



LABORATORIJ ZA PRECIZNA MJERENJA DUŽINA

55. GODIŠNJICA UTEMELJENJA
35. GODIŠNJICA USPOREDBENIH MJERENJA
20. GODIŠNJICA AKREDITACIJE

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Prolog

Velika mi je čast i zadovoljstvo biti sudionikom ovog znanstvenog kolokvija posebice što je namijenjen obilježavanju nastavnog, znanstvenog i stručnog djelovanja profesora emeritusa Nikole Solarića i profesora Miljenka Solarića. Dragi profesori, iskreno vam čestitam 80-ti rođendan uz želju za dobro zdravlje i zadovoljstvo u daljnjem životu.

Prof. Nikolu Solarića sam prvi put upoznao kao mladi asistent prije četrdesetak godina. Taj prvi susret ostao mi je u nezaboravnom sjećanju – upoznao sam profesora koji je po kulturi ophođenja, uvažavanja i ljudskog pristupa bio i ostao za mene uzor sveučilišnog profesora.

Intenzivna i neprekinuta suradnja između Laboratorija za mjerenja i mjernu tehniku Geodetskog fakulteta i Laboratorija za precizna mjerenja dužina Fakulteta strojarstva i brodogradnje traje više desetaka godina. Suradnja se odvijala u više vidova od kojih treba izdvojiti sljedeće:

- ✓ sudjelovanje na poslijediplomskom studiju,***
- ✓ članstvo u povjerenstvima za izbore u znanstvena i znanstveno-nastavna zvanja,***
- ✓ objavljivanje zajedničkih znanstvenih radova,***
- ✓ recenzije knjiga i znanstvenih radova,***
- ✓ raspoloživost u korištenju mjerne opreme,***
- ✓ suradnja u izdavanju potvrda o umjeravanju geodetskih instrumenata,***
- ✓ međusobna pomoć u razvoju mjernih postupaka i modernizaciji mjerne opreme.***

Vrijeme ide, mlade generacije su preuzele i preuzimaju znanstvene, nastavne i stručne djelatnosti naših laboratorija. S prof. Nikolom Solarićem dijelim zadovoljstvo što se i između naših nasljednika razvija vrlo uspješna suradnja. Mi ćemo, ponajviše s našim savjetima i poticanjima, napraviti sve što je u našoj mogućnosti da u skoroj budućnosti i Laboratorij za mjerenja i mjernu tehniku dobije akreditaciju i s tim u svezi ojača status koji mu pripada u RH i šire.



FAKULTET STROJARSTVA I BRODOGRADNJE HRVATSKI MJERITELJSKI INSTITUT Nacionalni laboratorij za duljinu





Laboratorijska prostorija za ispitivanje hrapavosti






SVEUČILIŠTE U ZAGREBU
FAKULTET STROJARSTVA I BRODOGRADNJE
NACIONALNI LABORATORIJ ZA DULJINU
NATIONAL LABORATORY FOR LENGTH

“Nano” laboratorij





Iz povijesti Laboratorija:

- 1959.** *utemeljenje laboratorija,*
 - 1966.** *izdavanje prve potvrde o umjeravanju (TAM iz Maribora),*
 - 1973.** *prvi znanstveni projekt (razvoj mjerne tehnike SR Hrvatske),*
 - 1979.** *prvo međunarodno usporedbeno mjerenje (usporedbeno mjerenje planparalelnih graničnih mjerki uz primjenu interferencijske metode s institutom INRIM),*
 - 1986.** *izrada vlastitoga niza referentnih etalona hrapavosti (u suradnji s RIZ-om),*
 - 1994.** *dobivanje međunarodne akreditacije (SIT),*
 - 1998.** *proglašenje državnoga etalona za duljinu (DZNM),*
 - 2002.** *prvo sudjelovanje u projektu EURAMET,*
 - 2007.** *prijava prvih osam CMC vrijednosti za uvrštenje u CIPM MRA KCDB,*
 - 2010.** *osnutak HMI-ja kojega je HMI/FSB-LPMD konstitutivni član,*
 - 2012.** *ostvarenje vrha mjeriteljske piramide za duljinu u RH (objavljen CMC),*
 - 2013.** *prijelaz na HAA-a akreditaciju.*
- 



55. godišnjica od utemeljenja Laboratorija





Prof.dr.sc. Ivo Hercigonja

Utemeljitelj i prvi voditelj
Laboratorija od 1959. do 1967.
Prvi doktor tehničkih znanosti u
Hrvata (1931.).



Prof.dr.sc. Federico Dusman **Voditelj Laboratorija od 1967. do 1992.**



Najzaslužniji za punu afirmaciju Laboratorija u domaćim i međunarodnim mjeriteljskim krugovima.

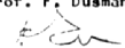
Bio je ispred svog vremena i svojom je sposobnošću i upornošću održao i razvio mjeriteljstvo na Fakultetu, te osigurao pretpostavke da danas Fakultet ima tri nacionalna mjeriteljska laboratorija.

Prof. Dusman je bio vrstan stručnjak i znanstvenik, vizionar i osoba koja se dugo pamti.

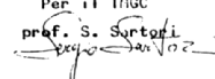
35. godišnjica prvog međunarodnog usporedbenog mjerenja

Lunghezza nominale	Risultati IMGC		Risultati LFSB		IMGC - LFSB		Matricola campione
	Scostamento	Incertezza	Scostamento	Incertezza	Massima differenza ammessa	Differenza riscontrata	
(mm)	(μm)	(μm)	(μm)	(μm)	(μm)	(μm)	
1,47	0	$\pm 0,03$	0	$\pm 0,03$	$\pm 0,06$	0	30132
3,5	- 0,05	$\pm 0,03$	- 0,03	$\pm 0,02$	$\pm 0,05$	- 0,02	30362
9,5	- 0,01	$\pm 0,03$	+ 0,01	$\pm 0,02$	$\pm 0,05$	- 0,02	30331
12	- 0,02	$\pm 0,03$	0	$\pm 0,02$	$\pm 0,05$	- 0,02	30402
24,5	+ 0,04	$\pm 0,03$	0	$\pm 0,03$	$\pm 0,06$	+ 0,04	30036
100	- 0,18	$\pm 0,10$	- 0,25	$\pm 0,03$	$\pm 0,13$	+ 0,07	40077

Per il LFSB
 prof. F. Dusan

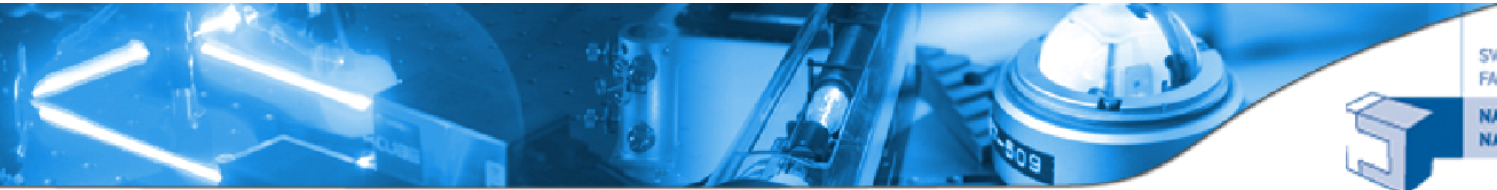


Per il IMGC
 prof. S. Sartori



Usporedbeno mjerenje planparalelnih graničnih mjerki uz primjenu interferencijske metode s talijanskim nacionalnim mjeriteljskim institutom IMGC (danas INRIM).





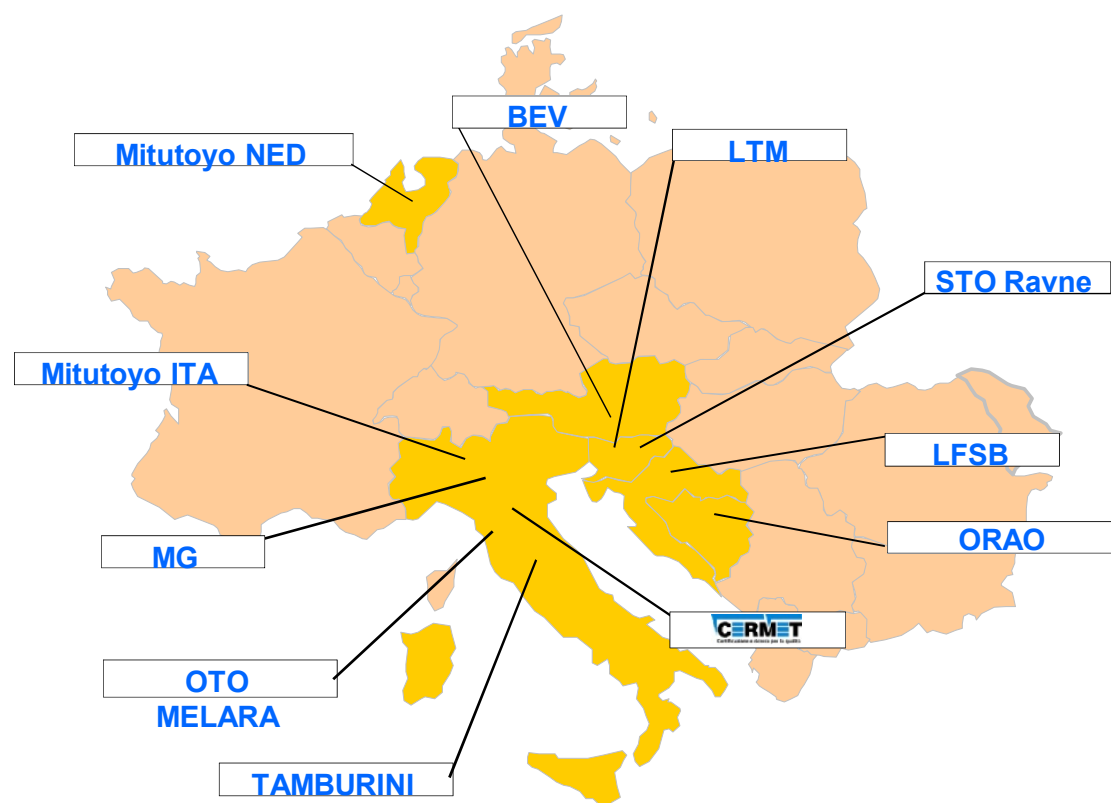
SVEUČILIŠTE U ZAGREBU
FAKULTET STROJARSTVA I BRODOGRADNJE
NACIONALNI LABORATORIJ ZA DULJINU
NATIONAL LABORATORY FOR LENGTH

SAZNAT ĆEMO KAKO MJERIMO AKO IZIĐEMO IZ LABORATORIJA !

U proteklih 35 godina Laboratorij je sudjelovao u više od 50 međunarodnih usporedbenih mjerenja duljine, kuta i hrapavosti.

