

# realisation of the awaited redefinition of the kilogram

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## abstract

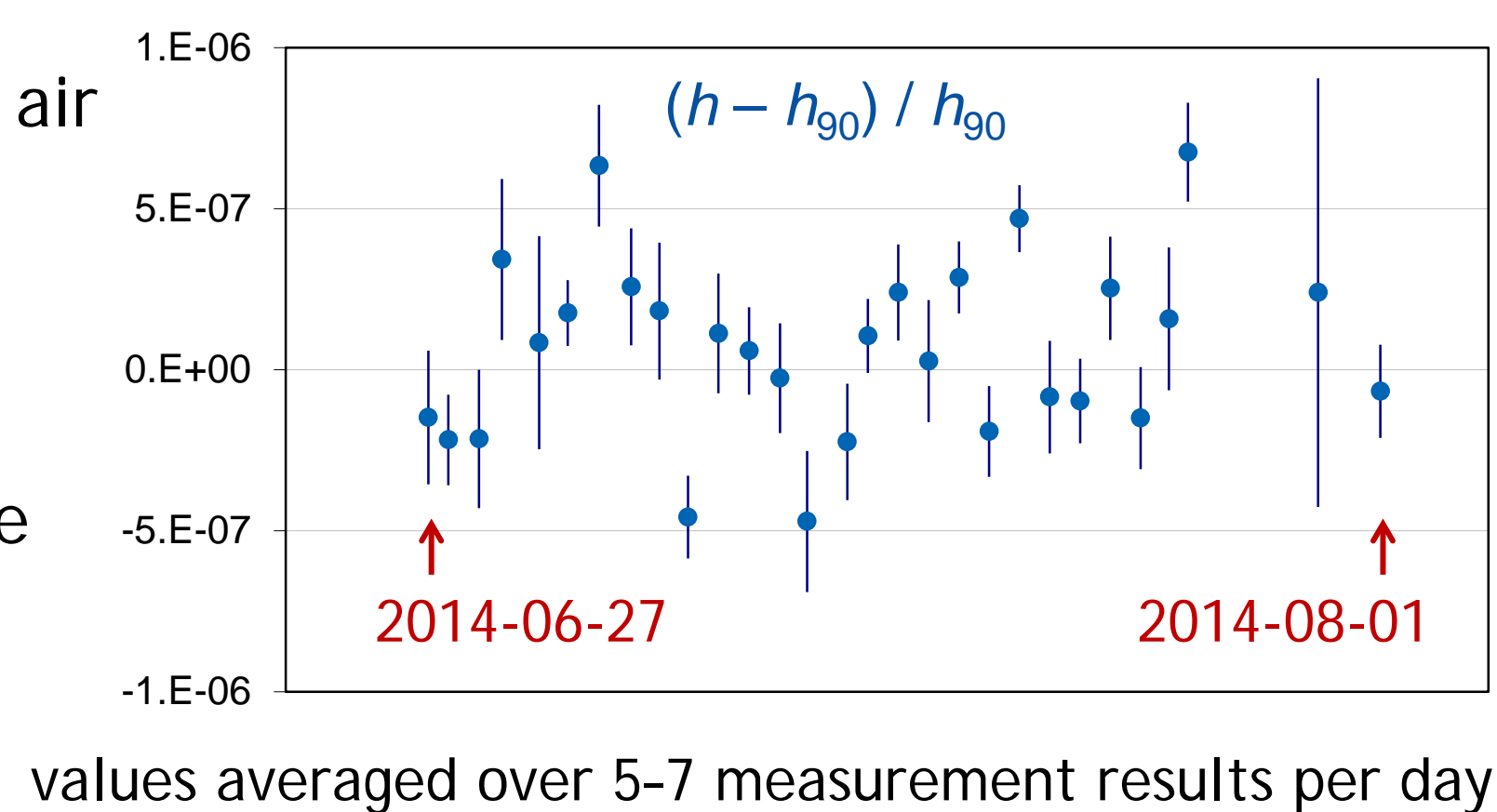
The European Metrology Research Programme funded this research project to address the discrepancy between the Planck and Avogadro constant values obtained via the watt balance experiments and by counting <sup>28</sup>Si atoms.

