Characterization of targets: ROMA1 – ROMA3 - LNL

Experimental activity

A list of several experimental activities should be planned in the future for an accurate determination of the thermo-mechanical properties of the targets.

1. **Measurement of the thermo-elastic properties of Graphite disks in a wide temperature range.**

2. **Measurement of thermal diffusivity and infrared emissivity via photo-thermal radiometry and infrared thermography. A training activity will be carried out to use the infrared camera in passive regime for emissivity measurements and surface temperature estimation, and in active regime with a lock-in system for the determination of internal fractures**.

3. **Detection of possible damage and thermomechanical stress when the target is subjected to intense laser beams. In fact, the thermomechanical performance of the target can be easily tested with photons bunches, instead of positron bunches, so to perform the measurements with an easier optical setup. The intensity and pulse duration of the optical source should be chosen so to generate analogous space-temporal temperature variations.**

Characterization of targets: ROMA1 – ROMA3 - LNL

Experimental activity

4. New setup for temperature measurements: a fast optical NIR sensor can be used for accurate measurement of high temperatures with high spatial and temporal resolution. A feasibility study should be initially performed.

5. **Ex ante and ex post measurements of the induced surface damage of targets subjected to intense laser beams with profilometry and other standard techniques (before and after the illumination)**

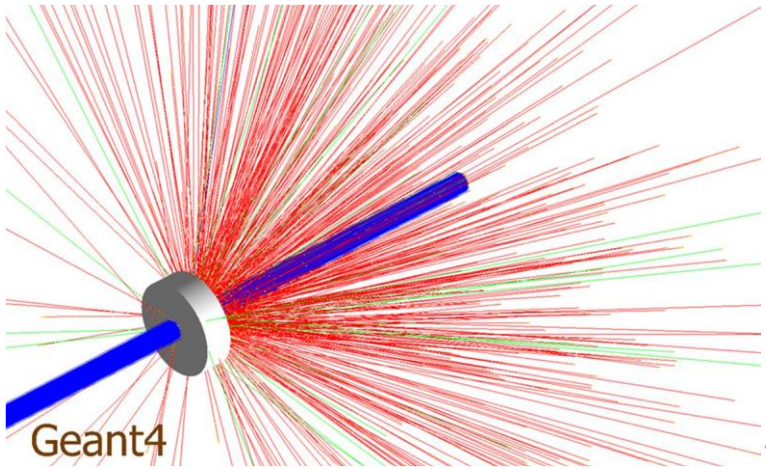
6. Theory - Thermal relaxation test on 2 or more solid targets with different geometric arrangements. The approach here is to use multiple targets to decrease the PEDD on a single target. A critical point is here the mutual position among the targets so to optimize the infrared radiation mechanism as happens for "*smart radiators*".

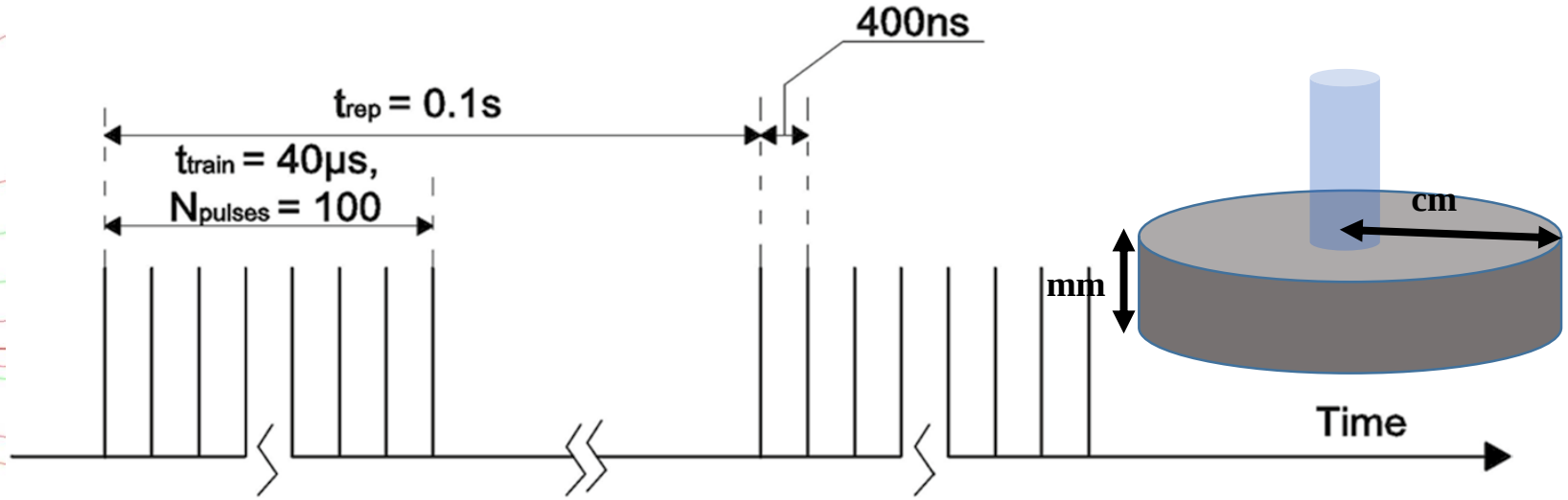
7. Future - Ex ante and ex post measurements by XRD of lattice constant changes due to thermoelastic stresses.

