Key comparison APMP.L-K2

MEASURAND : Central length of long gauge blocks measured by interferometry according to ISO 3650 or by comparison
gauge block material: steel

NOMINAL VALUES : 3 gauge blocks with lengths 200 mm, 250 mm and 500 mm

x_{ik} : result of measurement carried out by laboratory i for gauge block k with nominal
length L_k, expressed as the deviation from nominal length in nm

u_{ik} : combined standard uncertainty of x_{ik} reported by laboratory i

nominal length L_k (k = 1 to 3) ⟹

Lab i ⟱	200 mm			250 mm			500 mm			Date of measurement
	S/N 18743			S/N 980272			S/N 980387			
	x_{i1} / nm	u_{i1} / nm	Method	x_{i2} / nm	u_{i2} / nm	Method	x_{i3} / nm	u_{i3} / nm	Method	
NMIA(1)	301	24	Int.	181	28	Int.	412	50	Int.	January 2000
NMIA(2)	324	34	Int.	121	39	Int.	283	70	Int.	June 2000
MSL	420	160	Comp.	255	160	Comp.	455	200	Comp.	July 2000
CSIR-NML	265	90	Int.	215	90	Int.	155	140	Int.	August 2000
KRISS	343	24	Int.	90	41	Int.	310	214	Comp.	September 2000
NMIJ	336	20	Int.	118	23	Int.	280	39	Int.	October 2000
NIM	376	21	Int.	181	26	Int.	280	60	Int.	November 2000
NMIA(3)	338	24	Int.	112	28	Int.	270	50	Int.	January 2001
NPLI(1)	-100	183	Comp.	-200	191	Comp.	-600	228	Comp.	April 2001
NML-SIRIM	342	34	Int.	149	41	Int.	195	239	Comp.	May 2001
SCL	600	170	Comp.	240	200	Comp.	310	350	Comp.	May 2001
CMS/ITRI	210	100	Comp.	50	120	Comp.	100	230	Comp.	June 2001
NMIA(4)	349	24	Int.	87	28	Int.	199	50	Int.	September 2001
KIM-LIPI	189	260	Comp.	-185	338	Comp.	333	553	Comp.	January 2002
ITDI	13700	2400	Comp.	31700	1700	Comp.	-18000	1500	Comp.	March 2002
NPLI(2)	1600	413	Comp.	400	466	Comp.	-400	730	Comp.	September 2002
NMIA(5)	468	24	Int.	-1	28	Int.	17	50	Int.	December 2002

Methods: "Int." for interferometry, "Comp." for comparison.
SPRING Singapore was unable to participate due to instrument failure.
NPLI asked for a re-measure.
The artefacts were measured five times at the Pilot laboratory (NMIA) with the same method, in order to provide information on artefact changes
with time.

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Equivalence statements

The APMP key comparison reference value, x_{Rk}, for each gauge block k, is determined from the linear function $x_{Fk}(t)$, where t is the date of measurement, obtained by fitting a straight line to the participants' values x_{ik} (with weights based on each reported uncertainty u_{ik}), and by adding a value $C_k(t)$ chosen such that the reference value is the nominal length: $x_{Rk} = L_k = x_{Fk}(t) + C_k(t)$. The linear regression determines two constants A_k and B_k and assumes a linear change in length with time: $x_{Rk} = A_k + B_k t + C_k(t)$ (see sections 4 and 5 of the Final Report).
The standard uncertainty, u_{Rk}, of the reference value is computed as the internal standard deviation of the weighted mean.

nominal length L_k (k = 1 to 3)

	200 mm		250 mm		500 mm		
	S/N 18743		S/N 980272		S/N 980387		Lab i
Date of measurement t	x_{F1} / nm	u_{R1} / nm	x_{F2} / nm	u_{R2} / nm	x_{F3} / nm	u_{R3} / nm	
January 2000	311	11	191	14	354	28	NMIA(1)
June 2000	330	11	166	14	311	28	NMIA(2)
July 2000	334	11	161	14	302	28	MSL
August 2000	338	11	155	14	293	28	CSIR-NML
September 2000	342	11	150	14	285	28	KRISS
October 2000	346	11	145	14	276	28	NMIJ
November 2000	350	11	140	14	267	28	NIM
January 2001	358	11	129	14	250	28	NMIA(3)
April 2001	370	11	114	14	224	28	NPLI(1)
May 2001	374	11	109	14	216	28	NML-SIRIM
May 2001	374	11	109	14	216	28	SCL
June 2001	378	11	104	14	207	28	CMS/ITRI
September 2001	390	11	88	14	181	28	NMIA(4)
January 2002	406	11	68	14	146	28	KIM-LIPI
March 2002	414	11	58	14	129	28	ITDI
September 2002	438	11	27	14	77	28	NPLI(2)
December 2002	450	11	12	14	51	28	NMIA(5)