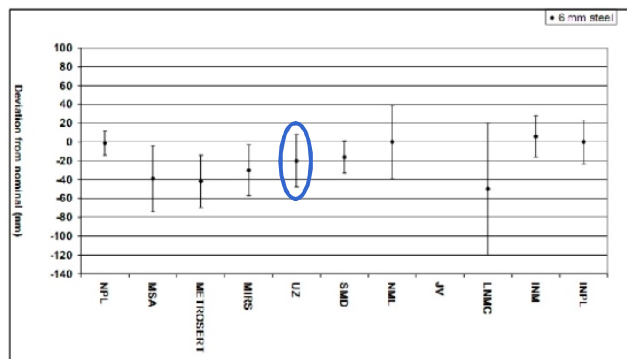


1998. – Osnivanje LABCOM-a

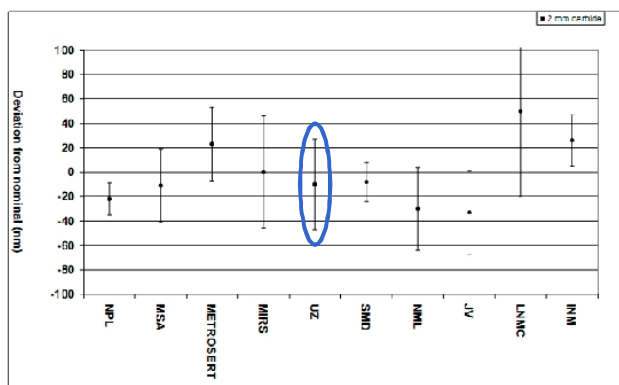


Iniciranje suradnje akreditiranih laboratorija na međunarodnoj razini.
(Od 2005. suradnja je formalizirana osnivanjem udruge laboratorija *LABCOM - Laboratory cooperation in measurements*).

2002. – Početak sudjelovanja u EURAMET projektima



Prvo usporedbeno mjerenje u okviru u EURAMET-a (*Projekt 652*).



Prvo usporedbeno mjerenje u okviru u EA (*Projekt EA ILC M23*).



20. godišnjica akreditacije

19.11.1994. SIT

03.11.1997. SIT (UNI-CEI-EN 45000)
21.02.2000. SIT (UNI-CEI-EN 45001)
31.10.2001. SIT (UNI-CEI-EN 45001)

20.11.2002. SIT (UNI-CEI-EN-ISO/IEC 17025)

23.05.2006. SIT (UNI-CEI-EN-ISO/IEC 17025: 2000)

15.05.2007. SIT (UNI-CEI-EN-ISO/IEC 17025: 2005)

26.11.2009. ACCREDIA (UNI-CEI-EN-ISO/IEC 17025: 2007)

31.10.2013. HAA (HRN-EN-ISO/IEC 17025: 2007)



EN 45001: 1989.
ISO/IEC 17025: 1999.





Dobivanje SIT (*Servizio di taratura in Italia*) akreditacije za hrapavost (1994).

Danas je u Laboratoriju akreditirano 29 postupaka umjeravanja.



1998. – Državni etalon duljine



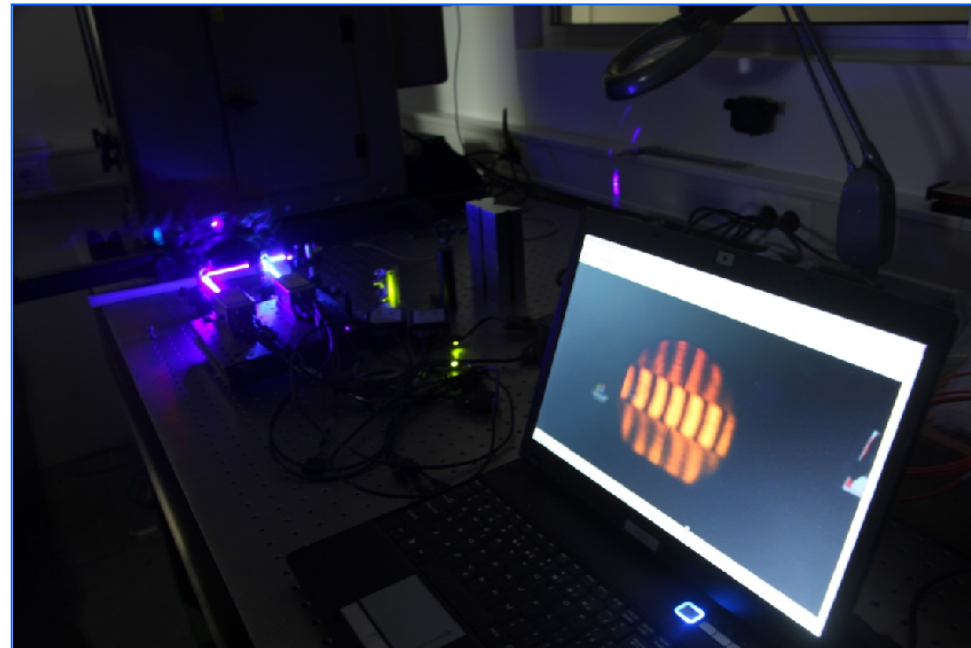
Prihvatanje referentnog etalona duljine za državni etalon (0,5 mm do 100 mm).



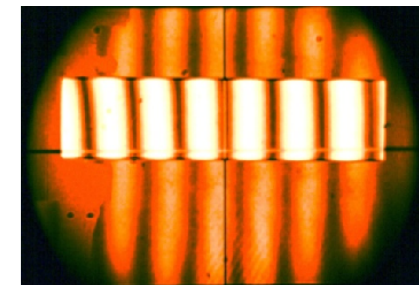
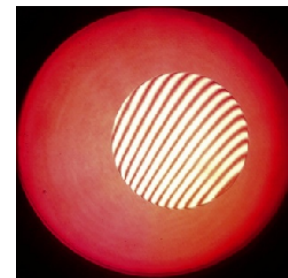
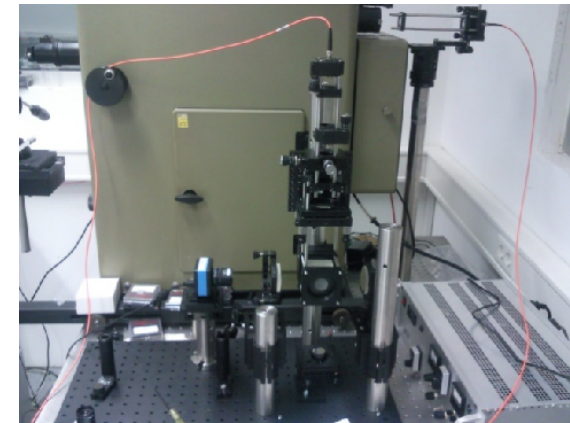
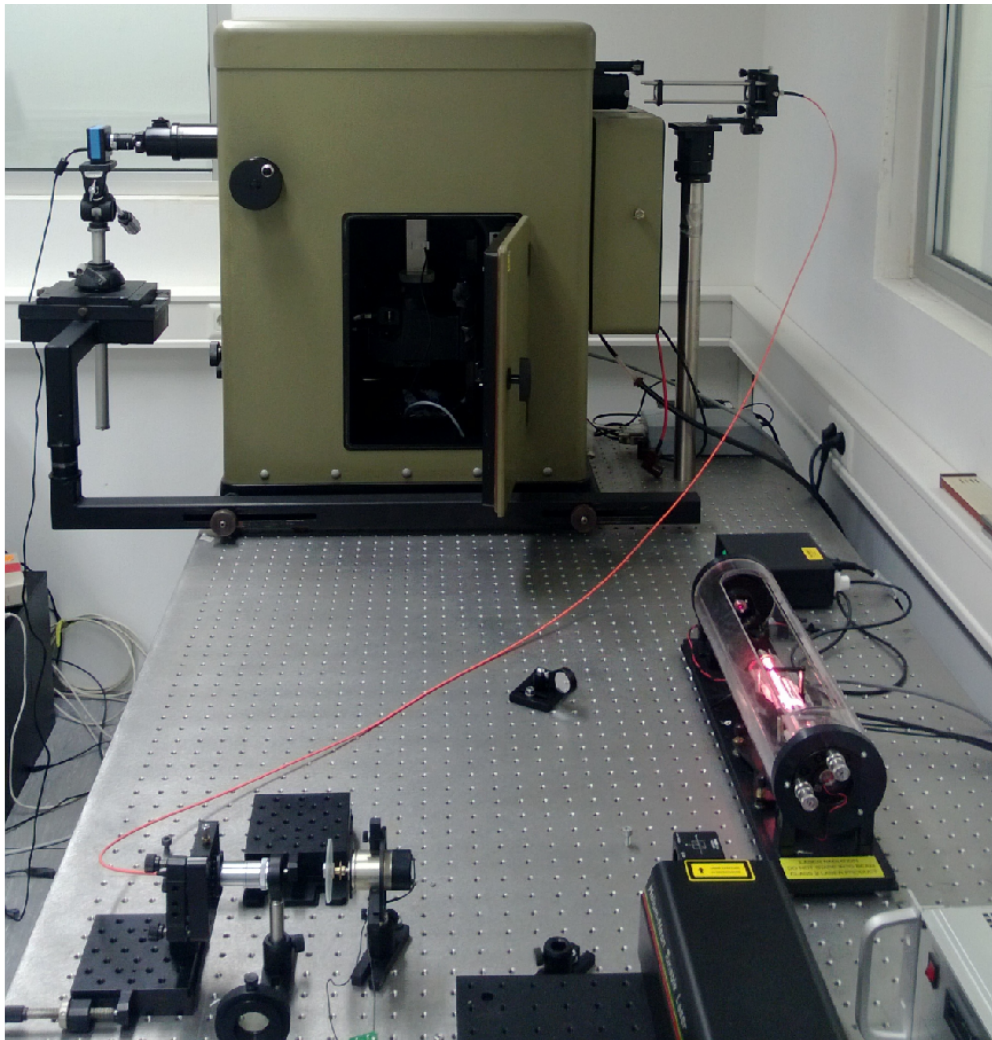
Rekonstrukcija interferencijskog komparatora

Projekti:

- Nacionalni laboratorij za duljinu (HR);
- EURAMET 1016, Interferometric measurements of gauge blocks.
- EURAMET 1138 (K1.2), Comparison of gauge blocks by interferometry