## participants

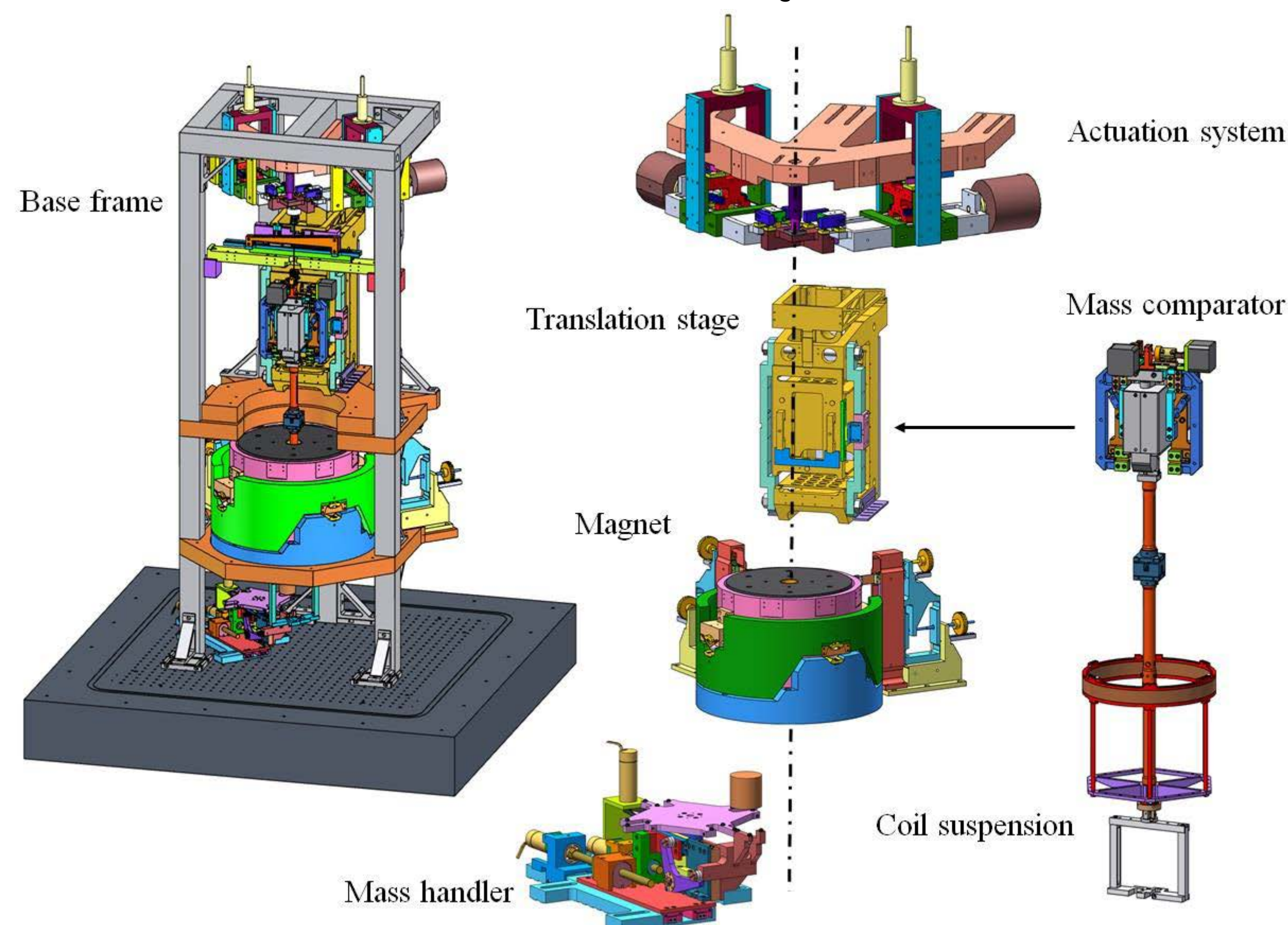
	ANSTO – Australian Nuclear Science and Technology Organisation (Australia)
	BIPM – Bureau International des Poids et Mesures
	CERN – European Organization for Nuclear Research
	CNAM – Conservatoire National des Arts et Métiers (France)
	EPFL-LSRO – Laboratoire de Systemes Robotiques (Switzerland)
	INRIM – Istituto Nazionale di Ricerca Metrologica (Italy)
	IOM – Leibniz Institute of Surface Modification (Germany)
	LNE – Laboratoire National de Métrologie et d'Essais (France)
	METAS – Federal Office of Metrology (Switzerland)
	MT – Mettler Toledo (Switzerland)
	NMIJ – National Metrology Institute of Japan (Japan)
	OBSPARIS – Observatoire de Paris (France)
	PTB – Physikalisch-Technische Bundesanstalt (Germany)
	UNICA – Università di Cagliari (Italy)

## watt-balance experiments

The LNE watt balance is operational in air with a mass of 0.5 kg. Measurements carried over July 2014 demonstrated a resolution and repeatability approaching 0.1 mW/W. Data analysis and the assessment of the uncertainty are under way.