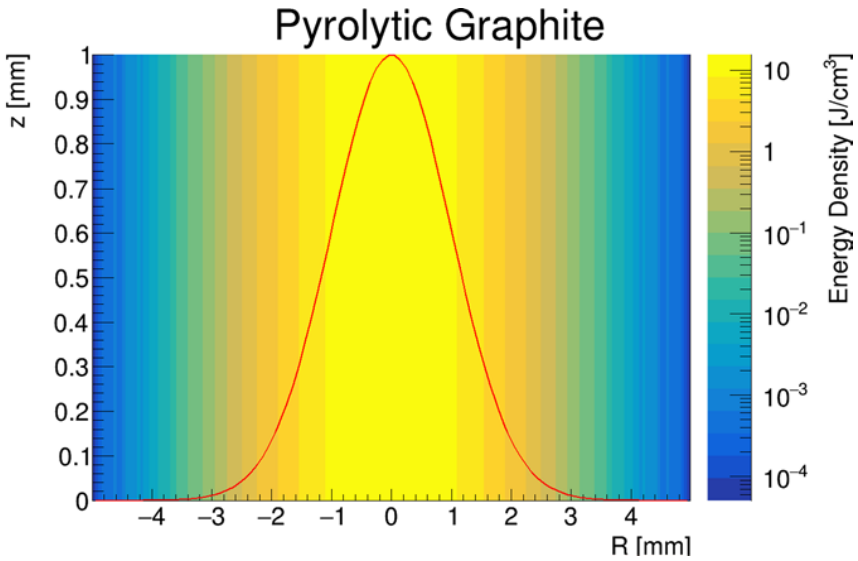
Theoretical Modeling for the Thermal Stability of Solid Targets in a Positron-Driven Muon Collider

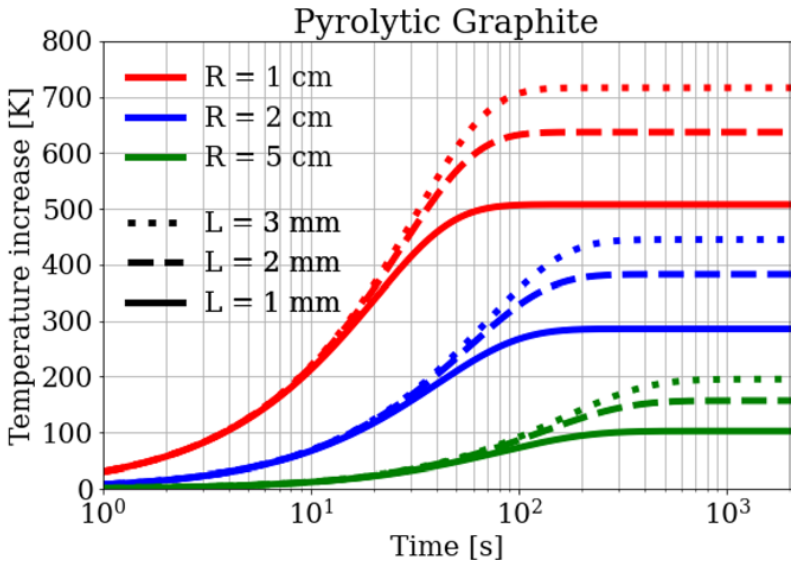
G.Cesarini et al.

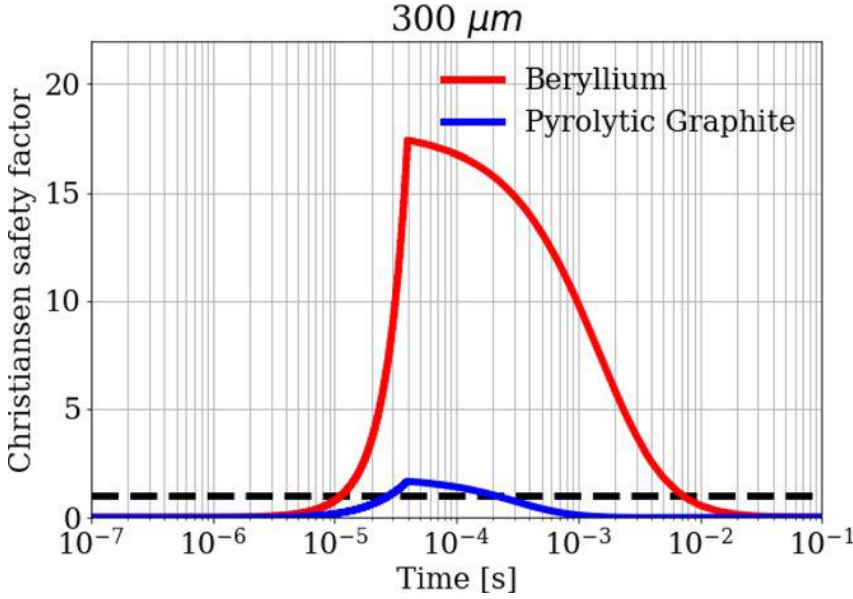
International Journal of Thermophysics (2021) 42:163
https://doi.org/10.1007/s10765-021-02913-x







