MEP 2003

IODINE ($\lambda \approx 633$ nm)

Absorbing molecule $^{127}I_2$, a_{16} or f component, R(127) 11-5 transition [(1)]

1. CIPM recommended values

The values $f = 473\ 612\ 353\ 604$ kHz
$\lambda = 632\ 991\ 212.58$ fm
with a relative standard uncertainty of 2.1×10^{-11} apply to the radiation of a He-Ne laser with an internal iodine cell, stabilized using the third harmonic detection technique, subject to the conditions:

- cell-wall temperature (25 ± 5) °C [(2)];
- cold-finger temperature (15.0 ± 0.2) °C;
- frequency modulation width, peak-to-peak, (6.0 ± 0.3) MHz;
- one-way intracavity beam power (i.e. the output power divided by the transmittance of the output mirror) (10 ± 5) mW for an absolute value of the power shift coefficient ≤ 1.0 kHz/mW.

These conditions are by themselves insufficient to ensure that the stated standard uncertainty will be achieved. It is also necessary for the optical and electronic control systems to be operating with the appropriate technical performance. The iodine cell may also be operated under relaxed conditions, leading to the larger uncertainty specified in section 2 below.

2. Source data

Adopted value:	$f = 473\ 612\ 353\ 604\ (10)$ kHz	$u_c/y = 2.1 \times 10^{-11}$
	for which:	
	$\lambda = 632\ 991\ 212.579\ (13)$ fm	$u_c/y = 2.1 \times 10^{-11}$

calculated from

f / kHz	u_c/y	source data
8.2	4.0×10^{-12}	[1, 2]
7.4	3.0×10^{-12}	[1, 3]
4.2	1.4×10^{-11}	See section 2.1
8.2	5.3×10^{-12}	[5]
Unweighted mean:	$(f_{\text{BIPM4}} - f_{\text{CIPM97}}) = 7.0$ kHz	

The source data are all given with respect to the BIPM4 laser standard frequency. The relative standard uncertainty includes the uncertainty in the absolute frequency measurement and the uncertainty obtained by comparing the different frequency standards with the BIPM4 standard. The CCL proposed that the recommended radiation for the R(127) 11-5 transition, using 633 nm He-Ne lasers, no longer correspond to the a_{13} or i component, but is replaced by the a_{16} or f component, which was decided by the CIPM 2001.

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(1) All transitions in I_2 refer to the $B^3\Pi\, 0_u^+ - X^1\Sigma_g^+$ system.

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

The CCL adopted a correction of the previous recommended frequency by +7 kHz, giving the frequency of the f component to be 473 612 353 604 kHz. The CCL also revised the coefficient of the tolerated one-way intracavity beam power influencing the average uncertainty of beat-frequency measurements between two stabilized lasers. This results in a combined uncertainty of u_c = 10 kHz, corresponding to a relative uncertainty of $u_c/y = 2.1 \times 10^{-11}$, see Section 2-2. The grouped laser comparisons from national laboratories undertaken by the BIPM (1993-2000) confirm that the choice of a relative standard uncertainty of 2.1×10^{-11} is valid [6–14]. This series of comparisons is a key comparison BIPM.L-K10 and is reported on the BIPM website http://www.bipm.org/kcdb.

For applications where relaxed tolerances, and the resultant wider uncertainty range are acceptable, a laser operated under the conditions recommended in 1983 [15, 16] would lead to a standard uncertainty of about 50 kHz (or a relative standard uncertainty of 1×10^{-10}).

Source data

2.1 Sugiyama et al. [14] give

f_f = 473 612 353 604.3 kHz u_c = 1.7 kHz as the frequency of the NRLM-P1 laser standard.

This value indicates that $f_f = f_{CIPM97} + f_{corr}$ where f_{corr} = 7.3 kHz.

In a comparison with the BIPM4 laser standard [34], they obtained

$f_f - f_{BIPM4}$ = 3.1 kHz u_c = 6.4 kHz.

Assuming that this frequency has been maintained since, one obtains

$(f_{BIPM4} - f_{CIPM97})$ = 4.2 kHz, u_c = 6.6 kHz..

