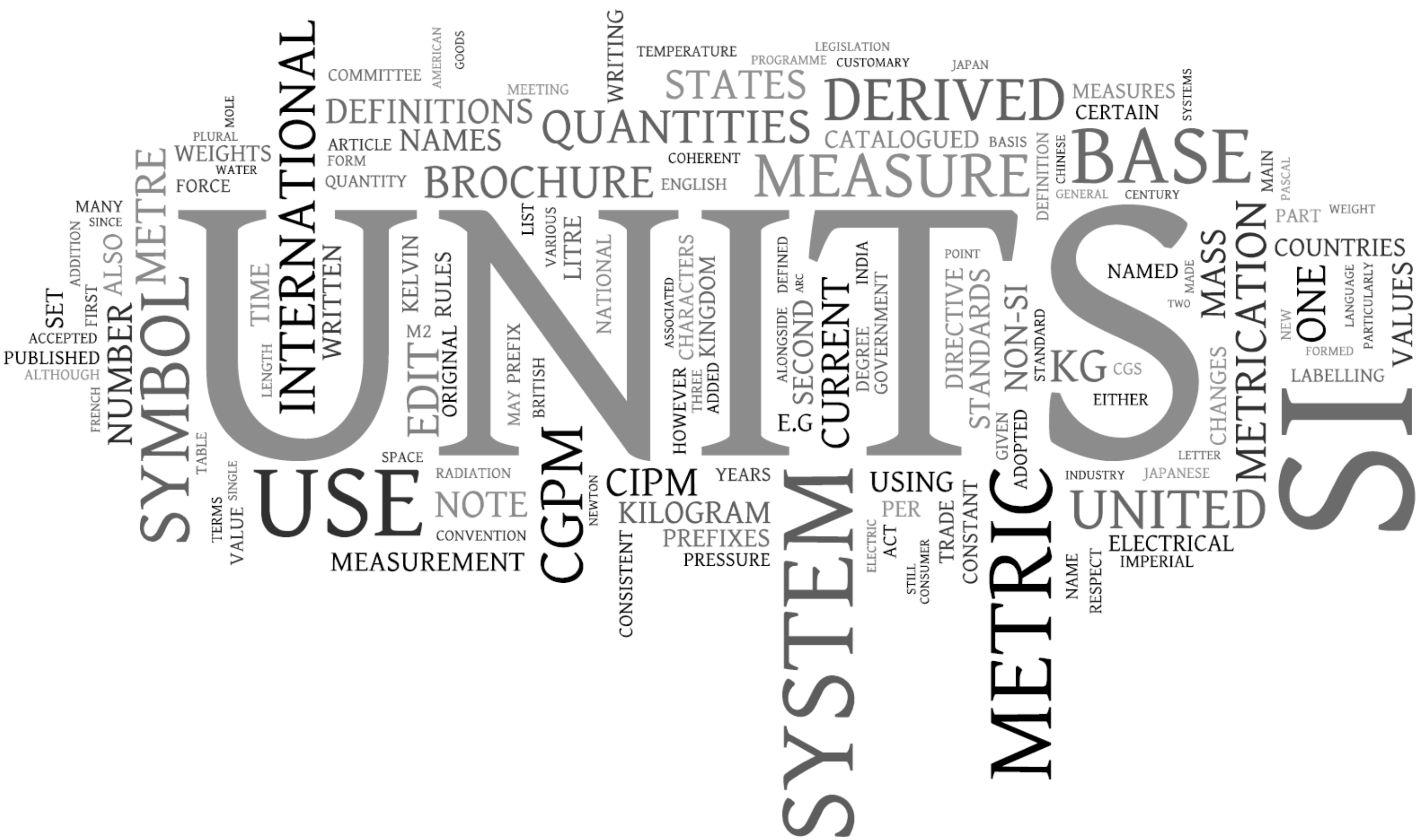
mednarodni sistem enot

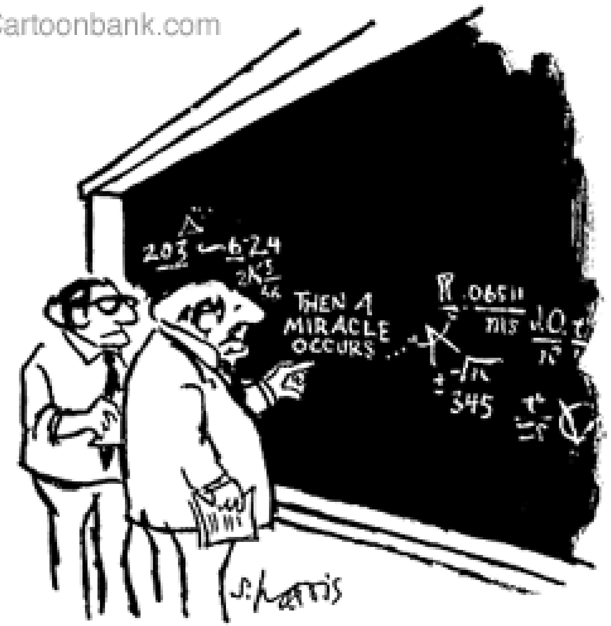
Système International d'Unités



značilen uvod v naravoslovni učbenik:

Glavna naloga naravoslovne znanosti je iskanje podrobnih zvez med količinami. Zaradi tega moramo količine meriti. Pri merjenju primerjamo velikost kake količine z enoto. Tako sta na primer enota za dolžino 1 meter in enota za čas 1 sekunda.

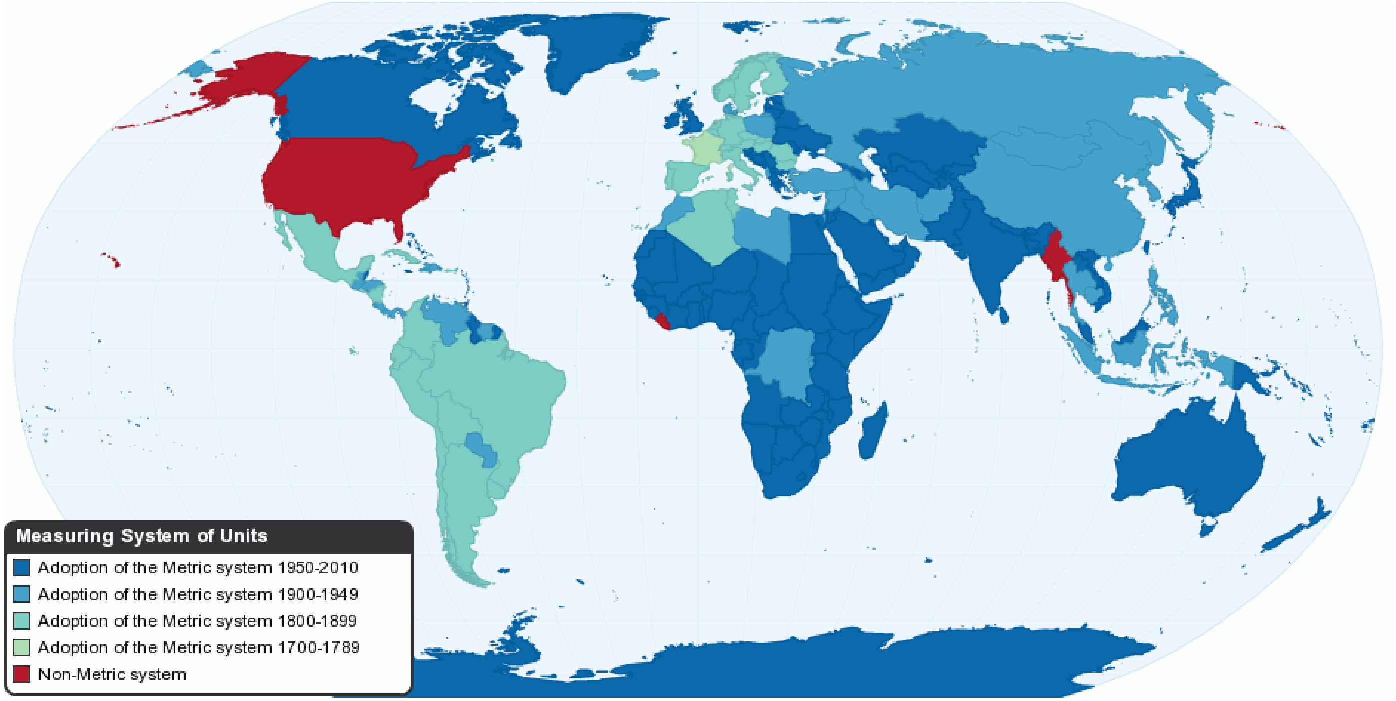
Odnose med objekti, ki jih opazujemo popisujemo z modeli, ki imajo določeno matematično formo. V modelih nastopajo fizikalne količine. Fizikalna količina je merljiva lastnost, ki jo pripišemo pojavom, telesom ali snovem.



"I think you should be more explicit here in step two."

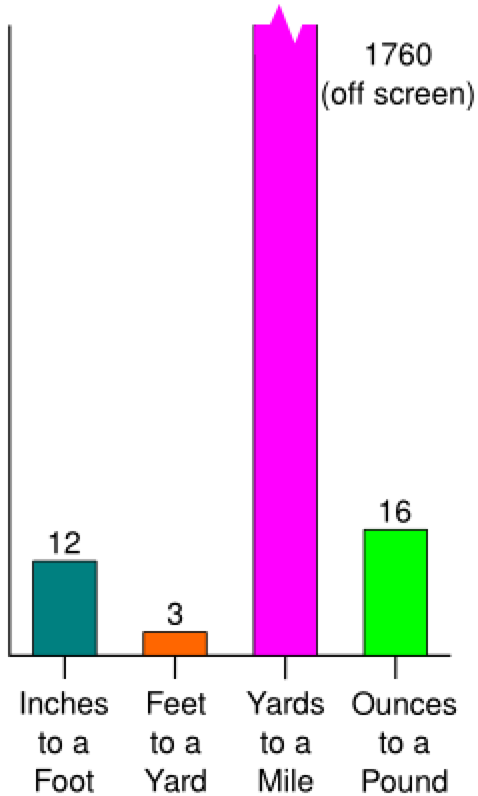
- **SI sestavlja sedem osnovnih količin s pripadajočimi enotami.**
- **Večje in manjše desetiške mnogokratnike osnovne enote izražamo z dogovorjenimi predponami.**
- **Iz teh osnovnih enot je izpeljana vrsta drugih enot.**

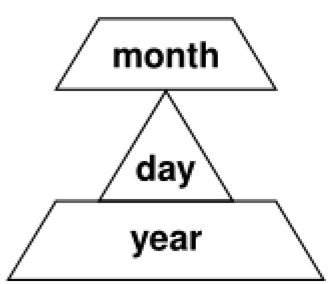
Od leta 1960 je v uporabi t.i. mednarodni sistem enot "Système International d'Unités", ki temelji na znanstveno utemeljenem sistemu osnovnih količin. V veljavi je v vseh državah sveta, razen Liberije, Burme in Združenih držav Amerike.



United States

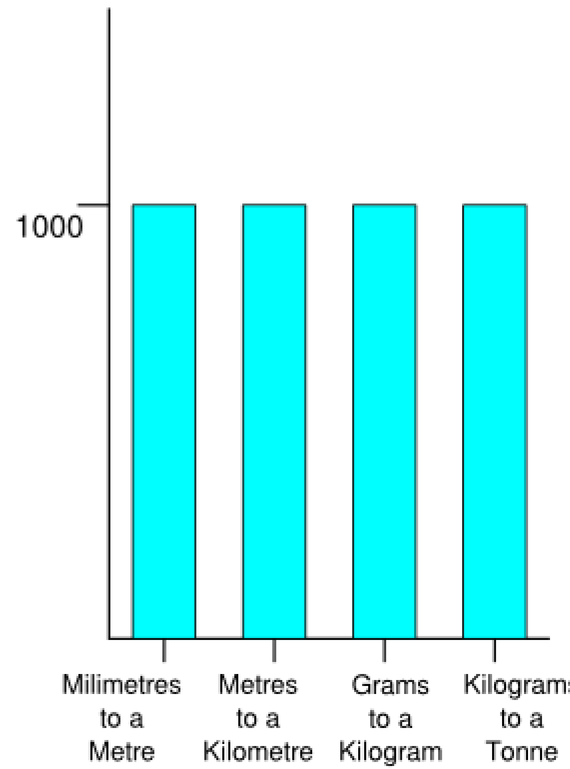
Arbitrary Retarded Rollercoaster





The Rest of the World

Logical Smooth Sailing



Mars Climate Orbiter

From Wikipedia, the free encyclopedia

The ***Mars Climate Orbiter*** (formerly the **Mars Surveyor '98 Orbiter**) was a 338 kilogram (750 lb) robotic space probe launched by NASA on December 11, 1998 to study the Martian climate, atmosphere, and surface changes and to act as the communications relay in the Mars Surveyor '98 program for Mars Polar Lander. However, on September 23, 1999, communication with the spacecraft was lost as the spacecraft went into orbital insertion, due to ground-based computer software which produced output in non-SI units of pound-seconds (lbf×s) instead of the metric units of newton-seconds (N×s) specified in the contract between NASA and Lockheed. The spacecraft encountered Mars on a trajectory

Mars Climate Orbiter

Artist's conception of the Mars Climate Orbiter

Mission type	Mars orbiter
Operator	NASA / JPL
COSPAR ID	1998-073A
Website	mars.jpl.nasa.gov/msp98/orbiter/
Mission duration	286 days Mission failure

Los Angeles Times

Mars Probe Lost Due to Simple Math Error

October 01, 1999 | ROBERT LEE HOTZ | TIMES SCIENCE WRITER

Email Share +1 2 Tweet 39

NASA lost its $125-million Mars Climate Orbiter because spacecraft engineers failed to convert from English to metric measurements when exchanging vital data before the craft was launched, space agency officials said Thursday.

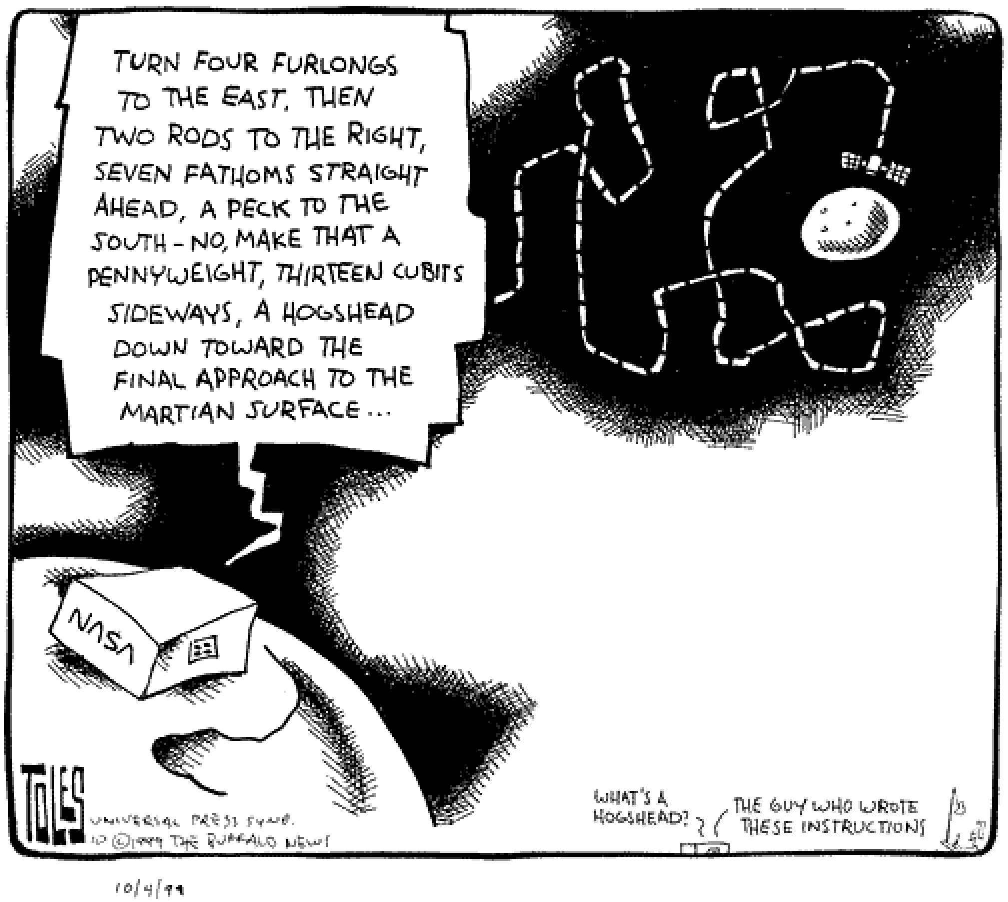
A navigation team at the Jet Propulsion Laboratory used the metric system of millimeters and meters in its calculations, while Lockheed Martin Astronautics in Denver, which designed and built the spacecraft, provided crucial acceleration data in the English system of inches, feet and pounds.

As a result, JPL engineers mistook acceleration readings measured in English units of pound-seconds for a metric measure of force called newton-seconds.

In a sense, the spacecraft was lost in translation.

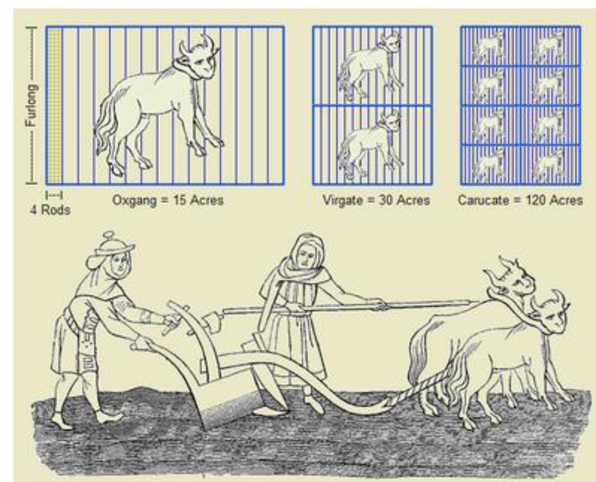
accident of NASA's Mars Climate Orbiter

The following cartoon was published on 1999 October 04 in the Buffalo (NY, USA) News following the accident of NASA's Mars Climate Orbiter. The expensive satellite crashed into the planet Mars because the spacecraft expected thrust values in newtons while the control center send a command in pound force



Zgodovinski razvoj definicije dolžinskih enot

Pojav merjenja je verjetno tako star kot je pojav trgovine, kar je skoraj gotovo v novejši kameni dobi (70-80000 l.p.n.š.), lahko pa tudi nekoliko prej. Meritve so ve teh časih temeljile na tipičnih človeških lastnostih kot npr. dolžini komolca, vendar so te teze bolj ali manj predmet ugibanj.
Za začetnike nekakšnega sistema enot štejemo stare Grke. Okoli leta 500 p.n.š. so imeli v Atenah že depozitorij dolžinskih in utežnih mer!
Rimski sistem je temeljil na grškem in je dobro dokumentiran.



Grške enote za dolžino

Smaller units of length

Unit	Greek name	Equal to	Metric equivalent	Description
daktylos	δάκτυλος		19.3 mm	finger
kondylos	κόνδυλος	2 daktyloi	38.5 mm	
palaistē or dōron	παλαιστή, δῶρον	4 daktyloi	77.1 mm	palm
dichas or hēmipodion	διχάς, ἡμιπόδιον	8 daktyloi	154.1 mm	half foot
lichas	λιχάς	10 daktyloi	192.6 mm	
orthodōron	ὀρθόδωρον	11 daktyloi	211.9 mm	
spithamē	σπιθαμή	12 daktyloi	231.2 mm	span of all fingers
pous	πούς	16 daktyloi	308.2 mm	foot
pygmē	πυγμή	18 daktyloi	346.8 mm	
pygōn	πυγών	20 daktyloi	385.3 mm	
pēchys	πῆχυς	24 daktyloi	462.3 mm	cubit

Except where noted, based on Smith (1851).[3] Metric equivalents are approximate.

Larger units of length

Unit	Greek name	Equal to	Metric equivalent	Description
pous	πούς		0.308 m	foot
haploun bēma[4]	ἁπλοῦν βῆμα	2.5 podes	0.77 m	single pace
bēma,[3] diploun bēma[4]	βῆμα, διπλοῦν βῆμα	5 podes	1.54 m	double pace
orgyia	ὀργυιά	6 podes	1.85 m	fathom
kalamos, akaina or dekapous	κάλαμος, ἄκαινα, δεκάπους	10 podes	3.08 m	
hamma	ἅμμα	60 podes	18.5 m	
plethron	πλέθρον	100 podes	30.8 m	
stadion	στάδιον	600 podes	184.9 m	
diaulos	δίαυλος	2 stadia	369.9 m	
hippikon	ἱππικόν	4 stadia	739.7 m	
milion	μίλιον	8 stadia	1479 m	Roman mile
dolichos[4]	δόλιχος	12 stadia	2219 m	
parasanges	παρασάγγες	30 stadia	5548 m	adopted from Persia[4]
schoinos	σχοινός	40 stadia	7397 m	adopted from Egypt[4]

Except where noted, based on Smith (1851).[3] Metric equivalents are approximate.

http://en.wikipedia.org/wiki/Ancient_Greek_units_of_measurement, 2012

Unit	Greek name	Equivalent	Attic/Euboic standard	Aeginetic standard
obol or obolus	ὀβολός		0.72g	1.05g
drachma	δραχμή	6 obols	4.31g	6.3g
mina	μνᾶ	100 drachmae	431g	630g
talent	τάλαντον	60 minae	25.86 kg	37.8 kg