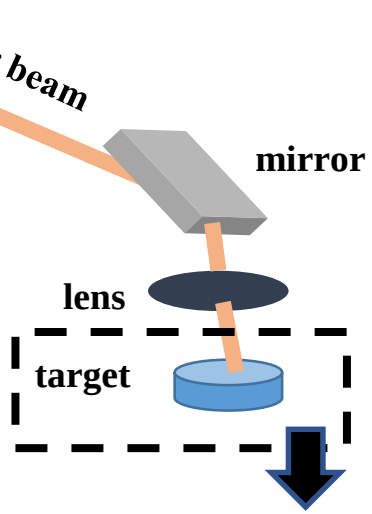




Characterization of targets: ROMA1 – ROMA3 - LNL

Nd:YAG laser
Roma1

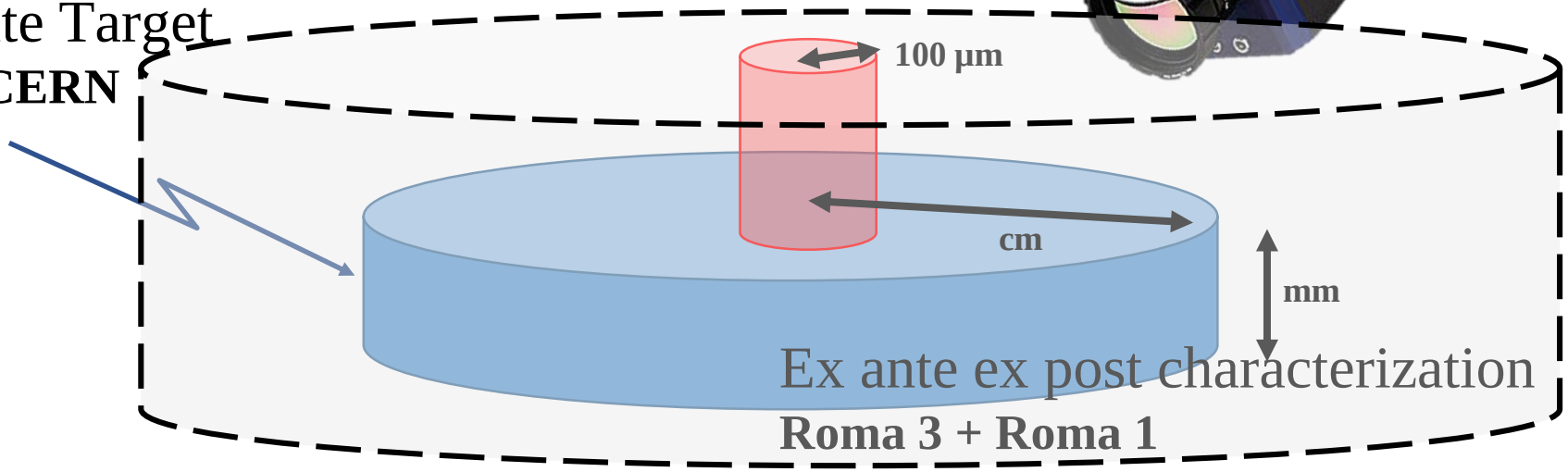
Lunghezza_d'onda (nm) 1064
Laser output pulse energy (J) 0.69
Peak power (mW) STIMATO = pulse energy (J)
/
Pulse width (s) = 0.69 / 5.7 GW = 0.35 GW
Average power (mW) 6900
Pulse repetition frequency (Hz) 10
Pulse width (s) 5.7ns



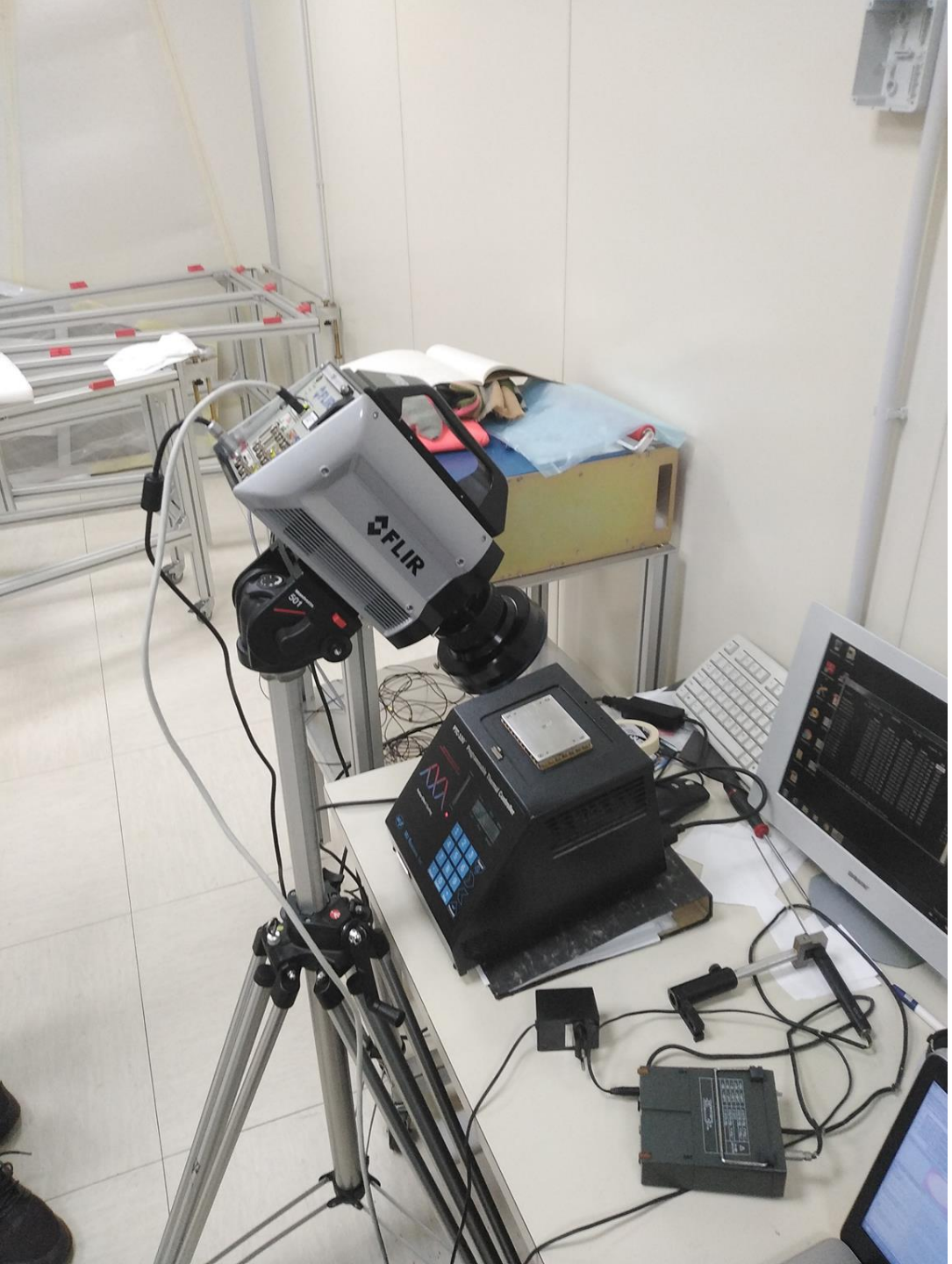
Infrared Camera
FLIR X6901sc SLS
LNF

Ottica 17 mm, calibrata -80°C +300°C
Modifiche proposte
1) Ottiche di adattamento ad uso microscopi
2) Corso FLIR per aggiornamento utilizzo camera