Rekonstrukcija interferencijskog komparatora

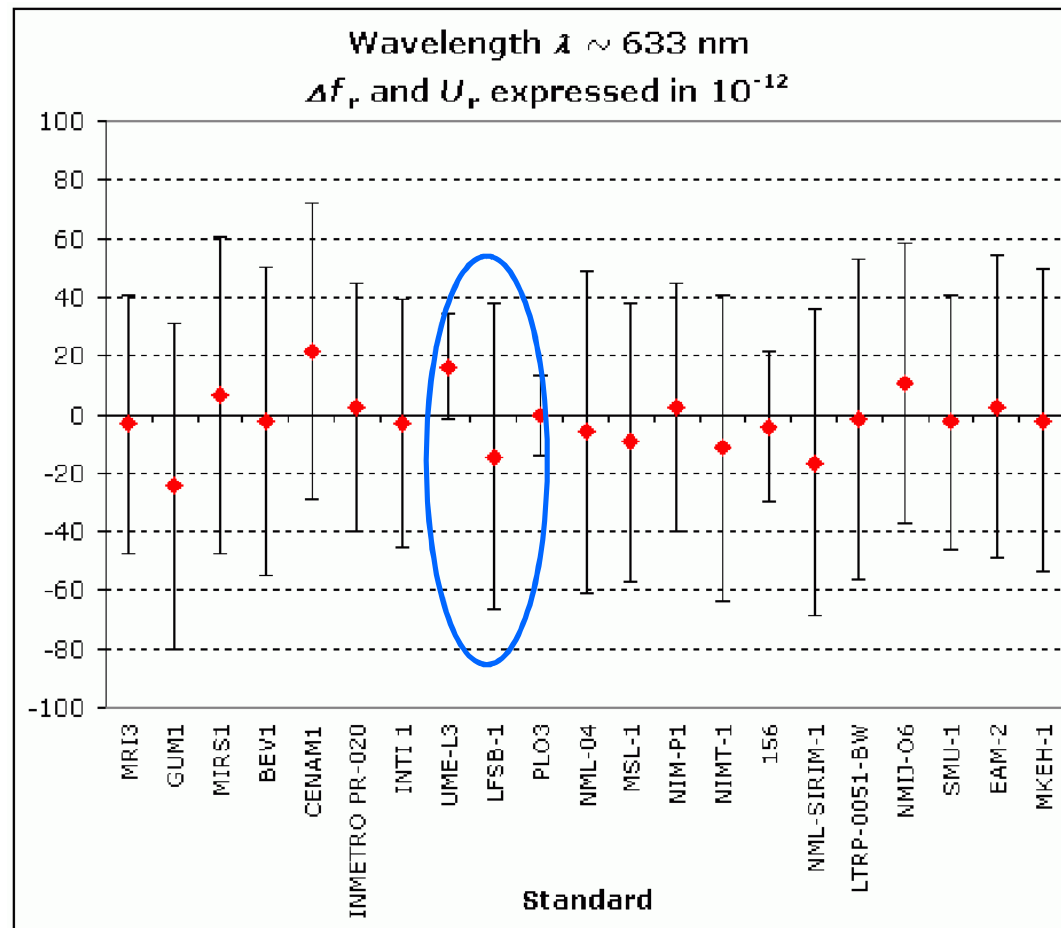


2003. - Ostvarenje primarnog etalona duljine



NPL - jedno stabilizirani He-Ne
laser 633 nm.

CCL - K11

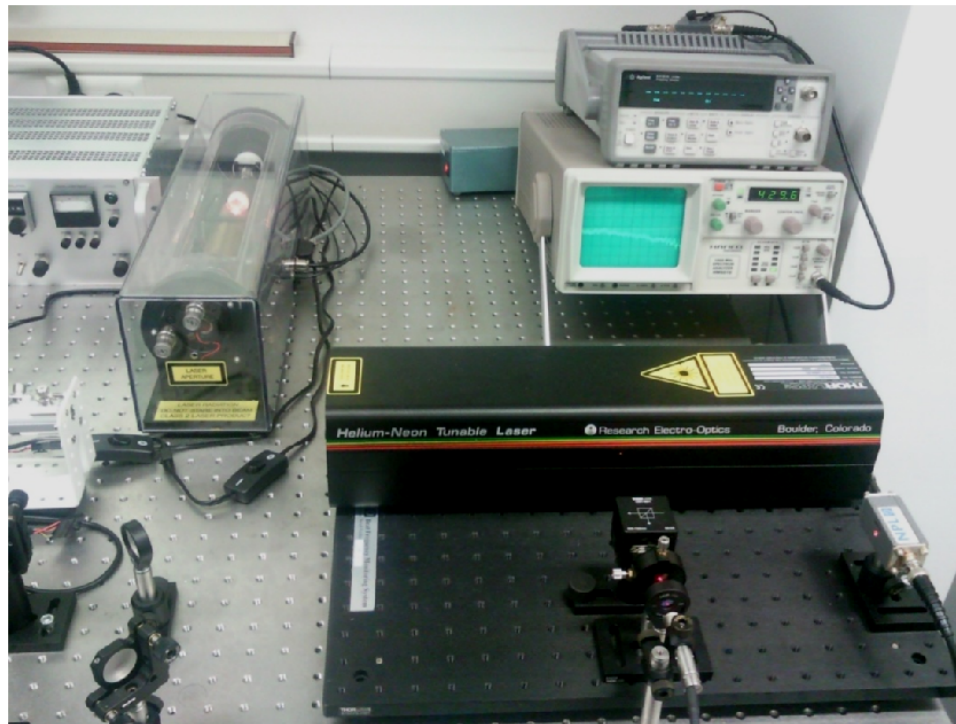




CCL - K11

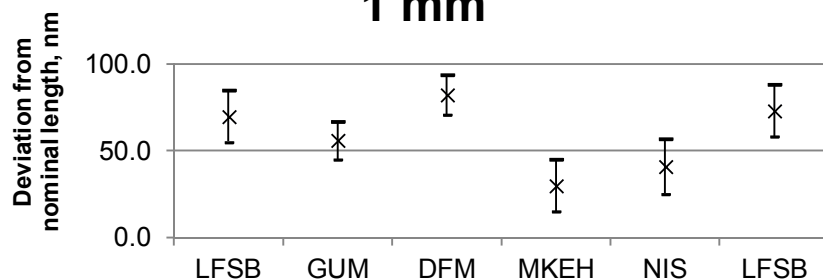
EURAMET country	BIPM.L-K10										Calib. at BIPM			BIPM.L-K11			CCL-K11				Last		NMI						
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007				2008	2009	2010			
Austria												●											●		2009	AT	BEV		
Belgium				●								●														1995	BE	SMD	
Bulgaria																										2001	BG	BIM	
Croatia																									●	2009	HR	DZM/LFSB	
Czech Rep.	●																								●	2010	CZ	CMI	
Denmark				●																						2005	DK	DFM	
Estonia																											EE	Metrosert	
Finland				●																						2007	FI	MIKES	
France	●				●																					2006	FR	LNE	
Germany	●			●																						2000	DE	PTB	
Greece																										2005	GR	EIM	
Hungary	●																									2010	HU	MKEH	
Ireland																											IE	NSAI NML	
Italy																										2006	IT	INRIM	
Latvia																											LV	LATMB-SAMC	
Lithuania																											LT	VMT/VMC	
Luxembourg																											LU	CRP-Henri Tudor	
Malta																											MT	MSA-NMS	
Netherlands																										2004	NL	VSL	
Norway																										2002	NO	JV	
Poland																										2007	PL	GUM	
Portugal																										2006	PT	IPQ	
Romania																										2005	RO	INM	
Serbia				●																						1990	RS	DMDM	
Slovenia																											2009	SI	MIRS/UM-FS
Slovakia																										2010	SK	SMU	
Spain																										2006	ES	CEM	
Sweden				●																						2004	SE	SP	
Switzerland				●																							CH	METAS	
Turkey																										2009	TR	UME	
UK																										2001	UK	NPL	

Umjeravanje He-Ne lasera

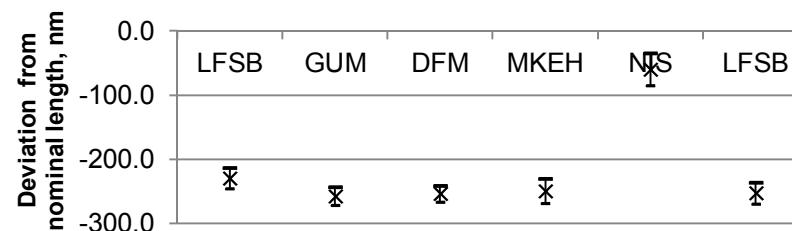


EURAMET 1138 (L.K1.2), Comparison of gauge blocks by interferometry

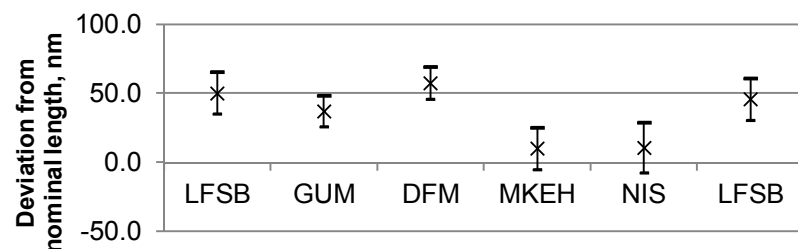
1 mm



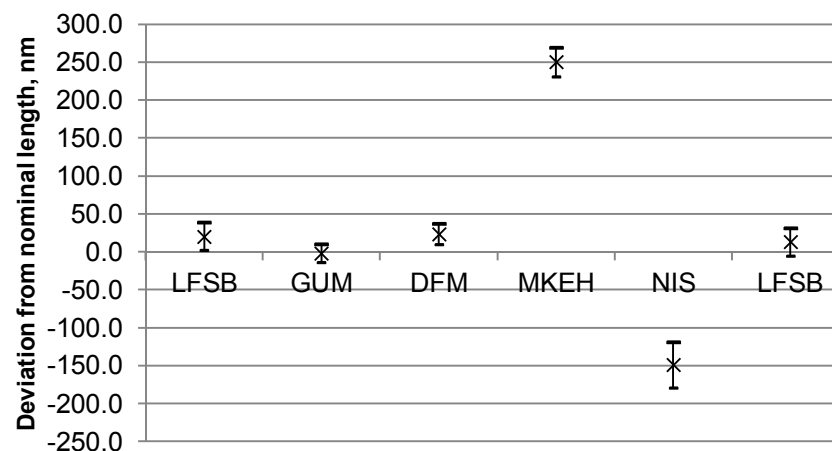
25 mm



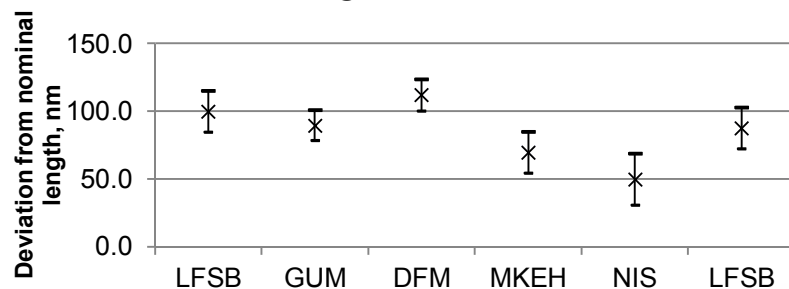
5 mm



40 mm



8 mm



2009. - Objavljivanje prvih CMC vrijednosti u CIPM MRA KCDB

BAZE PODATAKA MRA

Dodatak A: Potpisnici MRA;

Dodatak B: Rezultati ključnih i dodatnih usporedbi;

Dodatak C: Sposobnost umjeravanja i mjerenja (CMC) nacionalnih laboratorija;

Dodatak D: Popis usporedbi.