Key comparison APMP.L-K2

MEASURAND :	Central length of long gauge blocks measured by interferometry according to ISO 3650 or by comparison gauge block material: steel
NOMINAL VALUES :	3 gauge blocks with lengths 200 mm, 250 mm and 500 mm

Equivalence statements (Cont.)

The degree of equivalence of each laboratory i with respect to the reference value for each gauge block k is given by a pair of terms:
the difference D_{ik} and its expanded uncertainty U_{ik} (coverage factor: 2) with

$D_{ik} = x_{ik} + C_k - x_{Rk} = x_{ik} - x_{Fk}$ and $U_{ik} = 2(u_{ik}^2 - u_{Rk}^2 + u_{Ak}^2)^{1/2}$

where u_{Ak} represents the artefact uncertainty, determined from the pilot's measurements.

nominal length L_k (k = 1 to 3) ⟹

	200 mm	250 mm	500 mm
	S/N 18743	S/N 980272	S/N 980387
u_{Ak} / nm	11	8	19

The calculation of the degree of equivalence between two laboratories i and j is not recommended for comparisons involving several material standards, since it cannot be expressed with a single pair of terms.
It would have to be calculated separately for each gauge block k and would then be given by a pair of terms:
the difference D_{ijk} and its expanded uncertainty U_{ijk} (coverage factor: 2).

$D_{ijk} = x_{ik} - x_{jk}$ and $U_{ijk} = 2(u_{ik}^2 + u_{jk}^2)^{1/2}$.

Key comparison APMP.L-K2 is parallel to key comparison CCL-K2.
Numerical linking of these comparisons is not recommended due to artefact dependent offsets. Instead, laboratories participating competently in both key comparisons establish the link and assure equivalence.
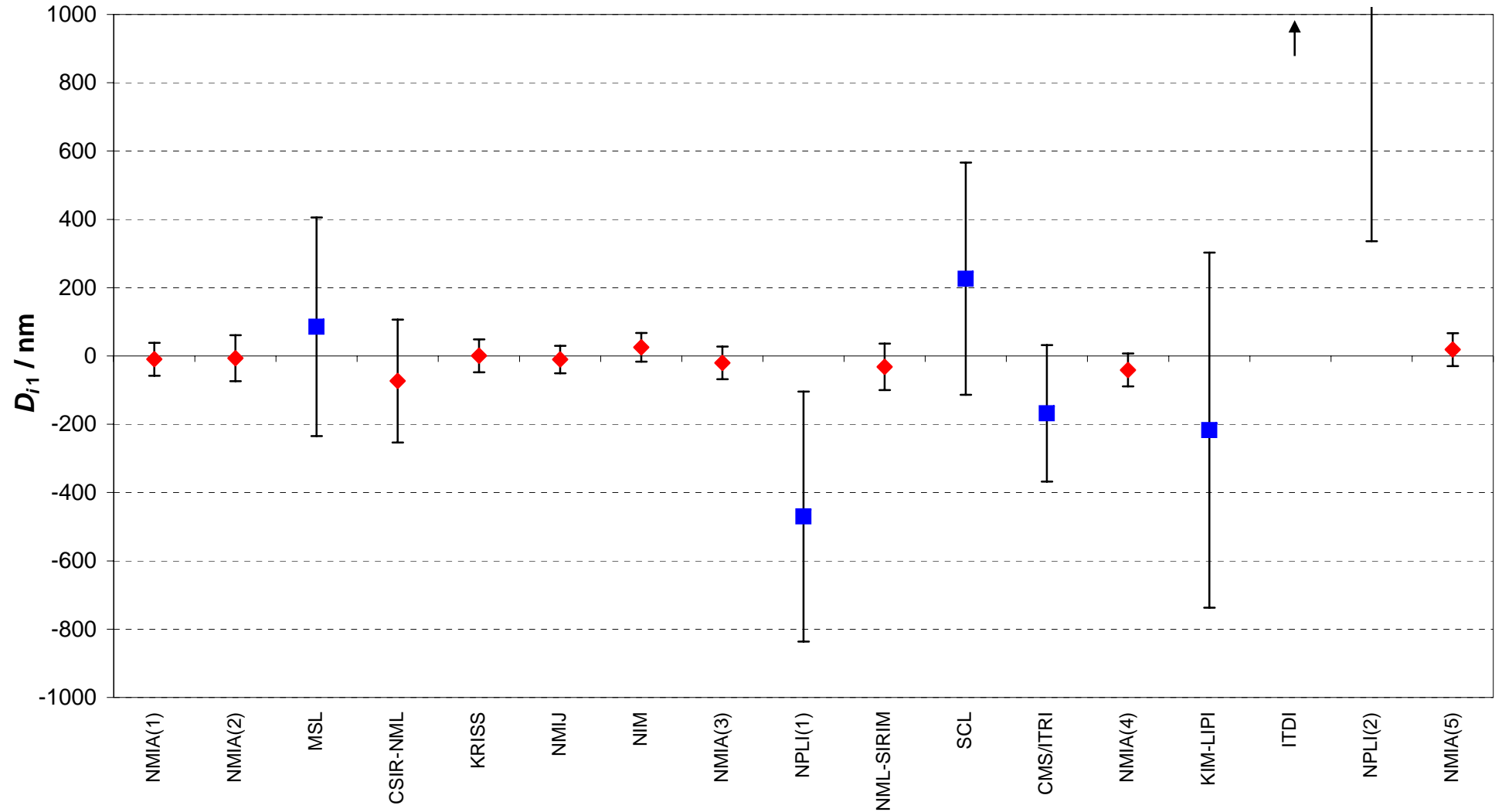
Key comparison APMP.L-K2

