16th International Congress of Metrology, 06015 (2013)
DOI: 10.1051/metrology/201306015

Laser standard with range of reproducing of lengths from 1 to 10^3м in boundary layer of atmosphere

Nikolai Kravchenko[1a]

[1] NSC “Institute of metrology”, 61002 Mironositskaya St 42, Ukraine

Abstract. Laser standard of length in the field of large lengths. The range of recreation from 1 to 10^3 meters. Total relative uncertainty of measuring on k=2 is 10^{-7} meters.

Work on creation of laser standard with the range of reproducing of lengths from 24 to 10^3 m were begun an author in 80th of past century in the former «Scientific Production amalgamation «Metrology». A necessity for such standard was related to creation in the USSR of the high-fidelity microwave and quantum systems of the trajectory measurings [1].

Analogical researches on creation of laser standards of length at that time were conducted in German federal REPUBLIC [2] and Japan [3]. Basis of standards [1-3] was a helium-neon laser with excitation of transition $3S_2$-$2P_4$ by a direct current and resonator, providing Tem_{ooq} type of vibrations.

For the increase of instrumental exactness of measurings and expansion of range of reproducing of lengths a laser standard in the National scientific center «Institute of metrology» there were low-noise twofrequency helium-neon lasers with excitation of basic transition the transversal microwave field 3S2-2P4 and weakly radiative transition $3S_2$-$2P_{10}$ neon in helium-neon plasma [4].

Original appearance of such lasers is rotined on Figure 1. A laser active element (LAE) is a glass tube 1 (Figure. 2) into which a capillary is 2, and on the outward surface of tube two metallic strips are placed 3, formative the segment of flat line.

Use A4 paper size (210 x 297 mm) and adjust the margins to those shown in Table 1. The final printed area will be 172 x 252 mm.

Figure 1. Helium-neon laser with microwave excitation.

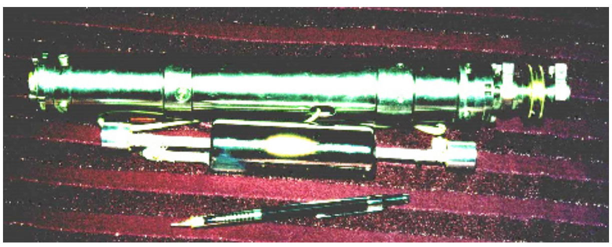
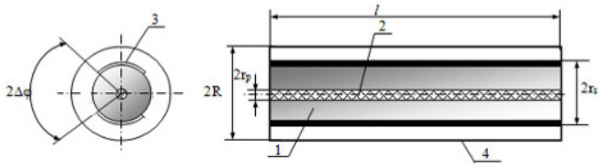


Figure 2. Model of helium-neon laser for electrodynamic researches



Excited strip line the microwave field generates helium-neon plasma, by the being lasant of LAE.

All of foregoing elements are placed in the metallic casing – 4, formative the corps of laser, to the butt ends of which mirrors, formative an optical resonator, are fastened. As a result, in the examined task a laser is a cylindrical resonator, loaded with a strip line, glass dielectric and plasma.

For the decision of task suppose an inductivity complex, that $\varepsilon = \varepsilon + i\overline{\varepsilon}$, and metallic details – ideally conducting. Butt ends of the system – metallic. Utillizing equalization of Maxwell, will complement their scope terms for electric E and magnetic H of the fields. The tangential components *of* E and H on metallic surfaces are equal to the zero, and on the scopes of dielectric environments – continuous. A task is decided in the cylindrical system of co-ordinates, at which the ax of z coincides with the ax of the system, and plane, proper φ = 0 passes through the ax of z and middle of electrodes of полосковой line. Suppose ≈ temporal dependence of the electromagnetic fields ≈ $e^{i\omega t}$.

An electrodynamic task is decided the method of frequency areas [4].