LFSB - CMC vrijednosti



Length, Croatia, HMI/FSB-LPMD (FSB - Laboratory for Precise Measurements of Length)

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty					NMI / Internal Service Identifier	Comments
Class	Instrument or Artifact: Measurand	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?		
End standards	Gauge block: central length, L	Mechanical comparison, comparator	0.5	100	mm			$(0.05 + 1.1L)$, L in m	μm	2	95%	No	1	Approved on 30 January 2009
End standards	Long gauge block	Length measuring machine	100	500	mm			$(0.35 + 1.0L)$, L in m	μm	2	95%	No	2	Approved on 30 January 2009
End standards	Micrometer setting rod and length bar: central length, L	Length measuring machine	0	500	mm			$(0.6 + 11.5L)$, L in m	μm	2	95%	No	3	Approved on 30 January 2009
Diameter standards	External cylinder (plug): diameter, L	Length measuring machine	0.1	100	mm			0.7	μm	2	95%	No	4	Approved on 03 November 2009
Diameter standards	External cylinder (plug): diameter	Length measuring machine	100	200	mm			1	μm	2	95%	No	4	Approved on 03 November 2009
Diameter standards	Internal cylinder (ring): diameter, D	Length measuring machine	8	150	mm			$(0.6 + 0.7D)$, D in m	μm	2	95%	No	5	Approved on 03 November 2009
Roughness standards	Roughness standards (ISO 5436-1 type C, D) ISO roughness parameter	Roughness instrument	0.02	30	μm	Average parameter, R_a	ISO 4287	$(12 + 38R_a)$, R_a in μm	nm	2	95%	No	8	Approved on 03 November 2009
Roughness standards	Roughness standards (ISO 5436-1 type C, D) ISO roughness parameter	Roughness instrument	0.025	100	μm	Peak parameter, R_z	ISO 4287	$(22 + 46R_z)$, R_z in μm	nm	2	95%	No	8	Approved on 03 November 2009
Line standards	Precision line scale: line spacing L	Laser interferometer and CCD microscope	0	300	mm			$(150 + L)$, L in mm	nm	2	95%	No	9	Approved on 03 August 2011
Laser radiations	Stabilized laser of the mise en pratique: vacuum wavelength	Optical beat frequency	633	633	nm	Temperature	$(20 \pm 5) ^\circ\text{C}$	0.04	fm	2	95%	No	10	Approved on 01 April 2010

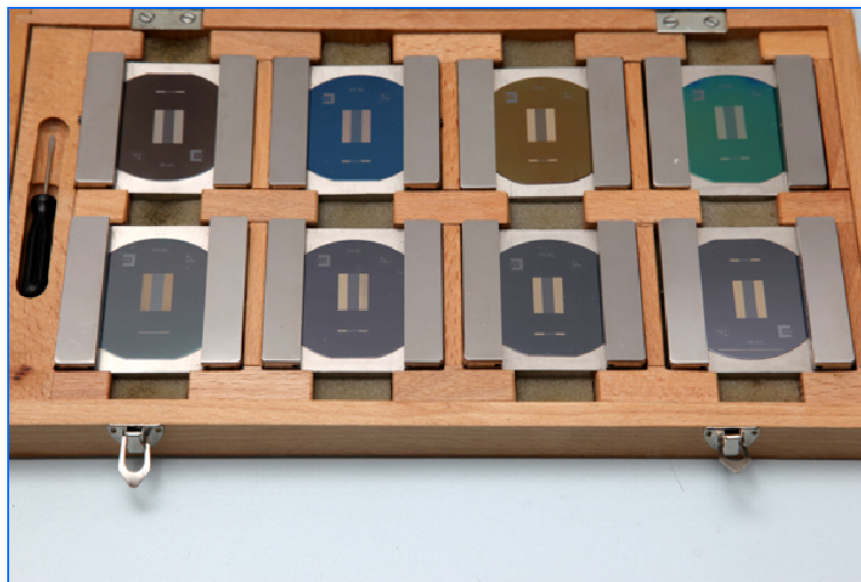


Length, Croatia, HMI/FSB-LPMD (FSB - Laboratory for Precise Measurements of Length)



Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty						
Class	Instrument or Artifact: Measurand	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	NMI / Internal Service Identifier	Comments
Laser radiations	Stabilized laser of the mise en pratique: absolute frequency	Optical beat frequency	474	474	THz	Temperature	(20 ± 5) °C	24	kHz	2	95%	No	10	Approved on 01 April 2010
Laser radiations	Other stabilised laser: vacuum wavelength	Optical beat frequency	633	633	nm			1.0E-09		2	95%	Yes	11	Approved on 01 April 2010
End standards	Gauge block: central length L	Interferometry, exact fractions	0.5	100	mm			Q[30, 0.5L], L in mm	nm	2	95%	No	20	Approved on 08 October 2012
Roundness standards	External cylinder (plug): roundness, R	Form tester stylus instrument	0	100	µm	Diameter	8 mm to 200 mm	Q[110, 20R], R in µm	nm	2	95%	No	12	Approved on 08 October 2012
Roundness standards	Internal cylinder (ring): roundness, R	Form tester stylus instrument	0	100	µm	Diameter	8 mm to 200 mm	Q[110, 20R], R in µm	nm	2	95%	No	13	Approved on 08 October 2012
Roundness standards	Hemisphere: roundness, R	Form tester stylus instrument	0	3	µm	Diameter	8 mm to 200 mm	Q[90, 20R], R in µm	nm	2	95%	No	14	Approved on 08 October 2012
Screw standards	Thread plugs, plain; simple pitch diameter	3 wire method, length measuring machine	1	60	mm	Pitch	0.25 mm to 6 mm	3.0	µm	2	95%	No	6	Approved on 20 February 2013
Screw standards	Thread rings, plain; simple pitch diameter	Two-ball stylus, length measuring machine	4	60	mm	Pitch	0.6 mm to 6 mm	3.0	µm	2	95%	No	7	Approved on 20 February 2013

1973. - Izrada vlastitog niza referentnih etalona hrapavosti



Etaloni su izrađeni u suradnji s tvrtkom RIZ – Zagreb.

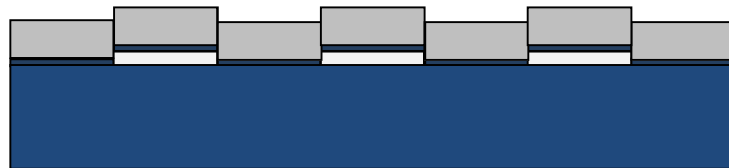
Doktorski rad prof.dr.sc. Sanjina Mahovića



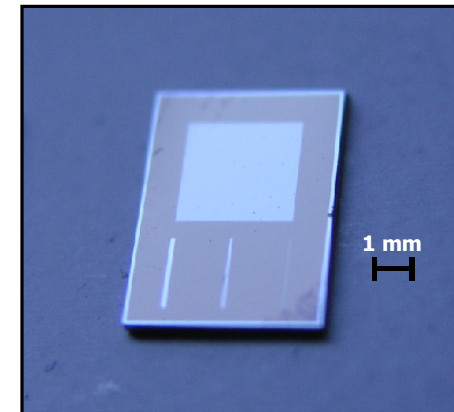
2011. - Realizacija novih etalona hrapavosti

Etaloni su realizirani u suradnji s tvrtkom MikroMasch Trading, Institutom Ruđer Bošković i institutom INRIM.

Doktorski rad dr.sc. Gorane Baršić.