MEASURAND :	Central length of long gauge blocks measured by interferometry according to ISO 3650 or by comparison gauge block material: steel
NOMINAL VALUES :	3 gauge blocks with lengths 200 mm, 250 mm and 500 mm

nominal length L_k (k = 1 to 3) ⟹

| Lab i	200 mm		250 mm		500 mm	
	S/N 18743		S/N 980272		S/N 980387	
	D_{i1} / nm	U_{i1} / nm	D_{i2} / nm	U_{i2} / nm	D_{i3} / nm	U_{i3} / nm
NMIA(1)	-10	48	-10	52	58	91
NMIA(2)	-6	67	-45	75	-28	134
MSL	86	320	94	319	153	398
CSIR-NML	-73	180	60	179	-138	277
KRISS	1	48	-60	79	25	426
NMIJ	-10	40	-27	41	3	67
NIM	26	42	41	47	13	113
NMIA(3)	-20	48	-17	52	20	91
NPLI(1)	-470	366	-314	381	-824	454
NML-SIRIM	-32	68	40	79	-21	476
SCL	226	340	131	399	94	699
CMS/ITRI	-168	200	-54	239	-107	458
NMIA(4)	-41	48	-1	52	18	91
KIM-LIPI	-217	520	-253	676	187	1105
ITDI	13286	4800	31642	3400	-18129	3000
NPLI(2)	1162	826	373	932	-477	1459
NMIA(5)	18	48	-13	52	-34	91