2.2 The uncertainties resulting from variations in operational parameters are listed below.

Parameter	Recommended value	Tolerance	Coefficient	u / kHz
Iodine cell				
cell-wall temperature	25 °C	5 °C	0.5 kHz/°C	2.5
cold-finger temperature	15 °C	0.2 °C	–15 kHz/°C	3.0
iodine purity				5.0
Frequency modulation width peak-to-peak	6 MHz	0.3 MHz	–10 kHz / MHz	3.0
One-way intracavity beam power	10 mW	5 mW	≤ 1.0 kHz / mW	5.0
Beat-frequency measurements between two lasers				5.0
			Combined standard uncertainty u_c = 10.0 kHz	

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**, 168-173 and Metrologia, 2003, **40**, 121-123.

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).

All transitions in molecular iodine refer to the B-X system.

Table 1

$\lambda \approx 633$ nm $^{127}I_2$ R(127) 11-5

a_n	x	$[f(a_n) - f(a_{16})]$ /MHz	u_c /MHz	a_n	x	$[f(a_n) - f(a_{16})]$/MHz	u_c/MHz
a_2	t	–721.8	0.5	a_{12}	j	–160.457	0.005
a_3	s	–697.8	0.5	a_{13}	i	–138.892	0.005
a_4	r	–459.62	0.01	a_{14}	h	–116.953	0.005
a_5	q	–431.58	0.05	a_{15}	g	–13.198	0.005
a_6	p	–429.18	0.05	a_{16}	f	0	—
a_7	o	–402.09	0.01	a_{17}	e	13.363	0.005
a_8	n	–301.706	0.005	a_{18}	d	26.224	0.005
a_9	m	–292.693	0.005	a_{19}	c	144.114	0.005
a_{10}	l	–276.886	0.005	a_{20}	b	152.208	0.005
a_{11}	k	–268.842	0.005	a_{21}	a	161.039	0.005

Frequency referenced to a_{16} (f), R(127) 11-5, $^{127}I_2$: f = 473 612 353 604 kHz [17]

Ref. [18–29]

Table 2

$\lambda \approx 633$ nm $^{127}I_2$ P(33) 6-3							
b_n	x	$[f(b_n) - f(b_{21})]$/MHz	u_c/MHz	b_n	x	$[f(b_n) - f(b_{21})]$/MHz	u_c/MHz
b_1	u	–922.571	0.008	b_{12}	j	–347.354	0.007
b_2	t	–895.064	0.008	b_{13}	i	–310.30	0.01
b_3	s	–869.67	0.01	b_{14}	h	–263.588	0.009
b_4	r	–660.50	0.02	b_{15}	g	–214.53	0.02
b_5	q	–610.697	0.008	b_{16}	f	–179.312	0.005
b_6	p	–593.996	0.008	b_{17}	e	–153.942	0.005
b_7	o	–547.40	0.02	b_{18}	d	–118.228	0.007
b_8	n	–487.074	0.009	b_{19}	c	–36.73	0.01
b_9	m	–461.30	0.03	b_{20}	b	–21.980	0.007
b_{10}	l	–453.21	0.03	b_{21}	a	0	—
b_{11}	k	–439.01	0.01				

Frequency referenced to a_{16} (f), R(127) 11-5, $^{127}I_2$: f = 473 612 353 604 kHz [17]
$f(b_{21}$, P(33) 6-3) – $f(a_{16}$, R(127) 11-5) = –532.42 (2) MHz [30]

Ref. [25, 30–34]

Table 3

$\lambda \approx 633$ nm $^{129}I_2$ P(54) 8-4							
a_n	x	$[f(a_n) - f(a_{28})]$/MHz	u_c/MHz	a_n	x	$[f(a_n) - f(a_{28})]$/MHz	u_c/MHz
a_2	z′	–449	2	a_{16}	i′	–197.73	0.08
a_3	y′	–443	2	a_{17}	h′	–193.23	0.08
a_4	x′	–434	2	a_{18}	g′	–182.74	0.03
a_5	w′	–429	2	a_{19}	f′	–162.61	0.05
a_6	v′	–360.9	1	a_{20}	e′	–155.72	0.05
a_7	u′	–345.1	1	a_{21}	d′	–138.66	0.05
a_8	t′	–340.8	1	a_{22}	c′	–130.46	0.05
a_9	s′	–325.4	1	a_{23}	a′	–98.22	0.03
a_{10}	r′	–307.0	1	a_{24}	n_2	–55.6 see m_8 table 7	0.5
a_{11}	q′	–298.2	1	a_{25}	n_1	–55.6 see m_8 table 7	0.5
a_{12}	p′	–293.1	1	a_{26}	m_2	–43.08	0.03
a_{13}	o′	–289.7	1	a_{27}	m_1	–41.24	0.05
a_{14}	n′	–282.7	1	a_{28}	k	0	—
a_{15}	j′	–206.1	0.2				