values averaged over 5–7 measurement results per day

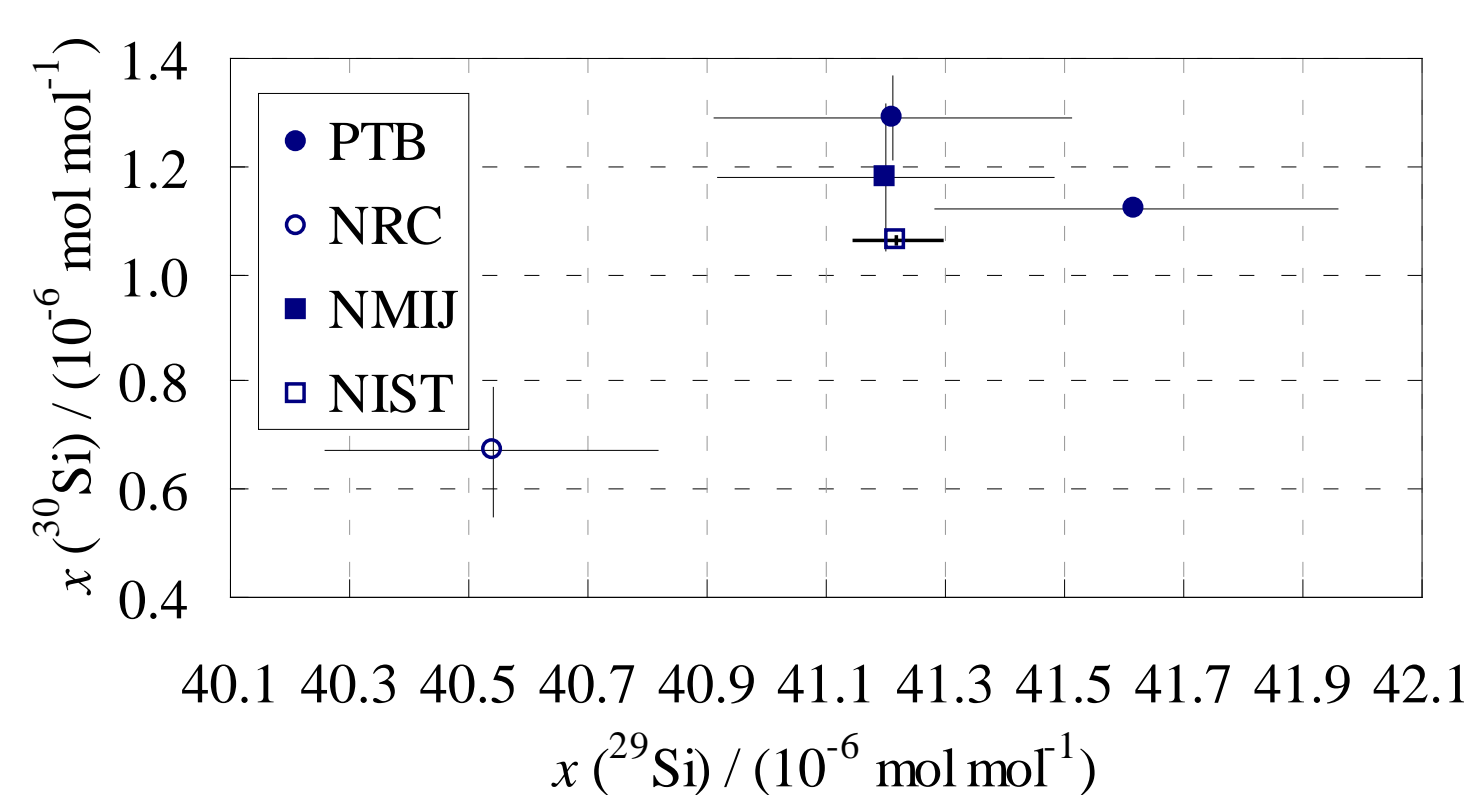


The assembling of the METAS watt is going on according the schedule; first test measurements are expected by the end of the year. A prediction of a different-than-usual correction of the speed-of-light effect on the measurement of the gravitational acceleration has been experimentally checked; the results disagree with the new prediction and confirm the presently accepted model.