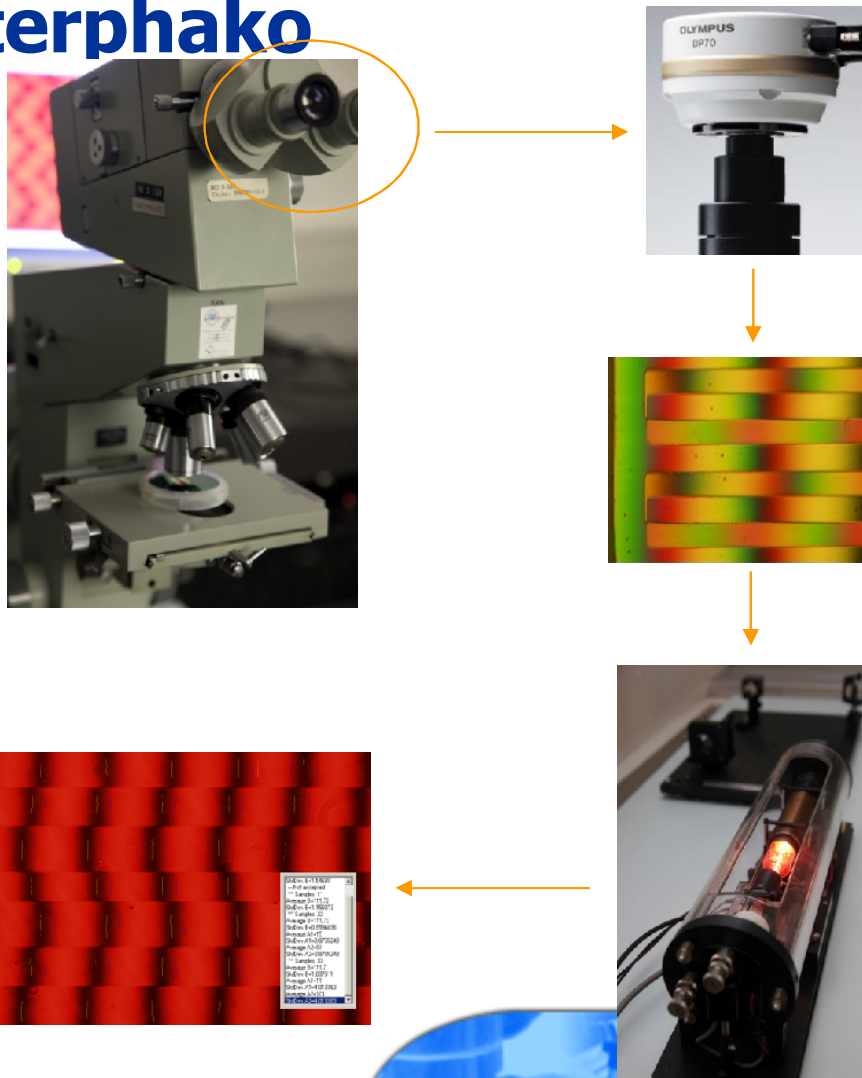
Presjek novog etalona hrapavosti



Novi etalon hrapavosti



Modifikacija interferencijskog mikroskopa Epival Interphako



EURAMET projekti

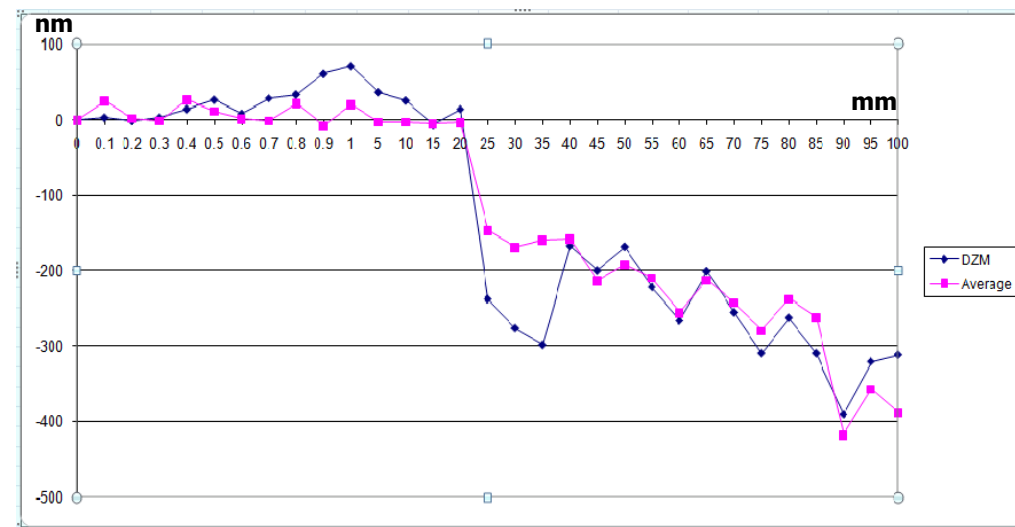
Red. br	Ref.	Započeo	Naslov	Institucija (Pilot)	Status	Vrsta	HMI Ogovorna osoba
1	1223	12.03.2012.	Supplementary comparison of parallel tread gauges	HMI/FSB-LPMD	proposed	comparison	Mudronja
2	1218	13.02.2012.	EURAMET.L-K1.2011: Calibration of Gauge Blocks by Interferometry	BEV	agreed/started	comparison	Mudronja
3	1138	23.11.2009.	Comparison of gauge blocks by interferometry	HMI/FSB-LPMD	agreed/started	comparison	Mudronja
4	1063	18.08.2008.	EURAMET link to the CCL key comparison CCL-K11	MIKES	agreed/started	comparison	Mudronja
5	1016	02.01.2008.	Interferometric measurements of gauge blocks	HMI/FSB-LPMD	completed	consultation	Mudronja
6	1012	01.02.2008.	Limitations of measuring methods for the depth of the groove	HMI/FSB-LPMD	completed	research	Mudronja
7	1003	09.11.2007.	Intercomparison of Measurements on Surface Texture Standards	LNE	agreed/started	comparison	Mudronja
8	914	01.09.2006.	Introduction of primary standard of length into a national metrology laboratory	MIRS/UM-FS/LTM	completed	consultation	Mudronja
9	882	01.02.2006.	Calibration of line scales EUROMET.L-K7	MIRS/UM-FS/LTM	agreed/started	comparison	Mudronja
10	812	01.01.2005.	Calibration of diameter standards (EUROMET.L-K4.2005)	INRIM	agreed/started	comparison	Mudronja
11	789	28.06.2004.	Using stabilized lasers for Kösters type gauge block interferometers.	BEV	completed	consultation	Mudronja
12	747	01.10.2003.	Workshop on software used in length metrology	NPL	completed	research	Mudronja
13	678	16.10.2002.	Workshop on recent technical developments at length laboratories	METAS	completed	research	Mudronja
14	652	01.03.2002.	Calibration of short steel gauge blocks by mechanical comparison	MIRS/UM-FS/LTM	completed	research	Mudronja
15	622	01.10.2001.	Workshop on uncertainty in length measurements	METAS	completed	research	Mudronja
16	588	01.04.2000.	Traceability of surveying and geodetic instruments	CEM	completed	research	Mudronja

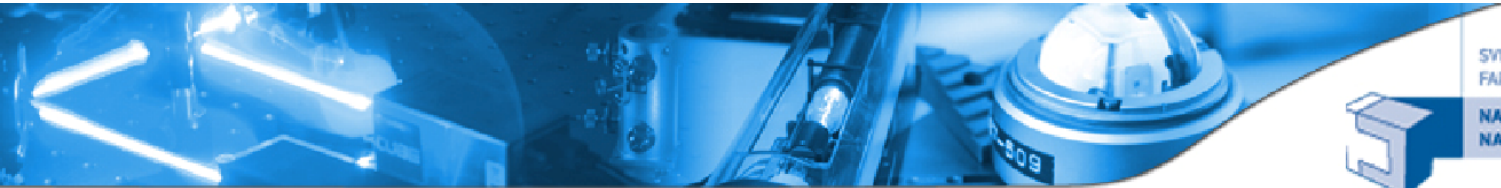
Umjeravanje preciznih mjernih skala



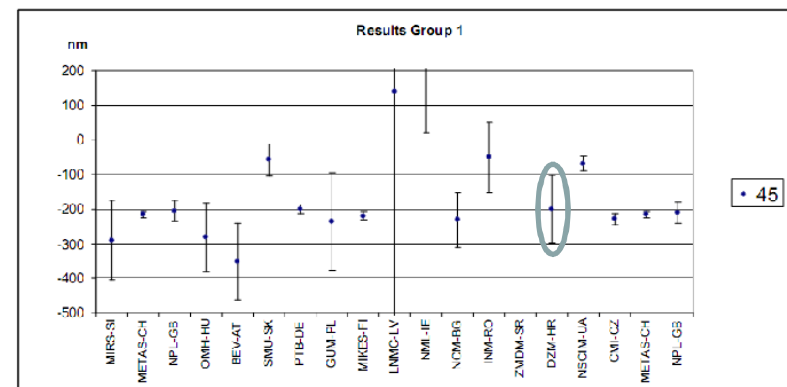
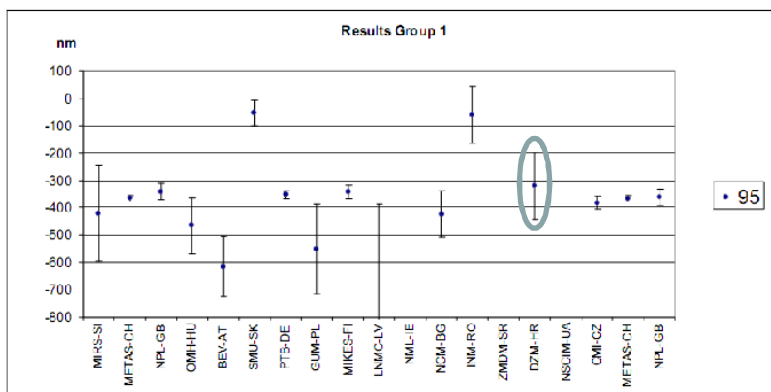
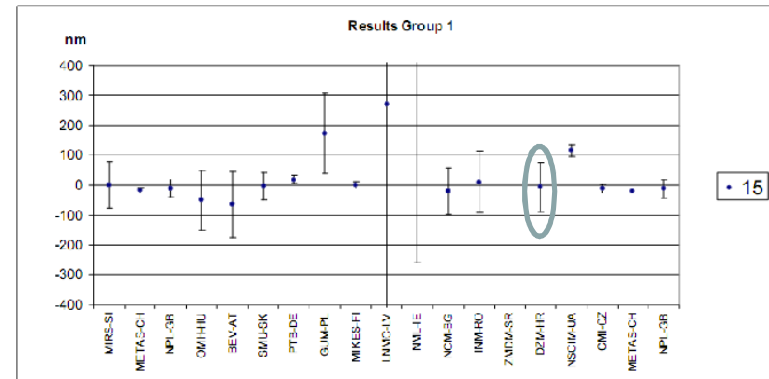
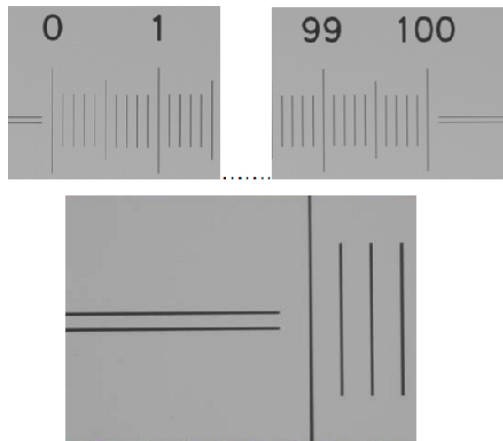
Projekti:

- TP - Uređaj za umjeravanje mjernih skala (HR);
- EURAMET L-K7, Calibration of line scales.



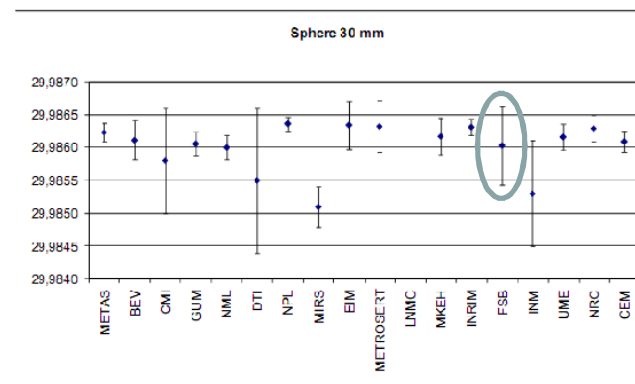
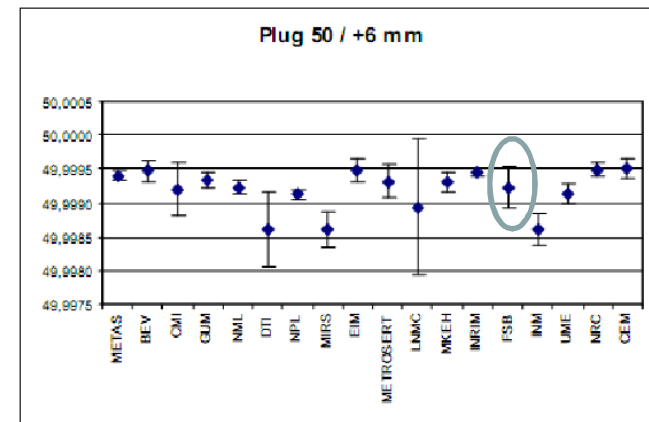
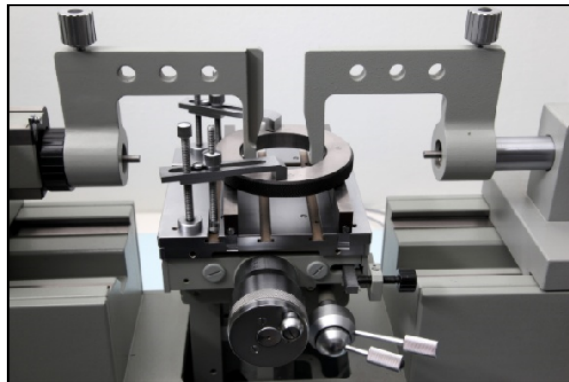


EURAMET L-K7, Calibration of line scales.