Frequency referenced to a_{16} (f), R(127) 11-5, $^{127}I_2$: f = 473 612 353 604 kHz [17]
$f(a_{28}$, P(54) 8-4) – $f(a_{16}$, R(127) 11-5 $\{^{127}I_2\}$) = –42.99 (4) MHz [35–36]

Ref. [35–43]

Table 4

$\lambda \approx 633$ nm $^{129}I_2$ P(69) 12-6							
b_n	x	$[f(b_n) - f(a_{28})]$ /MHz	u_c/MHz	b_n	x	$[f(b_n) - f(a_{28})]$/MHz	u_c/MHz
b_1	b′′′	99.12	0.05	b_{21}	q′	507.66	0.10
b_2	a′′′	116.08	0.05	b_{22}	o′	532.65	0.10
b_3	z′′	132.05	0.05	b_{23}	n′	536.59	0.10
b_4	s′′	234.54	0.05	b_{24}	m′	545.06	0.05
b_5	r′′	256.90 see m_{28} table 7	0.05	b_{25}	l′	560.94	0.05
b_6	q′′	264.84 see m_{29} table 7	0.05	b_{26}	k′	566.19	0.05
b_7	p′′	288.06	0.05	b_{27}	j′	586.27	0.03
b_8	k′′	337.75	0.1	b_{28}	i′	601.78	0.03
b_9	i_1′′	358.8	0.5	b_{29}	h′	620.85	0.03
b_{10}	i_2′′	358.8	0.5	b_{30}	g′	632.42	0.03
b_{11}	f′	373.80	0.05	b_{31}	f′	644.09	0.03
b_{12}	d′′	387.24	0.05	b_{32}	e′	655.47	0.03
b_{13}	c′′	395.3	0.2	b_{33}	d′	666.81	0.10
b_{14}	b′′	402.45	0.05	b_{34}	c′	692.45	0.10
b_{15}	a′′	407	4	b_{35}	b′	697.96	0.10
b_{16}	z′	412.37	0.05	b_{36}	a′	705.43	0.10
b_{17}	y′	417	4				

Frequency referenced to a_{16} (f), R(127) 11-5, $^{127}I_2$: f = 473 612 353 604 kHz [17]
$f(a_{28}$, P(54) 8-4) – $f(a_{16}$, R(127) 11-5 {$^{127}I_2$}) = –42.99 (4) MHz [35–36]

Ref. [38, 41–43]

Table 5

$\lambda \approx 633$ nm $^{129}I_2$ R(60) 8-4							
d_n	x	$[f(d_n) - f(a_{28})]$ /MHz	u_cMHz	d_n	x	$[f(d_n) - f(a_{28})]$ /MHz	u_c /MHz
d_{23}	A′	–555	5	d_{26}	M	–499	2
d_{24}	N	–511	2	d_{27}	M	–499	2
d_{25}	N	–511	2	d_{28}	K	–456	2

Frequency referenced to a_{16} (f), R(127) 11-5, $^{127}I_2$: f = 473 612 353 604 kHz [17]
$f(a_{28}$, P(54) 8-4) – $f(a_{16}$, R(127) 11-5 {$^{127}I_2$}) = –42.99 (4) MHz [35–36]

Ref. [38]

Table 6

$\lambda \approx 633$ nm $^{129}I_2$ P(33) 6-3							
e_n	x	$[f(e_n) - f(e_2)]$/MHz	u_c/MHz	e_n	x	$[f(e_n) - f(e_2)]$/MHz	u_c/MHz
e_1	A	−19.82	0.05	e_{10}	J	249	2
e_2	B	0	—	e_{11}	K	260	2
e_3	C	17.83	0.03	e_{12}	L	269	3
e_4	D	102.58	0.05	e_{13}	M	273	4
e_5	E	141	2	e_{14}	N	287	4
e_6	F	157	2	e_{15}	O	293	5
e_7	G	191	2	e_{16}	P	295	5
e_8	H	208	2	e_{17}	Q	306	6
e_9	I	239	2				

