601.52	CH_4 beam	PTB	1987-1989	[9-11]
601.77	Portable laser M101	VNIIFTRI	1985-1992	[2, 9]
600.12	Portable laser P1	VNIIFTRI	1985-1988	[2, 9]
598.5	Portable laser PL	VNIIFTRI	1986	[2]
600.96	Portable laser B.3	BIPM	1985-1992	[9]
601.33	Portable laser VB	BIPM	1988-1991	[9]
600.3	Portable laser VNIBI	BIPM	1991	[9, 12]
Unweighted mean :		f = 88 376 181 600.46 kHz		

where $f_{CH4} = (88\ 376\ 181\ 000 + x)$ kHz.

The standard deviation of one determination is 1.7 kHz. This is equivalent to a relative uncertainty of 1.9×10^{-11}, increased by the CCL to 2.3×10^{-11} to give an uncertainty of 2 kHz.

3. References

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[10] Weiss C. O., Kramer G., Lipphardt B., Garcia E., Frequency Measurement of a CH_4 Hyperfine Line at 88 THz/"Optical Clock", *IEEE J. Quant. Electron*., 1988, **24**, 1970-1972.

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