Promjeri i kružnost

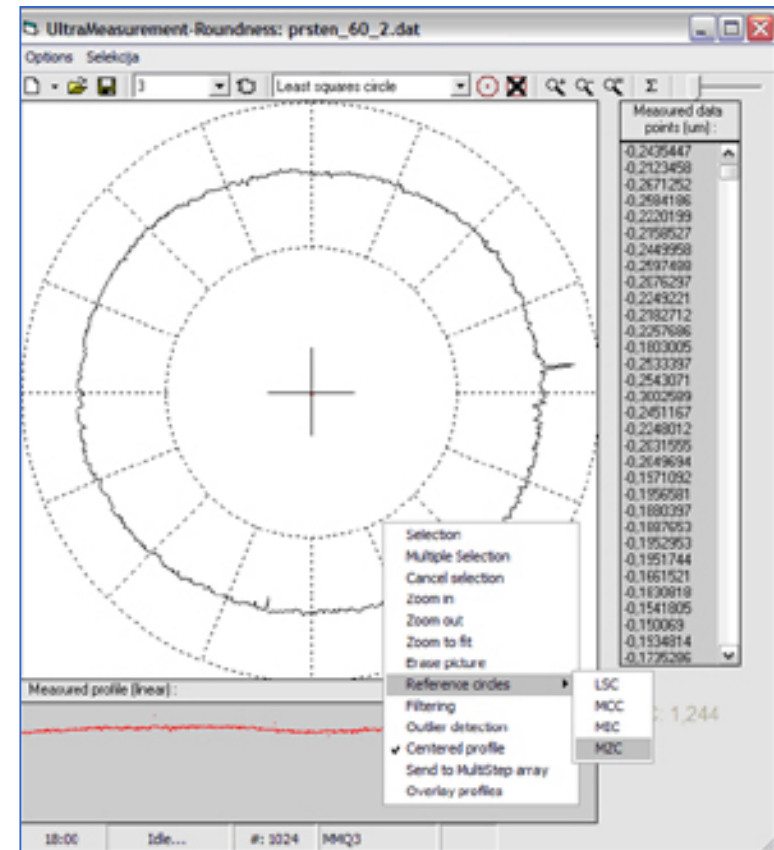
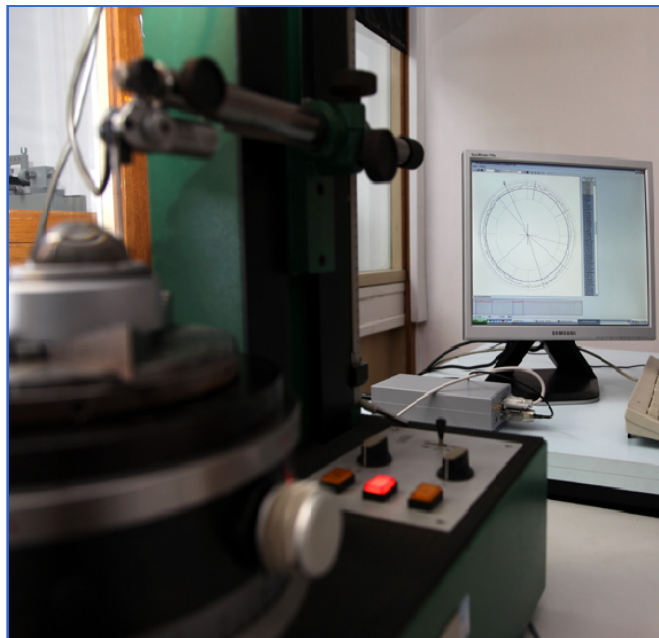
EURAMET L-K4.2005, Calibration of diameter standards.

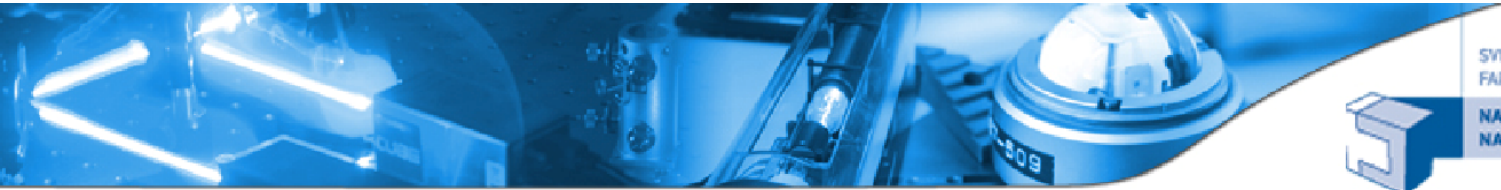


Izrada softvera i modifikacija uređaja za ispitivanje kružnosti

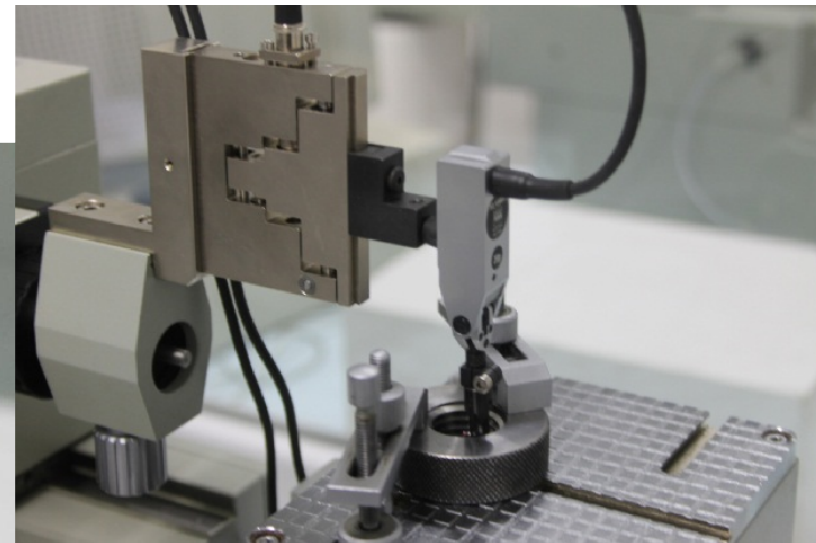
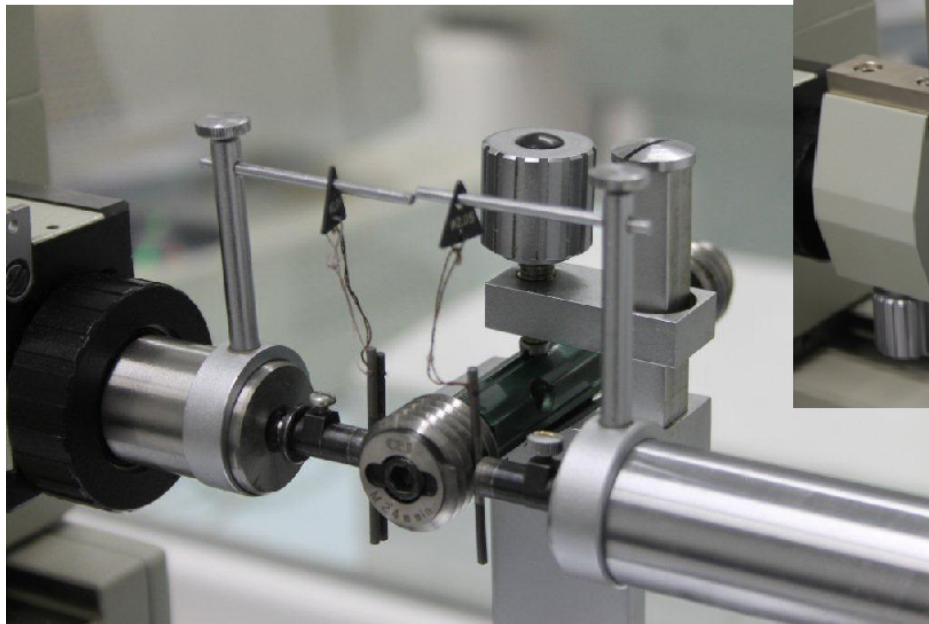
Projekti:

- Nacionalni laboratorij za duljinu (HR).
- EURAMET L-K4.2005, Calibration of diameter standards.