For the radius of plasma of r_β = 0,5 mm, radius of полосковой line of r_s = 4 mm, internal radius of resonator of r_k (corps of laser) 20 mm and length of resonator of l = 300 mm the followings descriptions are got:

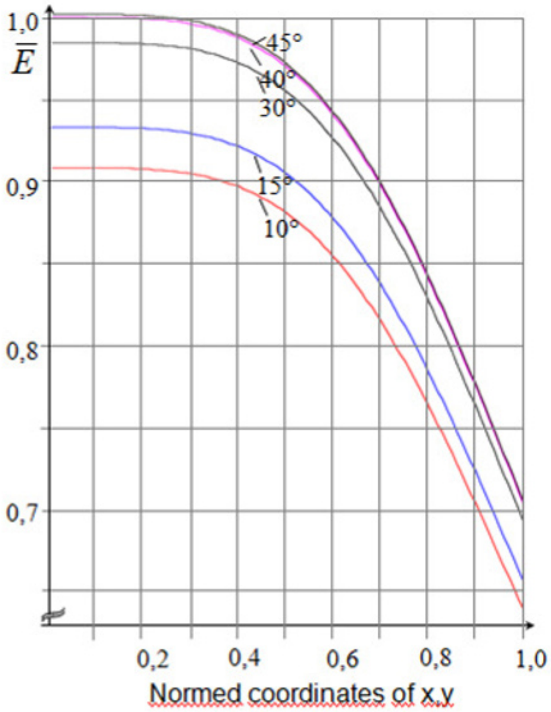
- calculation resonance frequency of $4{,}96 \cdot 10^8$ Hz;

[a] Corresponding author: kravchenko@metrology.kharkov.ua

Article available at http://cfmetrologie.edpsciences.org or http://dx.doi.org/10.1051/metrology/201306015

- distributing transversal electric component of the field *of* E_r, E_φ (Figure3) into a quartz tube with the internal capillary of 6 mm;
- the optimum width of metallic strip at $2r_s$ = 6 mm is equal 2,25 mm ($2\varphi_0 = 45°$).

Figure 3. Distributing transversal electric component of the microwave field in the crossrunner of laser active element.



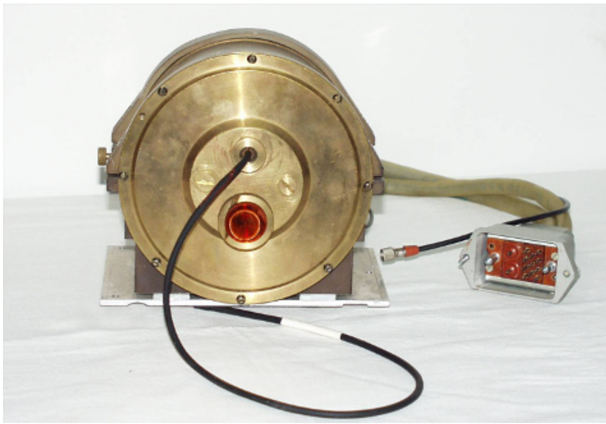
For setting of laser element, fastenings of mirrors and piezoelectric ceramics PP-4 the special corps, executed from an invar (N-36) and having titanic (WT-1) scray of the linear measurings of his length at measuring ambient temperatures, described in [4].

Such descriptions have mirrors of optical resonator: R1=0,50909 m, G1=0,997, R2=0,446 m, G2=0,98; attitude of pressure of isotopes of 3He toward pressure of isotopes of 20Ne is equal 7:1 at general pressure of working mixture of 2,5 mm mercury column experimental researches in NSC «Institute of metrology» was created new helium-neon laser with microwave excitation (μWE) for the laser standard of length, measuring the followings technical descriptions:

- wave-length radiation of 0,6328 μm;
- power of radiation from a working output more than 1,0 mW;
- power of radiation from a managing output no less than 0,1 mW;
- transversal type of oscillation of TEM_{00q};
- divergence no more than $2{,}5 \cdot 10^{-3}$ rad;
- a basic value of разностной frequency is 499,5 MHz;
- range of mechanical alteration of разностной frequency no less $\pm$ 1,5 MHz;
- range of electric alteration no less than 100 кHz;
- a relation is сигнал\ noise of order of $2 \cdot 10^3$;
- feed from the source of direct-current with tension 27 V and by a consumable current to 0,5 A.

For the decline of noises of resonance фотоприемных devices on the basis of semicoaxial resonator with taken away from his volume of photomultiplier with transformation of twofrequency laser bunches on a фотокатоде in microwaves the field and increases of exactness of measurings of laser bunches in NSC «Institute of metrology» autogenerator photodetectores [5-6] were created, one of which is rotined on Figure4.

