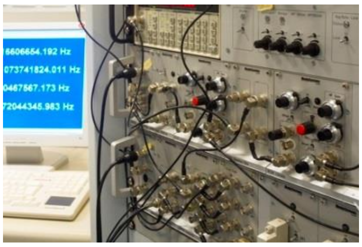
Laboratory **LENGTH**

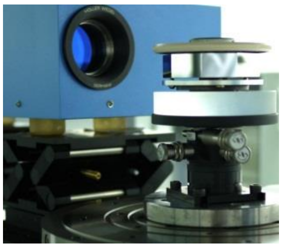
Instituto Português da Qualidade
PORTUGUESE INSTITUTE FOR QUALITY

LNM

FIELD OF ACTIVITY



Practical realization of the definition of the metre



Practical realization of the definition of the radian

Surface texture: Roughness

The length laboratory is responsible for the development of the length and plane angles national metrology standards and as the following incumbencies:

- the realization of the practical definition of the metre and radian;
- the realization of calibrations;
- participation and coordination of interlaboratorial comparisons;
- technical support to the legal metrology.

SI UNIT

International System (SI) Base Unit of Length:

metre defined as:

The metre, symbol m, is the SI unit of length. It is defined by taking the fixed numerical value of the speed of light in vacuum c to be 299 792 458 when expressed in the unit m/s, where the second is defined in terms of the caesium frequency $\Delta\nu_{Cs}$

SI derived unit of the quantity Plane angle:

radian (rad) defined as:

The plane angle situated between two radius that, in a circumference of a circle, intersects an arc length equal to the radius of the mentioned circle.

TRACEABILITY

Length Quantity

At IPQ, the realization of the definition of the metre can be performed by two different ways:

1. By means of the wavelength in vacuum λ of a plane electromagnetic wave of frequency f; this wavelength is obtained from the measured frequency f using the relation $\lambda = c_0 / f$ and the value of the speed of light in vacuum c_0 = 299 792 458 m/s.

The standard is an Optical Frequency Synthesizer (OFS) constituted by: an Nb:YVO_4 laser; an optical acoustic modulator, Kerr-lens mode-locked femtosecond Ti:sapphire laser and an optical fibre based on photonic crystals and an optical and electronic set that allows to determine the two frequencies that characterize the OFS, the offset frequency, f_0 , and the repetition frequency, f_r.

2. By means of one of the radiations included in the list recommended by BIPM, whose stated frequency wavelength in vacuum or whose stated frequency can be used with the uncertainty shown, provided that the given specifications and accepted good practice are followed.

The practical realization is based on the relation $c_0 = \lambda \times f$, and as the light speed, c_0 , is a constant and f (laser radiation frequency) is well determined, λ (wavelength) can be calculated.

In this case the standard is an He:Ne laser stabilized be molecular absorption in hyperfine iodine transition. Its traceability is obtained by the calibration with the OFS.

The use of this standards, or any other laser system calibrated by comparison with, allow the length measurements, ℓ, in terms of a number of wavelengths b , $\ell = \lambda \times b$, by interferometry.

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TRACEABILITY

Plane Angle

The realization of the radian definition is made in terms of the circle subdivision. The complete circle corresponds to 2π rad. As π is an irrational number the units used in angular metrology belongs to the sexagesimal system and are the grade (º), minute (′) and the second (″). As the sum of all intermediate angles of a circle is 360º and the sum of all errors of the same angles is zero, it is possible to produce matrixes and equations to determine the error of each intermediate angle of the circle. To make the practical realization of the radian definition, IPQ has an autocollimator (optical system used to measure small angular differences), an index table (allows the generation of angular positions) and gauge polygons. Nowadays, the traceability is reached through the calibration of the autocollimator at the international primary laboratory.

AVAILABLE SERVICES

Calibration

Length Domain

EQUIPMENT	METHOD	RANGE	UNCERTAINTY
Stabilized laser of the mise en pratique: vacuum wavelength/ absolute frequency	Optical beat frequency	633 nm / 474 THz	$1 \times 10^{-8}\ \lambda_0$
Other stabilized laser: vacuum wavelength	Optical beat frequency	633 nm	1×10^{-11}
Laser Interferometer system: error of indicated displacement	Comparison to master length interferometer	(0 to 3000) mm	Q[0,3;4,6E02*L*] µm
Laser Interferometer system: error of indicated displacement		(0 to 10 000) mm	$(1,3 + 1,6 \times 10^{-4}\ L)$ µm
Depth standard (ISO 5436-1 type A2): Parameter: depth *d*	Stylus instrument	0,1 µm to 10 µm	(60 + 2*d*) nm *d* em µm
Roughness standard (ISO 5436-1 type C): ISO roughness parameters: *Ra* *Rz, Rp, Rv, Rt*	Stylus instrument	0,1 µm to 10 µm 0,1 µm to 20 µm	Q[50,30*Ra*] nm Q[50,30*Rz*] nm
Roughness standard (ISO 5436-1 type D): ISO roughness parameters: *Ra* *Rz, Rp, Rv, Rt*	Stylus instrument	0,1 µm to 10 µm 0,1 µm to 20 µm	Q[50,30*Ra*] nm Q[50,40*Rz*] nm

Angle Domain

EQUIPMENT	METHOD	RANGE	UNCERTAINTY
Autocollimator	Angle comparator	error of indicated angle in "	0,3″
Angle block: included angle	Index table and autocollimator	0° to 90°	1,0″
Optical polygon: face angle	Cross calibration versus index table and autocollimator	4 to 24 faces	
Index table: index angle		(0° to 360°) step size: 30°, 40° or 60°	
Optical Square (pentaprism)	2-mirror method	90º	0,5″
Interferometer optical angular	Comparison with index table	N/A	0,50 µm

(L in mm) $Q[a, bL] = \sqrt{a^2 + (bL)^2}$

CONTACTS

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