Grške enote za maso

Rimske enote za dolžino

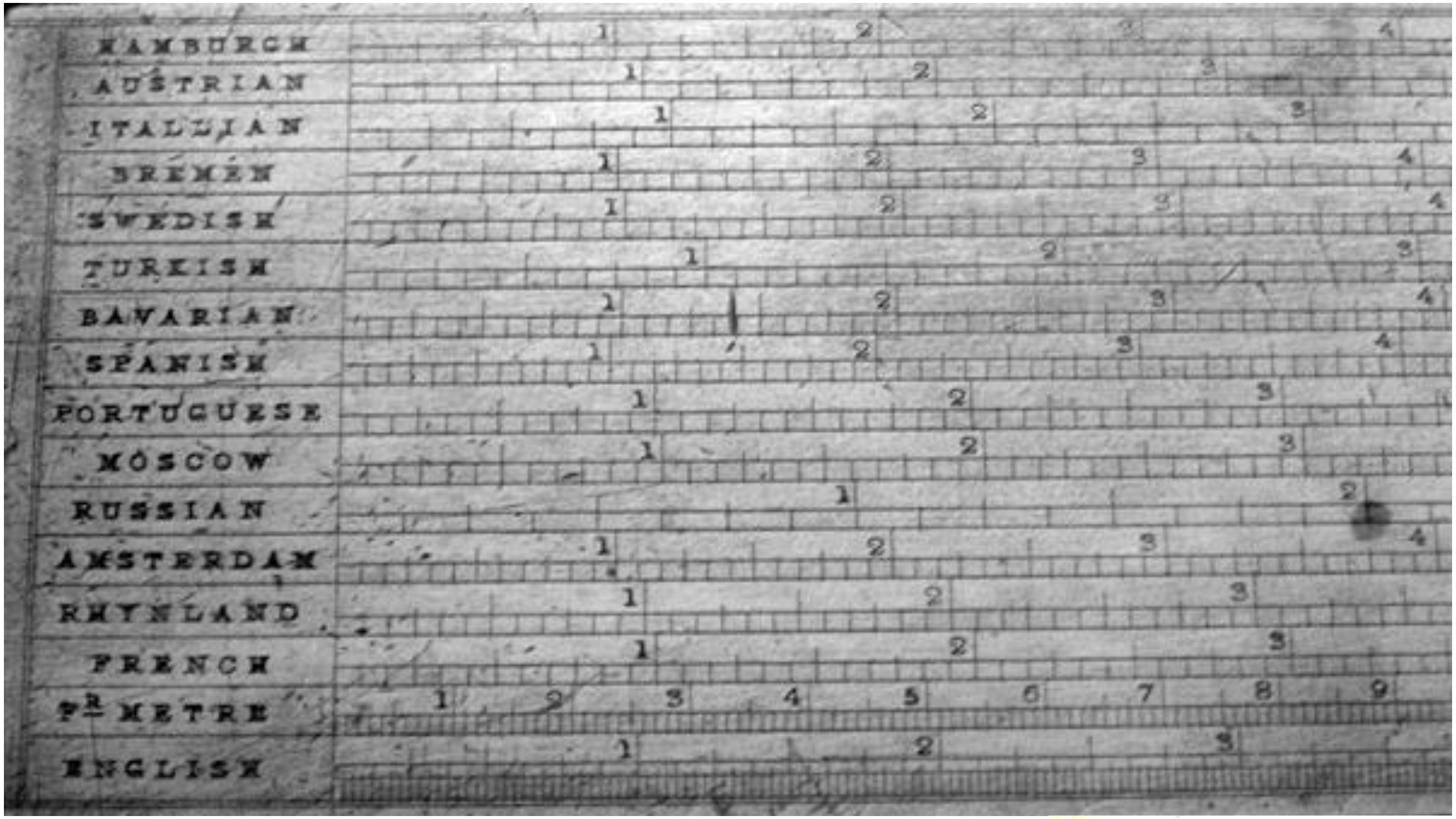
Ancient Roman units of length

Roman unit	English name	Equal to	English equivalent	Metric equivalent	Description
digitus	finger	$^1/_{16}$ pes	0.0607 ft (0.728 in)	18.5 mm	
uncia or pollex	inch or thumb	$^1/_{12}$ pes	0.0809 ft (0.971 in)	24.6 mm	
palmus	palm width	$^1/_4$ pes	0.243 ft	74 mm	
palmus major	palm length	$^3/_4$ pes	0.728 ft	222 mm	in late times
pes	foot		0.971 ft	296 mm	
palmipes		$1^1/_4$ pedes	1.214 ft	370 mm	
cubitus	cubit	$1^1/_2$ pedes	1.456 ft	444 mm	
gradus or pes sestertius	step	$2^1/_2$ pedes	2.427 ft	0.74 m	
passus	(double) pace	5 pedes	4.854 ft	1.48 m	
decempeda or pertica		10 pedes	9.708 ft	2.96 m	
actus (in length)		120 pedes	116.496 ft	35.5 m	
mille passuum or milliarium[5][6][7]	mile	5000 pedes	4854 ft (0.919 standard mi)	1.48 km	
Gallic leuga	league	7500 pedes	7281 ft (1.379 standard mi)	2.22 km	

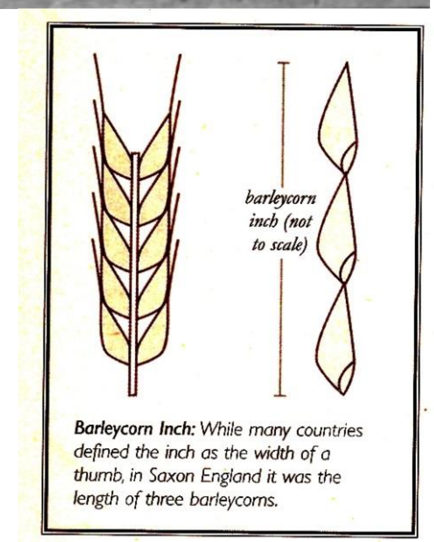
Except where noted, based on Smith (1851).[2] English and Metric equivalents are approximate, converted at 1 pes = 0.9708 English feet and 296 mm respectively.

http://en.wikipedia.org/wiki/Ancient_Roman_units_of_measurement , 2012

Druge definicije dolžinskih enot



Palec (inch) so po nekaterih virih nekoč definirali kot razdaljo med koncem palca in prvim sklepom. Drugi viri poročajo, da je bil palec definiran kot del yarda, ki naj bi bil definiran kot razdalja med nosom in palcem angleškega kralja Henrya I.Kako nejasen je izvor vidimo iz tega, da spet drugi viri poročajo o tem, da je bil palec definiran kot dolžina treh zrn je mena (barleycorn).



Barleycorn Inch: While many countries defined the inch as the width of a thumb, in Saxon England it was the length of three barleycorns.

Etalon ali Postopek?

Osnovno merilo (etalon) lahko izvedemo kot artefakt ali pa definiramo postopek s katerim je določena enota ali njen del.

Egipčanski kubit 0,52 m

1625

shakuhachi ~

1 + 1/8

1 shaku =

0.3030 m

ZGODOVINSKI POGLED NA RAZVOJ STANDARDA

dva nasprotujoča principa definicije metra:

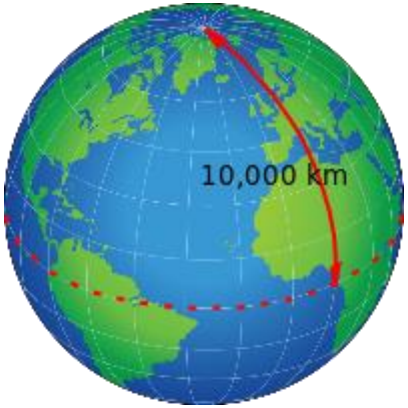
1. **dolžina nihala s periodo 2 s pri 45°N in morski gladini**

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$F = \frac{G\,m_1\,m_2}{r^2}$$

napaka zaradi sploščenosti zemlje

2. **$1/10^7$ dolžine (1/4) obsega zemlje;**

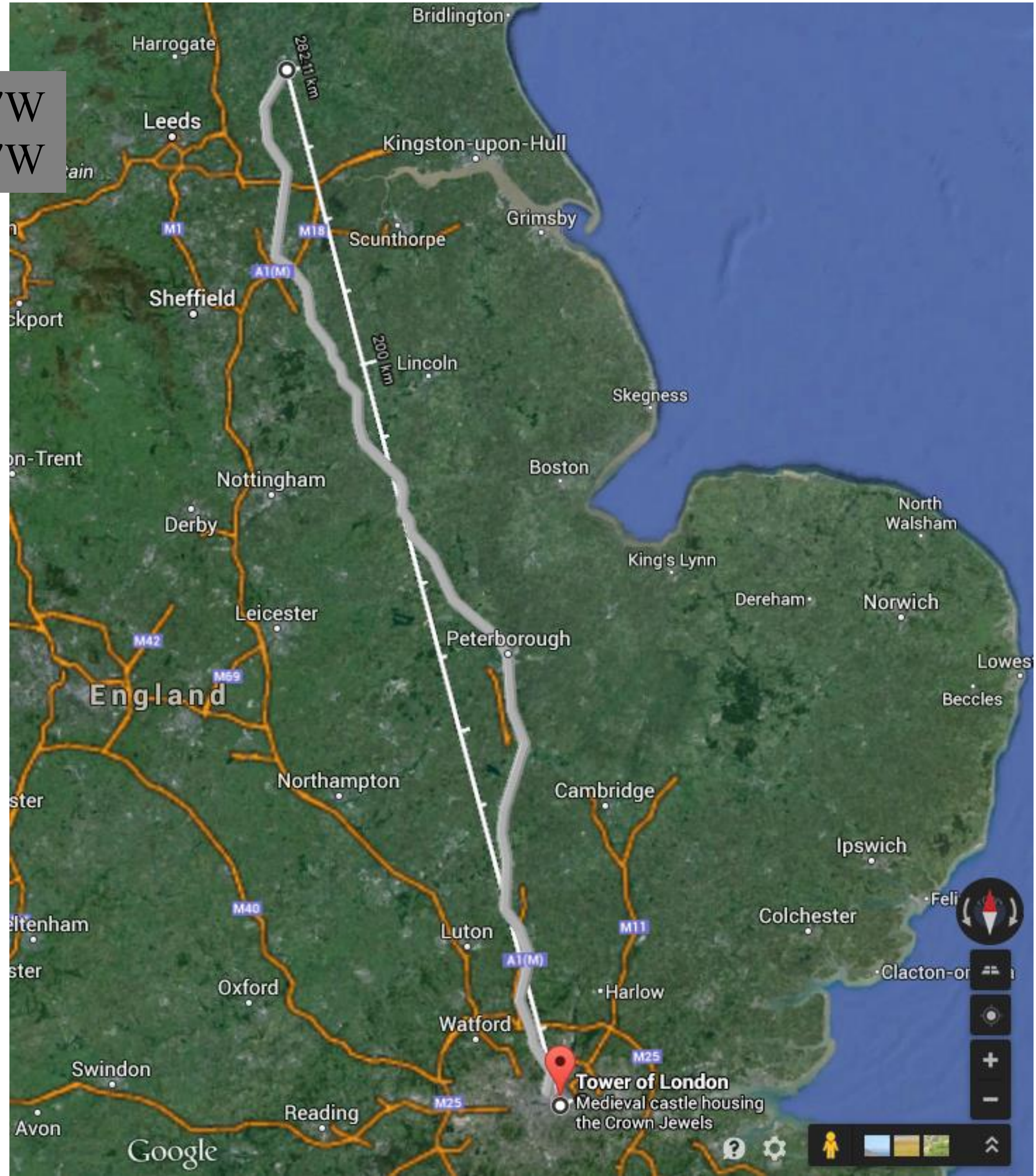


r = 6378,1 m
obseg(meridian) = 40.007.860 m
1/4 obsega ~ 10.000.000 m

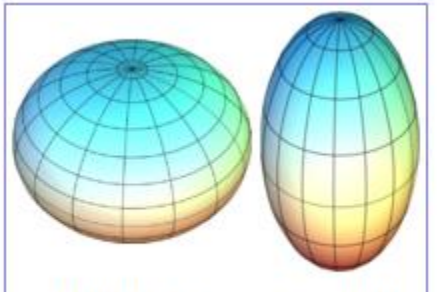
Idejo enotnega metričnega sistema enot je francoski ustavodajni skupščini marca 1790 razložil škof in državnik Talleyrand. Imenoval ga je decimalni metrični sistem.

London	51°30′26″N 0°7′39″W
York	53°57′30″N 1°4′49″W

1633 - 1635
Richard Norwood
111.13 km za eno stopinjo



1735 francoska akademija znanosti predlaga dve odpravi, ki bi izmerili lok na zemeljski površini, ki pripada 1 kotni stopinji



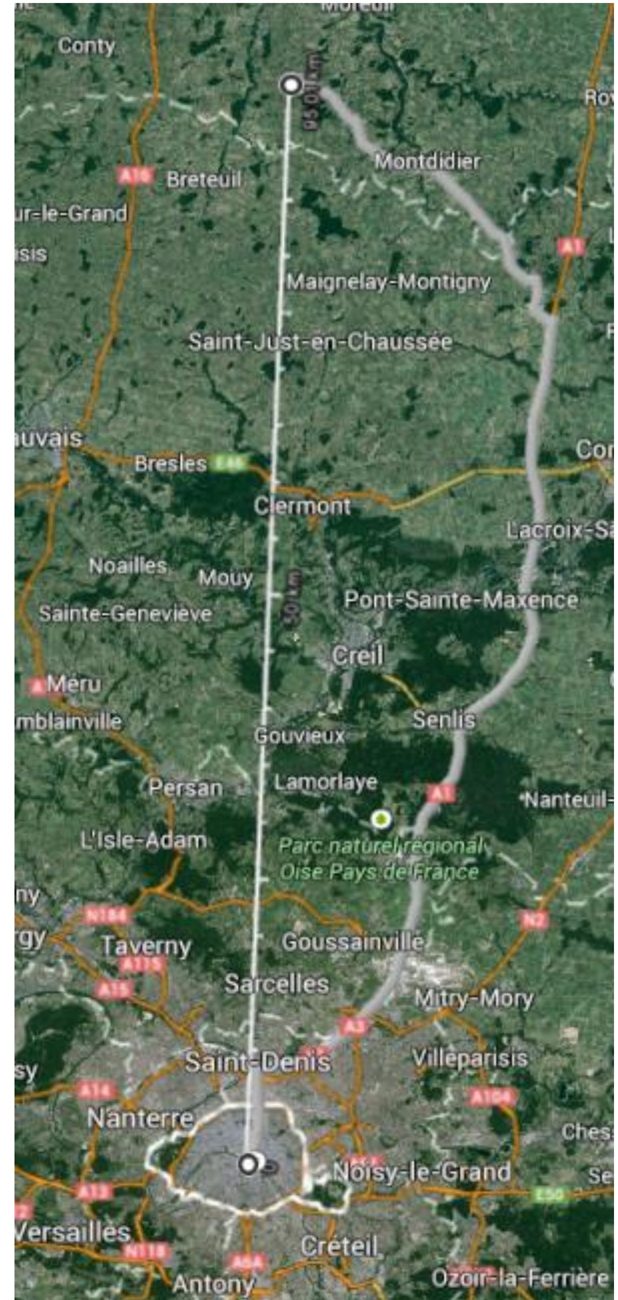
<u>Peru</u>: Bouguer, Louis Godin, de La Condamine, Antonio de Ulloa, Jorge Juan

<u>Lappland</u>: Maupertuis, Clairaut, Camus, Le Monnier, Abbe Outhier, Celsius

Storming of the Bastille, 14 July 1789.

Paris	48°51′24″N	2°21′03″E
Sourdon	49°42′39″N	2°23′54″E

1669 - 1670
Charles Marie de La Condamine
Pierre Bouguer



1735 francoska akademija znanosti predlaga
Peru: Bouguer, Louis Godin, de La Condamine, Antonio de Ulloa, Jorge Juan
Lappland: Maupertuis, Clairaut, Camus, Le Monnier, Abbe Outhier, Celsius

Charles Marie de La Condamine
Pierre Bouguer

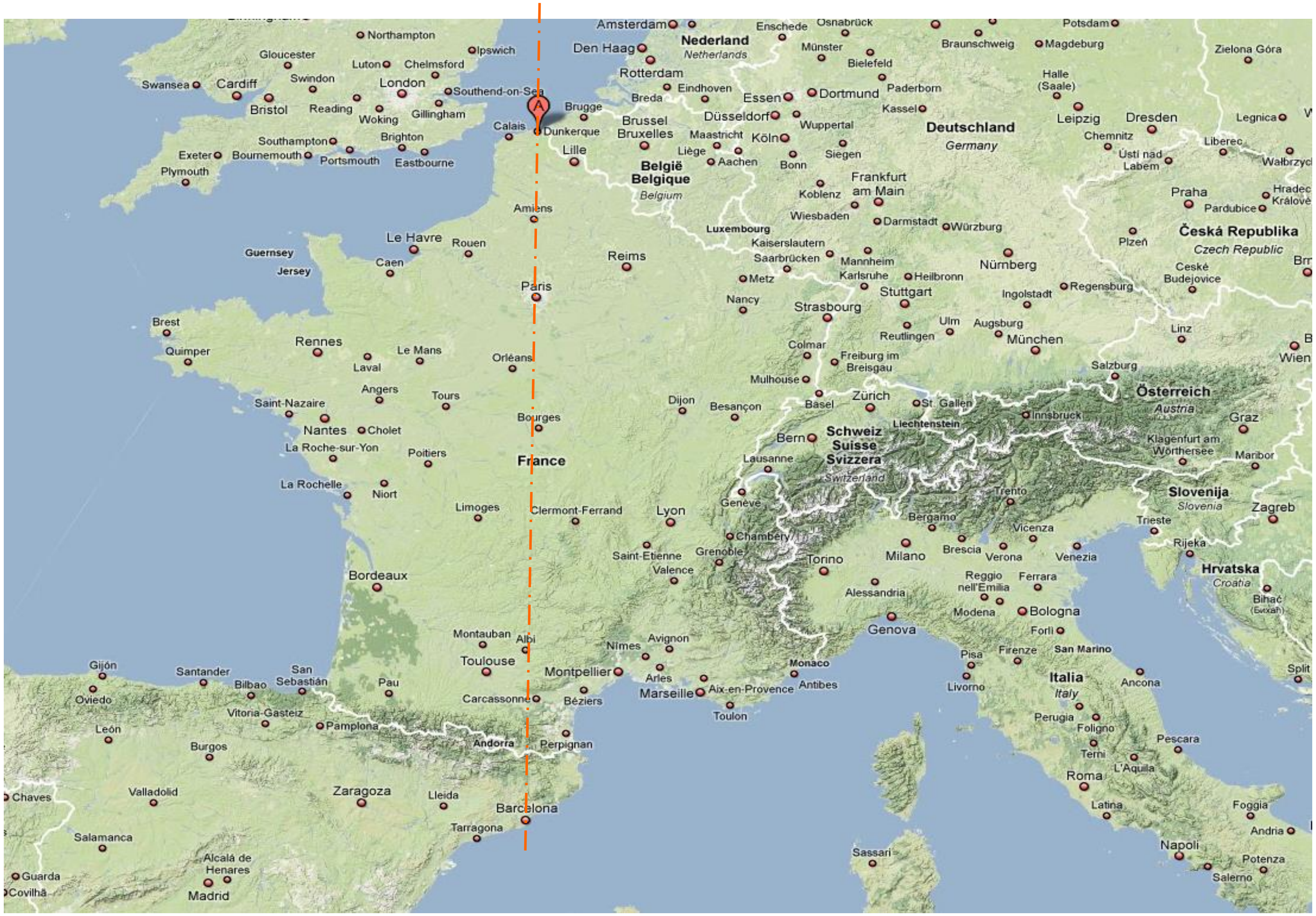
Yaruqui (Quito)	00°15′00″S	78°35′00″W
Cuenca	2°53′57″S	79°00′55″W
~ 300 km		

1735 - 1743

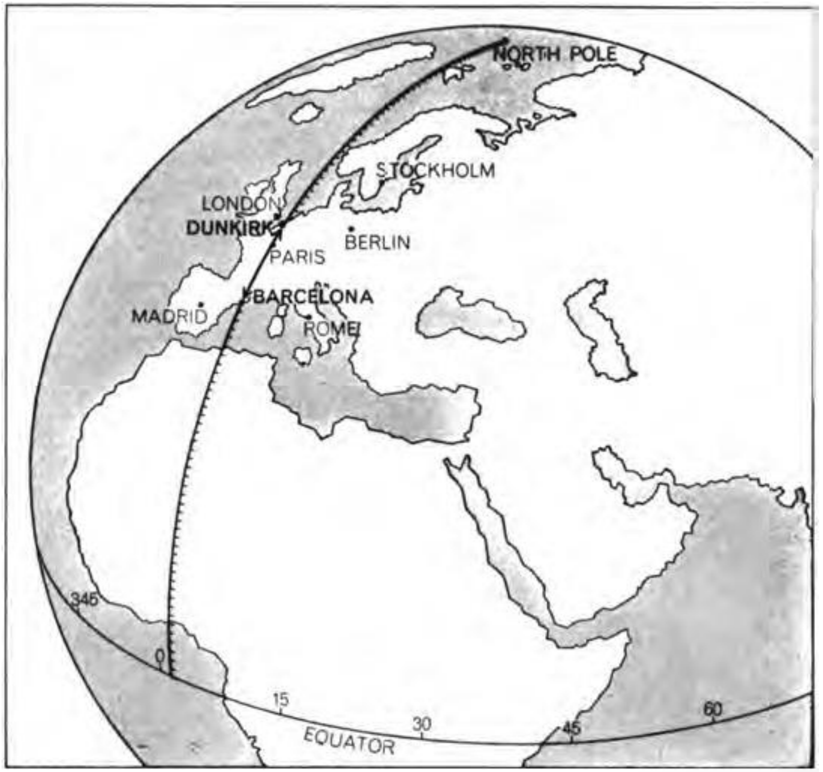
Charles Marie de La Condamine

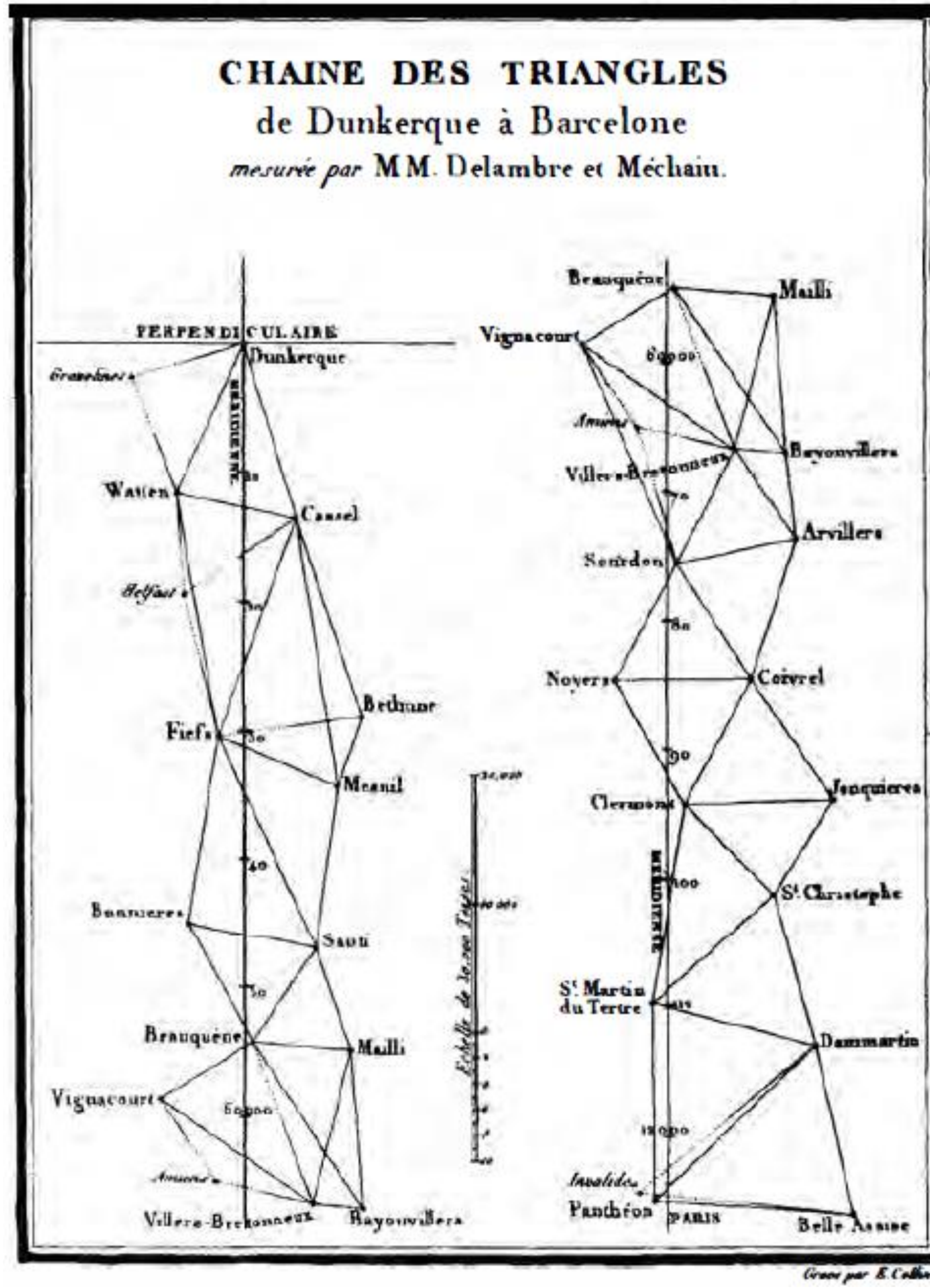
Pierre Bouguer

1792-1799 meritev razdalje med krajema Dunkerque and Barcelona:



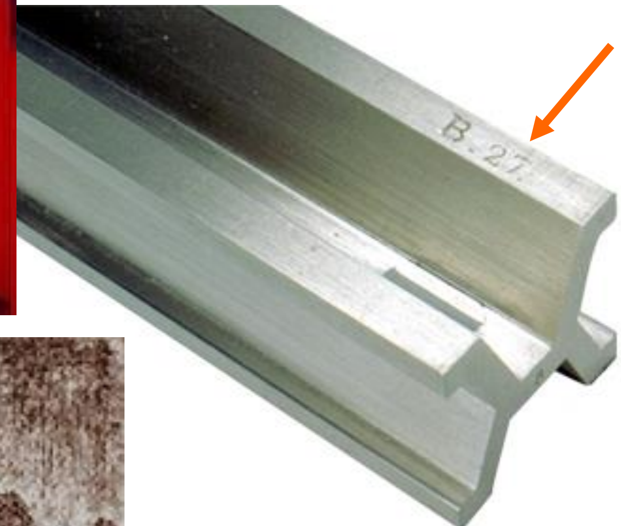
- **23 znanstvenikov (Francozi, Nizozemci, Švicarji, Španci)**
- **iz razdalje so s pomočjo astronomije izračunali dolžino četrtine pariškega poldnevnika = 5 130 740 klaftr**
- **definirali so en meter - je enak 10-milijontemu delu četrtine pariškega poldnevnika**
- Jean Baptiste Joseph Delambre and Pierre Méchain


NORTH POLE
STOCKHOLM
LONDON
DUNKIRK
BERLIN
PARIS
BARCELONA
MADRID
ROME
345
0
15
30
45
60
EQUATOR

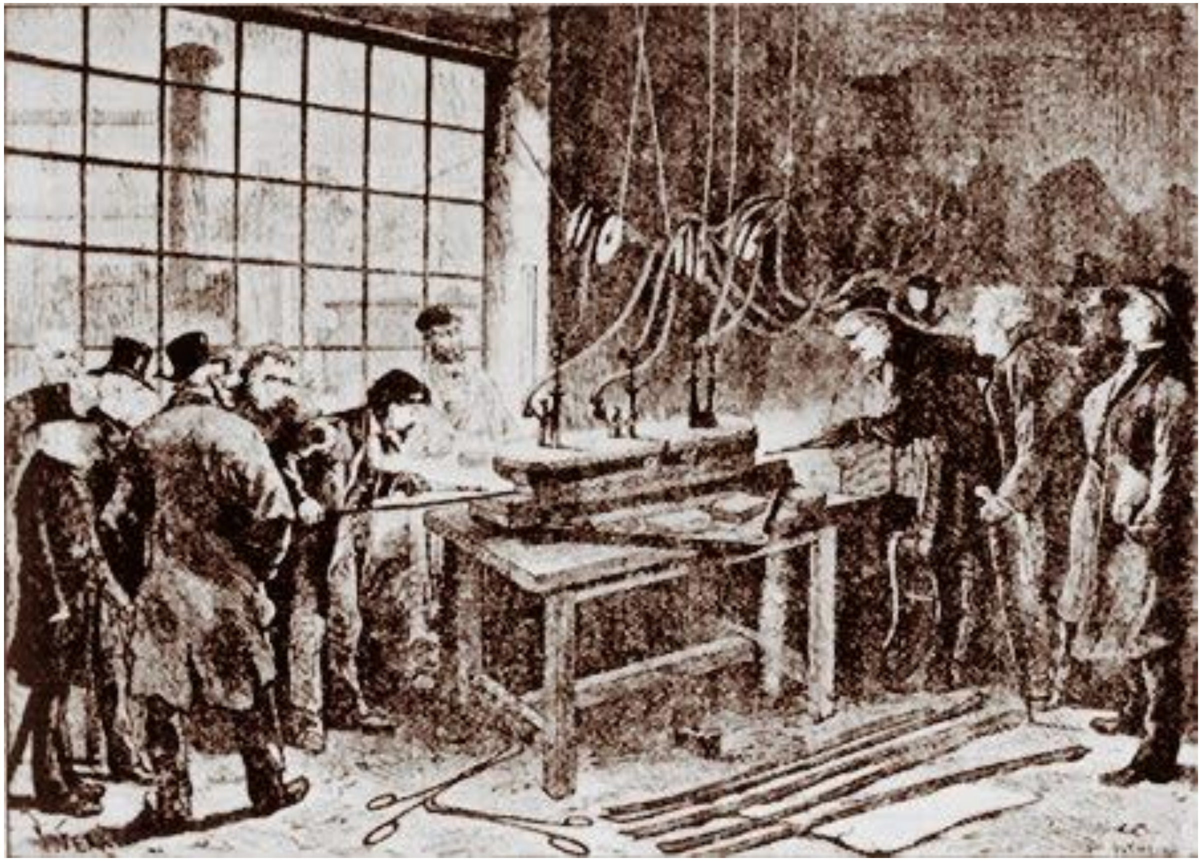

CHAINE DES TRIANGLES
de Dunkerque à Barcelone
mesurée par MM. Delambre et Méchain.
PERPENDICULAIRE
MÉRIDIENNE
Dunkerque
Watten
Cassel
Fiefs
Bethune
Mesnil
Saulti
Brauquène
Mailli
Vignacourt
Villers-Bretonneux
Bayonvillers
Arvillers
Sourdon
Noyers
Coivrel
Clermont
Jonquieres
St. Christophe
St. Martin du Tertre
Dammartin
Invalides
Panthéon
PARIS
Belle Assise

22 JUNIJA 1799

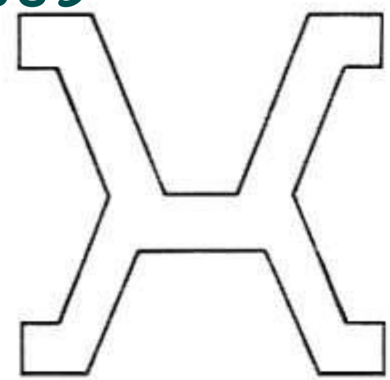
mètre des Archives



Pra-meter



novi standard 1889

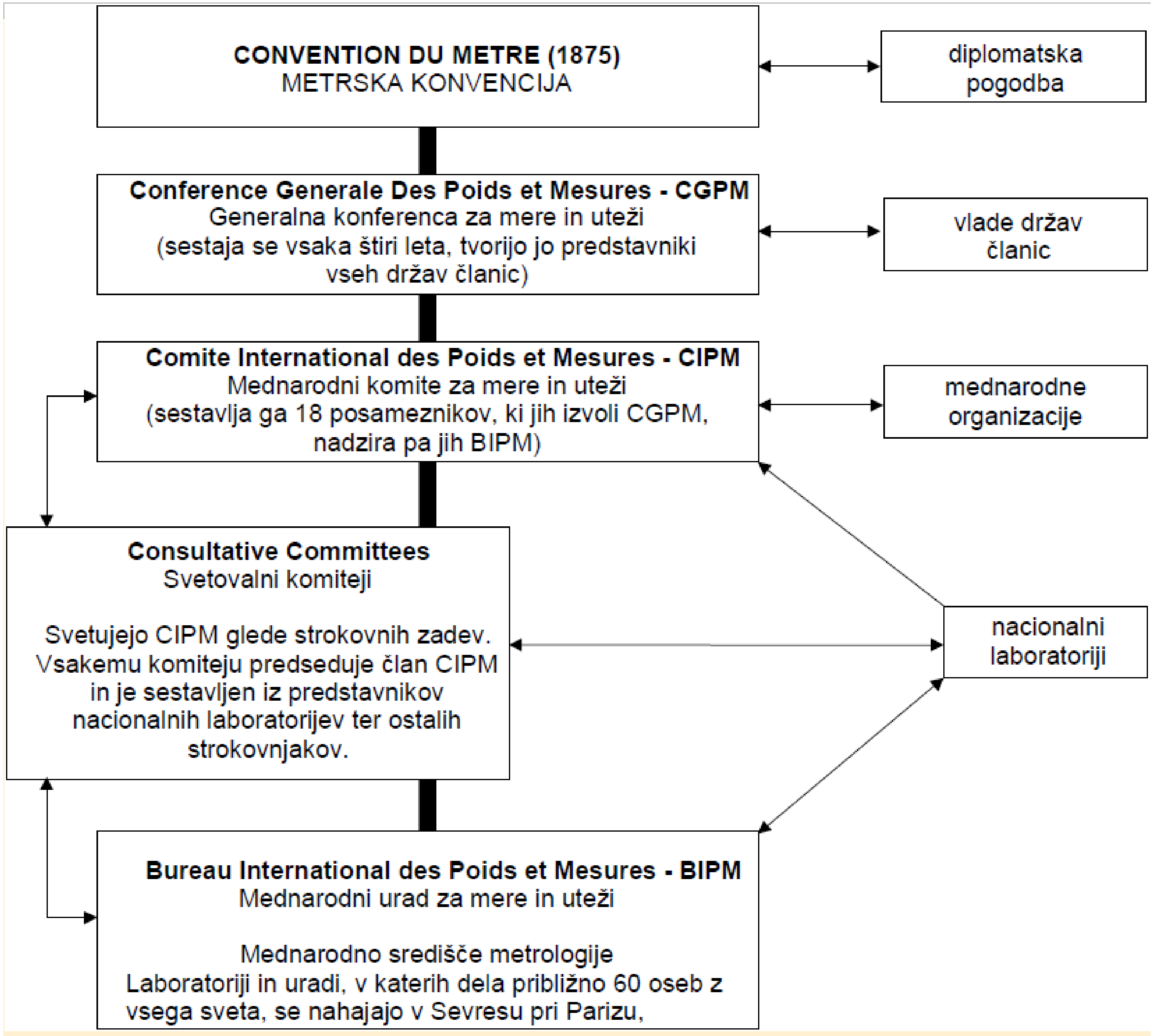


Pt-Ir; 10% Ir

Pt-Ir (zlitina iz leta 1874)/ prekratek za 0,2 mm

http://museum.nist.gov/object.asp?ObjID=37

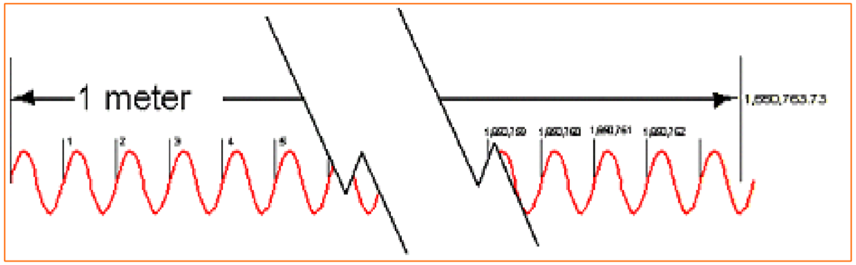
http://en.wikipedia.org/wiki/History_of_the_metre

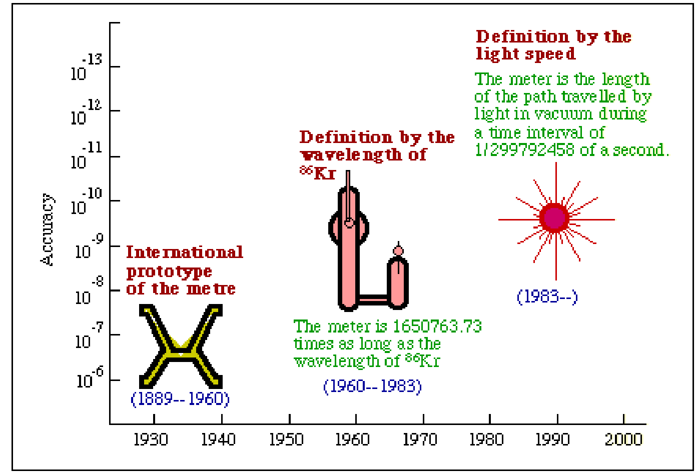


Shema organizacije „Metrske konvencije“

Vir: LMK, FE, UNI-LJ

Razvoj definicije metra

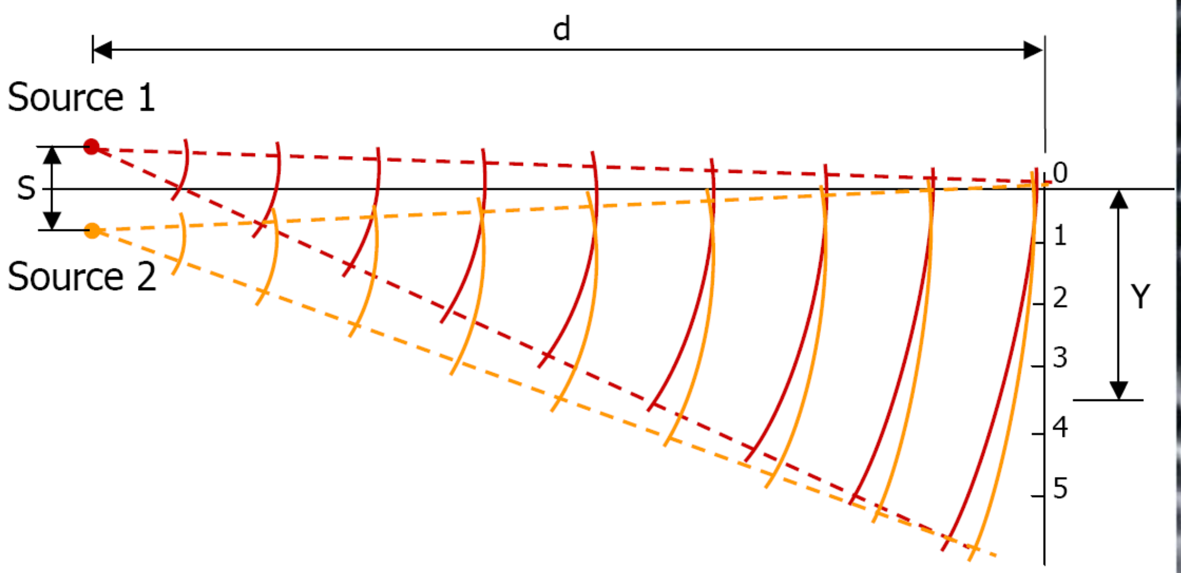


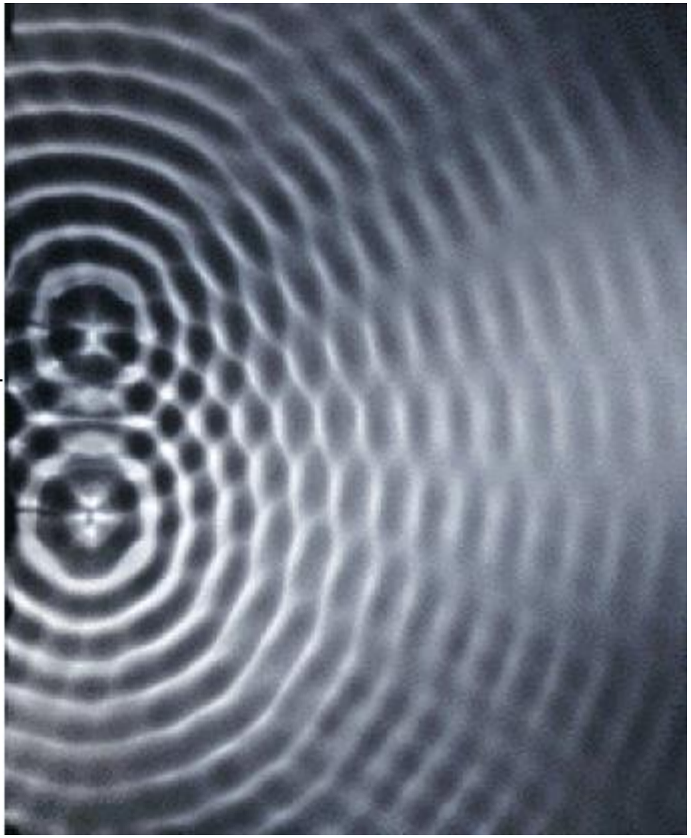


Datum	Definicija metra	Negotovost realizacije
1791	Četrtina poldnevnika Zemlje	± 0.06 mm
1889	Mednarodni prototip metra	± 0.002 mm
1960	Kriptonova svetilka	± 0.000 007 mm
1983	Hitrost svetlobe	± 0.000 000 7 mm
danes	Hitrost svetlobe z izboljšano točnostjo He-Ne laserja	± 0.000 000 02 mm

Vir: LMK, FE, UNI-LJ

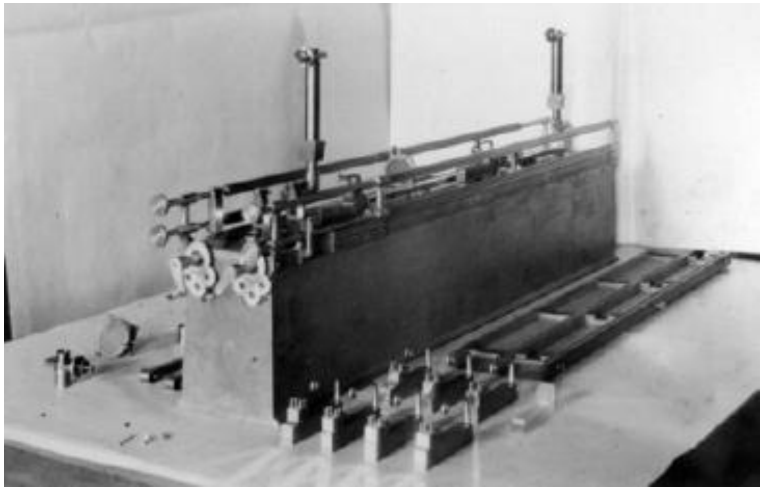
Interferenca svetlobe

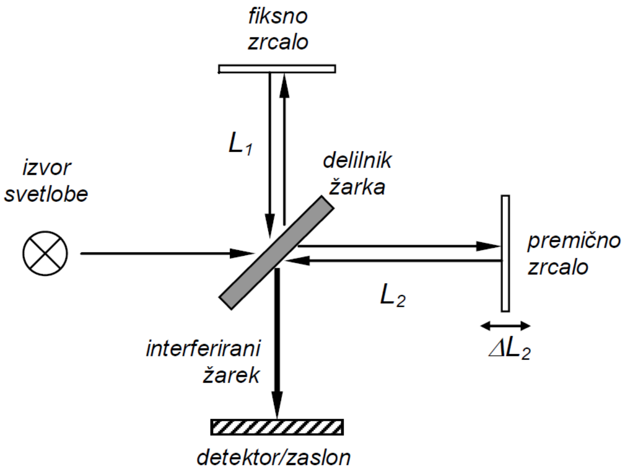




Interferenca svetlobe

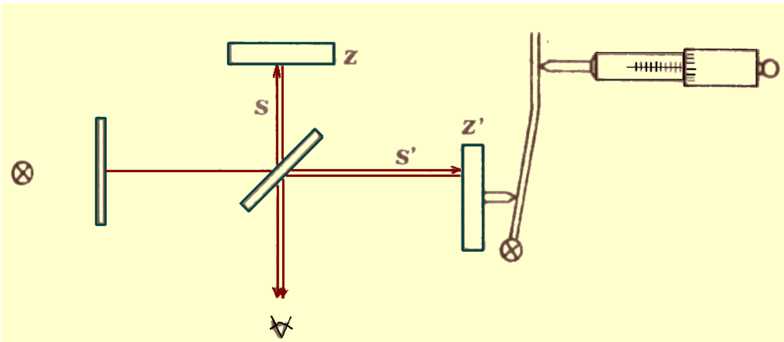
1887 Ameriški fizik poljskega rodu Albert Abraham Michelson (1853 - 1931) je predlagal uporabo optičnega interferometra za merjenje dolžine
Leta 1907 je (med drugim) za uporabo interferometrije v meroslovju dobil Nobelovo nagrado za fiziko



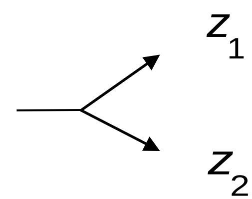


http://en.wikisource.org/wiki/On_a_method_for_making_the_wave_length_of_sodium_light_the_actual_and_practical_standard_of_length

Interferenca svetlobe



optični poti žarkov



vpadlo valovanje opišemo: $E_{vp} = E_0 \sin \omega t$

oko zazna

$$I \approx \overline{E_{\mathrm{iz}}^2} \approx \overline{\left[\sin(\omega t + kz_1) + \sin(\omega t + kz_2)\right]^2}$$

$$I \approx \left[1 + \cos 2\pi \frac{(z_1 - z_2)}{\lambda}\right]$$

Izstopna jakost svetlobe je odvisna od razlike poti delnih žarkov.

pogoja za ojačitev in oslabitev interferiranega valovanja

$$I \approx \left[1 + \cos 2\pi \frac{(z_1 - z_2)}{\lambda} \right]$$

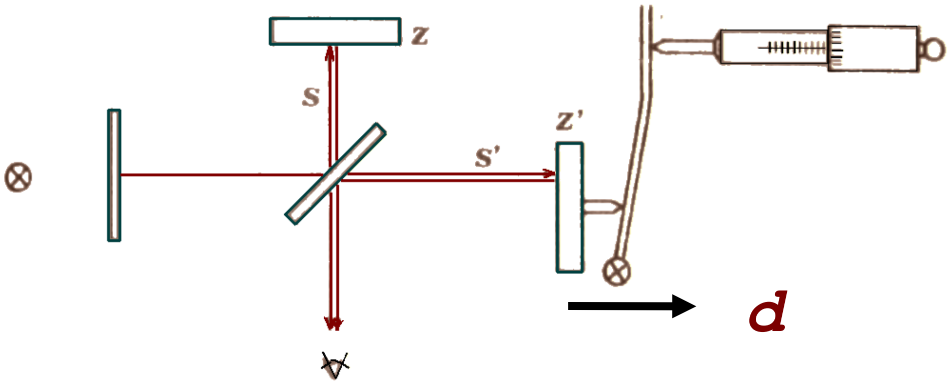
Pogoj za svetlo polje: cos mora biti +1

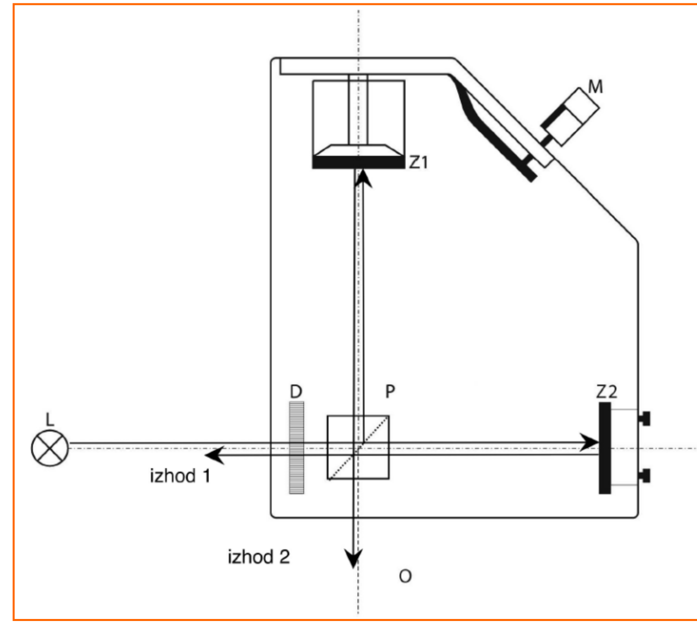
$$\rightarrow \quad \frac{(z_1 - z_2)}{\lambda} = n \quad (n = 1, 2, 3, \ldots)$$