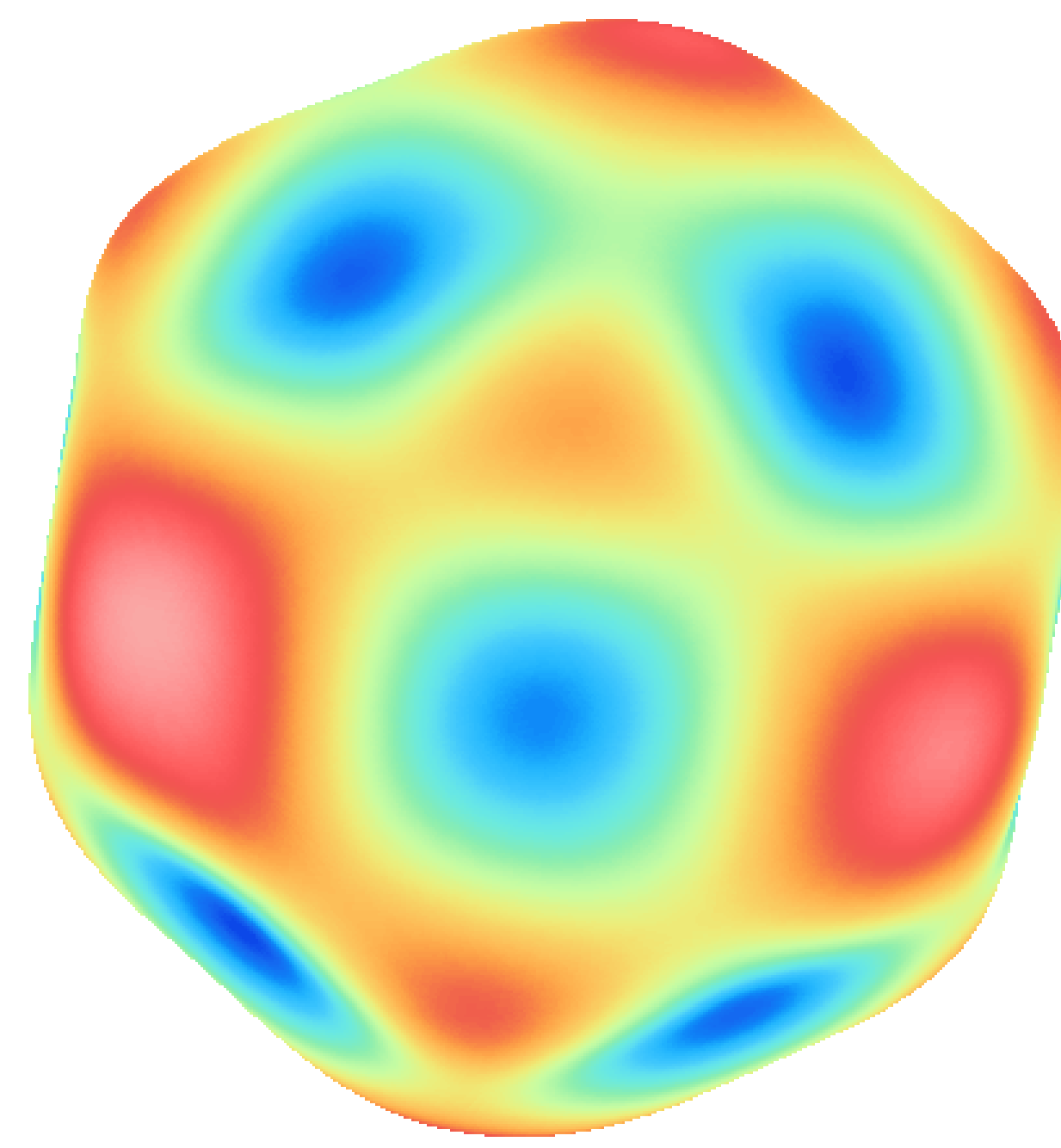
## <sup>28</sup>Si counting

INRIM and ANSTO are carrying out nuclear activation analyses of the <sup>28</sup>Si crystal. Preliminary tests included 59 out of the 90 possible contaminants; for 42 of them the detection limit is already at the 1 ng/g level or better.

The molar mass value has been confirmed by PTB, NRC, NIST, and NMIJ. A further check will be carried out by applying nuclear activation at the INRIM and ANSTO.