Frequency referenced to a_{16} (f), R(127) 11-5, $^{127}I_2$: f = 473 612 353 604 kHz [17]
$f(e_2$, P(33) 6-3) − $f(a_{16}$, R(127) 11-5 {$^{127}I_2$}) = 849.4 (2) MHz [45–46]

Ref. [38, 43, 45, 47]

Table 7

$\lambda \approx 633$ nm $^{127}I^{129}I$ P(33) 6-3							
m_n		$[f(m_n) - f(a_{28})]$/MHz	u_c/MHz	m_n		$[f(m_n) - f(a_{28})]$/MHz	u_c/MHz
m_1	m′	–254	3	m_{26}	u″	212.80	0.05
m_2	l′	–233.71	0.10	m_{27}	t″	219.43	0.05
m_3	k′	–226.14	0.10	m_{28}	r″	256.90, see b_5 table 4	0.10
m_4	j′	–207	2	m_{29}	q″	264.84, see b_6 table 4	0.05
m_5	b′	–117.79	0.10	m_{30}	o″	299.22	0.05
m_6	p	–87.83	0.15	m_{31}	n″	312.43	0.05
m_7	o	–78.2	0.5	m_{32}	m″	324.52	0.03
m_8	n	–56, see a_{24} and a_{25} table 3	1	m_{33}	l″	333.14	0.03
m_9	l	–17.55	0.05	m_{34}	k_2″	337.7	0.5
m_{10}	j	12.04	0.03	m_{35}	k_1″	337.7	0.5
m_{11}	i	15.60	0.03	m_{36}	j″	345.05	0.05
m_{12}	h	33.16	0.03	m_{37}	h″	362.18	0.10
m_{13}	g_2	39.9	0.2	m_{38}	g″	369.78	0.03
m_{14}	g_1	41.3	0.2	m_{39}	e″	380.37	0.03
m_{15}	f	50.72	0.03	m_{40}	d″	385	4
m_{16}	e	54.06	0.10	m_{41}	x′	431	4
m_{17}	d	69.33	0.03	m_{42}	w′	445	4
m_{18}	c	75.06	0.03	m_{43}	v′	456.7	0.5
m_{19}	b	80.00	0.03	m_{44}	u′	477.17	0.05
m_{20}	a	95.00	0.03	m_{45}	t′	486.43	0.05
m_{21}	y″	160.74	0.03	m_{46}	s′	495.16	0.05
m_{22}	x″	199.52	0.03	m_{47}	r′	503.55	0.05
m_{23}	w″	205.06	0.05	m_{48}	p′	515.11	0.05
m_{24}	v_2″	207.9	0.5				
m_{25}	v_1″	207.9	0.5				

Frequency referenced to a_{16} (f), R(127) 11-5, $^{127}I_2$: f = 473 612 353 604 kHz [17]
$f(a_{28}$, P(54) 8-4) – $f(a_{16}$, R(127) 11-5 $\{^{127}I_2\})$ = –42.99 (4) MHz [35–36]

Ref. [38, 44, 41–43]

4. References

[1] Ye J., Yoon T. H., Hall J. L., Madej A. A., Bernard J. E., Siemsen K. J., Marmet L., Chartier J.-M., Chartier A., Accuracy Comparison of Absolute Optical Frequency Measurement between Harmonic-Generation Synthesis and a Frequency-Division Femtosecond Comb, *Phys. Rev. Lett.*, 2000, **85**, 3797-3800.

[2] Yoon T. H., Ye J., Hall J. L., Chartier J.-M., Absolute frequency measurement of the iodine-stabilized He-Ne laser at 633 nm, *Appl. Phys. B.*, 2001, **72**, 221-226.

[3] Bernard J. E., Madej A. A., Siemsen K. J., Marmet L., Absolute frequency measurement of the HeNe/I_2 standard at 633 nm, *Opt. Commun.*, 2001, **187**, 211-218.