APMP.L-K2   200 mm steel gauge block, S/N 18743

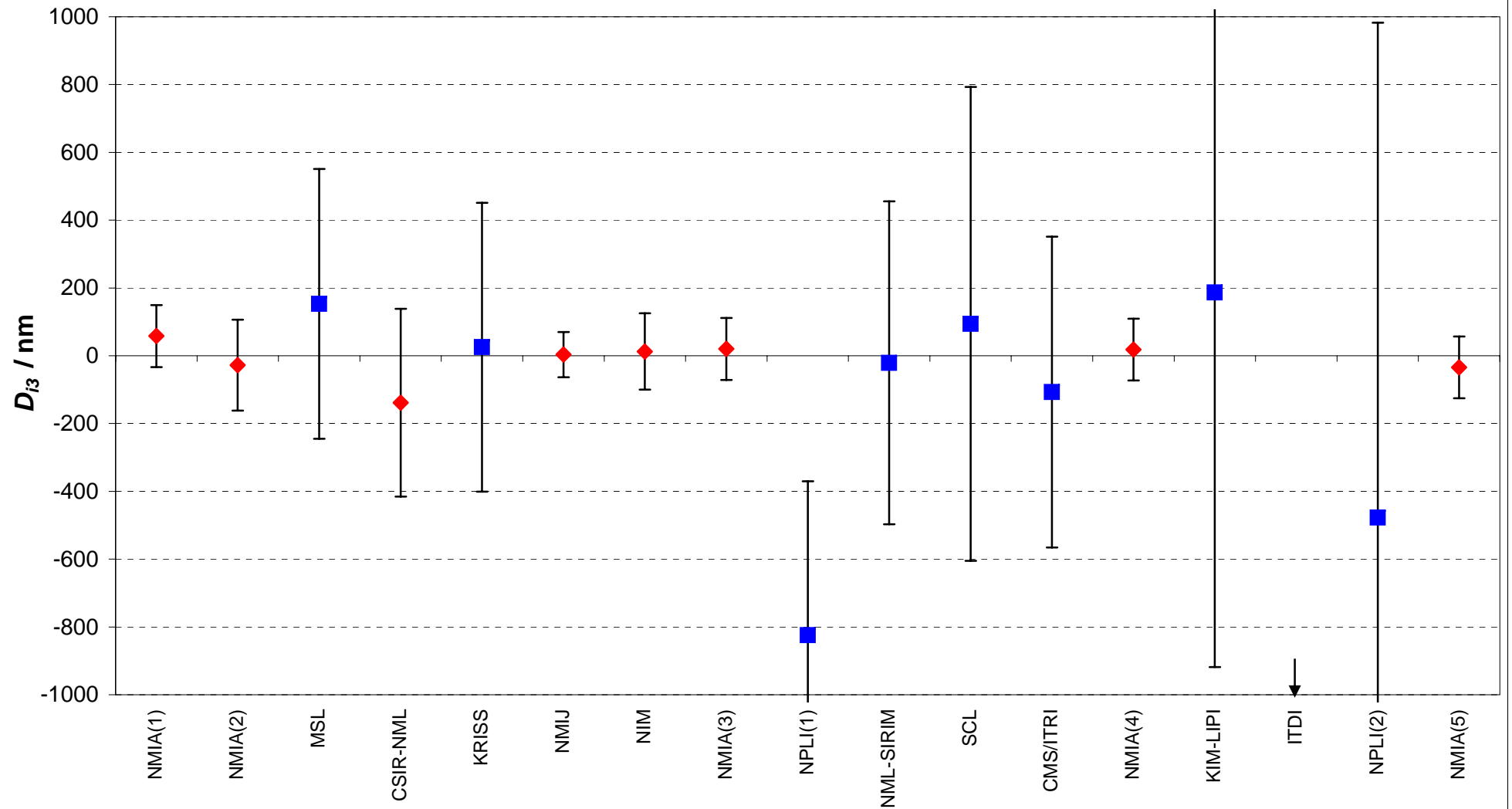Degrees of equivalence [D_{i1} and its expanded uncertainty (coverage factor: 2) U_{i1}]

D_{i1} / nm

X-axis categories: NMIA(1), NMIA(2), MSL, CSIR-NML, KRISS, NMIJ, NIM, NMIA(3), NPLI(1), NML-SIRIM, SCL, CMS/ITRI, NMIA(4), KIM-LIPI, ITDI, NPLI(2), NMIA(5)

Red diamonds : measurements by interferometry, **Blue squares** : measurements by comparison
D_{ITDI} = 13286 nm and U_{ITDI} = 4800 nm (Comparison); $D_{\text{NPLI(2)}}$ = 1162 nm and $U_{\text{NPLI(2)}}$ = 826 nm (Comparison)