Graphite Target
LNL - CERN

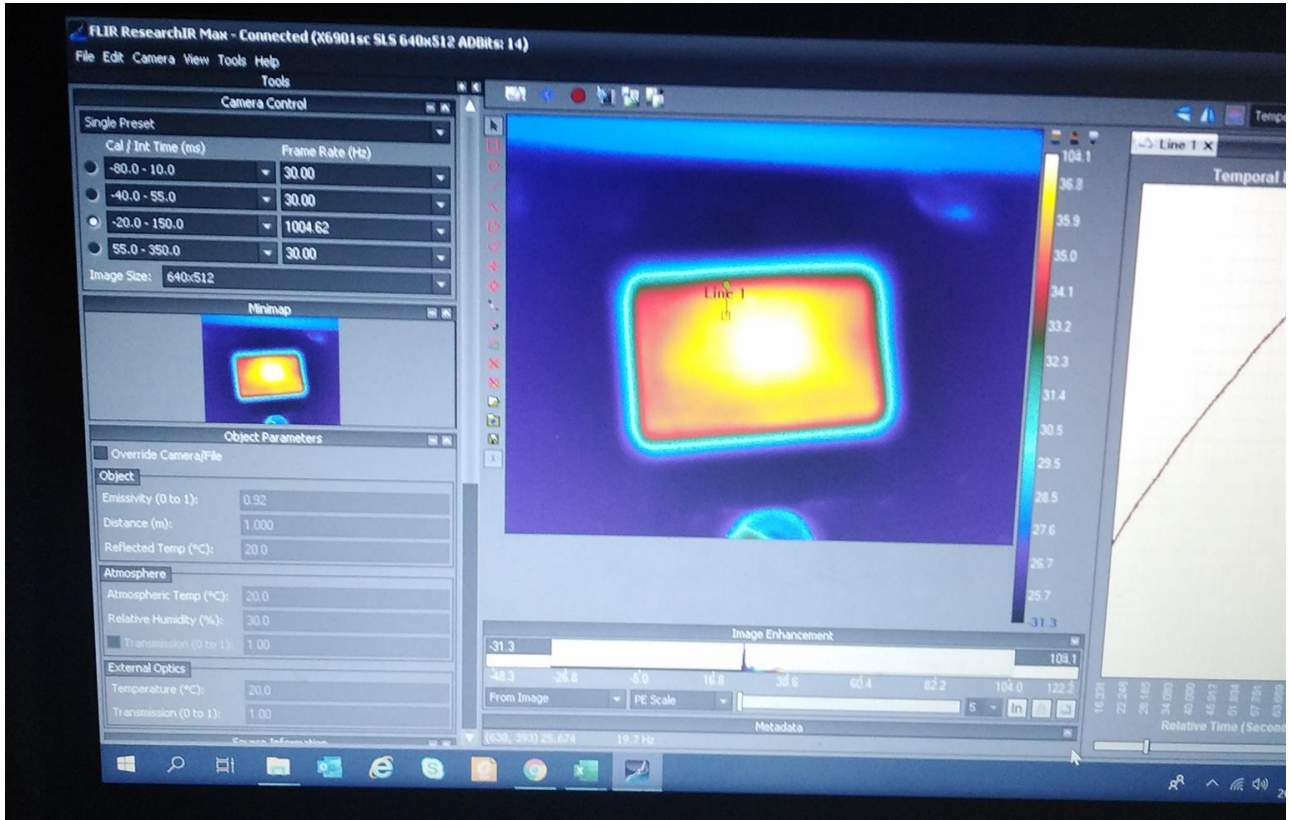


Ex ante ex post characterization
Roma 3 + Roma 1



Infrared Lock-in Thermography per determinare, utilizzando gli stessi principi della photothermal radiometry, le proprietà termiche dei materiali costituenti i bersagli ed inoltre eventuali anisotropie della diffusività termica. La camera considerata per le misure è la **FLIR X6901sc SLS** presente presso i **Laboratori Nazionali di Frascati** (LNF).

Ottica appropriata acquistata (**LNF**) nel 2020. La calibrazione della camera con la nuova ottica è in corso.



Laboratorio di analisi delle superfici a Roma Tre:

Strumentazione per la caratterizzazione chimica e strutturale dei campioni

Stilus Profilometer

- z resolution < 1 nm
- Large area analysis (stitching)

FTIR

Study between 100 cm^{-1} and 27000 cm^{-1}
Equipped with microscope

- Molecolar analysis
- Functional group determination

Low-energy ion beam analysis (ToF-SIMS)

- Gun 1: Bi^+ 30keV
- Gun 2: Cs^+ 0.2-11 keV
- Gun 3: Electron floodgun (20 V)
- Mapping with a lateral resolution < 100 nm
- Depth profiling < 1 nm
- 1 a.m.u. - 15000 a.m.u. detector range
- Detector ToF
- Limit of detection ~ ppm