[4] Sugiyama K., Onae A., Hong F.-L., Inaba H., Slyusarev S. N., Ikegami T., Ishikawa J., Minoshima K., Matsumoto H., Knight J. C., Wadsworth W. J., Russel P. St. J., Optical frequency measurement using an ultrafast mode-locked laser at NMIJ/AIST, *6th Symposium on Frequency Standards and Metrology*, Ed. Gill P, World Scientific (Singapore), 2002, 427-434.

[5] Lea S. N., Margolis H. S., Huang G., Rowley W. R. C., Henderson D., Barwood G. P., Klein H. A., Webster S. A., Blythe P., Gill P., Windeler R. S., Femtosecond Optical Frequency Comb Measurements of Lasers Stabilised to Transitions in $^{88}Sr^{+}$, $^{171}Yb^{+}$, and I_2 at NPL, *6th Symposium on Frequency Standards and Metrology*, Ed. Gill P, World Scientific (Singapore), 2002, 144-151.

[6] Chartier J.-M., Chartier A., I_2 Stabilized 633 nm He-Ne Lasers: 25 Years of International Comparisons, Laser Frequency Stabilization, Standards, Measurement, and Applications, *Proceedings of SPIE*, 2001, **4269**, 123-132.

[7] Chartier J.-M., Chartier A., International comparisons of He-Ne lasers stabilized with $^{127}I_2$ at $\lambda \approx 633$ nm (July 1993 to September 1995) Part I : General, *Metrologia*, 1997, **34**, 297-300.

[8] Ståhlberg B., Ikonen E., Haldin J., Hu J., Ahola T., Riski K., Pendrill L., Kärn U., Henningsen J., Simonsen H., Chartier A., Chartier J.-M., International comparisons of He-Ne lasers stabilized with $^{127}I_2$ at $\lambda \approx 633$ nm (July 1993 to September 1995) Part II : Second comparison of Northern European lasers at $\lambda \approx 633$ nm, *Metrologia*, 1997, **34**, 301-307.

[9] Navratil V., Fodreková A., Gàta R., Blabla J., Balling P., Ziegler M., Zeleny V., Petrû F., Lazar J., Veselá Z., Gliwa-Gliwinski J., Walczuk J., Bánréti E., Tomanyiczka K., Chartier A., Chartier J.-M., International comparisons of He-Ne lasers stabilized with $^{127}I_2$ at $\lambda \approx 633$ nm (July 1993 to September 1995) Part III : Second comparison of Eastern European lasers at $\lambda \approx 633$ nm, *Metrologia*, 1998, **35**, 799-806.

[10] Darnedde H., Rowley W. R. C., Bertinetto F., Millerioux Y., Haitjema H., Wetzels S., Pirée H., Prieto E., Mar Pérez M., Vaucher B., Chartier A., Chartier J.-M., International comparisons of He-Ne lasers stabilized with $^{127}I_2$ at $\lambda \approx 633$ nm (July 1993 to September 1995) Part IV : Comparison of Western European lasers at $\lambda \approx 633$ nm, *Metrologia*, 1999, **36**, 199-206.

[11] Brown N., Jaatinen E., Suh H., Howick E., Xu G., Veldman I., Chartier A., Chartier J.-M., International comparisons of He-Ne lasers stabilized with $^{127}I_2$ at $\lambda \approx 633$ nm (July 1993 to September 1995) Part V : Comparison of Asian-Pacific and South African lasers at $\lambda \approx 633$ nm, *Metrologia*, 2000, **37**, 107-113.

[12] Abramova L., Zakharenko Yu., Fedorine V., Blajev T., Kartaleva S., Karlsson H., Popescu GH., Chartier A., Chartier J.-M., International comparisons of He-Ne lasers stabilized with $^{127}I_2$ at $\lambda \approx 633$ nm (July 1993 to September 1995) Part VI : Comparison of VNIIM (Russian Federation), NCM (Bulgaria), NMS (Norway), NILPRP (Romania) and BIPM lasers at $\lambda \approx 633$ nm, *Metrologia*, 2000, **37**, 115-120.