## <sup>28</sup>Si counting (cont.)

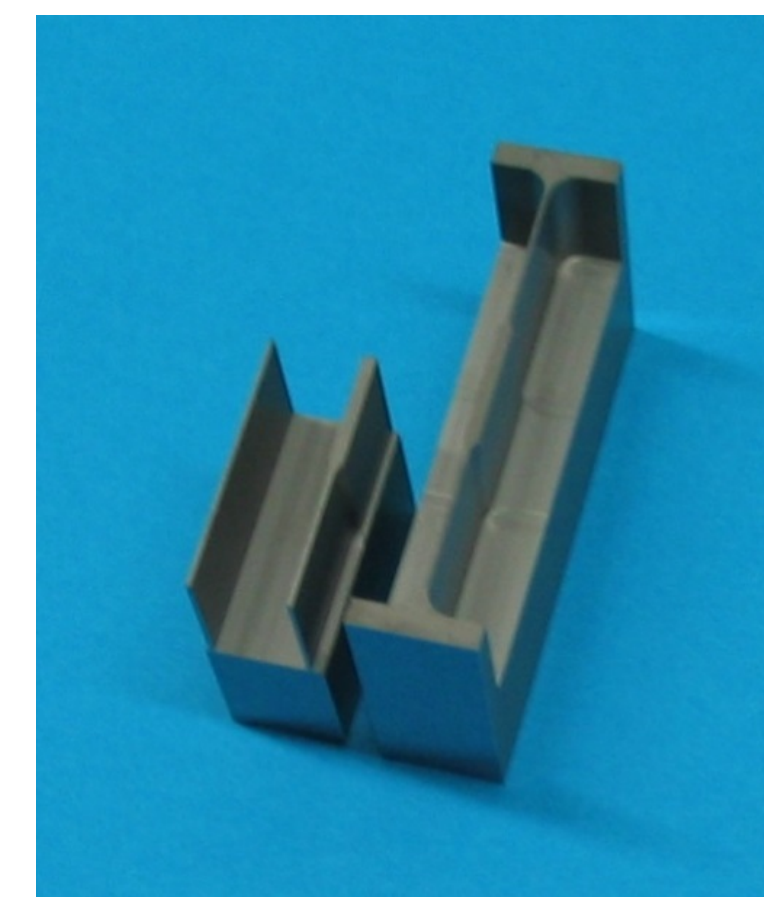


The AVO28-S5 and AVO28-S8 spheres have been polished anew with errors limited only by the crystallographic asymmetry (cuboctahedron shape, 35 nm peak-to-valley).

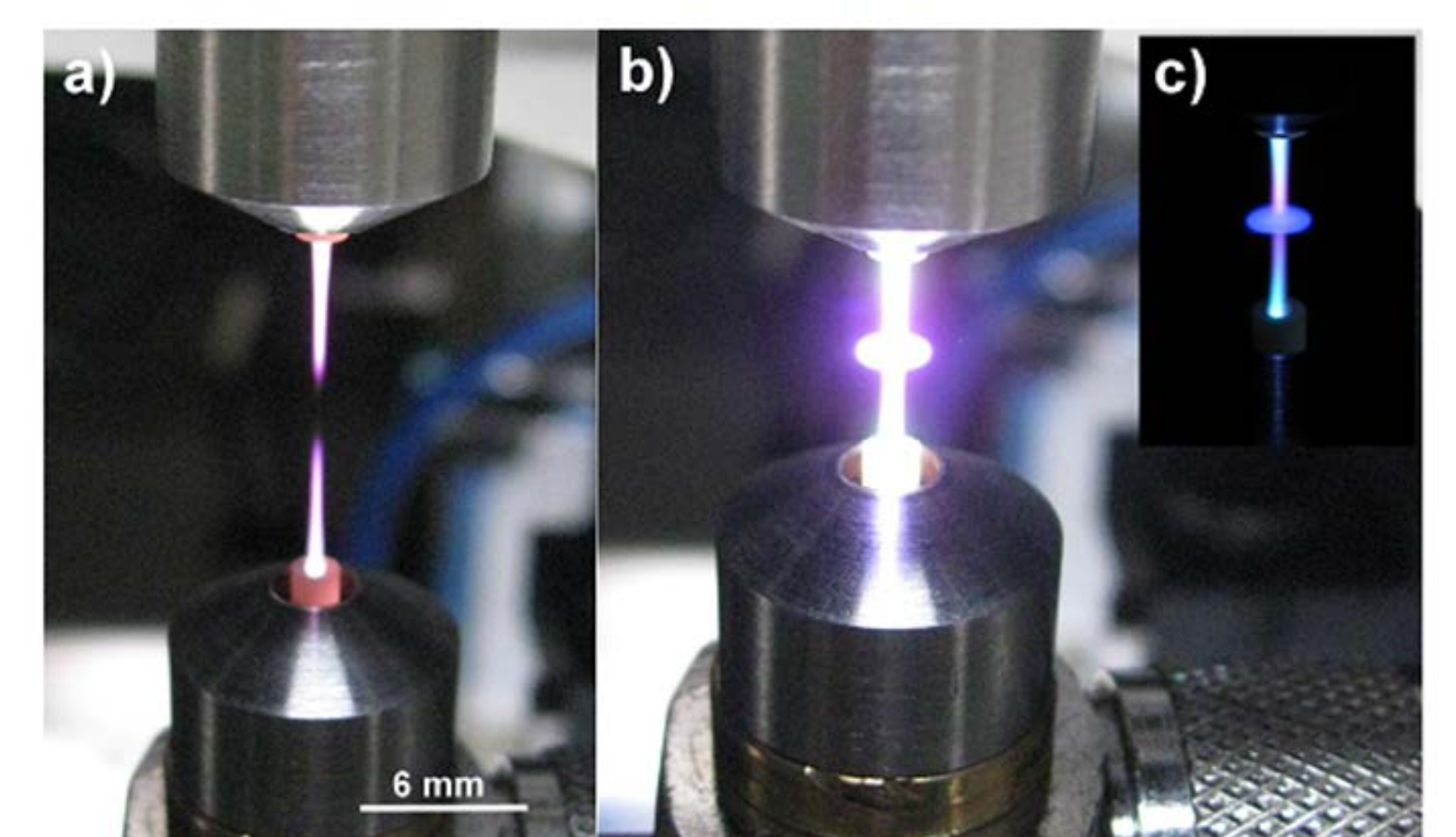
They have been characterized (by PTB, NMIJ, and BIPM) in terms of mass, volume, surface topography and chemistry.