Publications

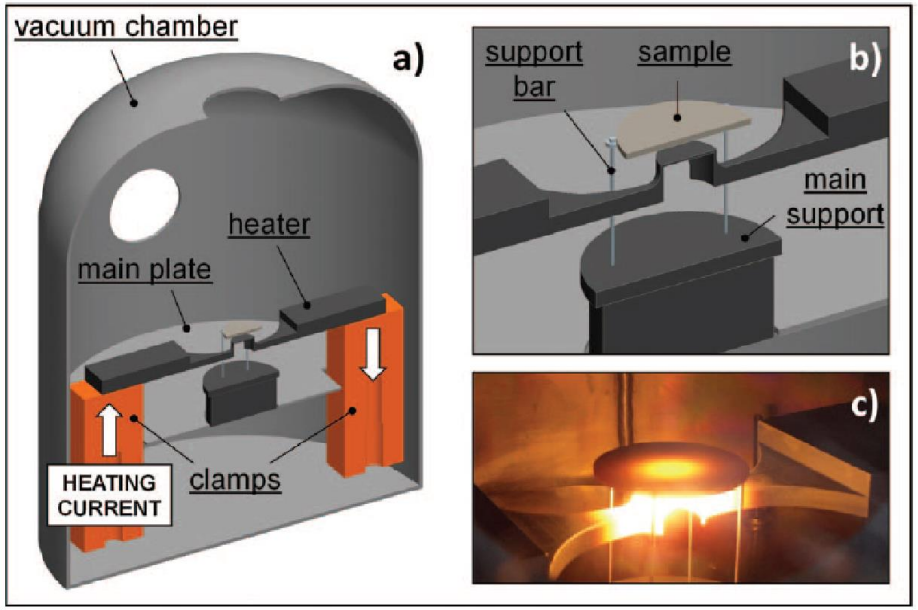
FTIR: https://www.mdpi.com/2076-3417/9/15/3016

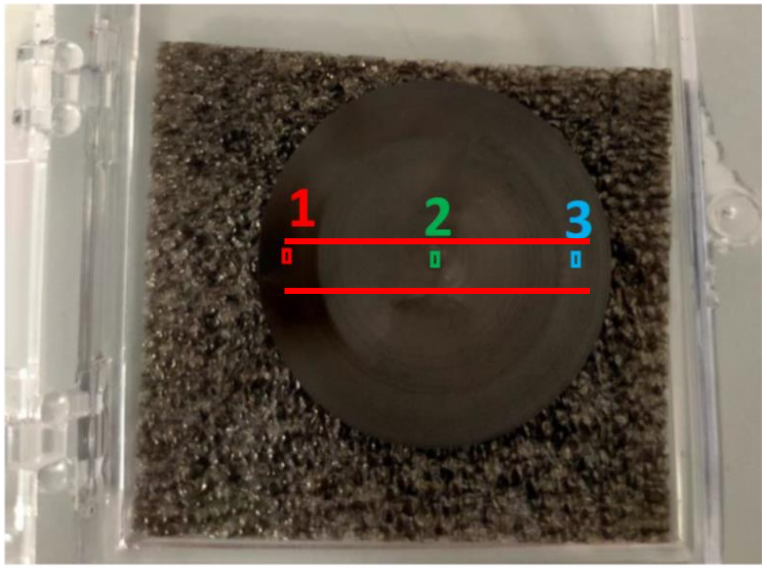
ToF-SIMS: https://www.sciencedirect.com/science/article/pii/S0169433218310572

Misure di profilometria a RM3 su target sottoposti a stress termico

Targets provided by S.Corradetti (LNL) :

- 2 graphite disks: thickness 1 mm, radii 1.5 and 2.0 cm
- Machine cut @LNL in 2017 from graphite cylinders POCO EDM 3
- Both thermo cycled ~ 5 times in vacuum: Tmax ~ 1500 °C in the center (~1100 °C on the edges)
- Thermal conductivity measured (optimal function well reproduced)

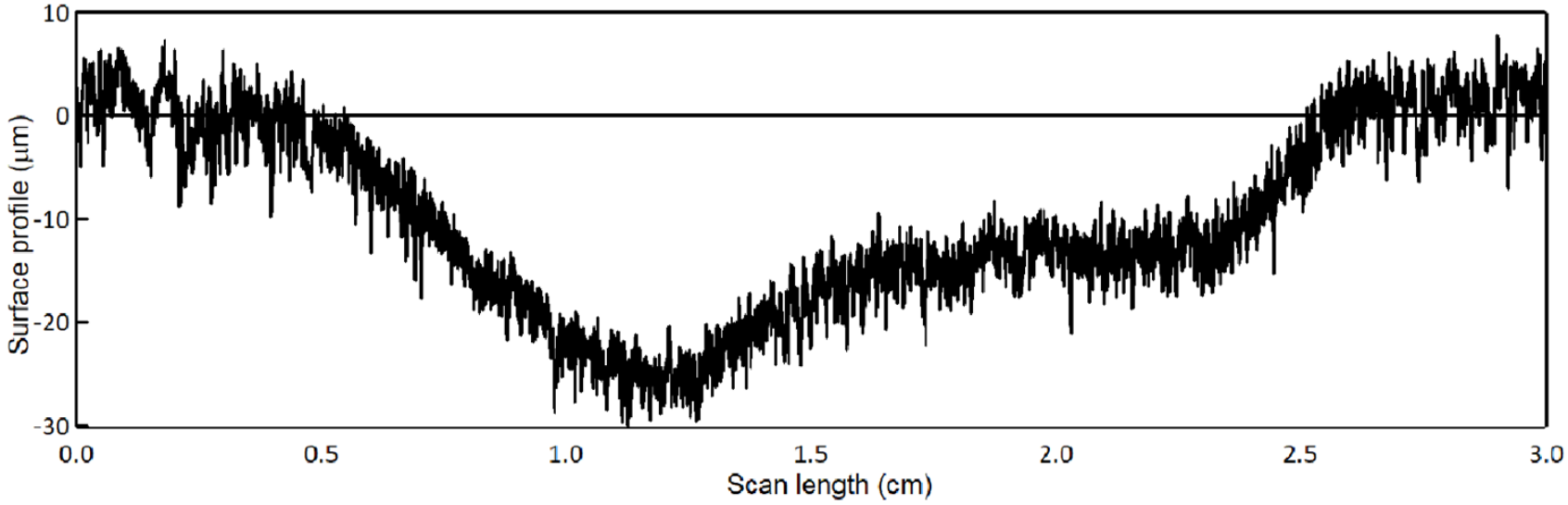




On each target Profile Scanned
3 regions 1x2 mm^2 and
2 segments «almost-diameters»