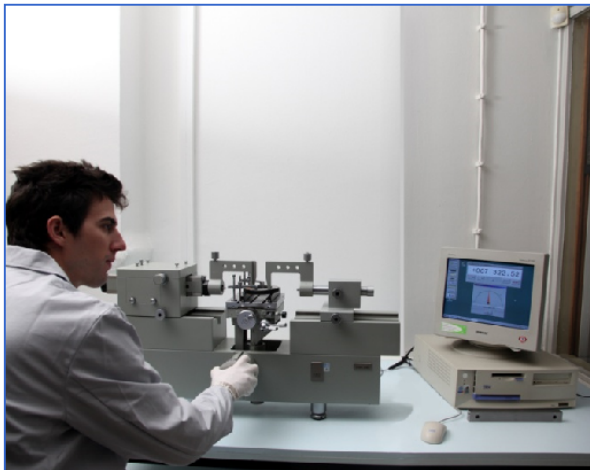


EURAMET L.S21, Supplementary comparison of parallel tread gauges





Usluge mjerenja i umjeravanja

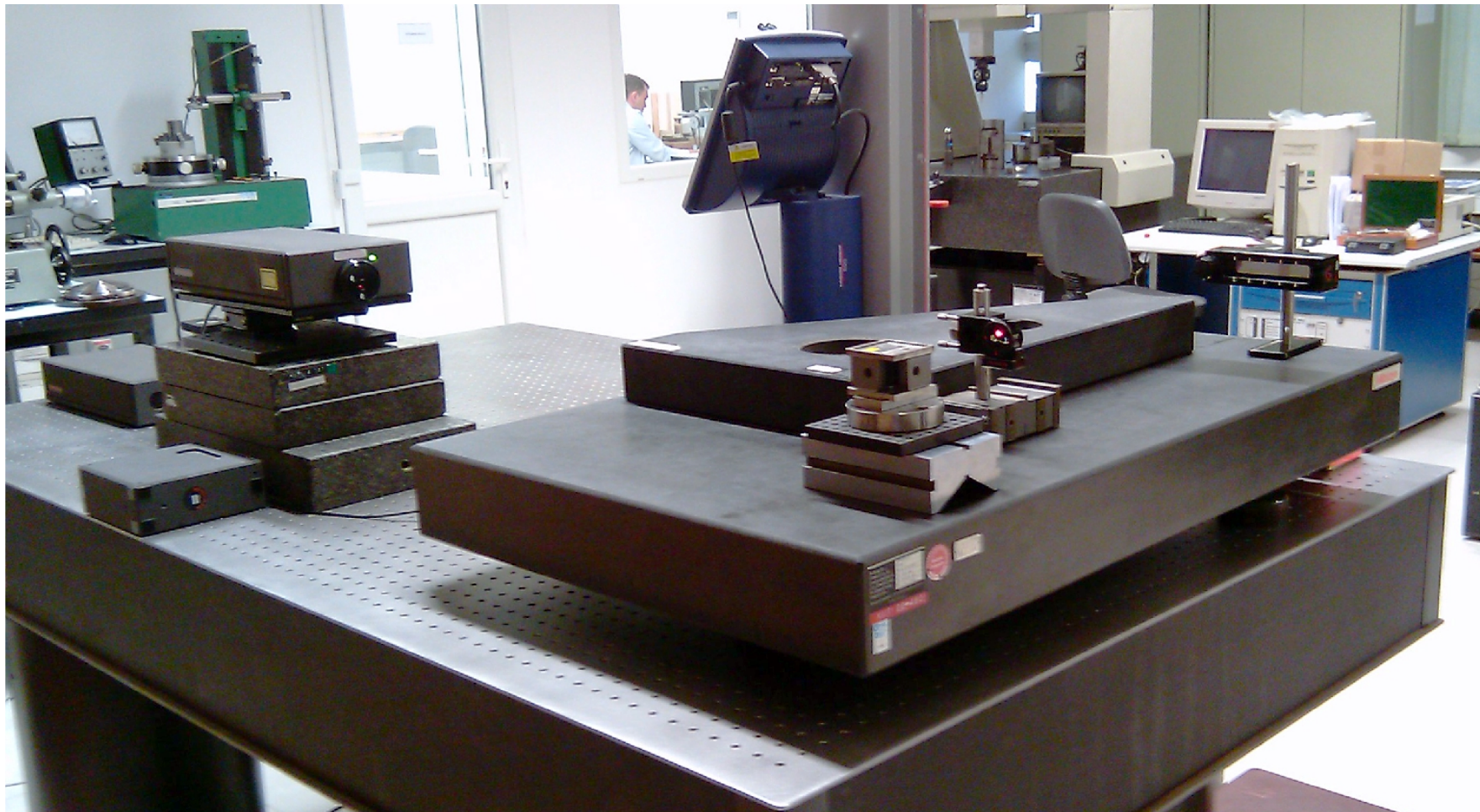


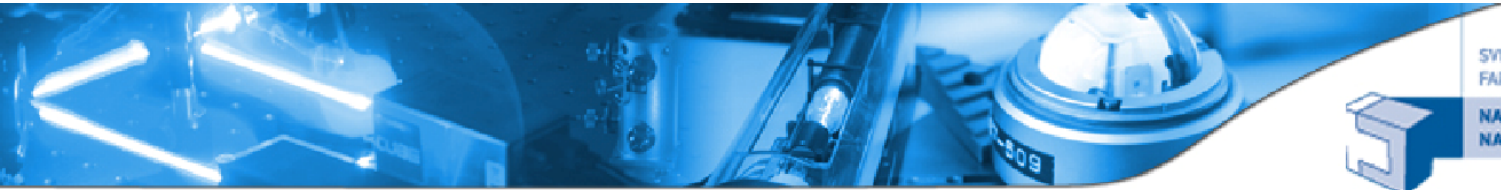
Laboratorij danas godišnje vrši usluge mjerenja i umjeravanja za više od 400 gospodarskih subjekata iz Hrvatske i regije (Bosna i Hercegovina, Crna Gora, Makedonija).



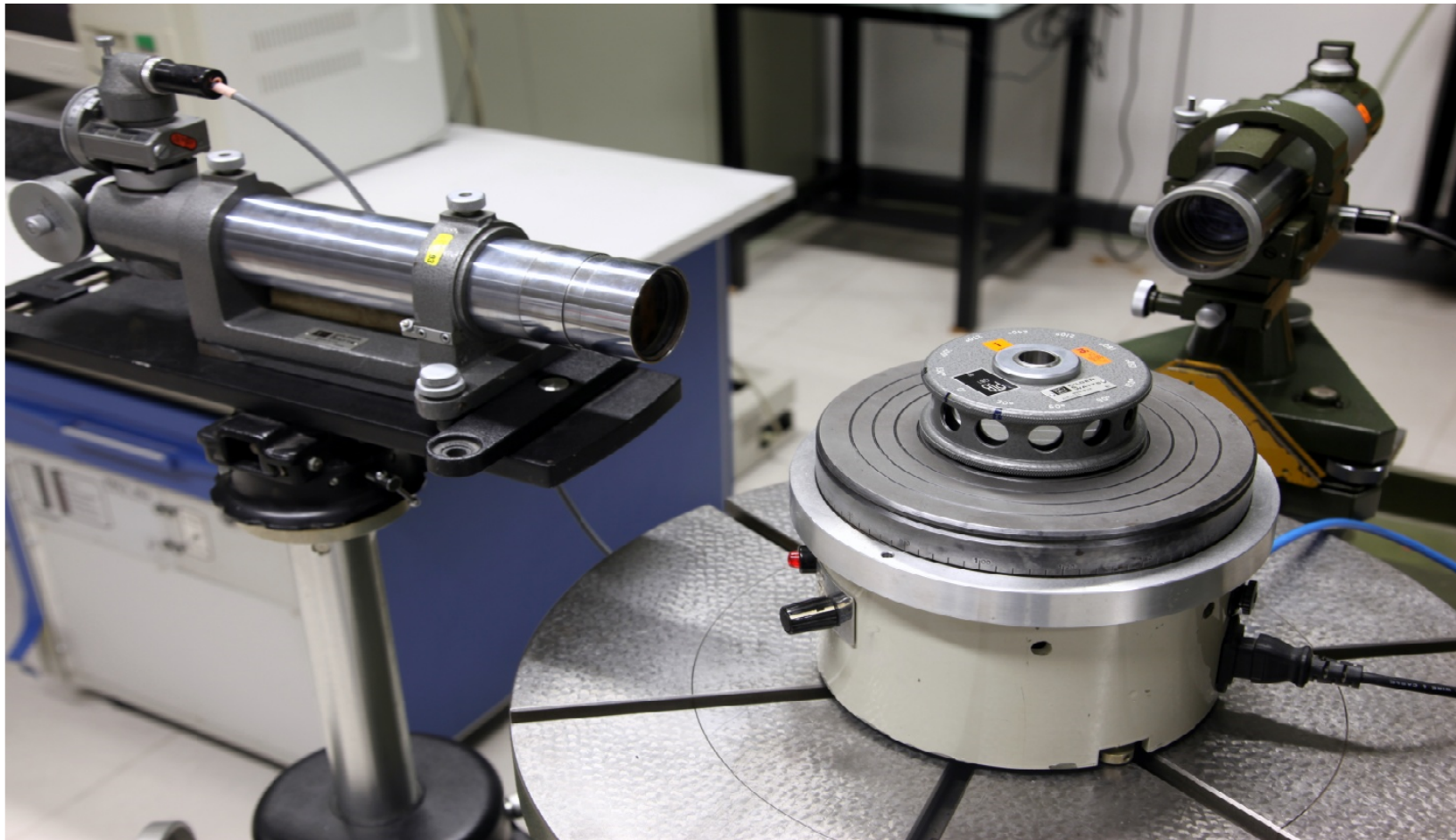


Umjeravanje kutnika





Umjeravanje kutnog poligona



Optičko mjerenje primjenom rekonstruiranog alatnog mikroskopa i laserskog interferometra



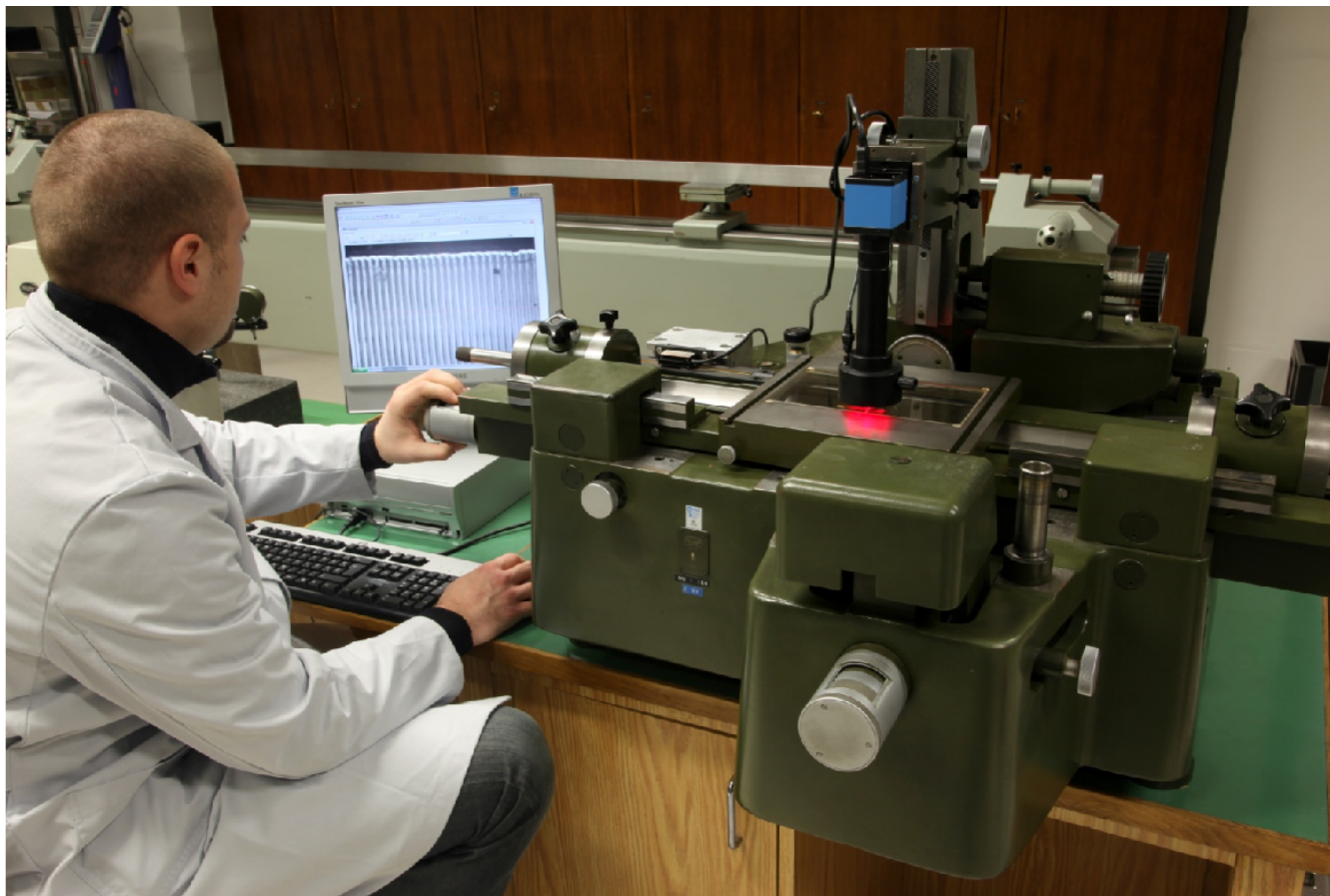


Umjeravanje stepenaste mjerke primjenom TMU "Ferranti" i laserskog interferometra