Pogoj za temno polje: cos mora biti -1

$$\rightarrow \quad \frac{(z_1 - z_2)}{\lambda} = \frac{n}{2} \quad (n = 1, 3, 5, \ldots)$$

ločljivost Michelsonovega interferometra

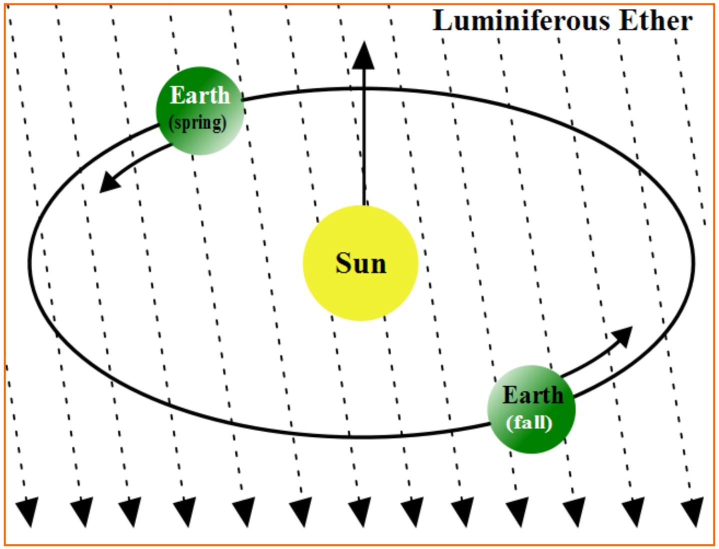


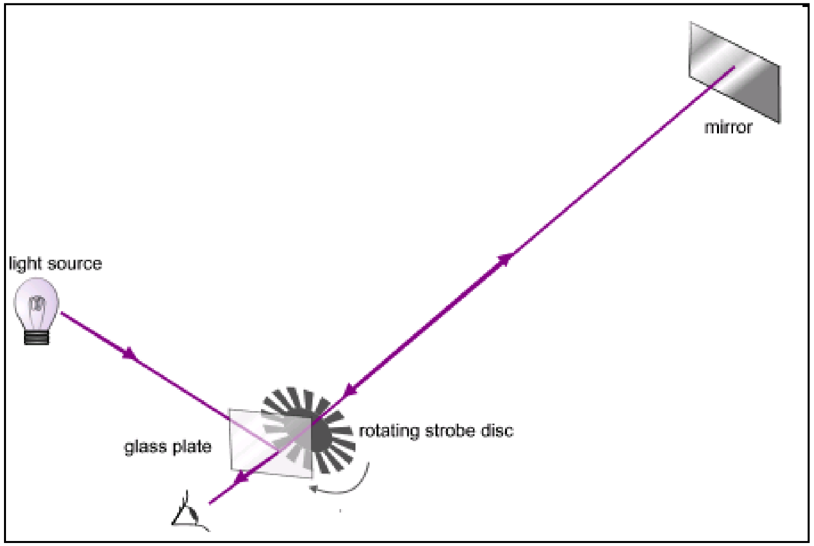


pri premiku zrcala za *d* se poveča optična pot za 2*d* in nastane/izgine en kolobar/črta

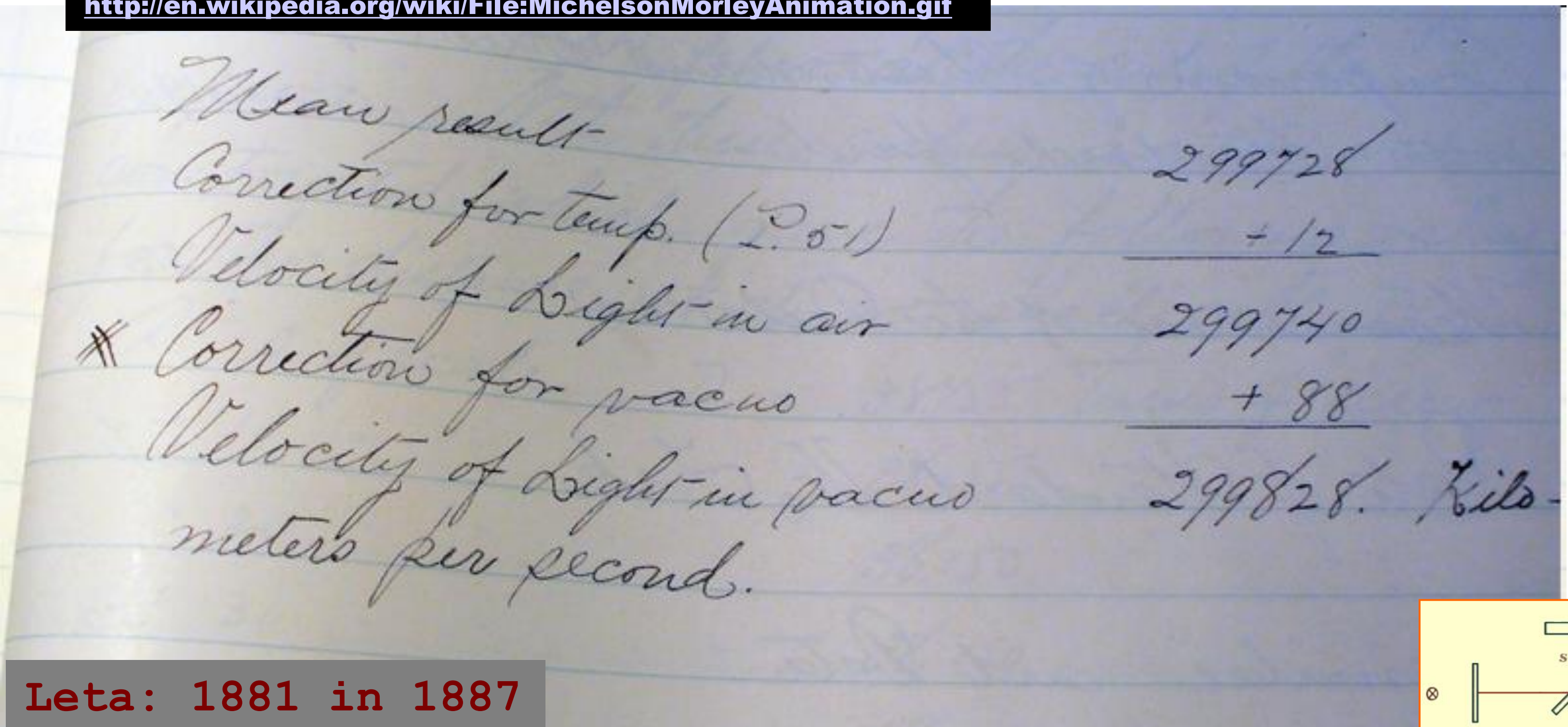
premiku črte lahko sledimo do stotinke razmika med sosednjima črtama ➔ merimo lahko na $\lambda/100$ natančno

Michelson-Morley: hitrost zemlje okoli sonca = 30 km/s, ...



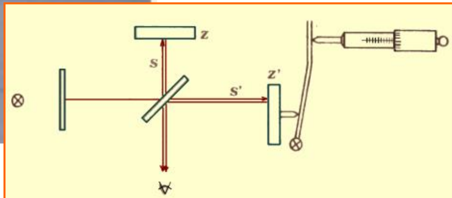


http://en.wikipedia.org/wiki/File:MichelsonMorleyAnimation.gif



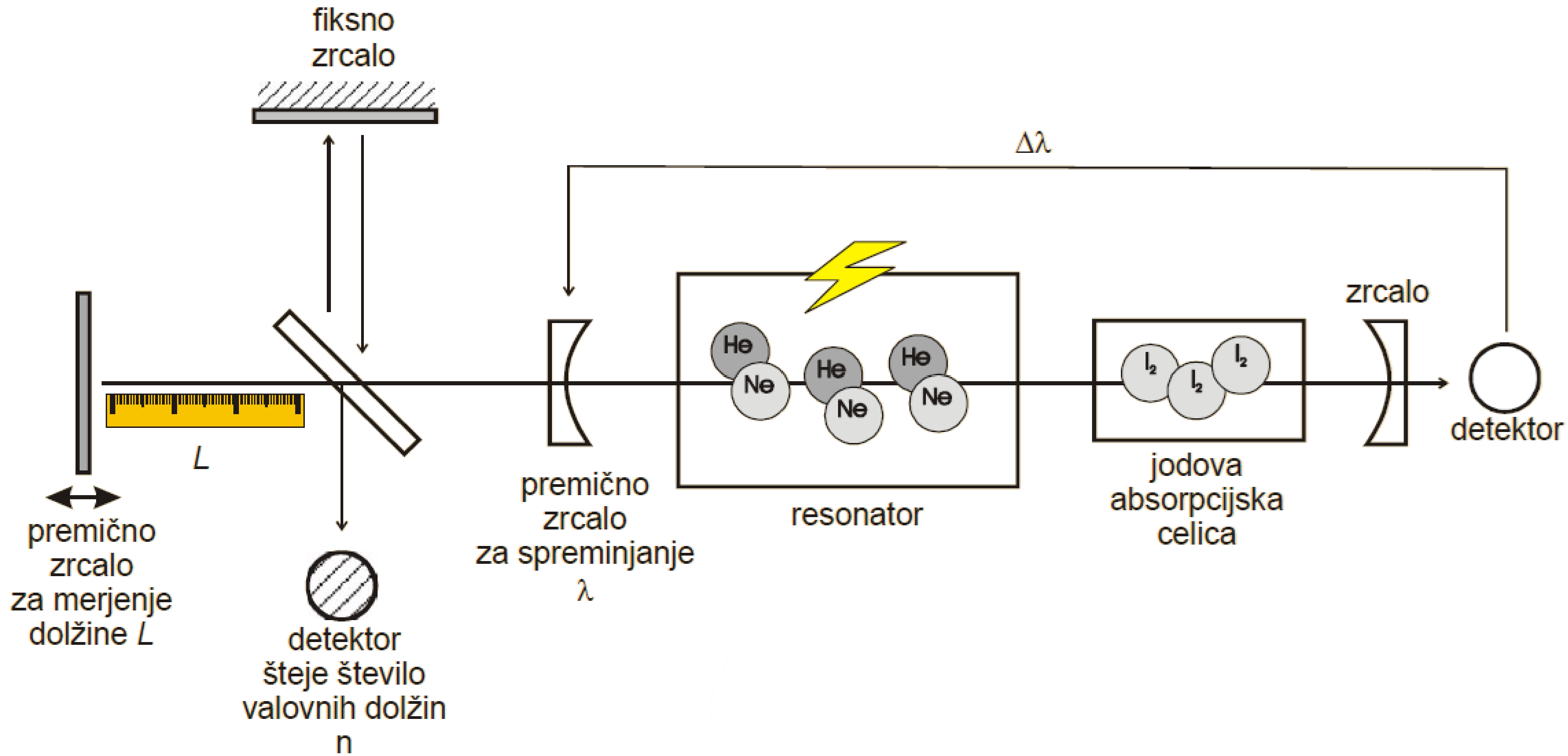
Mean result	299728
Correction for temp. (2.5)	+ 12
Velocity of Light in air	299740
* Correction for vacuo	+ 88
Velocity of Light in vacuo	299828. Kilo-

meters per second.



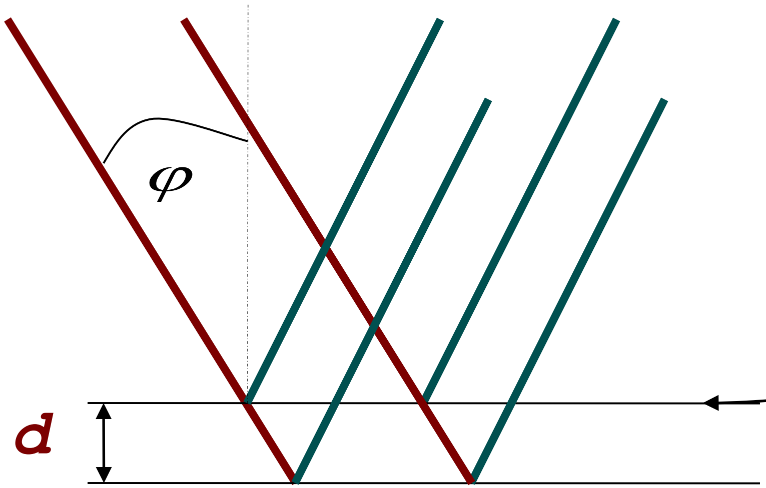
Leta: 1881 in 1887

Realizacija metra s stabiliziranim laserjem in interferometrom



Vir: LMK, FE, UNI-LJ

merjenje tankih plasti



razlika poti: $\delta = 2d - \left(\frac{\lambda}{2}\right)$

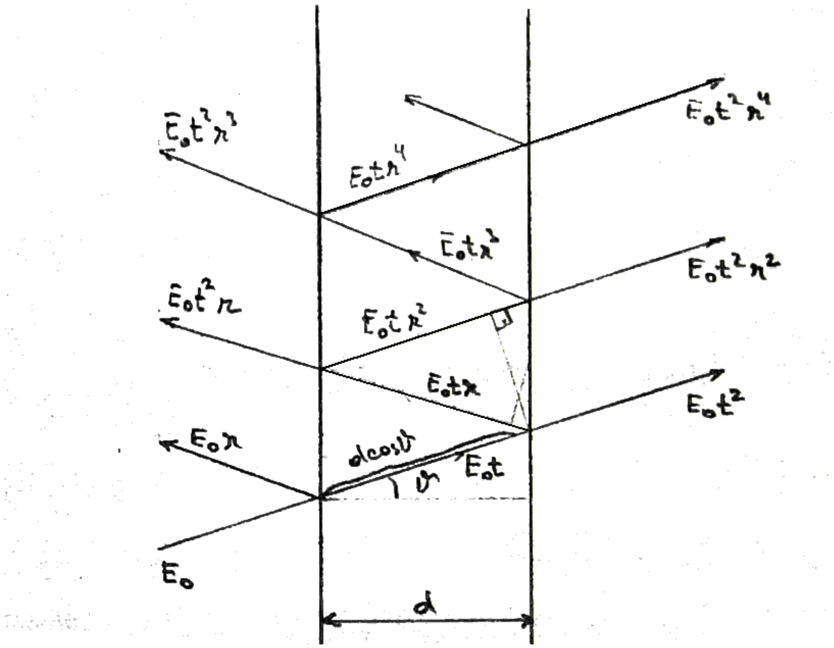
fazni premik zaradi odboja na optično gostejši plasti

pogoj za ojačitev

$$2d - \left(\frac{\lambda}{2}\right) = n\lambda$$

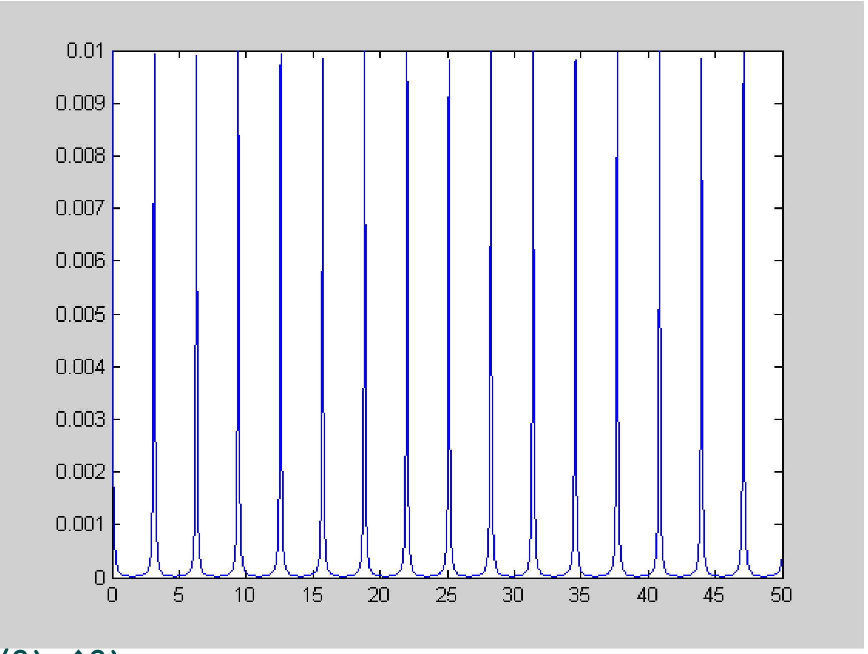
$$d = (2n+1)\frac{\lambda}{4}$$

Fabry-Perotov interferometer



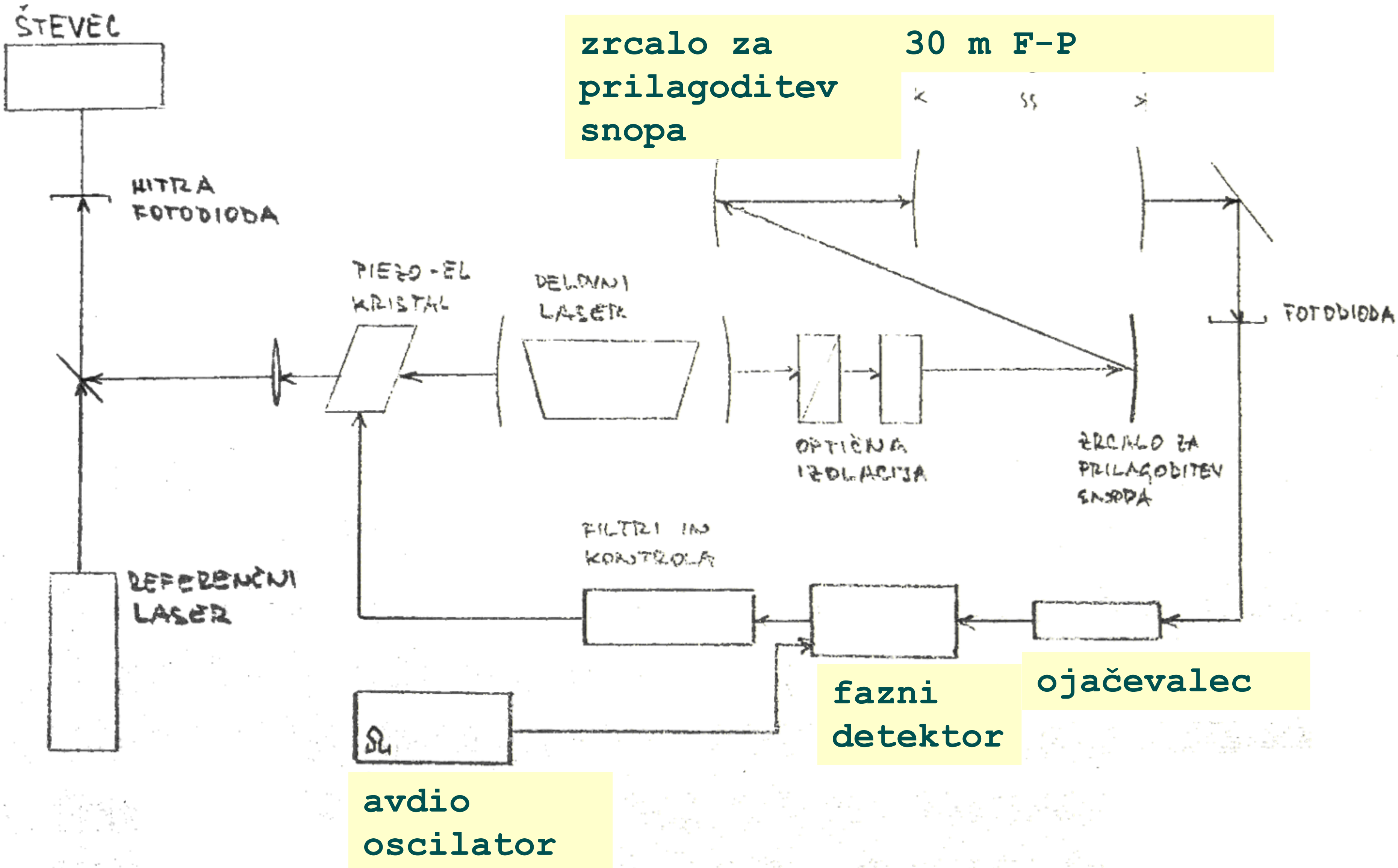
Airy-jeva form.

$$I_T = \frac{I_0}{1+\frac{4R}{(1-R)^2}\sin^2\frac{\Delta}{2}}$$

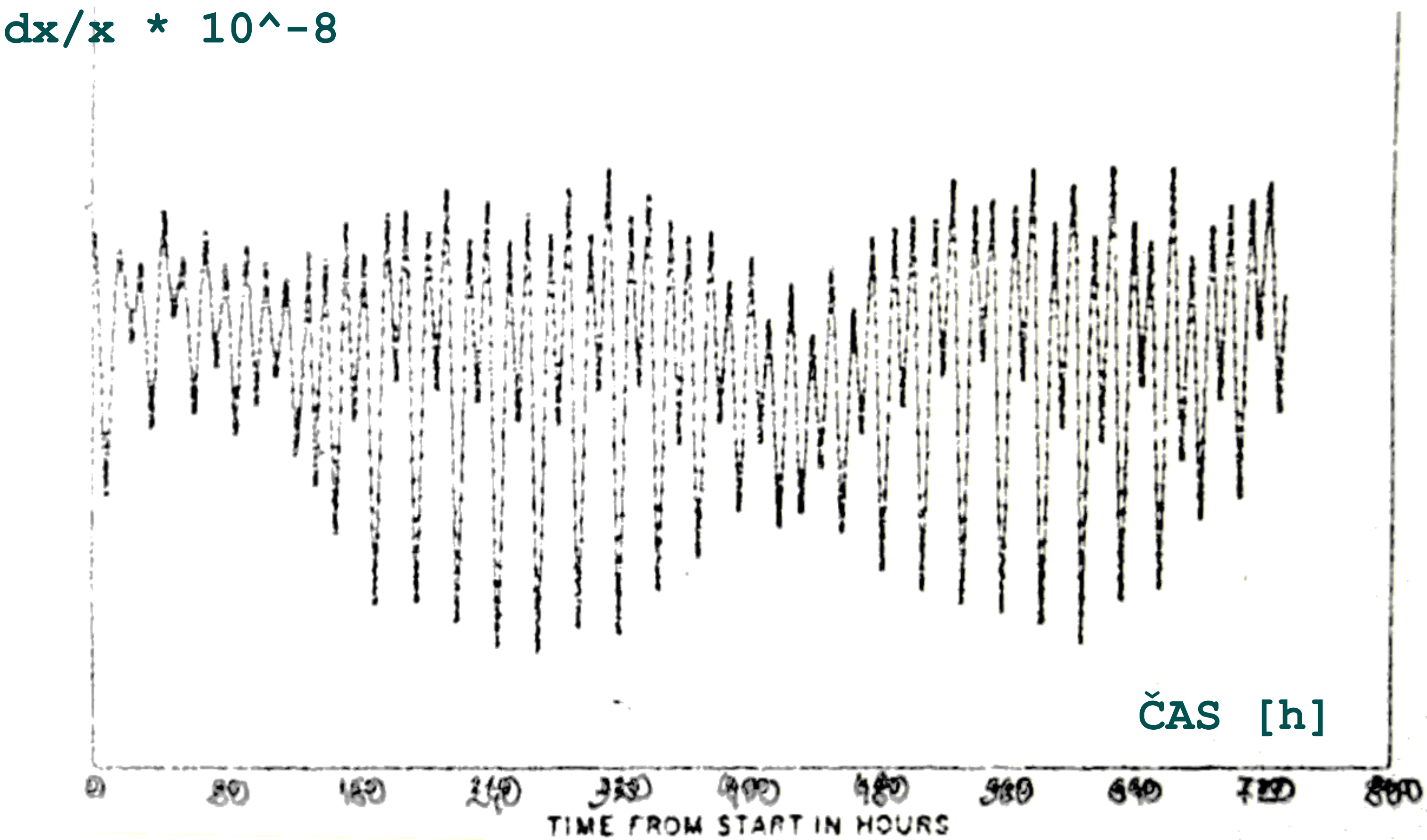



```
R=0.9;
d=0:0.1:20;
It=ones(size(d))./(1+4*R/(1-R).^2*sin(d./2).^2);
```

F-P merilni sistem za meritve majhnih premikov



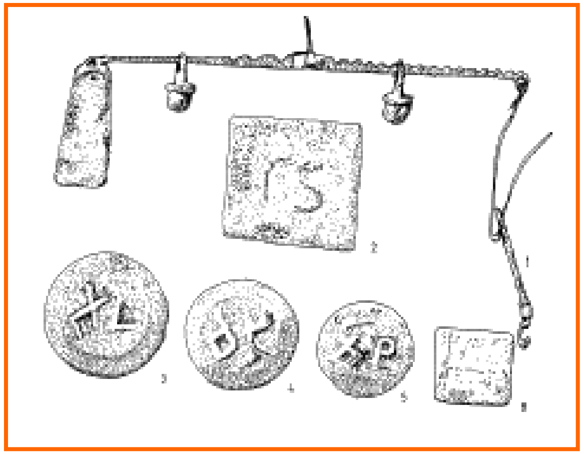
meritve z F-P interferometrom



SI sistem merskih enot - osnovne veličine

veličina	enota	simbol
dolžina	meter	m
masa	kilogram	kg
čas	sekunda	s
električni tok	amper	A
termodinamična temperatura	kelvin	K
množina snovi	mol	mol
svetilnost	kandela	cd

[www.usm.mzt.si/SPLOSNO/si_sistem_me_enot.htm]



Veličina: masa
Enota: kilogram
Simbol:kg

Definicija:

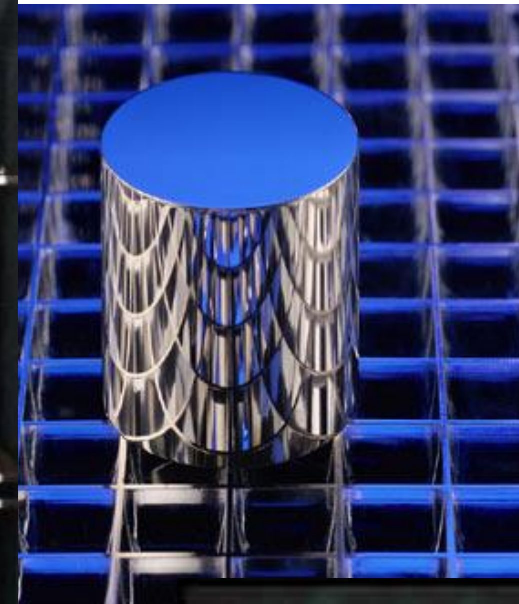
Masa je količina snovi, ki meri upiranje telesa pri pospeševanju in vplivu gravitacijskega polja na telo. Kilogram je enak masi mednarodnega prototipa - prakilograma, ki ga hrani Mednarodni urad za uteži in mere (BIPM) v Parizu. Ker je to kilogram po definiciji in se ne veže na noben naravni pojav ali zakonitost, ta prakilogram nima negotovosti.