The international prototype of the kilogram was used to calibrate the working standards of the BIPM; the spheres were weighed traceable to the newly calibrated standards.

The better the sphere and x-ray interferometer geometry, the more accurate the volume and lattice parameter measurements. Work stated at the IOM to improve the surface topography by means of ultra precision surface machining using plasma-jet and ion-beam figuring.

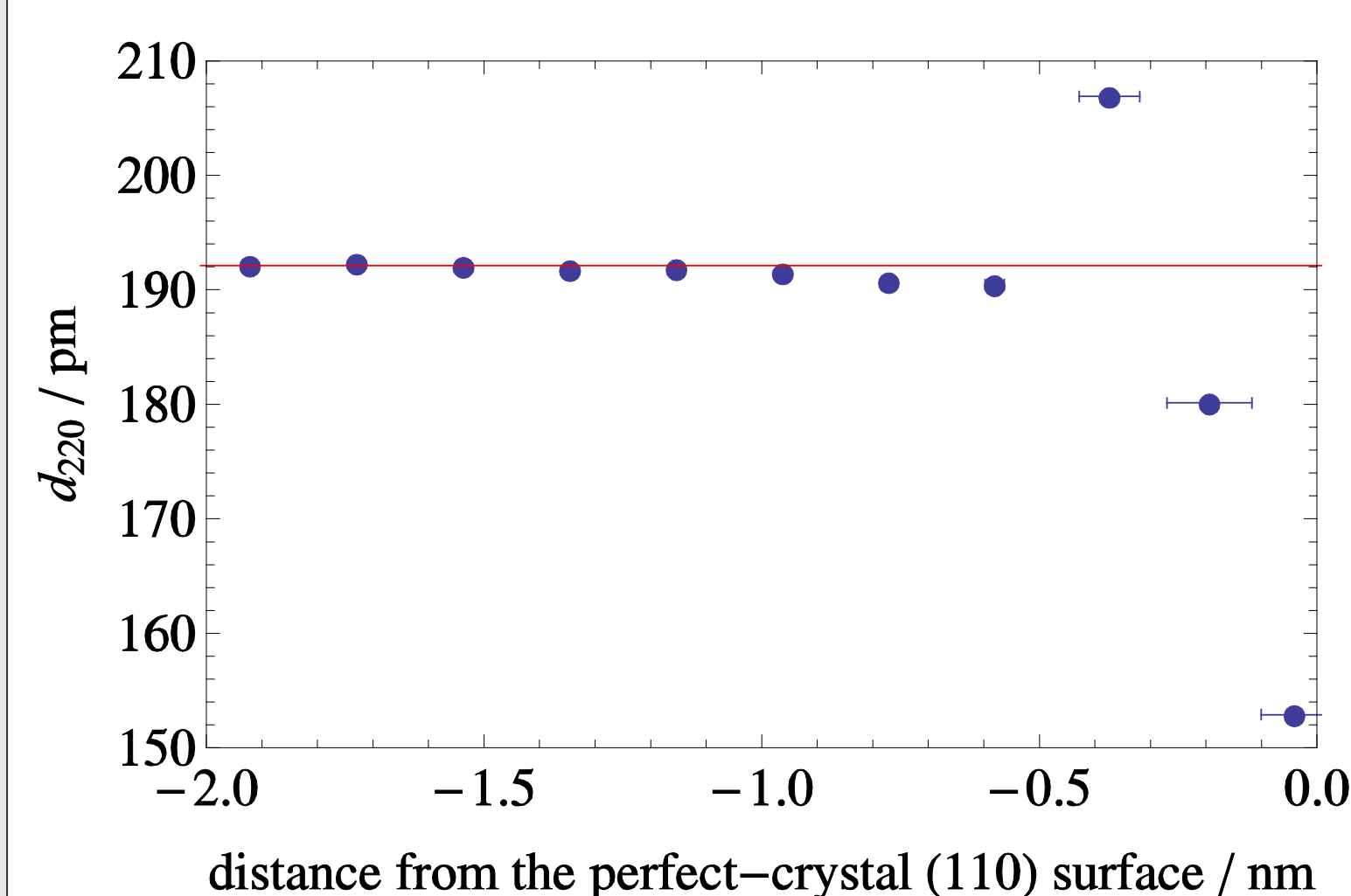
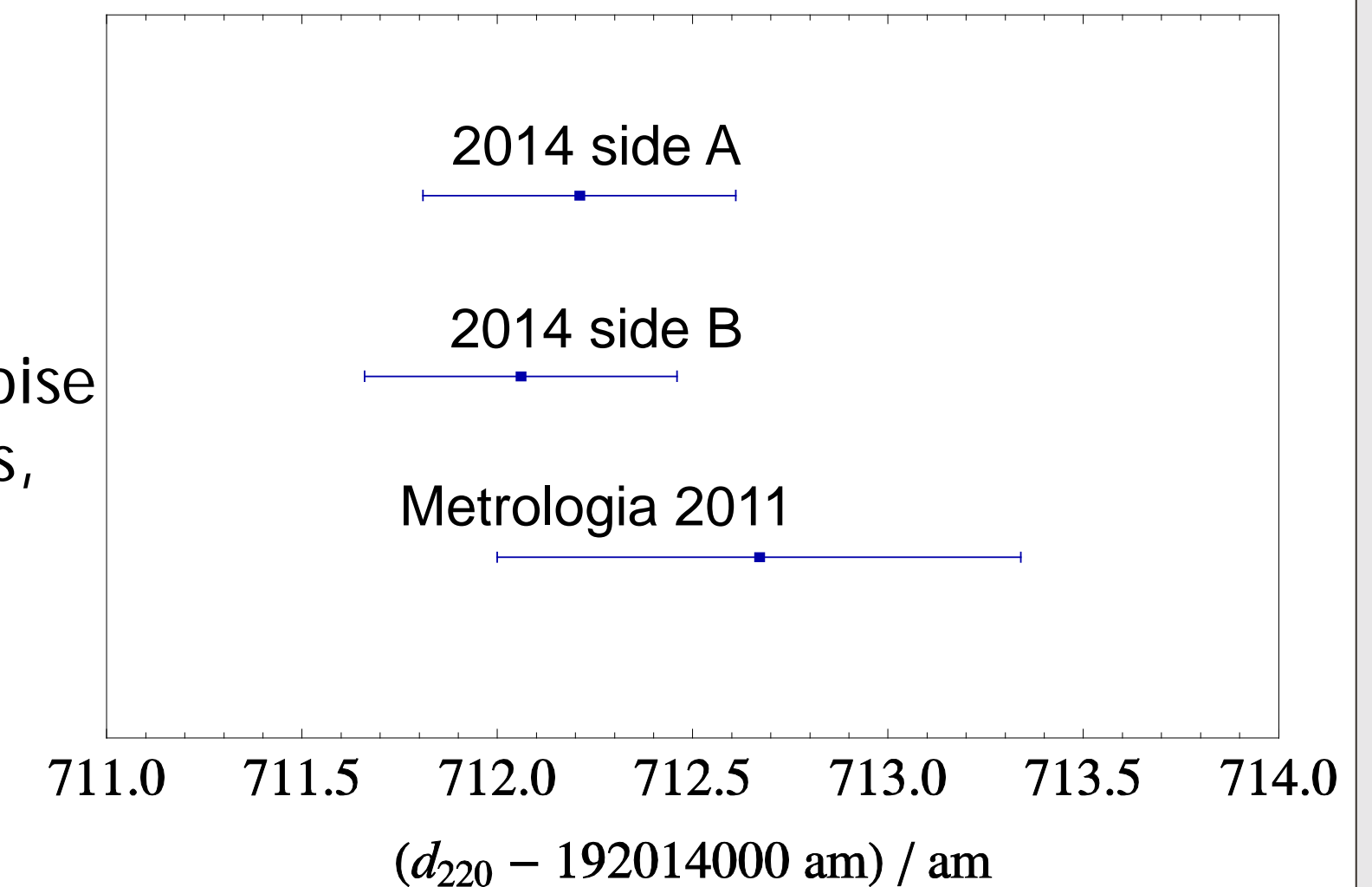