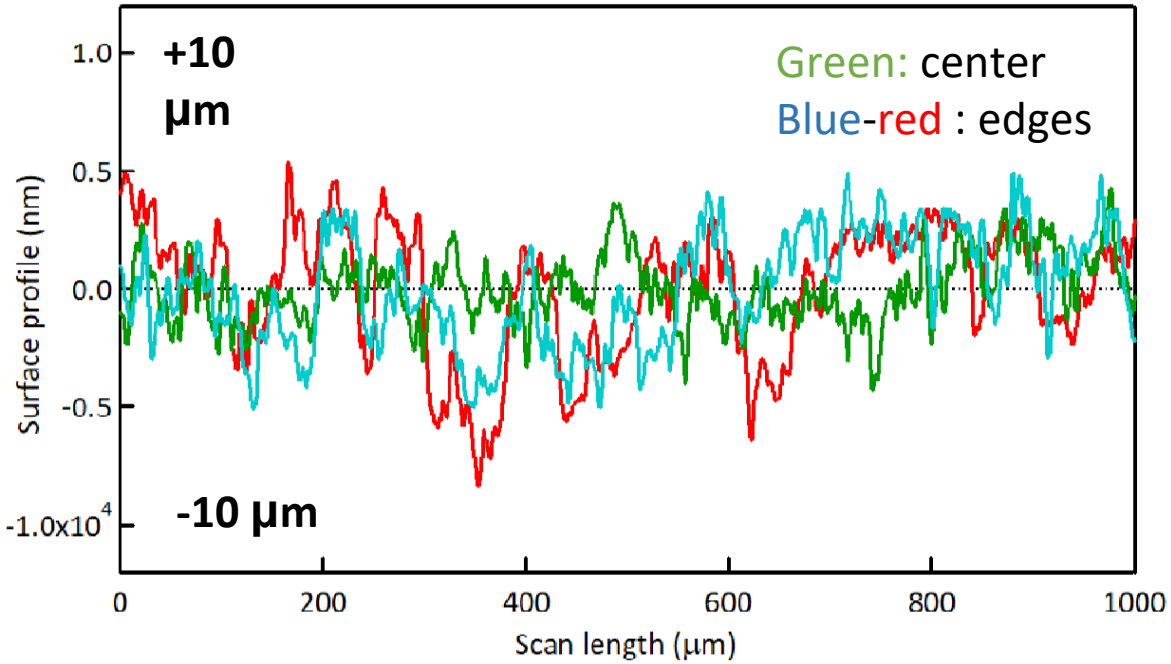
Tencor P-7 profilometer
Height resolution ~ few nm
used a stylus with 2 µm radius

Diameter scan:



Area scan:

10 profile scans averaged in each selected region



- good local planarity
- Significant surface effects on larger distances, possibly due to thermal stress (no reference before heating)

Attività in programma

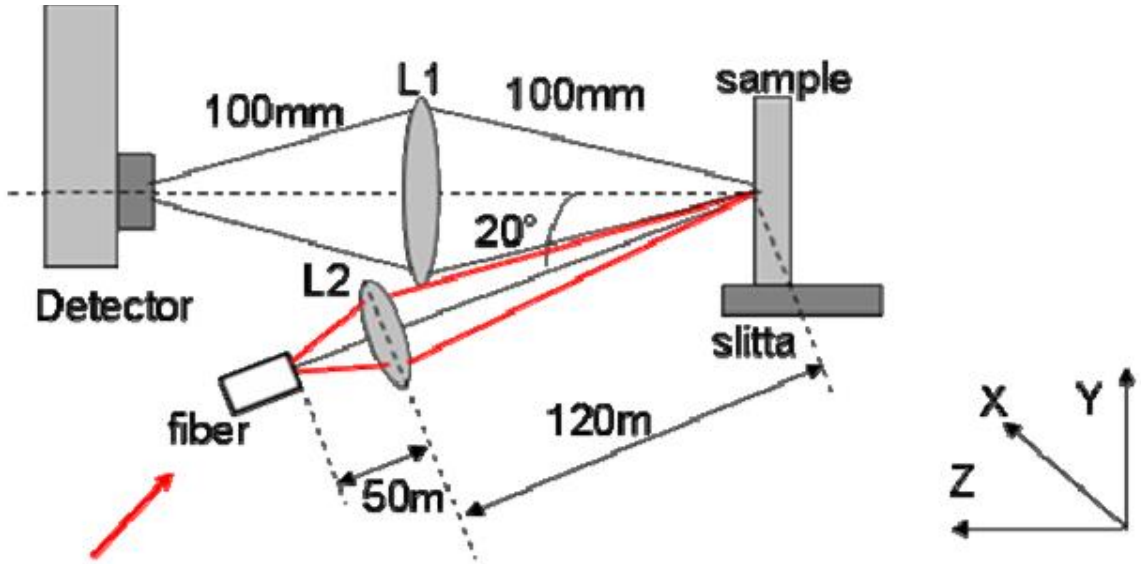
In coordinamento con i gruppi di Roma1 e di LNL:

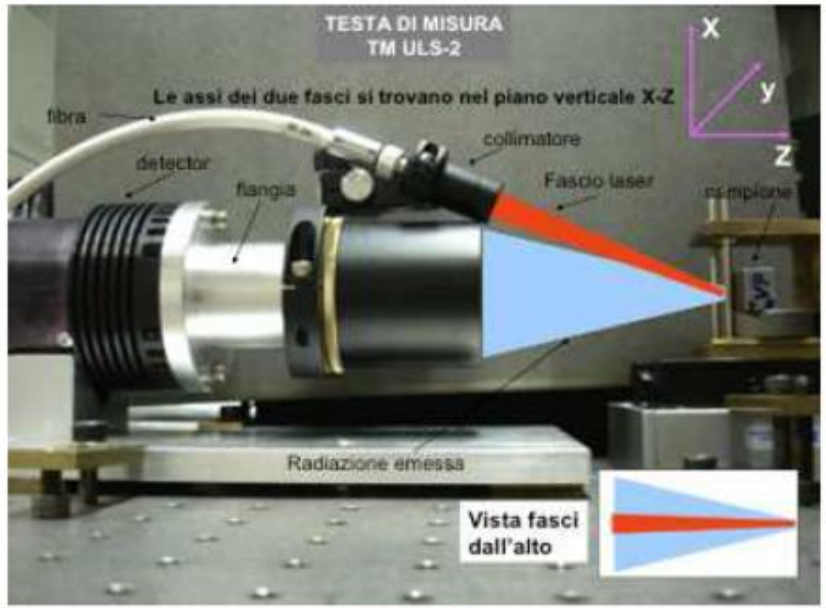
- Misure di profilometria prima e dopo stress termomeccanico e/o irraggiamento di target campione
- Check chimico e strutturale delle superfici con tecnologia ToF-SIMS (low energy ion beam)
- Partecipazione irraggiamenti. Test setup misura temperatura online con sensori IR

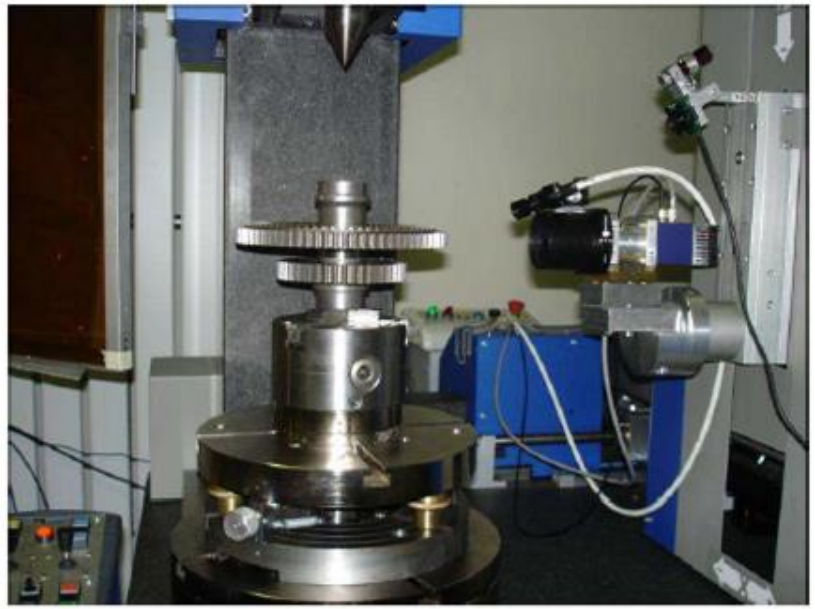
Spot di misura Ø 4 mm a una distanza di 20 cm.
Tempo di risposta 15 ms
Sensibilità 3° C
Dimensione 9 x 3.5 x 2 cm^3

Costo 1 canale completo di amplificatore ~ 1 k€

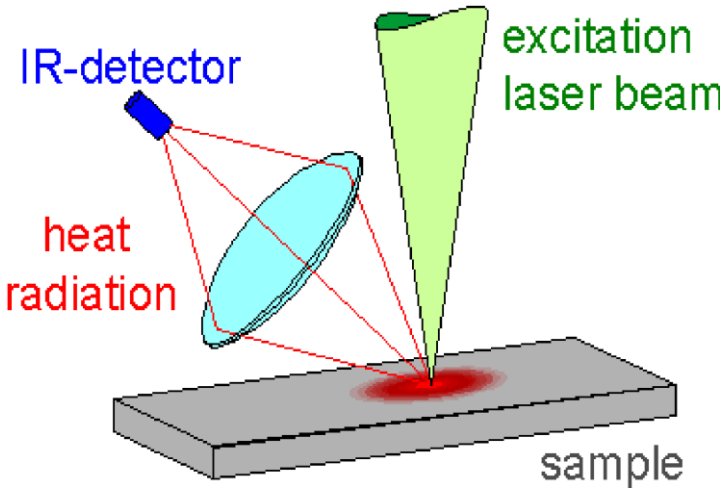
Depth Profiling by Photothermal Radiometry