[13] Viliesid M., Gutierrez-Munguia M., Galvan C. A., Castillo H. A., Madej A., Hall J. L., Stone J., Chartier A., Chartier J.-M., International comparisons of He-Ne lasers stabilized with $^{127}I_2$ at $\lambda \approx 633$ nm, Part VII : Comparison of NORAMET $^{127}I_2$-stabilized He-Ne lasers at $\lambda \approx 633$ nm, *Metrologia*, 2000, **37**, 317-322.

[14] Shen S., Ni Y., Qian J., Liu Z., Shi C., An J., Wang L., Iwasaki S., Ishikawa J., Hong F.-L., Suh H. S., Labot J., Chartier A., Chartier J.-M., International comparisons of He-Ne lasers stabilized with $^{127}I_2$ at $\lambda \approx 633$ nm (July

1997), Part VIII : Comparison of NIM (China), NRLM (Japan), KRISS (Republic of Korea) and BIPM lasers at $\lambda \approx 633$ nm, *Metrologia*, 2001, **38**, 181-186.

[15] *BIPM, Proc. Verb. Com. Int. Poids et Mesures*, 1983, **51**.

[16] Documents Concerning the New Definition of the Metre, *Metrologia*, 1984, **19**, 163-178.

[17] Recommendation CCL3 (*BIPM Com. Cons. Long.*, 10th Meeting, 2001) adopted by the Comité International des Poids et Mesures at its 91th Meeting as Recommendation 1 (CI-2002).

[18] Rowley W. R. C., Wallard A. J., Wavelength values of the 633 nm laser, stabilized with $^{127}I_2$-saturated absorption, *J. Phys. E.*, 1973, **6**, 647-651.

[19] Hanes G. R., Baird K. M., DeRemigis J., Stability, Reproducibility, and Absolute Wavelength of a 633 nm He-Ne Laser Stabilized to an Iodine Hyperfine Component, *Appl. Opt.,* 1973, **12**, 1600-1605.

[20] Cérez P., Brillet A., Hartmann F., Metrological Properties of the R(127) Line of Iodine Studied by Laser Saturated Absorption, *IEEE Trans. Instrum. Meas*., 1974, **IM-23**, 526-528.

[21] Bayer-Helms F., Chartier J.-M., Helmcke J., Wallard A., Evaluation of the International Intercomparison Measurements (March 1976) with $^{127}I_2$-Stabilized He-Ne Lasers, *PTB-Bericht*, 1977, **Me-17**, 139-146.

[22] Bertinetto F., Rebaglia B. I., Performances of IMGC He-Ne ($^{127}I_2$) Lasers, *Euromeas, 77, IEEE*, 1977, **152**, 38-39.

[23] Tanaka K., Sakurai T., Kurosawa T., Frequency Stability and Reproducibility of an Iodine Stabilized He-Ne Laser, *Jap. J. Appl. Phys.*, 1977, **16**, 2071-2072.

[24] Blabla J., Smydke J., Chartier J.-M., Gläser M., Comparison of the $^{127}I_2$-Stabilized He-Ne Lasers at 633 nm Wavelength of the Czechoslovak Institute of Metrology and the Bureau International des Poids et Mesures, *Metrologia*, 1983, **19**, 73-75.

[25] Morinaga A., Tanaka K., Hyperfine Structure in the electronic spectrum of $^{127}I_2$ by saturated absorption spectroscopy at 633 nm, *Appl. Phys. Lett.*, 1978, **32**, 114-116.

[26] Blabla J., Bartos M., Smydke J., Weber T., Hantke D., Philipp H., Sommer M., Tschirnich J., Frequency Intervals of HFS Components of an $^{127}I_2$-Stabilized He-Ne Laser at 633 nm Wavelength, *ASMW Metrologische Abhandlungen 3*, 1983, **4**, 285-290.

[27] Chartier J.-M., Results of International Comparisons Using Methane-Stabilized He-Ne Lasers at 3.39 µm and Iodine Stabilized He-Ne Lasers at 633 nm, *IEEE Trans. Instrum. Meas.*, 1983, **IM-32**, 81-83.

[28] Chartier J.-M., Robertsson L., Fredin-Picard S., Recent Activities at BIPM in the Field of Stabilized Lasers - Radiations Recommended for the Definition of the Meter, *IEEE Trans. Instrum. Meas.*, 1991, **40**, 181-184.