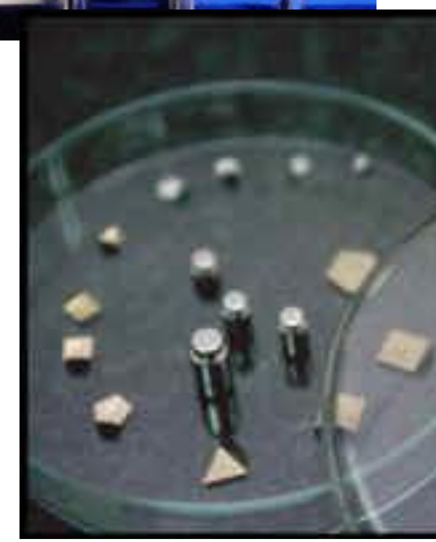
Velikostni razredi

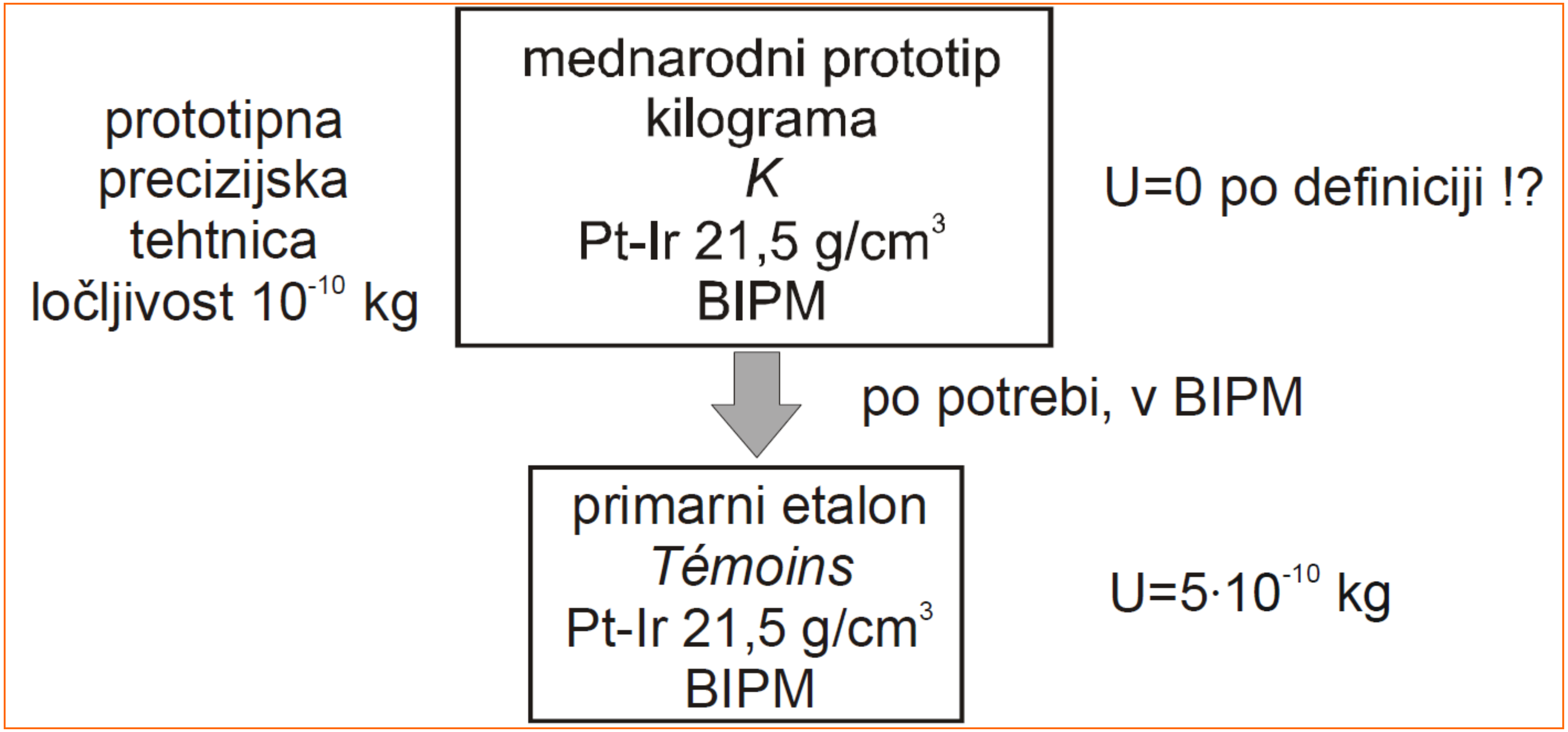
2 000 000 000 000 000 000 000 000 000 000 kg	2×10^{30} kg	Sonce
7 100 000 kg	$7{,}1 \times 10^{6}$ kg	Eifflov stolp
7 500 kg	$7{,}5 \times 10^{3}$ kg	afriški slon
635 kg	635 kg	uradno najdebelejši človek
0,006 4 kg	$6{,}4 \times 10^{-3}$ kg	kovanec za 5 tolarjev
0,000 39 kg	$3{,}9 \times 10^{-4}$ kg	sponka za papir
0,000 000 000 000 000 000 000 000 001 67 kg	$1{,}67 \times 10^{-27}$ kg	masa vodikovega atoma

Vir: LMK, FE, UNI-LJ

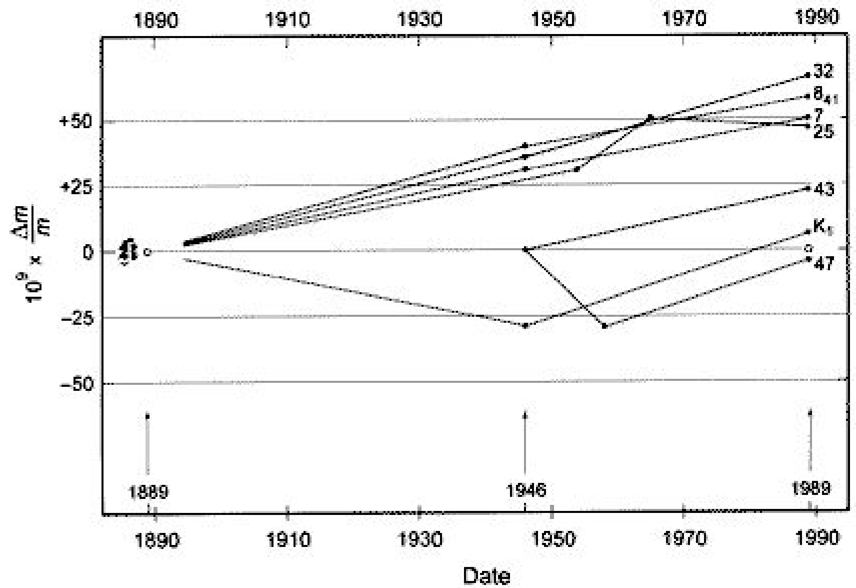
Pra-kilogram

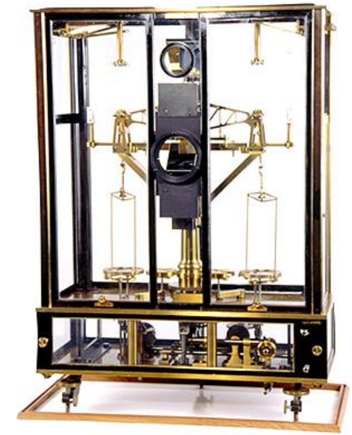






- **izdelan leta 1879, izbran za K leta 1883**
- **material 90% Pt in 10% Ir**
- **gostota 21500 kg/m3(jeklo 8 000 kg/m3)**
- **premer in višina okoli 39 mm**
- **hranjen na temperaturi 19°C ±1°C**
- **pod tremi steklenimi zvoni v Parizu**
- **do sedaj le 3x uporabljen v neposredni primerjavi in sicer leta 1889, 1946 in 1989**





NIST: 1945 - 1960

Témoins so bili do sedaj le trikrat primerjani s prakilogramom K. Pri tem je bilo ugotovljeno, da njihove mase proti K v stotih letih povprečno rastejo za okoli 0.5 µg/leto.

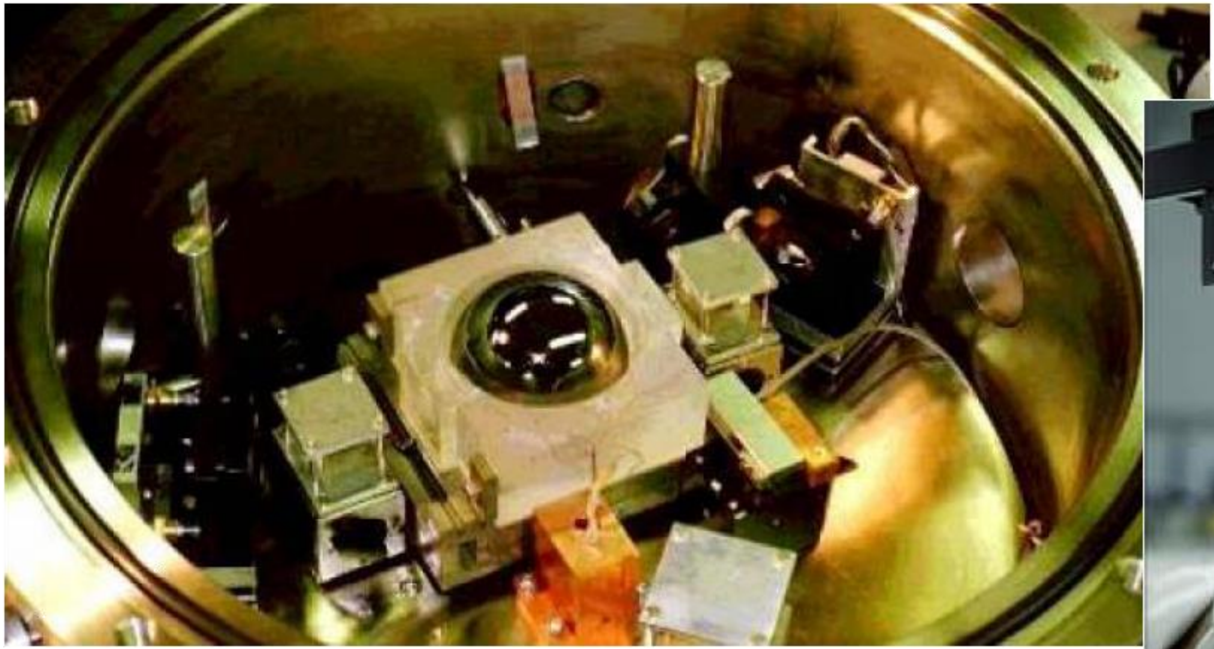
Vir: LMK, FE, UNI-LJ

Problematika obstoječe definicije kilograma

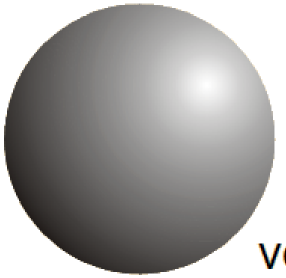
- K je fizično telo iz kovine(poškodbe)
- časovno spremenljiv(ni točno znano, kako)
- dostopen le na enem mestu na Zemlji

Nastopa tudi v definiciji ampera, mola in kandele!

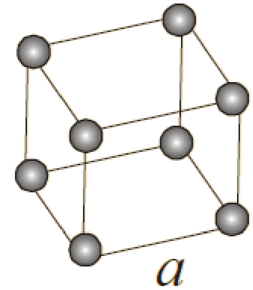
Projekt Avogadro



Merjenje premera silicijeve krogle z lasersko interferometrijo.
Premer krogle se lahko določi z relativno negotovostjo 10^{-7}



volumen krogle V



$$n_{Si} = 8\frac{V}{a^3}$$

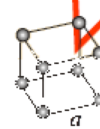
$m = m_{Si}\ n_{Si}$ masa krogle = masa enega Si atoma × število Si atomov

$$\boxed{m = 8\frac{M_{Si}}{N_A}\frac{V}{a^3}}$$

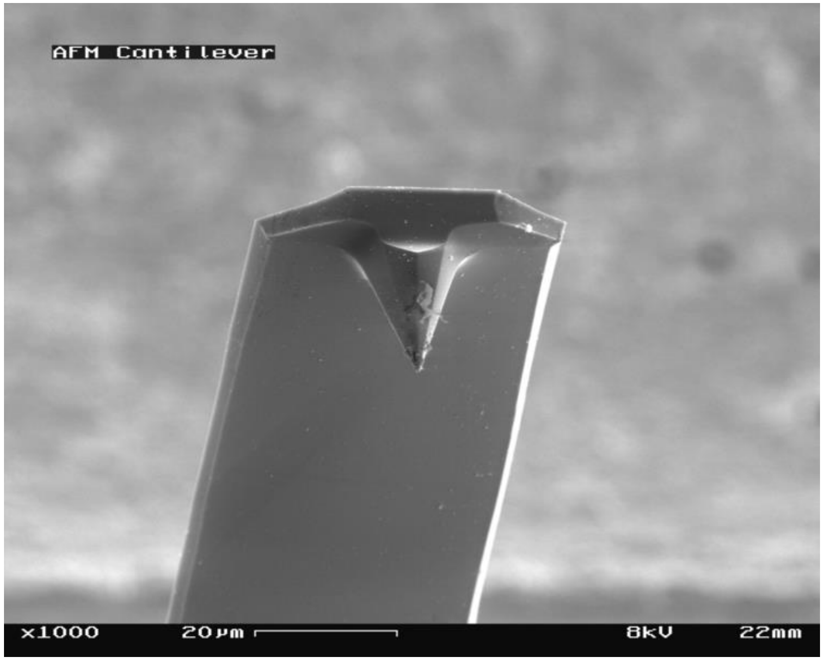
negotovost metode

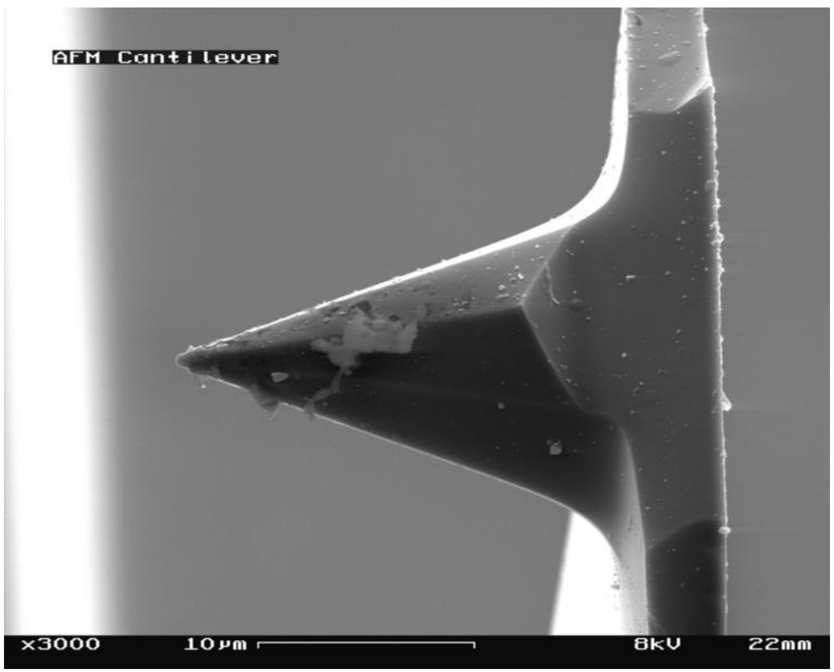
2×10^{-7}

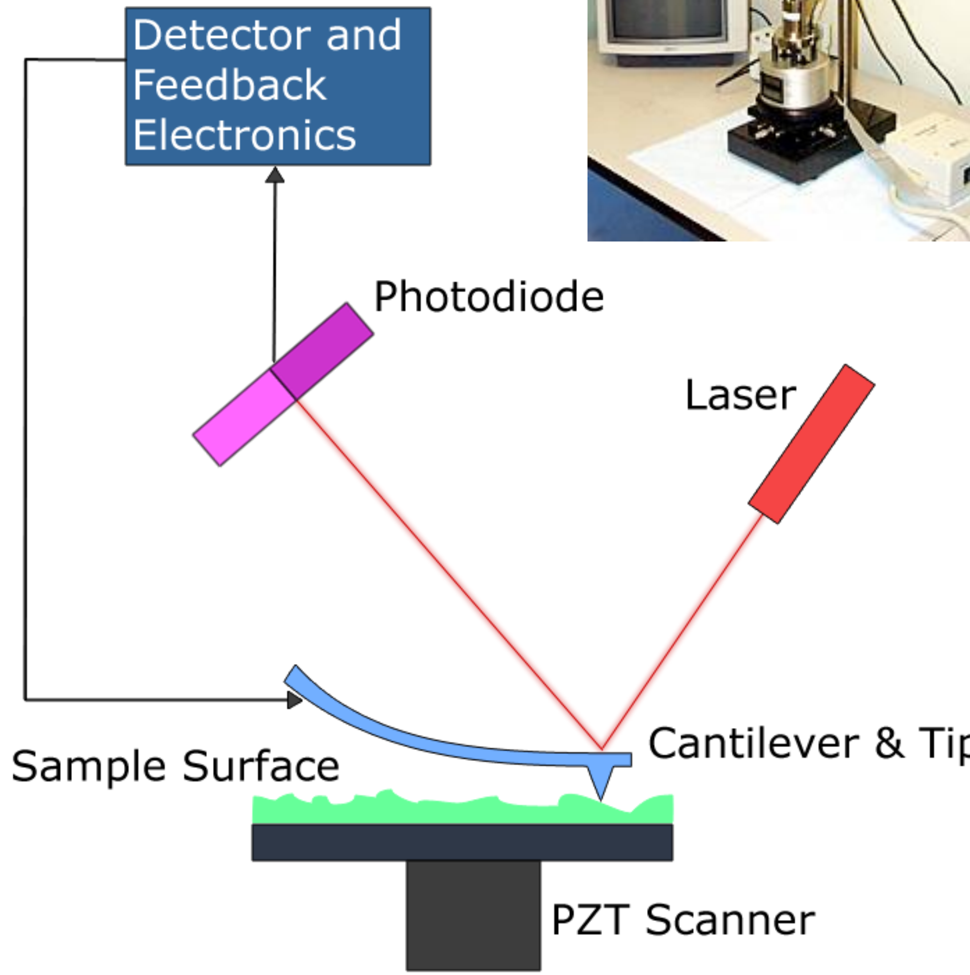
M_{Si} - molarna masa Si
V - prostornina
N_A - Avogadrovego število
a - stranica kubičnega elementa Si