Umjeravanje mjernog lineala

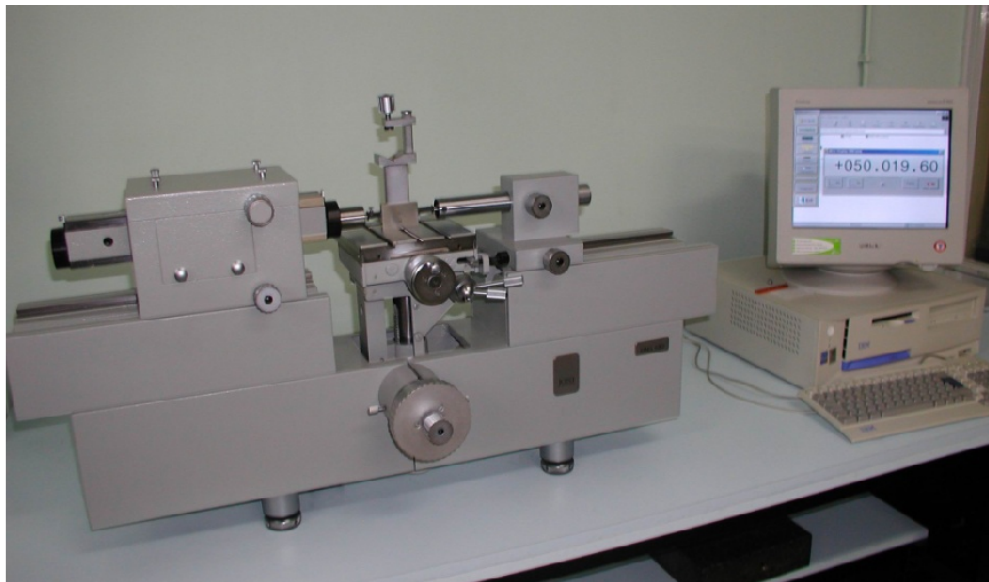




Ispitivanje hrapavosti

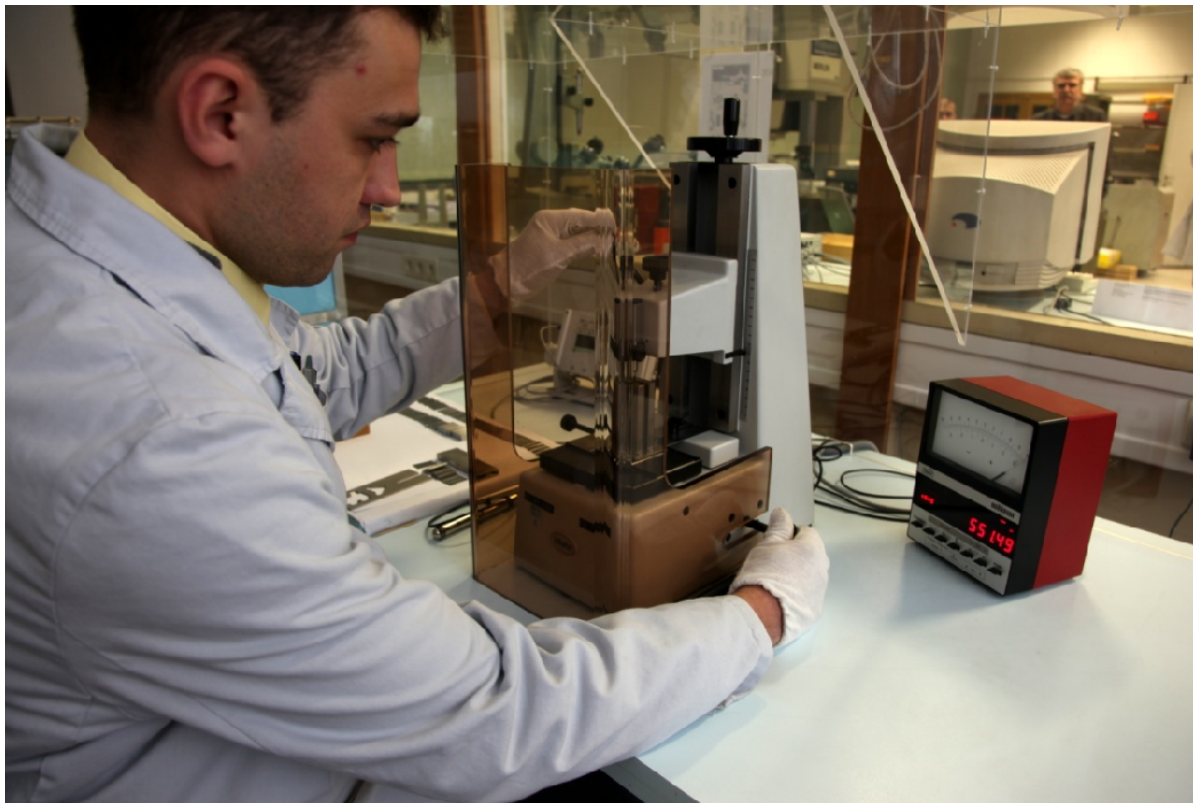


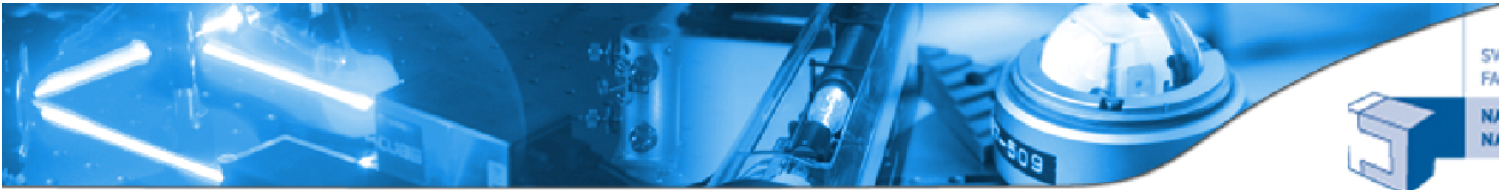
Umjeravanje mjernog prstena



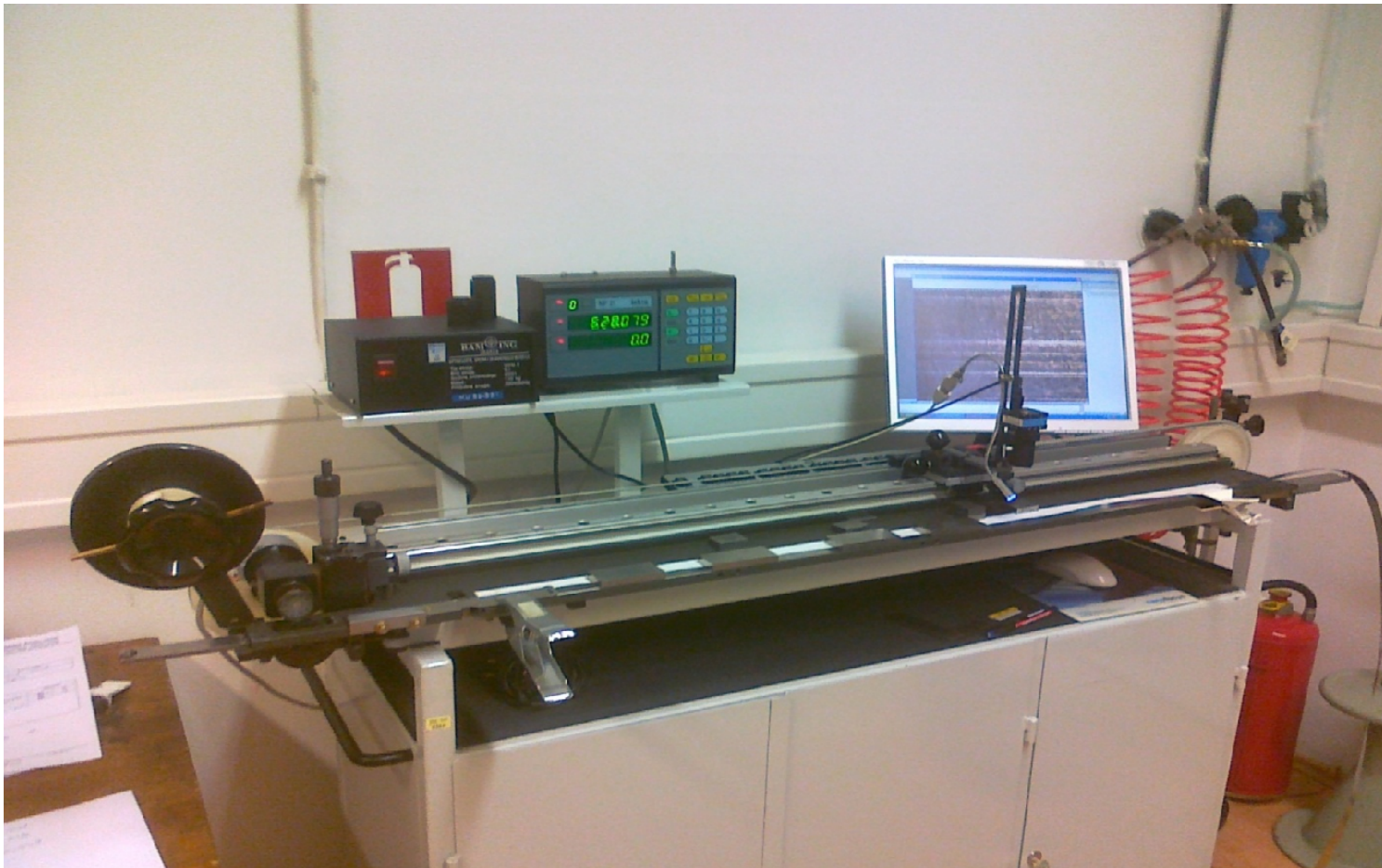


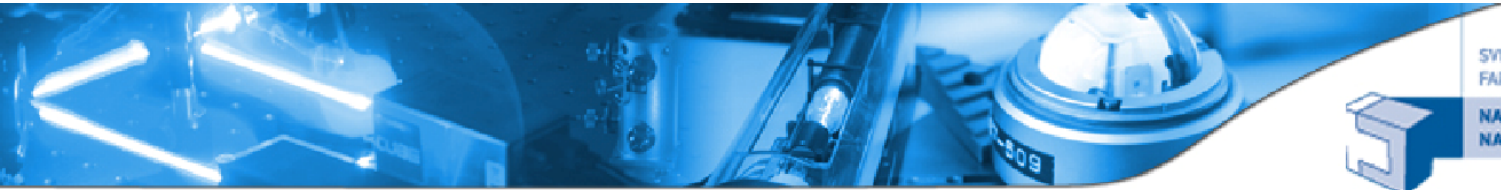
Umjeravanje planparalelne granične mjerke





Umjeravanje savitljive mjerne trake





Etaloni za provedbu umjeravanja





Umjesto zaključka

Pitamo se da li je kome stalo do rezultata koje je Laboratorij ostvario predstavljajući državu u Europi i svijetu. Što bi se dogodilo da nije bilo nikakvih rezultata?