Figure4. The autogenerator photodetector for the laser standard of reproducing of length.



In works [5,7] autogenerator photodetectores are investigational in theory and experimentally. There are of interest autogenerator photodetectores with the reflector-absorbers of the field (Figure5 and Figure6).

Figure 5. Section of PKR with the reflector-absorbers of the field

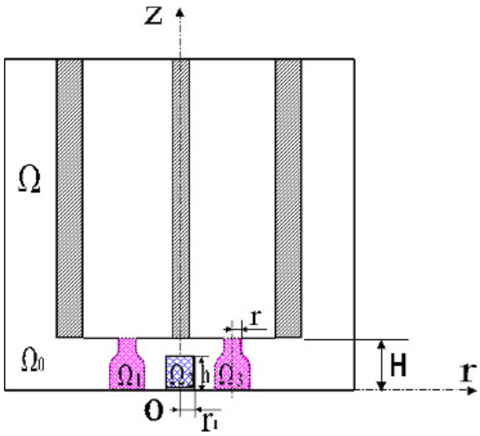
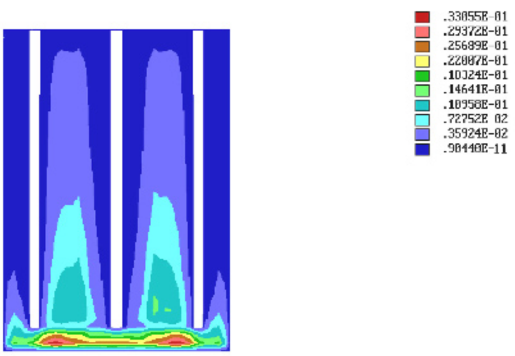


Figure 6. Original appearance of reflector-absorbers of the field and focon.

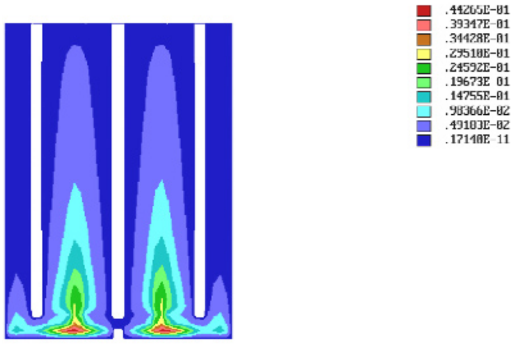
On Figure7 presented the Figureure of distributing of electric potential is presented with placed in PKR focons-reflector-absorbers, made from quartz glass with $\varepsilon = 5$, $r_1 = 1$ mm.

Figure 7. Distributing of electric potential of the electromagnetic field with focons ($r_1 = 1$ mm) from quartz glass.



On Figure8 distributing of electric potential is presented in PKR and out-of-limit cylindrical resonators with built-in photomultiplier at presence of in a center PKR of cylindrical explorer by the radius of 2 mm and height 5 mm, and by focons from quartz glass.

Figure 8. Distributing of electric potential of the electromagnetic field at presence of reflector-absorber ($r_2 = 5$ mm) with focons from quartz glass

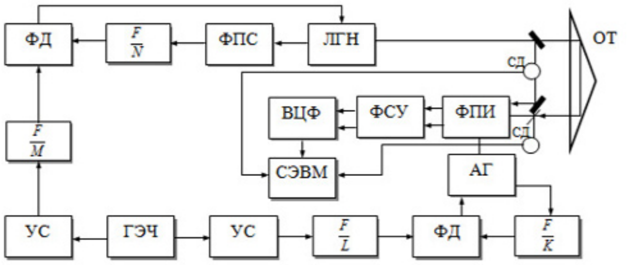


The got results testify that introduction of cylindrical body from an ideally conducting metal in a center PKR and application of reflector-absorbers-focons from quartz glass allowed to form a necessary structure electric components of the electromagnetic field in the area of transformation of laser radiation in photomultiplier (Figure 8) with maximal in size *Ez*-component. The calculations *of Ez-* and *Er*-component of electric-field were also conducted for focons-reflector-absorbers, made from quartz glasses of C40-1 with $\varepsilon = 5$ and C63-1 with $\varepsilon = 14$ with the purpose of increase of relation *of Ez/Er* in the area of transformation. It should be noted that for C40-1 this relation is equal 16, and for C63-1 – 100.