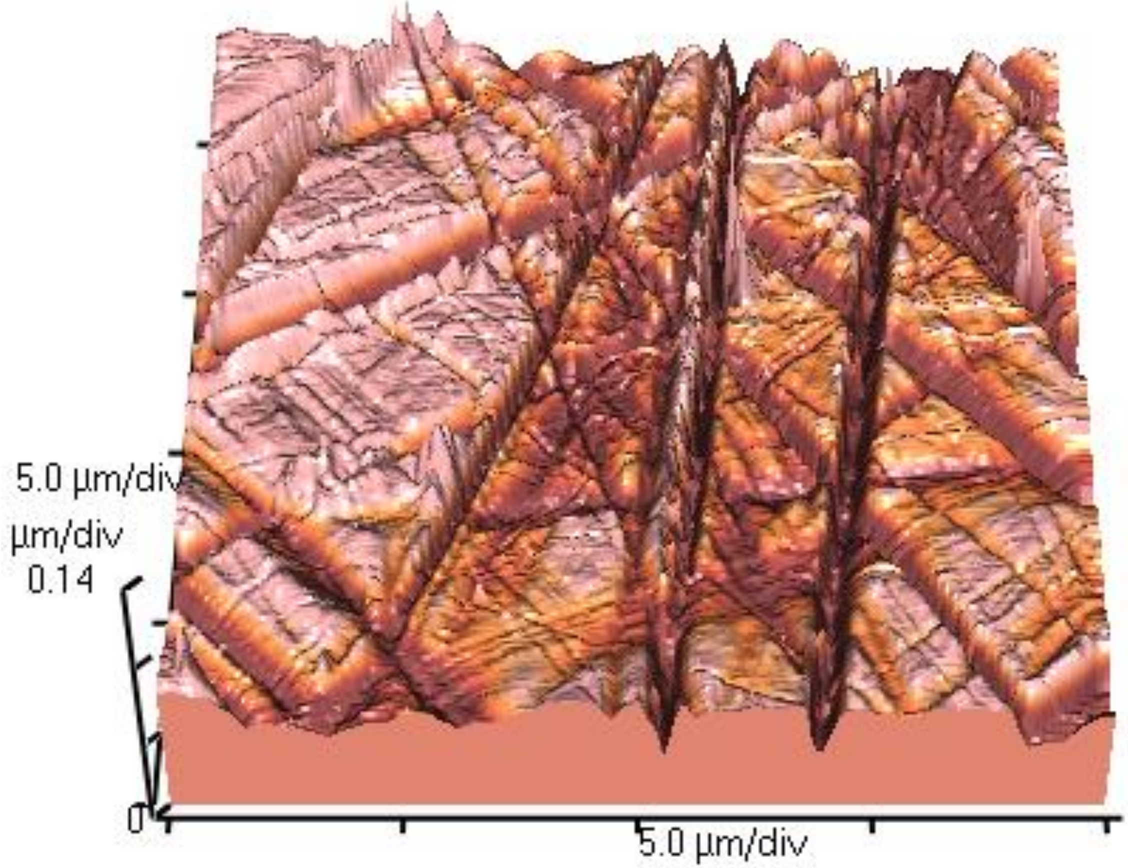


Vir: LMK, FE, UNI-LJ

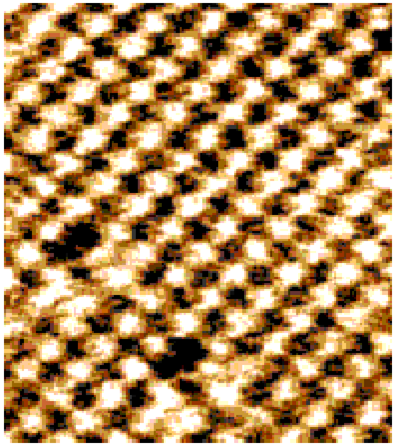

AFM Cantilever
x1000
20µm
8kV
22mm


AFM Cantilever
x3000
10µm
8kV
22mm

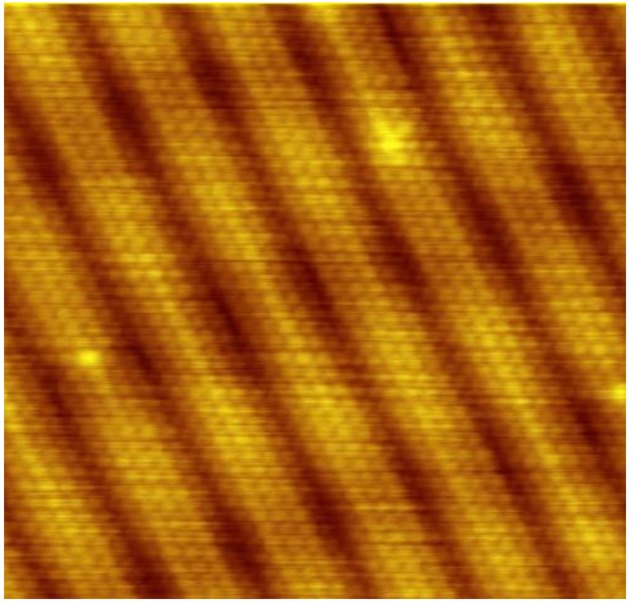

Detector and Feedback Electronics
Photodiode
Laser
Cantilever & Tip
Sample Surface
PZT Scanner



površina stekla



kristal NaCl



površina zlata STM

Realizacija enote za čas skozi zgodovino

leto	realizacija	ocenjena negotovost ure
3500 p.n.š.	sončna ura	± 10 minut
17	ura na nihalo	± 10 sekund na dan
1762	Harrisonov kronometer	± 1 sekunda na 3 dni
okoli 1930	vrtenje Zemlje	± 1 sekunda na 3 leta
okoli 1950	kvarčna zapestna ura	± 1 sekunda na 30 let
1955	Essnova cezijeva ura	± 1 sekunda na 300 let
1980	moderna cezijeva ura	± 1 sekunda na 300 000 let
1995	cezijeva fontana	± 1 sekunda na 15 000 000 let
21. stoletje	atomska ura z ionsko pastjo	± 1 sekunda na 15 000 000 000 let

Vir: LMK, FE, UNI-LJ

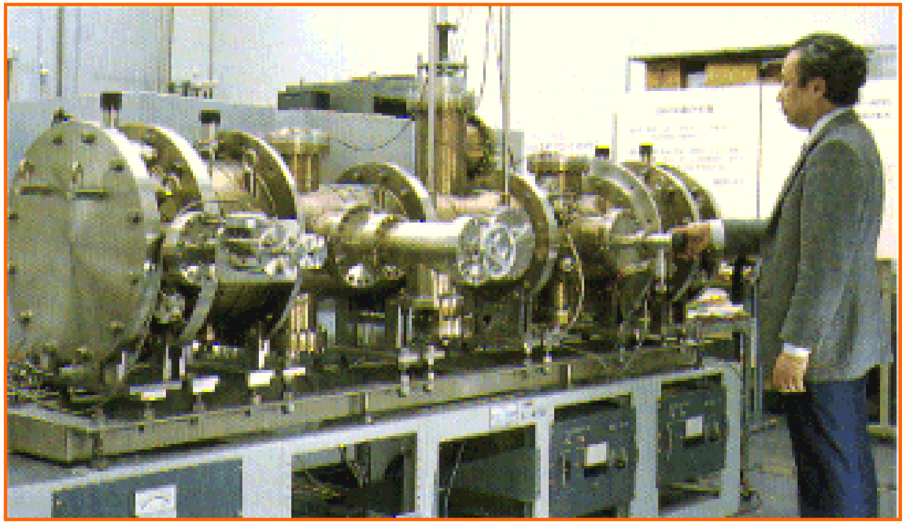
v 2000 letih se je zemlja zaradi plimovanja upočasnila rotacija zemlje. Komulativno smo "izgubili" 3 ure. Danes je dan za 0,0016 s daljši kot pred 100 leti.

Veličina: čas
Enota: sekunda
Simbol: s

čas

oscilator – vir enakomernih utripov

Umetnost zasnove in izdelave natančne ure se skriva v znanju kako oscilator zaščititi pred zunanjimi vplivi.



primer standarda za intervalne meritve časa v ZDA med 1904 in 1929

DEFINICIJA ČASA SE JE SPREMINJALA:

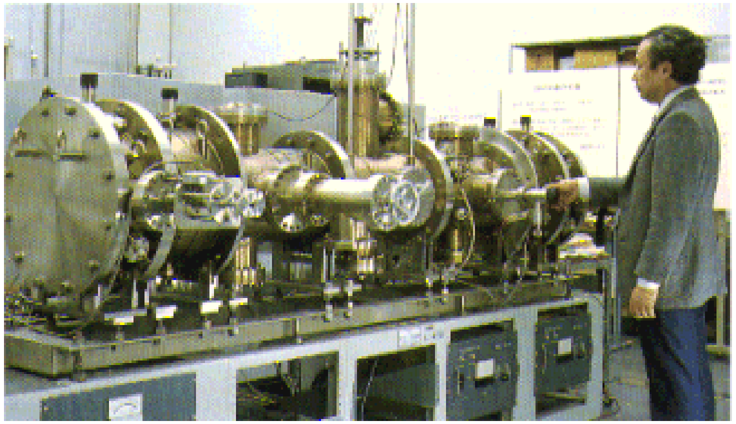
→ 1956 z rotacijo zemlje okoli osi
1 dan = 86.400 s

1956 → 1967 z rotacijo zemlje okoli sonca
1 leto = 31.556.925.974 s

1967 → danes z nihaji atomske ure ^{133}Cs
1 s = 9.192.631.770

čas

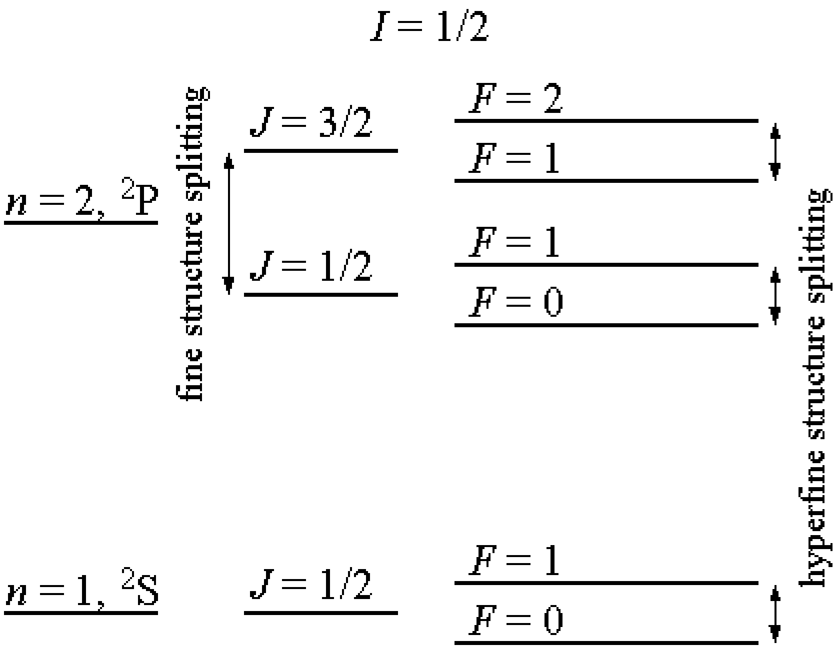
Veličina: čas
Enota: sekunda
Simbol: s



Definicija:

Sekunda je trajanje 9.192.631.770 period sevanja, ki ustreza prehodu med dvema hiperfinima nivojema osnovnega stanja atoma cezija 133.

Ralizacija sekunde se vrši s pomočjo cezijeve ure, ki ima pogrešek eno sekundo v 300.000 letih.



Primer hiperfinega razcepa za vodik

oscilator ki izpolnjuje zahtevo je atom cezija ^{133}Cs.
Zunanji e^- ima lahko dva spina ➔ dve fina struktura
magnetni moment zaradi različnega spina in stanja krožnega vrtilnega momenta ➔ hipefina struktura ^{133}Cs.
Med stanjema preklapljamo z zunanjo motnjo – EM valovanjem.
Frekvenca fotonov, ki preklapljajo med stanjema je ~9,2GHz.

ATOMSKA URA S POVRATNO ZANKO USKLADI FREKVENCO EM VALOV S FREKVENCO PREHODA MED HIPERFINIMA STANJEMA ^{133}Cs.

I.I.Rabi, Nobelova nagrada 1944
N. Ramsey v ’50 izboljšal metodo, Nobelova nagrada 1989

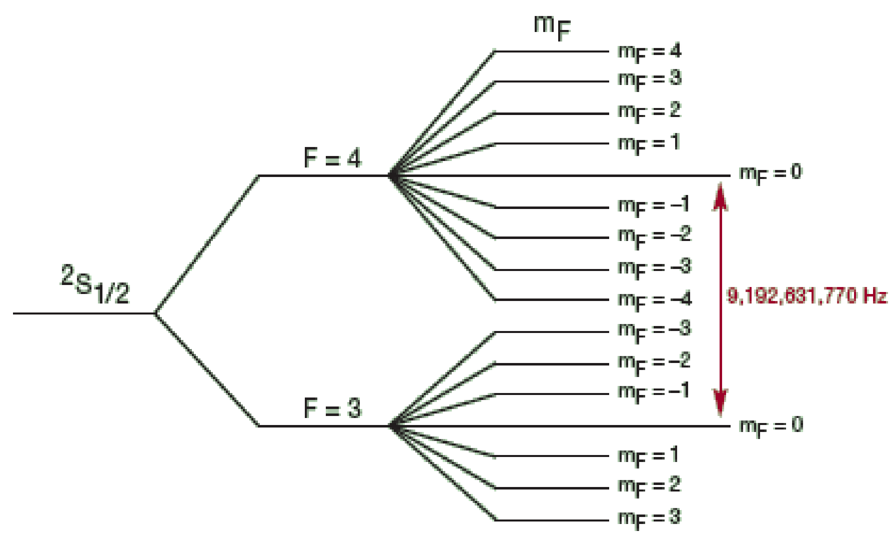
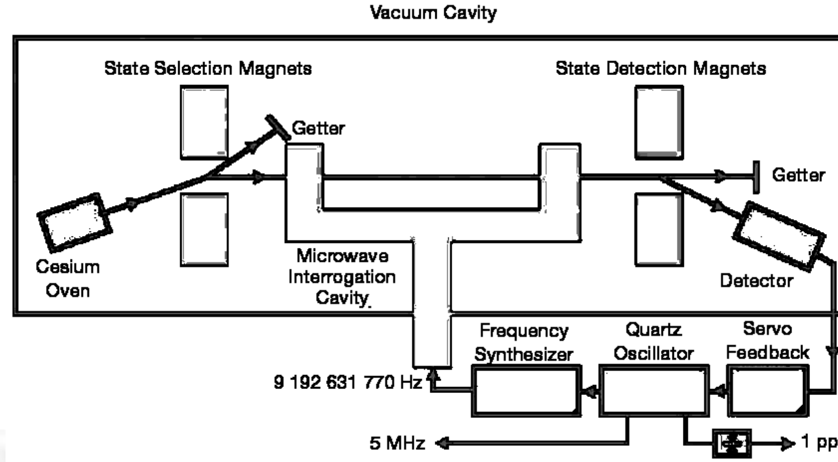
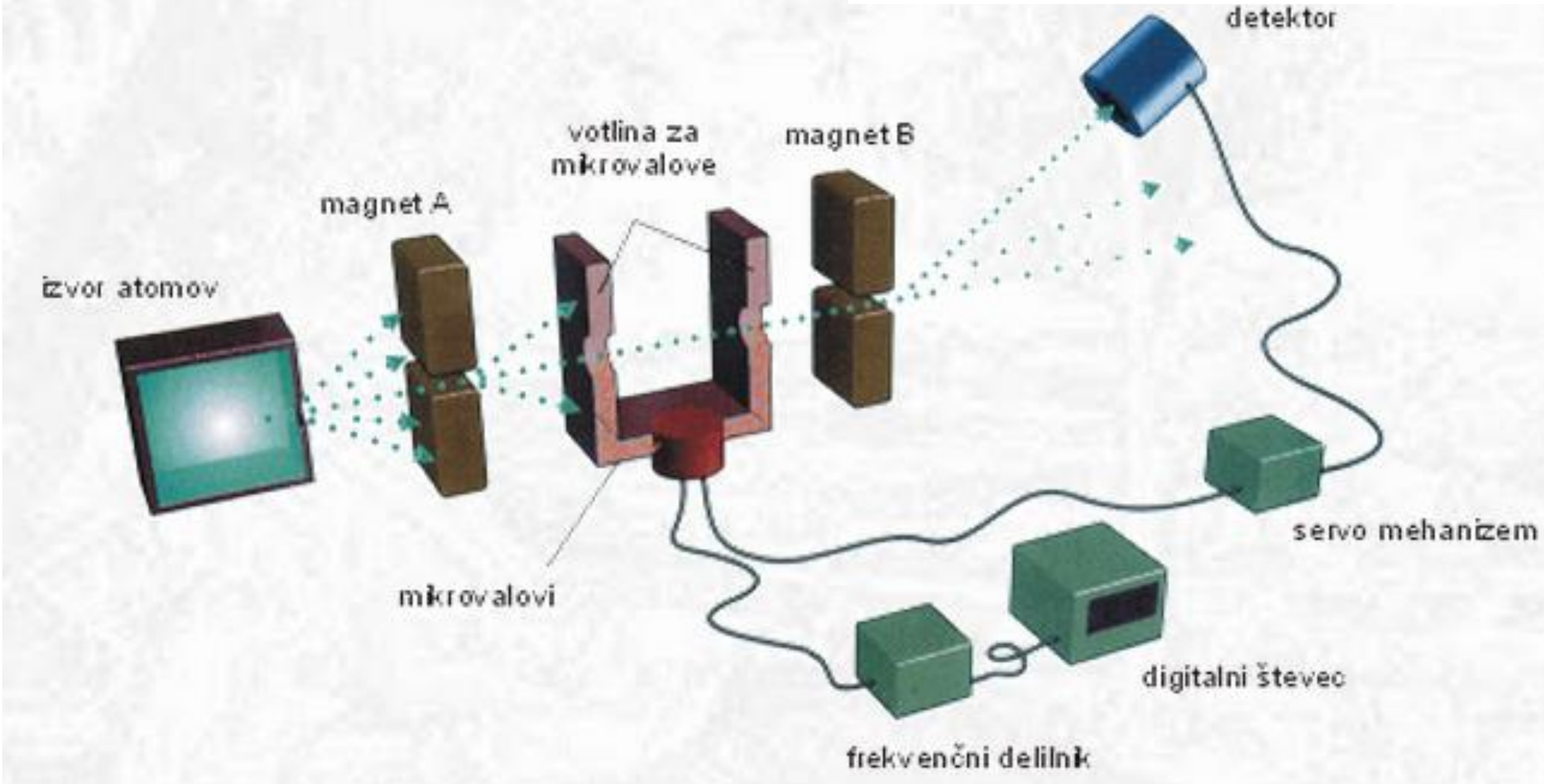


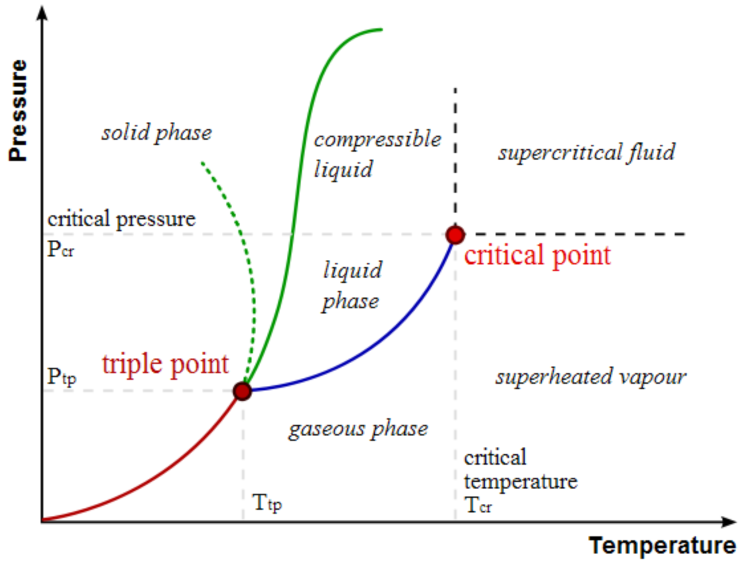
Figure 8. Schematic diagram of the cesium clock transition.

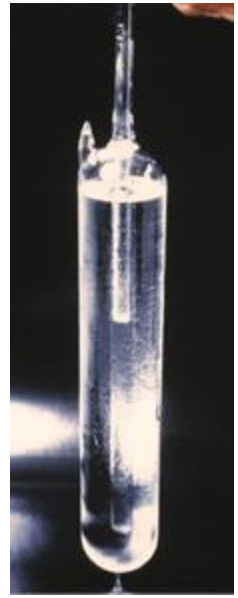
Danes uporabljamo oscilatorje iz atomskega sveta. Tudi ti oscilatorji so obremenjeni z motnjami:

- trki med atomi,
- trki z naključnimi fotoni,
- motnje zaradi zunanjih magnetnih polj,
- Dopplerjev pojav zaradi lastnega gibanja atomov
- širino frekvence EM sevanja določa načelo nedoločenosti.









termodinamična temperatura

Veličina: Termodinamična temp.

Enota: kelvin

Simbol: K

Definicija:

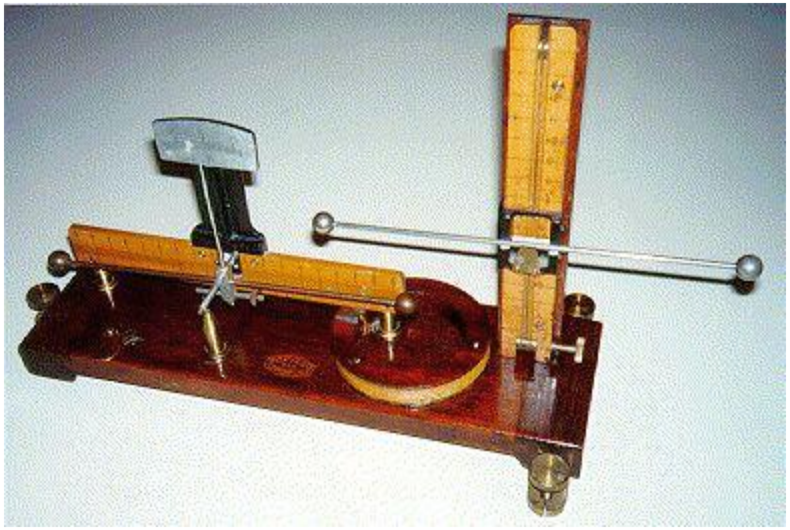
Kelvin je enota termodinamične temperature, ki je enaka 273,16 delu termodinamične temperature trojne točke vode. Temperatura trojne točke vode v diagramu stanj ustreza trojnemu stanju, kjer so pri določenem tlaku v ravnovesju vse tri agregatne faze čiste snovi: trdna (led), kapljevinska (tekoča voda), plinska (vodna para).

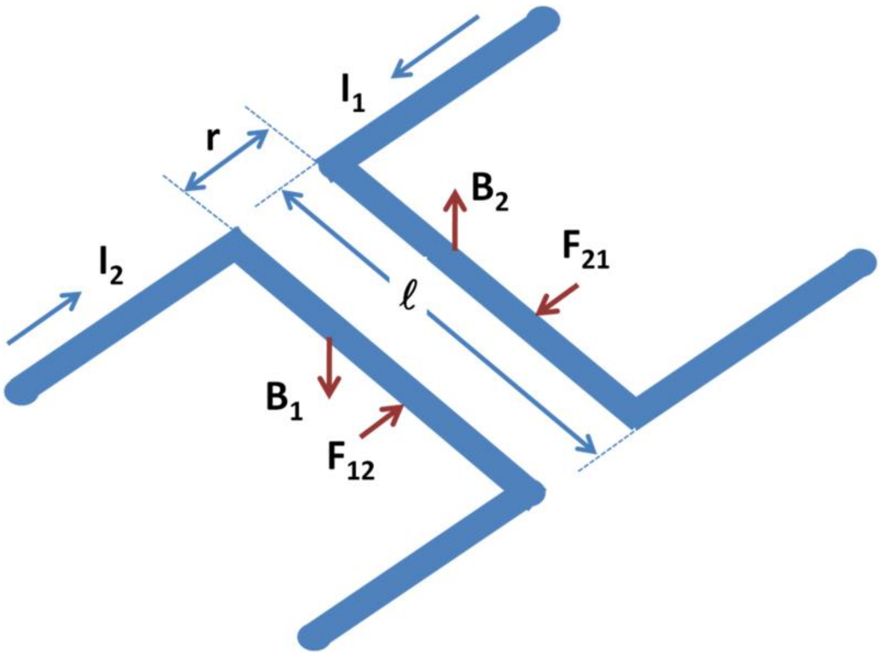
Realizacija termodinamične temperature temelji na trojni točki vode, (izvedeni v posebni celici) fiksne točke ITS.

Veličina: električni tok

Enota: amper

Simbol: A





Definicija:

Amper je jakost enosmernega električnega toka, ki povzroča v vakuumu pri prehodu skozi dva ravna, en meter oddaljena, neskončno dolga, vzporedna vodnika z zanemarljivo majhnim krožnim presekom silo 2.10-7 N na meter dolžine.

Realizacija ampera se vrši s pomočjo tokovne tehtnice.

množina snovi

Veličina: množina snovi
Enota: mol
Simbol: mol

Definicija:
Mol je tista množina snovi, ki vsebuje toliko delcev, kolikor je atomov v 12 gramih ogljikovega izotopa ^{12}C.
Mol ni realiziran neposredno iz definicije, pač pa na različne posredne načine.