[29] Petru F., Popela B., Vesela Z., Iodine-stabilized He-Ne Lasers at λ = 633 nm of a Compact Construction, *Metrologia*, 1992, **29**, 301-307.

[30] Razet A., Gagnière J., Juncar P., Hyperfine Structure Analysis of the 33P (6-3) Line of $^{127}I_2$ at 633 nm Using a Continuous-wave Tunable Dye Laser, *Metrologia*, 1993, **30**, 61-65.

[31] Hanes G. R., Lapierre J., Bunker P.R., Shotton K.C., Nuclear Hyperfine Structure in the Electronic Spectrum of $^{127}I_2$ by Saturated Absorption Spectroscopy, and Comparison with Theory, *J. Mol. Spectrosc.*, 1971, **39**, 506-515.

[32] Bergquist J. C., Daniel H.-U., A Wideband Frequency-Offset Locked Dye Laser Spectrometer Using a Schottky Barrier Mixer, *Opt. Commun.*, 1984, **48**, 327-333.

[33] Simonsen H. R., Iodine –Stabilized Extended Cavity Diode Laser at λ = 633 nm, *IEEE Trans. Instrum. Meas.*, 1997, **46**, 141-144.

[34] Edwards C. S., Barwood G. P., Gill P., Rowley W. R. C., A 633 nm iodine-stabilized diode laser frequency standard, *Metrologia*, 1999, **36**, 41-45.

[35] CCDM/82-2, NPL, Rowley W. R. C., Beat frequency measurements, $^{129}I_2$(k) – $^{127}I_2$(i).

[36] Chartier J.-M., Lasers à He-Ne asservis sur l'absorption saturée de l'iode en cuve interne (λ = 633 nm), *BIPM, Proc.-Verb. Com. Int. Poids et Mesures*, 1984, **52**, 44.

[37] Chartier J.-M., Détermination et reproductibilité de l'intervalle de fréquence ($^{129}I_2$, k) - ($^{127}I_2$, i), *Rapport BIPM*, 1982, **82/10**.

[38] Gerlach R. W., *Thesis*, University Cleveland, 1975.

[39] Knox J. D., Pao Y.-H., High-Resolution Saturation Spectra of the Iodine Isotope $^{129}I_2$ in the 633 nm Wavelength Region, *Appl. Phys. Lett.*, 1971, **18**, 360-362.

[40] Tesic M., Pao Y.-H., Theoretical Assigment of the Observed Hyperfine Structure in the Saturated Absorption Spectra of $^{129}I_2$ and $^{127}I^{129}I$ vapors in the 633 nm Wavelength Region, *J. Mol. Spectrosc.*, 1975, **57**, 75-96.

[41] Magyar J. A., Brown N., High Resolution Saturated Absorption Spectra of Iodine Molecules $^{129}I_2$, $^{129}I^{127}I$, and $^{127}I_2$ at 633 nm, *Metrologia*, 1980, **16**, 63-68.

[42] Chartier J.-M., Mesures d'intervalles entre composantes hyperfines de I_2, *BIPM Proc. Verb. Com. Int. Poids et Mesures*, 1978, **46**, 32-33.

[43] Chartier J.-M., Mesures d'intervalles de fréquence entre composantes hyperfines des transitions 8-4, P(54) ; 12-6, P(69) ; 6-3, P(33) de $^{129}I_2$ et 6-3, P(33) de $^{127}I^{129}I$, *Rapport BIPM*, 1993, **93/3**.

[44] CCDM/82-19a, BIPM, Réponse au questionnaire CCDM/82-3.

[45] Schweitzer Jr. W.G., Kessler Jr. E.G., Deslattes R. D., Layer H. P., Whetstone J. R., Description, Performances, and Wavelengths of Iodine Stabilized Lasers, *Appl. Opt.*, 1973, **12**, 2927-2938.

[46] Chartier J.-M., Lasers à He-Ne asservis sur l'absorption saturée de l'iode en cuve interne (λ = 633 nm), *BIPM Proc.-Verb. Co. Int. Poids et Mesures*, 1985, **53**, 50.

[47] Helmcke J., Bayer-Helms F., He-Ne Laser Stabilized by Saturated Absorption in I_2, *IEEE Trans. Instrum. Meas.*, 1974, **IM-23**, 529-531.