APMP.L-K2   250 mm steel gauge block, S/N 980272

Degrees of equivalence [D_{i2} and its expanded uncertainty (coverage factor: 2) U_{i2}]
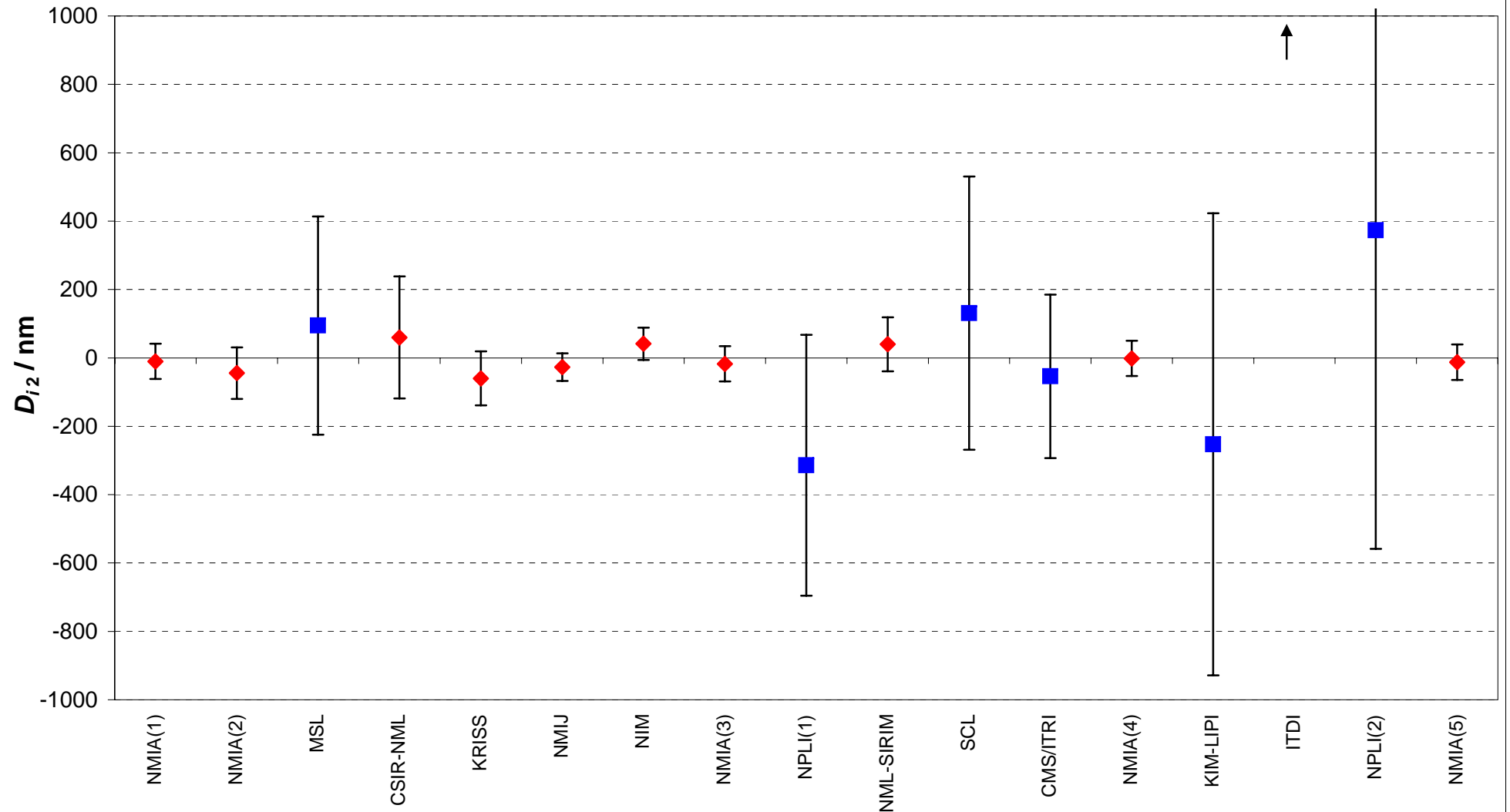
Red diamonds : measurements by interferometry, Blue squares : measurements by comparison
D_{ITDI} = 31642 nm and U_{ITDI} = 3400 nm (Comparison)

APMP.L-K2   500 mm steel gauge block, S/N 980387

Degrees of equivalence [D_{i3} and its expanded uncertainty (coverage factor: 2) U_{i3}]

D_{i3} / nm

NMIA(1) NMIA(2) MSL CSIR-NML KRISS NMIJ NIM NMIA(3) NPLI(1) NML-SIRIM SCL CMS/ITRI NMIA(4) KIM-LIPI ITDI NPLI(2) NMIA(5)

Red diamonds : measurements by interferometry, **Blue squares** : measurements by comparison

D_{ITDI} = -18129 nm and U_{ITDI} = 3000 nm (Comparison)