V 12 g C12 je NA atomov.
$N_A = 6.02214179(30) \times 10^{23}$

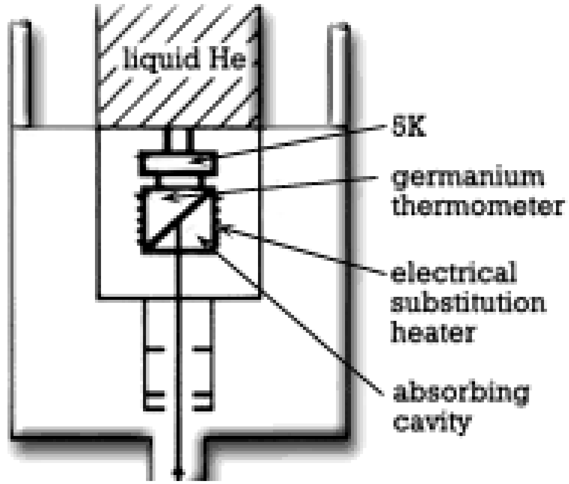
Silicijeva sfera za določitev NA

Veličina: svetilnost
Enota: kandela
Simbol: cd

Definicija:

Kandela je svetilnost vira sevanja v določeni smeri, ki oddaja monokromatsko sevanje s frekvenco 540 THz in katerega energijska jakost v tej smeri je 1/683 (W/sr).

Realizacija kandele se vrši s pomočjo kyrogenskega radiometra, ki primerja učinek segrevanja optičnega sevanja z električno močjo



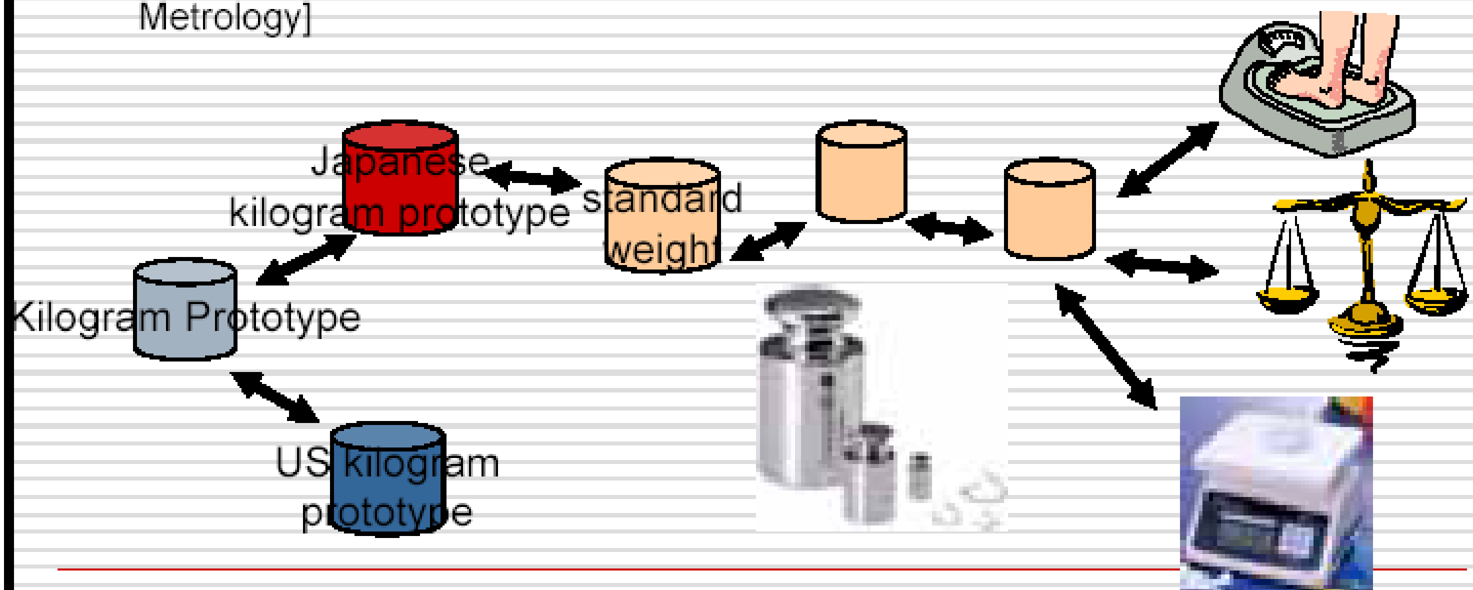
Vprašanja

- Čemu je namenjen mednarodni merski sistem?
- Ali je dolžina določena s postopkom ali prototipom?
- Kako je določena enota za maso?

Sledljivost meril

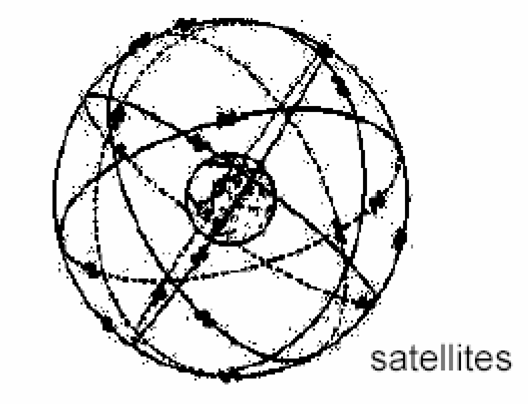
Traceability

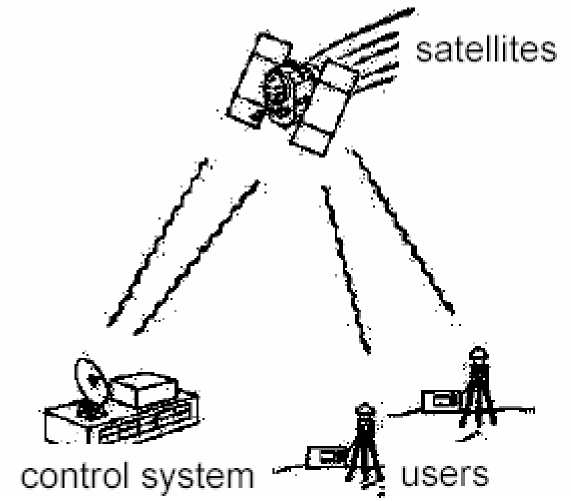
- Property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties. [International Vocabulary of Basic and General Terms in Metrology]



Koncept sledljivosti na primeru GPS

NAVSTAR GPS
(Navigational Satellite Timing and Ranging –
Global Positioning System)

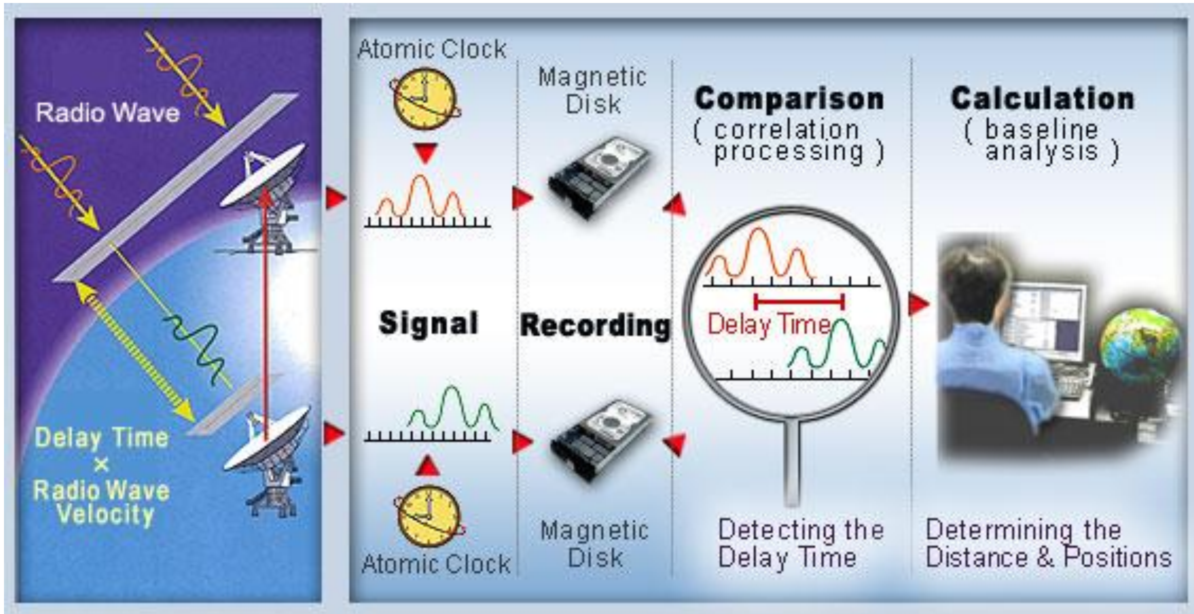




3D pozicijo in čas, kjerkoli na Zemlji lahko določimo s pomočjo sistema umetnih satelitov - GPS.

GSI VLBI

Very Long Baseline Interferometry by Geographical Survey Institute, Japan

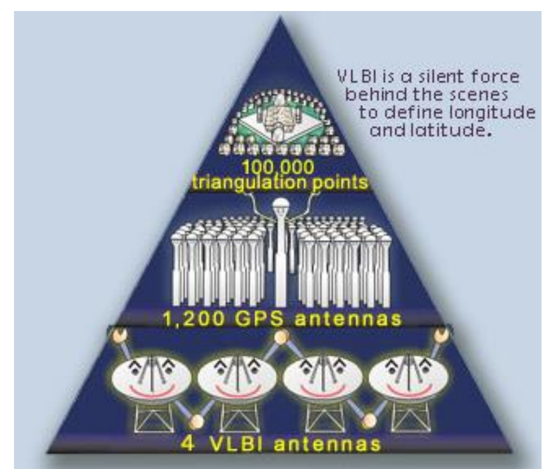


Land surveying and navigation require a geodetic reference system, a combination of ground-based control points and a set of site coordinates of those points. With the introduction of space geodetic techniques such as VLBI and GPS that can measure the Earth from space, the world common geodetic reference system becomes reality for the first time.

In Japan, as of April 2002, the century old Tokyo Datum was legally superseded by a brand new one, the Japanese Geodetic Datum 2000 (JGD2000), which is a local realization of International Terrestrial Reference System.

VLBI je zemljemerska tehnika, ki lahko meri razdaljo med mnogo tisoč kilometrov oddaljenimi antenami na zemlji z natančnostjo nekaj milimetrov.

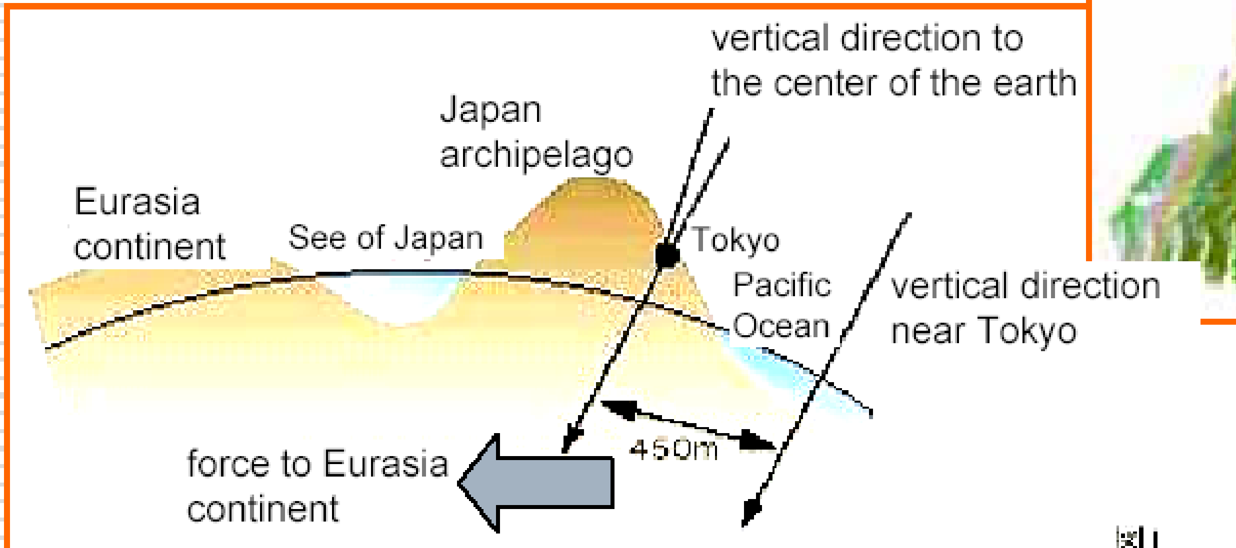
Metoda temelji na zaznavanju skoraj vzporednih radijskih valov iz izvorov (quasi-stellar radio sources = quasar), ki so oddaljenih ~10^9 svetlobnih let.



vir: http://vldb.gsi.go.jp/sokuchi/vlbi/en/whatisvlbi/principle.html

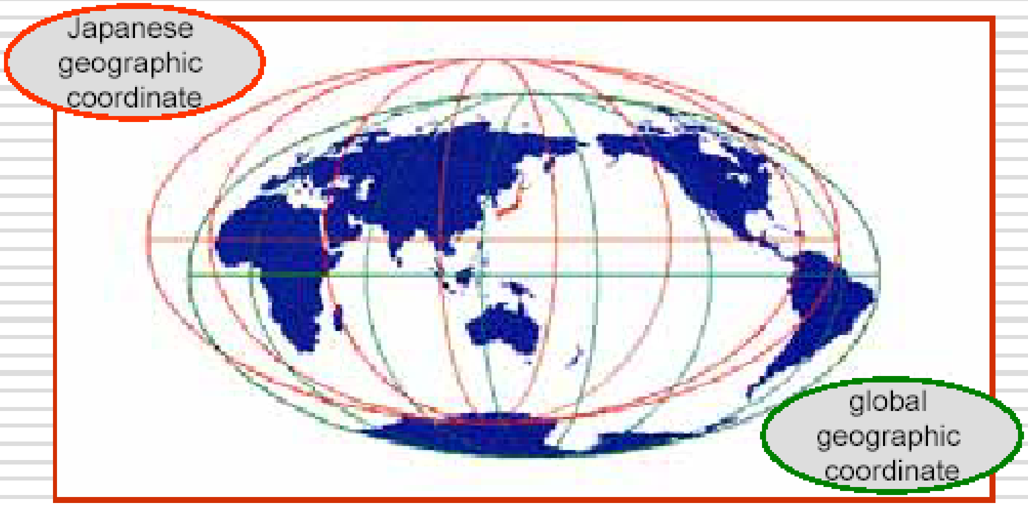
Movement of Japanese Archipelago ?

- By the positional measurement by GPS, Japanese archipelago moved by 450 m to southeastward.
- Why Japanese archipelago moved?



Global Geographic Coordinate System

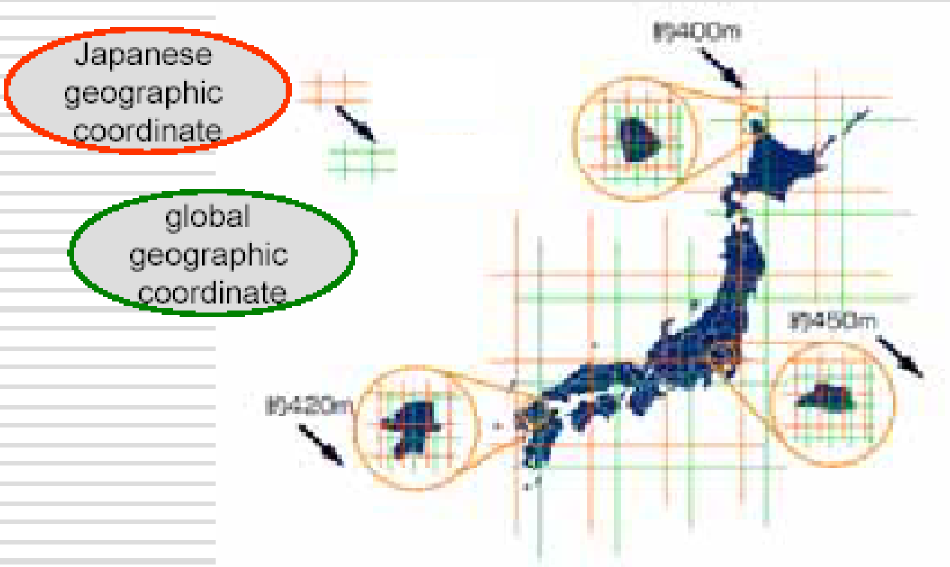
- Longitude and latitude are the scale to measure the earth
  - The absolute scale in Japan is deferent from the global scale.
  - The high accuracy of scale does not mean the absolute correctness of the scale.
- Japanese geographic coordinate system changed to the global geographic coordinate system on 1st April 2002.



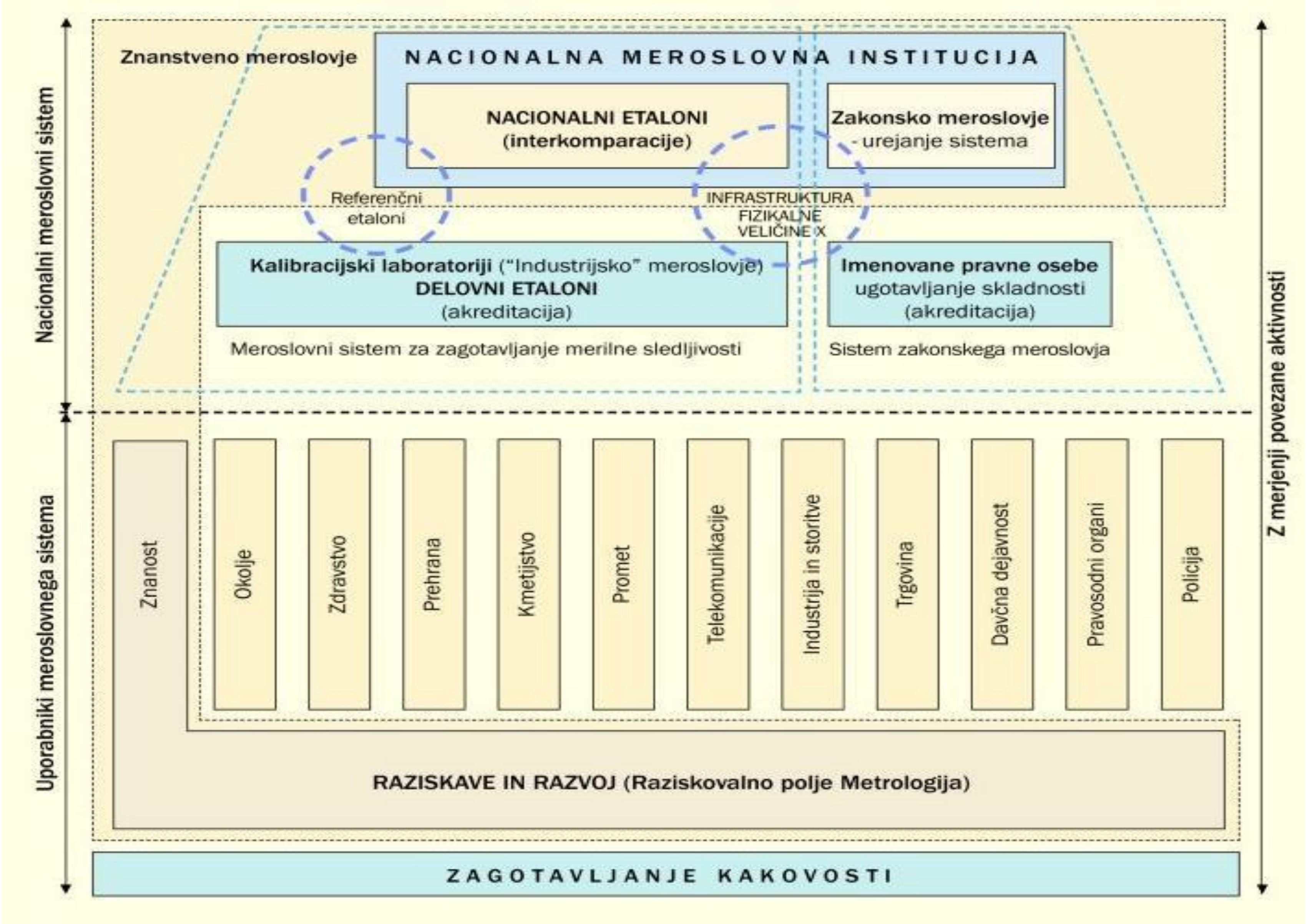
Differences of geographic coordinate systems

- Differences between global and Japanese geographic coordinate systems
- Latitude differences longitude differences

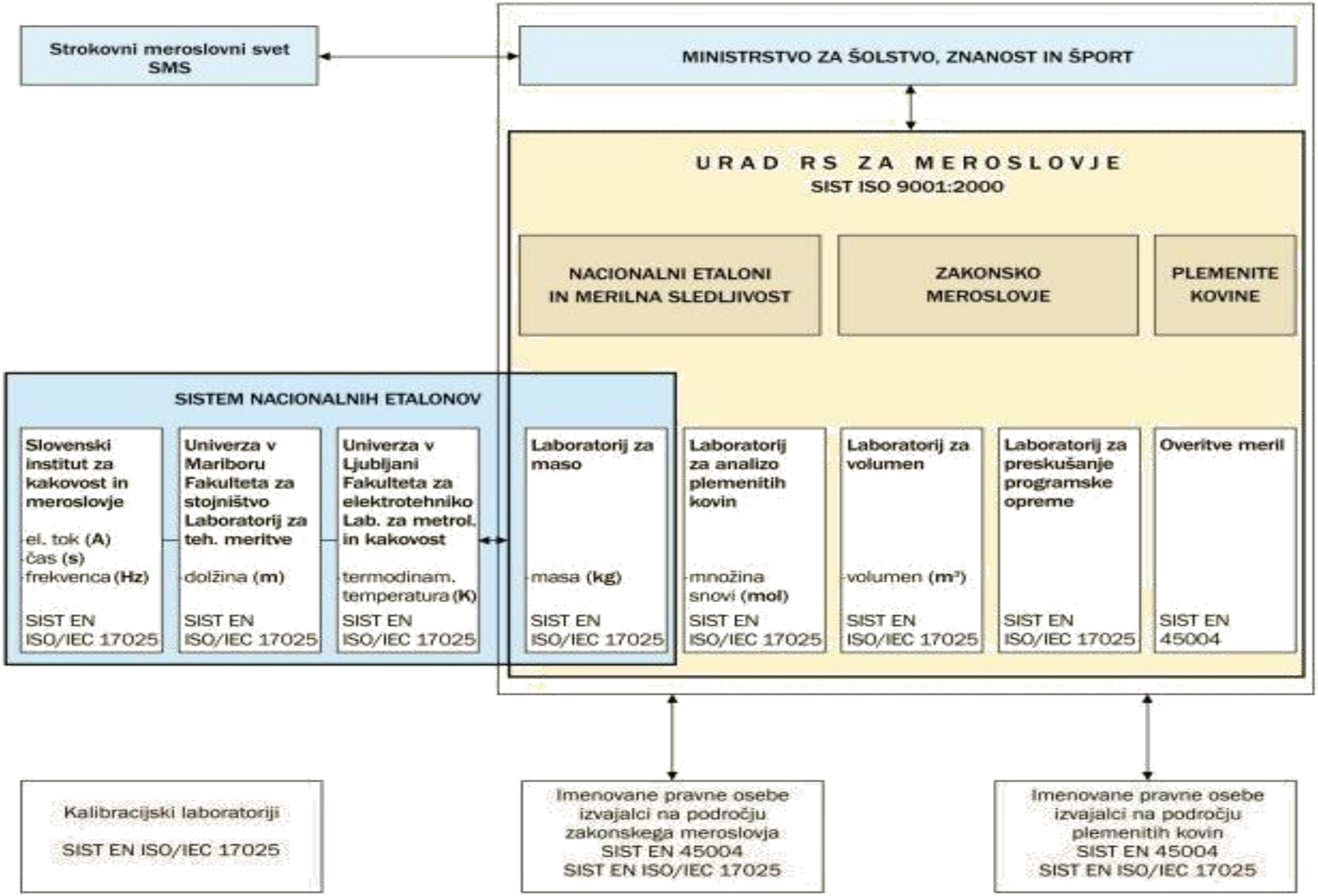
Wakkanai	+8 second (240 m)	-14 second (350m)
Tokyo	+12 second (360 m)	-12 second (300m)
Fukuoka	+12 second (360m)	-8 second (200m)
Naha	+14 second (420m)	-7 second (180m)