variable thicknesses x-ray interferometer



plasma jet machining of a Si wafer

The INRIM repeated a measurement of the <sup>28</sup>Si lattice parameter with an upgraded apparatus (rebuilt optical interferometer, on-line monitor of the laser-beam alignment, better signal-to-noise ratio, sub-mK temperature measurements, check of the diffraction correction). The result confirms the previously published value with a reduction of the uncertainty of a factor of two.



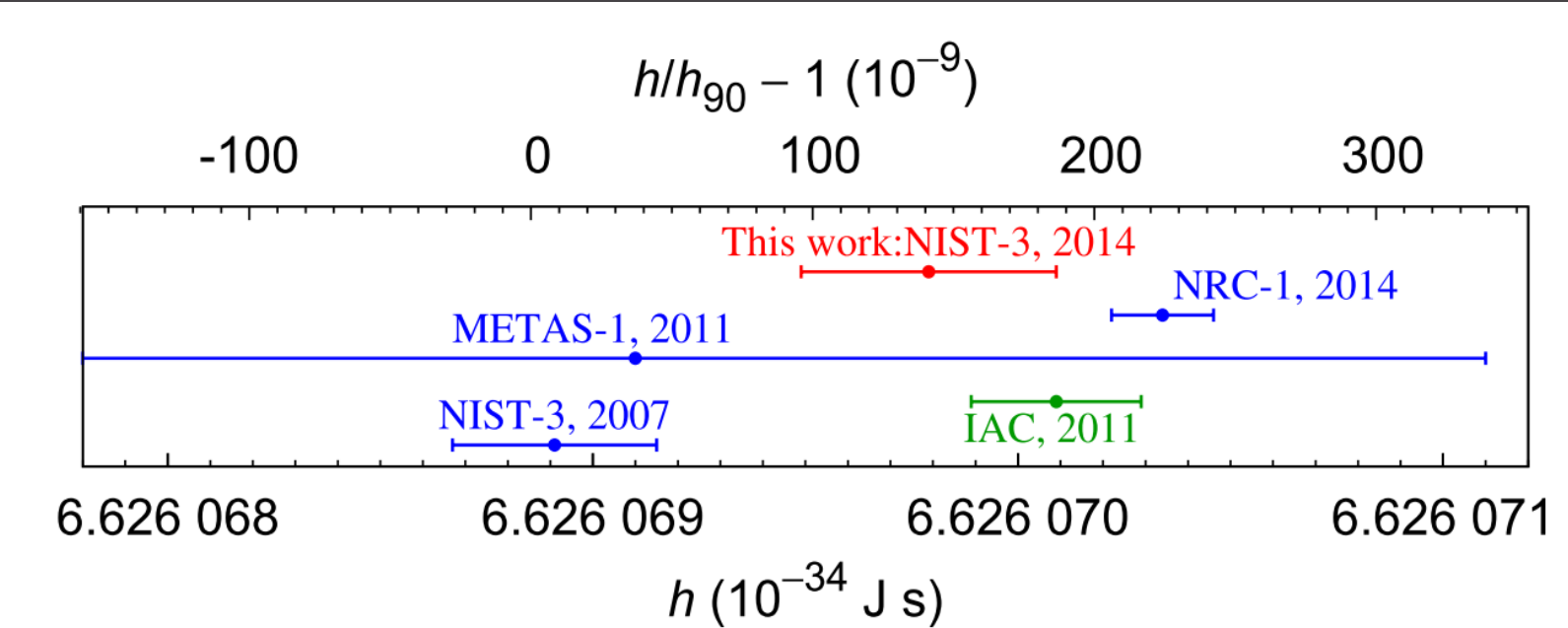
Spacing of the (220) lattice planes vs. the distance from the (110) surface; the outermost 4 atom-layers are amorphized by quenching at 800 °C.

Surface stress and strain depend on the crystal size and geometry.

Hence, the interferometer lattice parameter might be different from that of the Si spheres.

UNICA started work to investigate the surface potential to affect the lattice parameter and volume measurements.

## outlooks



The NIST reported about a re-determination of the Planck constant. The measured value is in substantial agreement with the values obtained by the METAS and NRC watt balances and by counting Si atoms. Although no reason has been found for the shift with respect to the previous value, this agreement is increasing the confidence in the kilogram realization from the Planck's constant value.

## acknowledgements

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