Created low-noise helium-neon laser with microwave excitation and autogenerator photodetector on the basis of microwave semicoaxial resonator with the reflector-absorber of the electromagnetic field and focons concentrating laser bunches in the area of their double heterodyning in photomultiplier allowed to develop the laser standard of length (Figure9), the flow diagram of which is resulted on Figure10.

Figure 9. Laser reproducing standard lengths ranging from 1 to 103m.

Figure10. The flow diagram of laser standard of reproducing of length in a range from 1 to 10^3 m.



The laser standard of reproducing of length with a red laser bunch consists of supporting measuring channel (MC), informative MC and MC index of refraction of air of boundary layer of atmosphere on the route of laser radiation. Backup and informative laser bunches fall on a twochannel autogenerator heterodyne photodetector with the signal of beatings of longitudinal fashions of laser shaping by the photocathode of photomultiplier, built-in in the endovibrator of microwave ascillator, synchronized on a phase resonance frequency of stabilizing of beatings of longitudinal fashions of laser. On loadings of photodetector select two sinusoidal voltage with amplitude of 1V, by frequency of 1 KHz and difference of phases to proportional optical length of measureable base.

Physical length of base is calculated by the embedded industrial computer on equalization of measurings of M.I. Kravchenko (Patent 77437 UA, МКИ H03L 7/26, H01P 7/00) taking into account the formula of P.E.Ciddor (Ibid.-1996,-35.-P.1566-1573) – indirect measuring of index of refraction of air in a point on the direct measurings of thermodynamics descriptions (temperature, pressure, humidity) and gas composition of air.

During metrology attestation of laser standard the size of unit of length 1 m was passed from the national standard of unit of length of Ukraine ГЕТ 01-03-98, and sizes of units of temperature, pressure, humidity, index of refraction from the national standards of Ukraine and Russia of ДЕТУ 06-05-96, ДЕТУ 04-02-97, ГЕТ 151-2010, ГЕТ 138-2010.

The laser standard of reproducing of length took part in regional comparison with the base standards of length of Central research institute of geodesy, aerial survey and cartography the name of F.N.Krasovskogo (Russia) and standard of Institute of geophysics and engineering seismology the name of A.G.Nazarova (Republic Armenia).

Total relative uncertainty of measuring (k=1) of bases of 1 m, 12 m, 24 m, 96 m, 192 m, 576 m, 1000 m does not exceed $1 \cdot 10^{-7}$.

References

1. Кравченко Н.И., Копыл В.К., Купко В.С. Вопросы метрологического обеспечения ИИС траекторных измерений II Всесоюзная конференция «Метрологическое обеспечение ИИС и АСУ ТП» Тезисы докладов. Ч.2 Львов: НПО «Система», 1988, с.86-87.
2. Leherer M. Entwicklung eines weitreichenden Präszisionsdistanzmessers alz Grundlage für ein Mehrwellengerät. München.: Dissertationen, Heft Nr, 272; 1982. 109s.
3. Newsu Yamasaki Fault. Louthwest Japan Journal of the Geodetic. Keyreken Newsu, Japan, 1989, v.37, No8, p.1-8.
4. Кравченко Н.И., Сидоренко Г.С., Стрелец В.А. Создание двухмодового гелий-неонового лазера с СВЧ-возбуждением. Украинский метрологический журнал. 2000, вып.4, с.31-34
5. Патент 77437. Україна, МПК (2006) H03L 7/26 H01P 7/00. Спосіб перетворення частоти лазерного випромінювання та пристрій для його реалізації /Кравченко М.І., Неєжмаков П.І. -№ 2004032277; Заявл. 29.03.2004; Опубл. 16.12.2006. -4 с.
6. Кравченко Н.И., Неежмаков П.И. Автогенераторные фотоприемные устройства на основе полукоаксиального резонатора для лазерных измерительных систем больших длин //Український метрологічний журнал. -2001. -Вип. 3. -С. 61–65.
7. Кравченко Н.И., Неежмаков П.И. Исследования полукоаксиального резонатора автогенераторного фотоприемного устройства лазерных измерительных систем больших длин //Український метрологічний журнал. -2001. -Вип. 4. -С. 31–35.