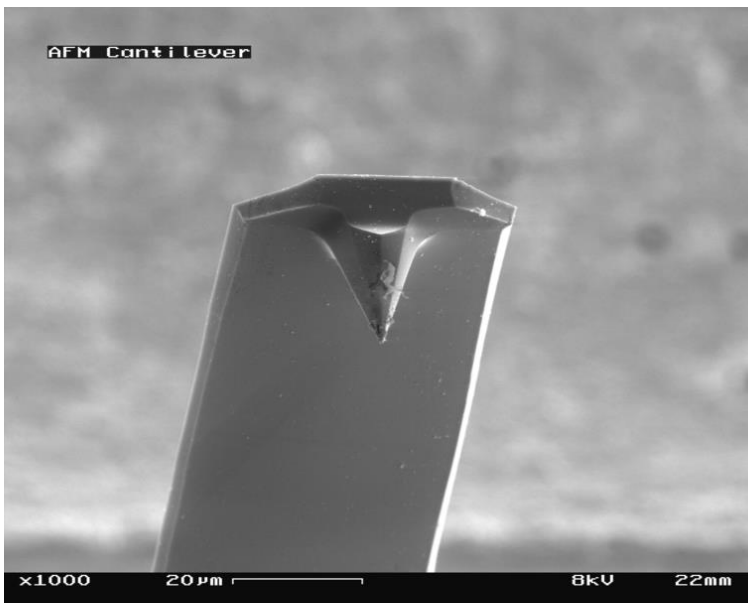
NACIONALNI MEROSLOVNI SISTEM

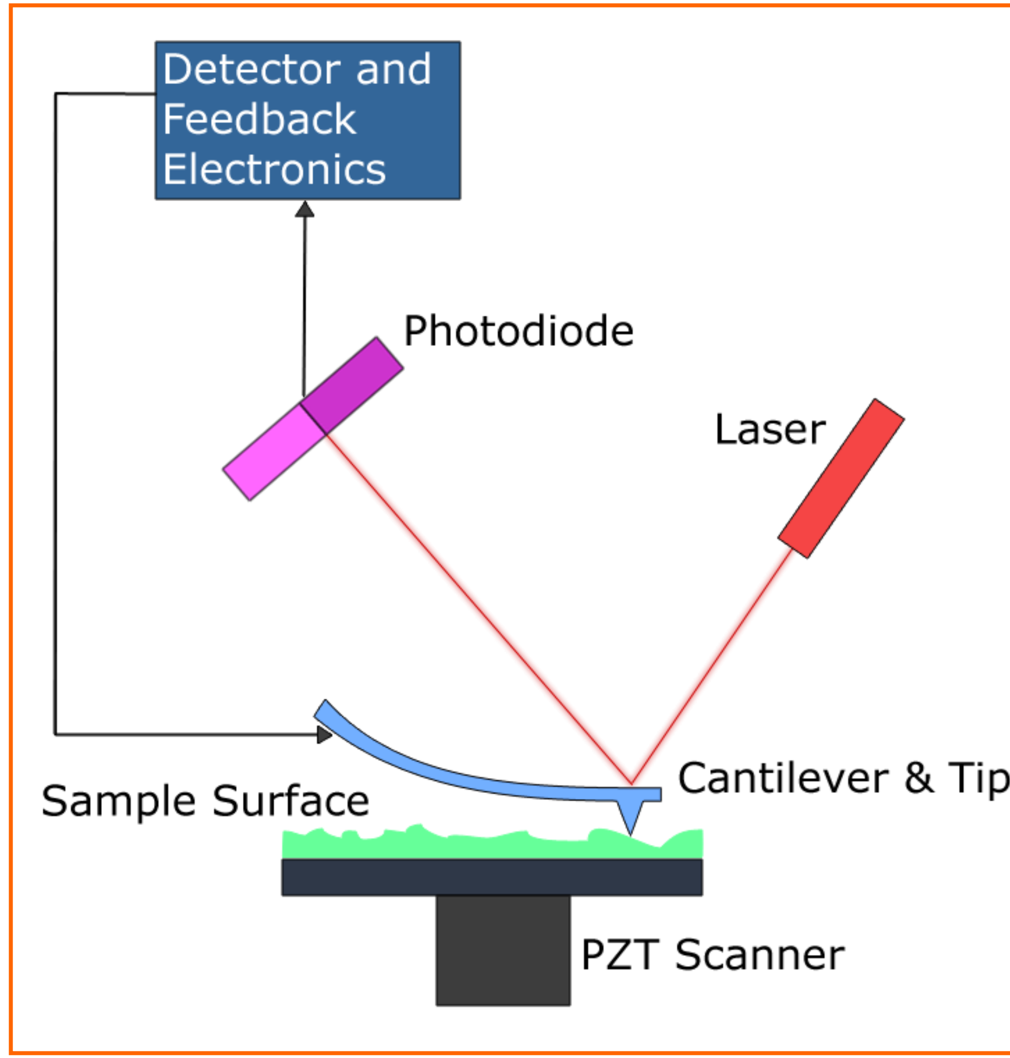


DISTRIBUIRAN MEROSLOVNI SISTEM

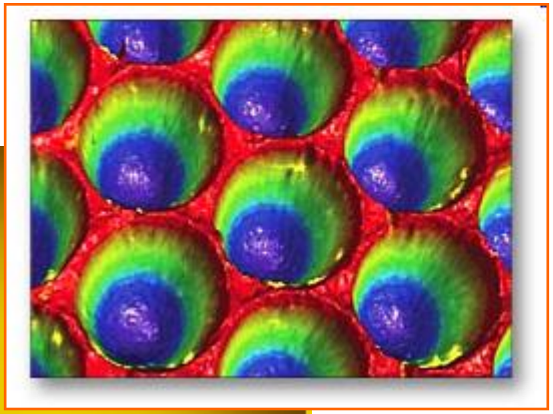


Delovanje AFM demonstrira:
SPM_as_a_surface_analyser.flv





Interferometer na belo svetlobo
White light scanning interferometer



Zmogljivosti WLSI
White light scanning interferometer

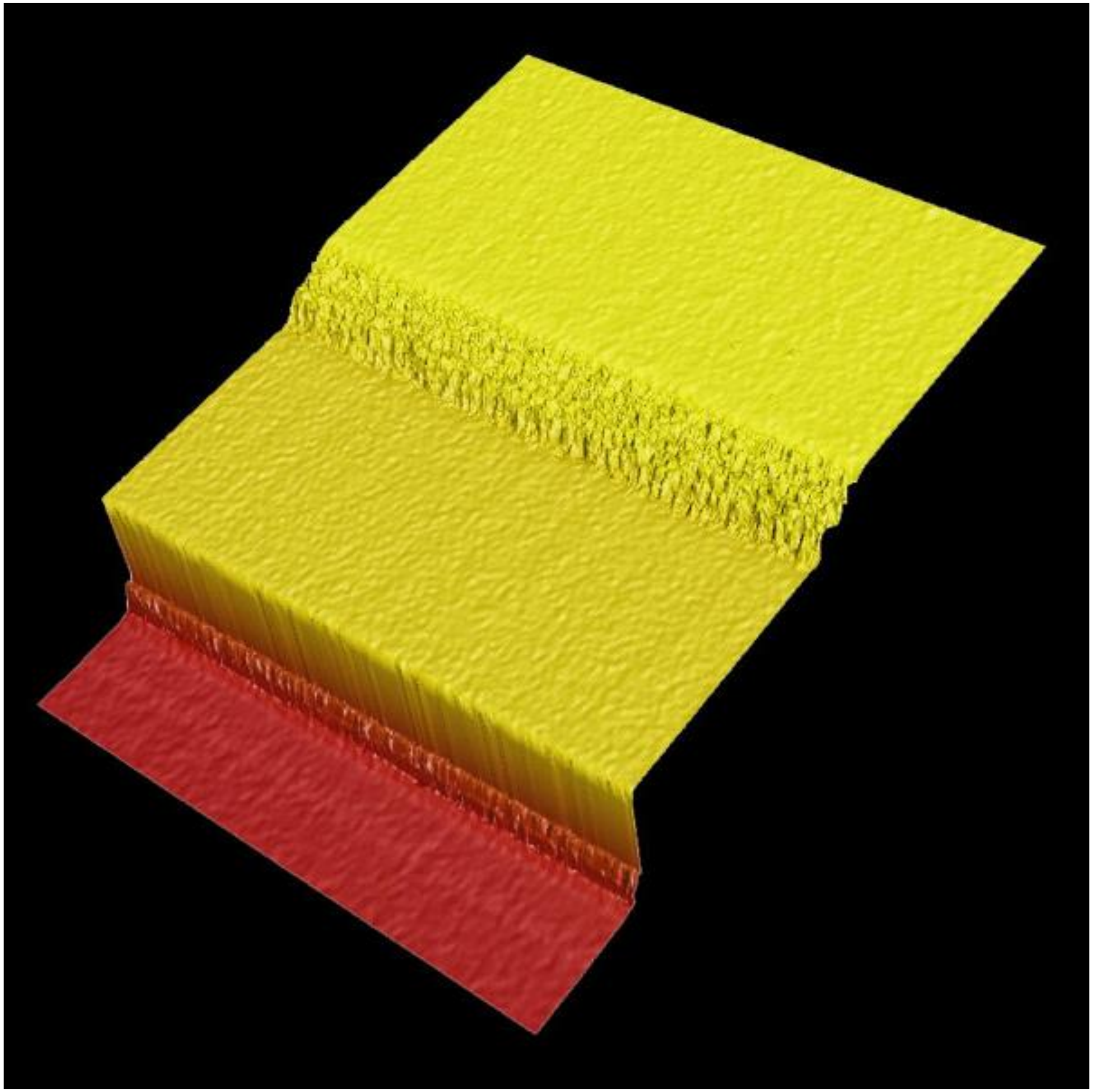
	NewView 600™ Series		NewView 7000™ Series	
				
Model:	**600p**	**600s**	**7200**	**7300**
Core Technology:	Phase-Shifting Interferometry (PSI)	Scanning White-Light Interferometry (SWLI)		
Vertical Scan Speed:	n/a	≤ 15 µm/s	≤ 26 µm/s	≤ 135 µm/s
Maximum Step Height:	~ 138 nm	~ 150 µm	~ 20000 µm	
System Zoom:	Fixed		Manual	Automated
Z Stage:	Manual		Automated	
X/Y Stage:	Manual		Manual or Automated (optional)	
Field of View:	≤ 3.5 mm		≤ 14 mm*	
Objective Turret:	6-position, Manual or Automated			

* A larger field of view is possible with the megapixel camera and/or stitching option.

Zmogljivosti WLSI

Max. Stopnica:
do 20 mm !!!

Ločljivost
< 1 nm



Origin and Development of Some Common Customary Units. -

The origin and development of units of measurement has been investigated in considerable detail and a number of books have been written on the subject. It is only possible to give here, somewhat sketchily, the story about a few units.

Units of length:

The **cubit** was the first recorded unit used by ancient peoples to measure length. There were several cubits of different magnitudes that were used. The common cubit was the length of the forearm from the elbow to the tip of the middle finger. It was divided into the span of the hand (one-half cubit), the palm or width of the hand (one sixth), and the digit or width of a finger (one twenty-fourth).

The **Royal or Sacred Cubit**, which was 7 palms or 28 digits long, was used in constructing buildings and monuments and in surveying.

The inch, foot, and yard evolved from these units through a complicated transformation not yet fully understood. Some believe they evolved from cubic measures; others believe they were simple proportions or multiples of the cubit.

In any case, the Greeks and Romans inherited the foot from the Egyptians. The Roman foot was divided into both 12 unciae (inches) and 16 digits. The Romans also introduced the mile of 1000 paces or double steps, the pace being equal to five Roman feet. The Roman mile of 5000 feet was introduced into England during the occupation. Queen Elizabeth, who reigned from 1558 to 1603, changed, by statute, the mile to 5280 feet or 8 furlongs, a furlong being 40 rods of 5-1/2 yards each. The introduction of the yard as a unit of length came later, but its origin is not definitely known. Some believe the origin was the double cubit, others believe that it originated from cubic measure. Whatever its origin, the early yard was divided by the binary method into 2, 4, 8, and 16 parts called the half-yard, span, finger, and nail. The association of the yard with the "gird" or circumference of a person's waist or with the distance from the tip of the nose to the end of the thumb of Henry I are probably standardizing actions, since several yards were in use in Great Britain.

vir: http://ts.nist.gov/ts/htdocs/230/235/h44-06/PDF/AppendB-06-HB44-Final.pdf

1790 May 8 — The French National Assembly decides that the length of the new metre would be equal to the length of a pendulum with a half-period of one second.

1791 March 30 — The French National Assembly accepts the proposal by the French Academy of Sciences that the new definition for the metre be equal to one ten-millionth of the length of the Earth's meridian along a quadrant through Paris, that is the distance from the equator to the north pole.

1795 — Provisional metre bar constructed of brass.

1799 December 10 — The French National Assembly specifies the platinum metre bar, constructed on 23 June 1799 and deposited in the National Archives, as the final standard.

1889 September 28 — The first General Conference on Weights and Measures (CGPM) defines the metre as the distance between two lines on a standard bar of an alloy of platinum with ten percent iridium, measured at the melting point of ice.

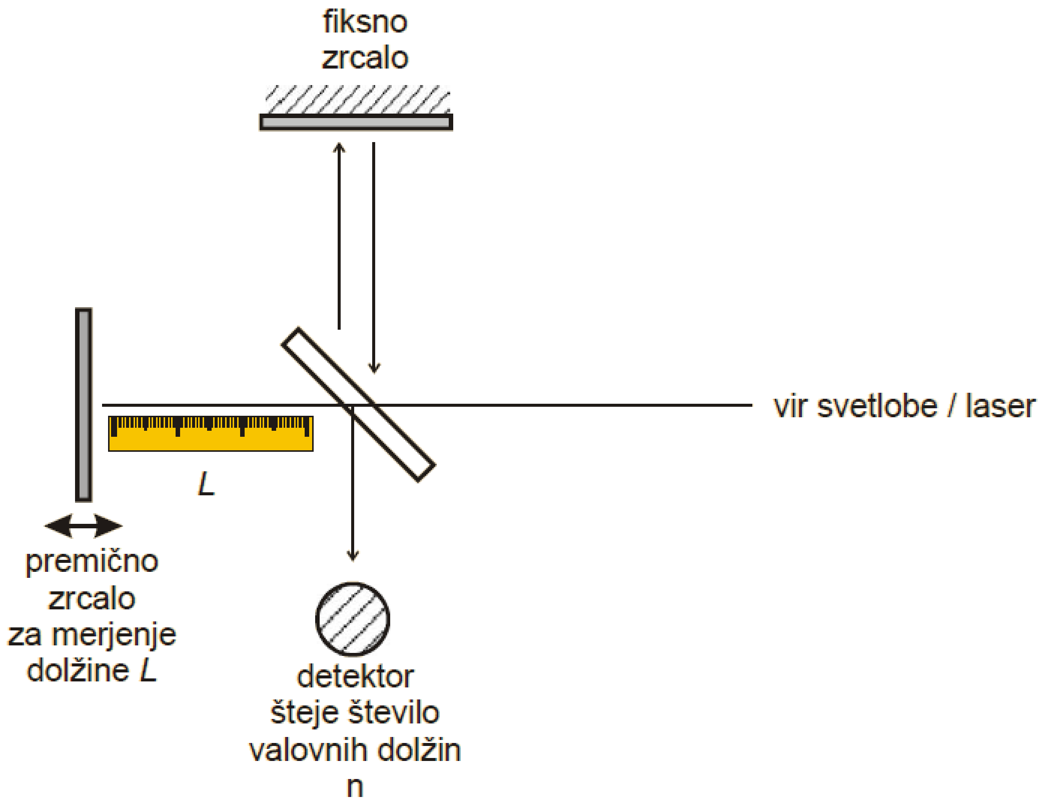
1927 October 6 — The seventh CGPM adjusts the definition of the metre to be the distance, at 0 °C, between the axes of the two central lines marked on the prototype bar of platinum-iridium, this bar being subject to one standard atmosphere of pressure and supported on two cylinders of at least one centimetre diameter, symmetrically placed in the same horizontal plane at a distance of 571 millimetres from each other.

1960 October 20 — The eleventh CGPM defines the metre to be equal to 1,650,763.73 wavelengths in vacuum of the radiation corresponding to the transition between the 2p10 and 5d5 quantum levels of the krypton-86 atom.

1983 October 21 — The seventeenth CGPM defines the metre as equal to the distance travelled by light in vacuum during a time interval of 1⁄299,792,458 of a second.

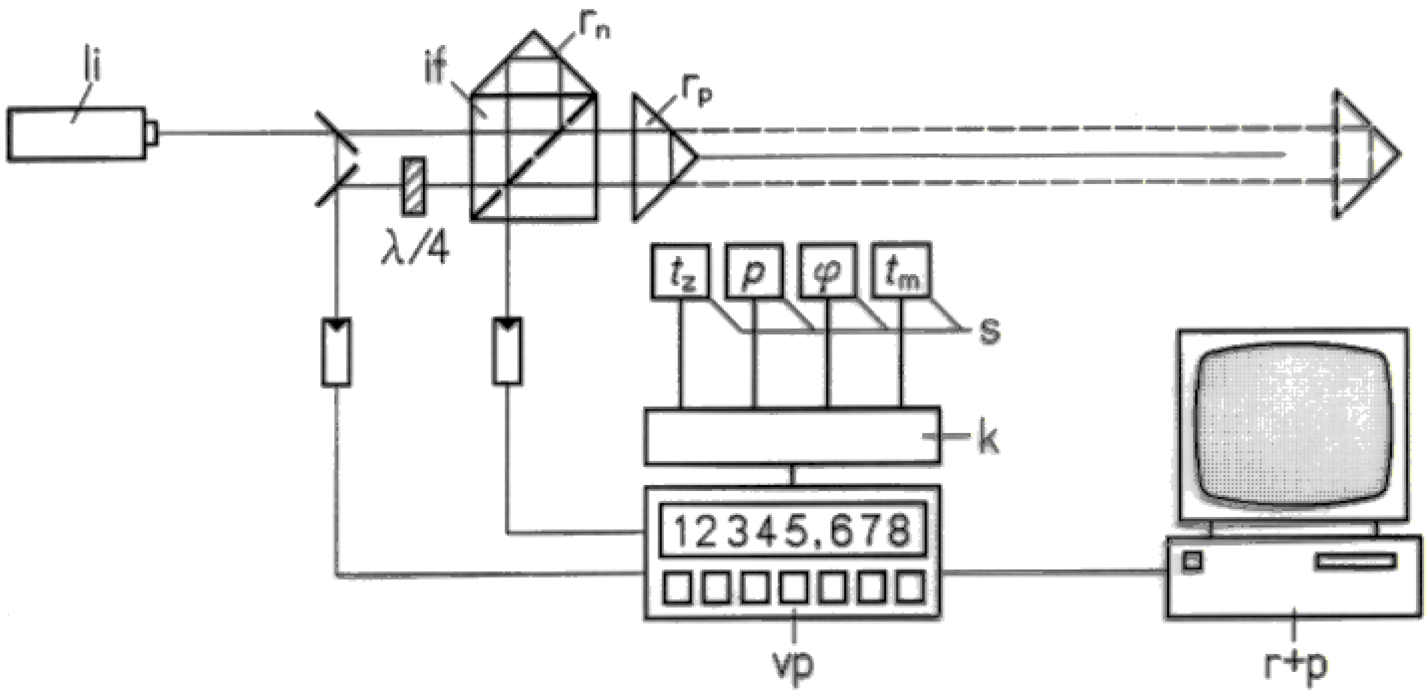
2002 — The International Committee for Weights and Measures (CIPM) recommends this definition be restricted to "lengths ℓ which are sufficiently short for the effects predicted by general relativity to be negligible with respect to the uncertainties of realisation."

Realizacija metra z laserjem in interferometrom



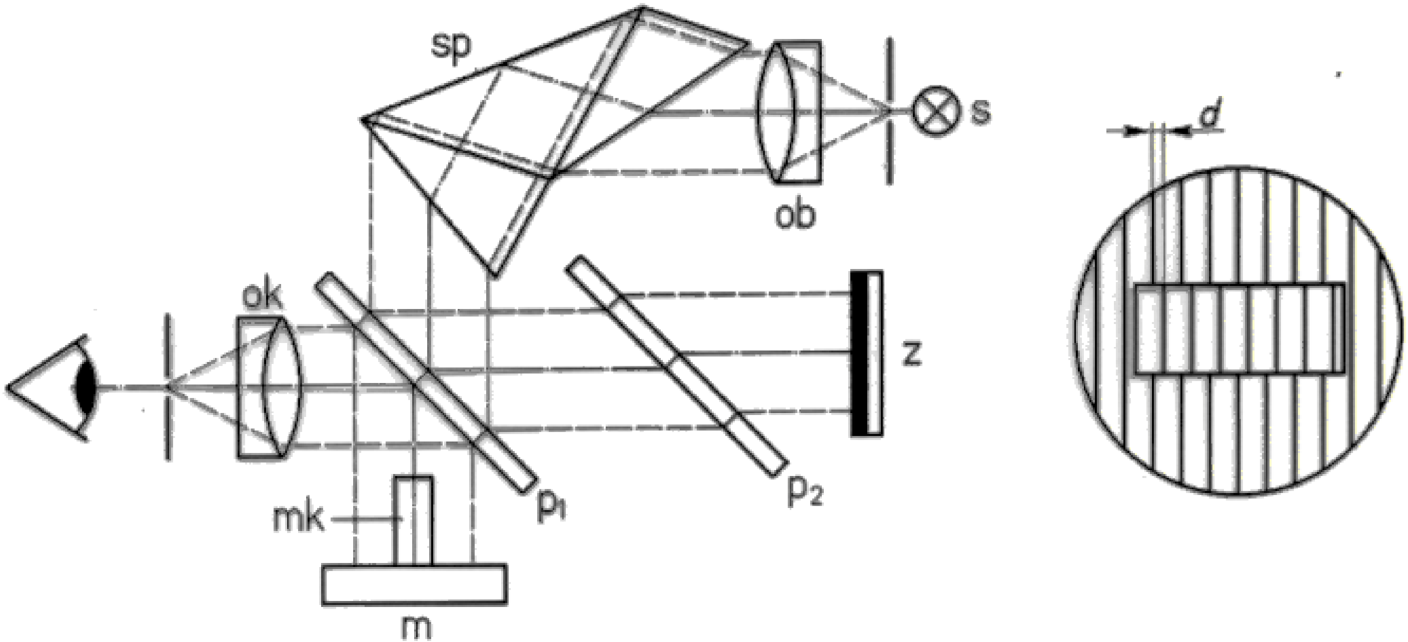
Vir: LMK, FE, UNI-LJ

Laserski interferometer



li-laserski izvor,if-polprepustno zrcalo,r_n-nepremični reflektor, r_p-premični reflektor,s-senzorji na temperaturo in tlak zraka ter termperaturo merjenca,k-kompenzator,vp-vrednotenje meritve, r+p-računalnik s programsko opremo

Interferometrični komparator



s-izvor svetlobe,ob-objektiv,sp-vrtljiva prizma,p_1,p_2-planparalelni plošči, m-merilna mizica, mk-merjenec, ok-okular

INTERFERENČNI VZORCI