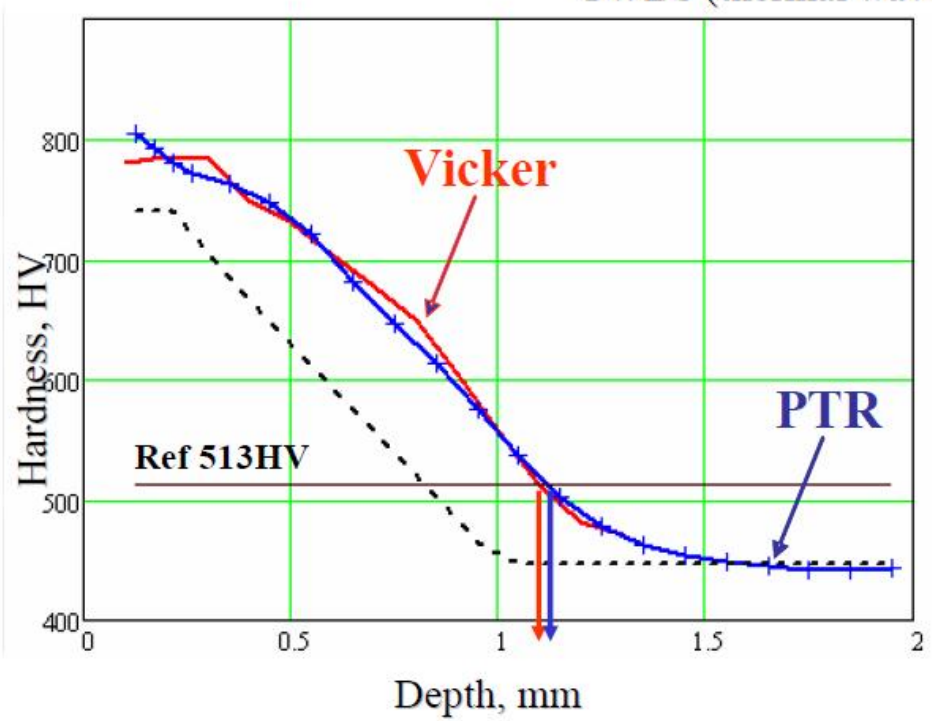


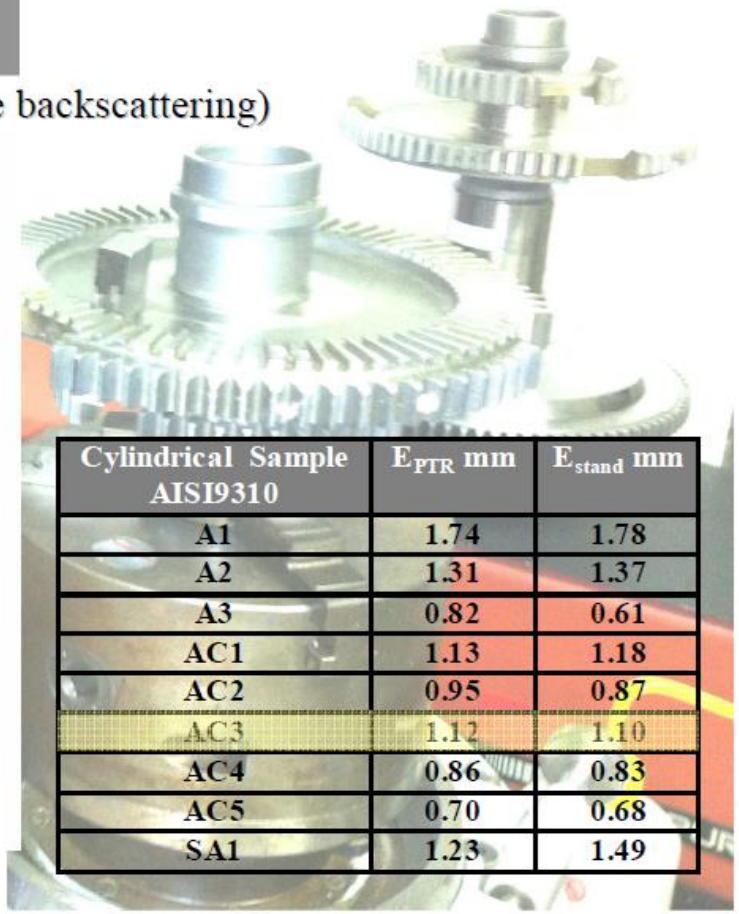


Example stratigraphy of thermal diffusivity and hardness of steels



TWBS (thermal wave backscattering)





Cylindrical Sample AISI9310	E_{PTR} mm	E_{stand} mm
A1	1.74	1.78
A2	1.31	1.37
A3	0.82	0.61
AC1	1.13	1.18
AC2	0.95	0.87
AC3	1.12	1.10
AC4	0.86	0.83
AC5	0.70	0.68
SA1	1.23	1.49

R. Li Voti, G. Leahu and C. Sibilia, "A New Device for High-Accuracy Measurements of the Hardness Depth Profile in Steels" in Proc. of 4th Int.Conference in Software Engineering for Defence Applications SEDA 2015 in Advances in Intelligent Systems and Computing ISBN 978-3-319-27896-4, pp..239-242 Vol. 422 (2016)

Thermal Characterization of Carbon Nanotubes by Photothermal Techniques

Sample	Thickness (μm)	Diameter (nm)	Thermal diffusivity ($m^2 \cdot s^{-1}$)	Thermal conductivity ($W \cdot m^{-1} \cdot K^{-1}$)	IR skin depth (μm)
CNT1	70	20–50	$(3.9 \pm 0.1) \times 10^{-5}$	0.80 ± 0.04	23 ± 6
CNT2	170	20–50	$(1.57 \pm 0.02) \times 10^{-4}$	1.57 ± 0.03	33.5 ± 2.5
CNT3	240	20–50	$(1.20 \pm 0.03) \times 10^{-4}$	4.0 ± 0.1	<5
CNT4	100	3–20	$(1.87 \pm 0.03) \times 10^{-5}$	2.25 ± 0.02	4.95 ± 0.15

The optothermal properties retrieved from PTR measurements are reported in column 4 (thermal diffusivity), in column 5 (thermal conductivity), and in column 6 (infrared skin depth)

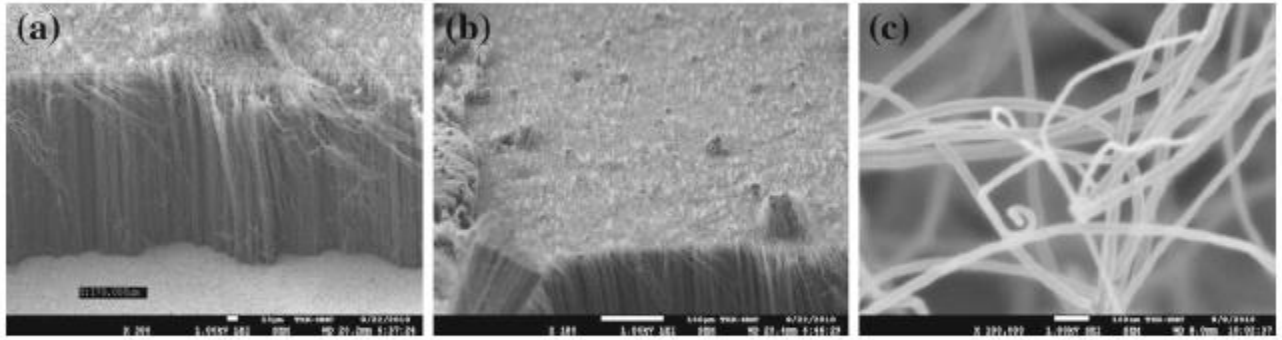
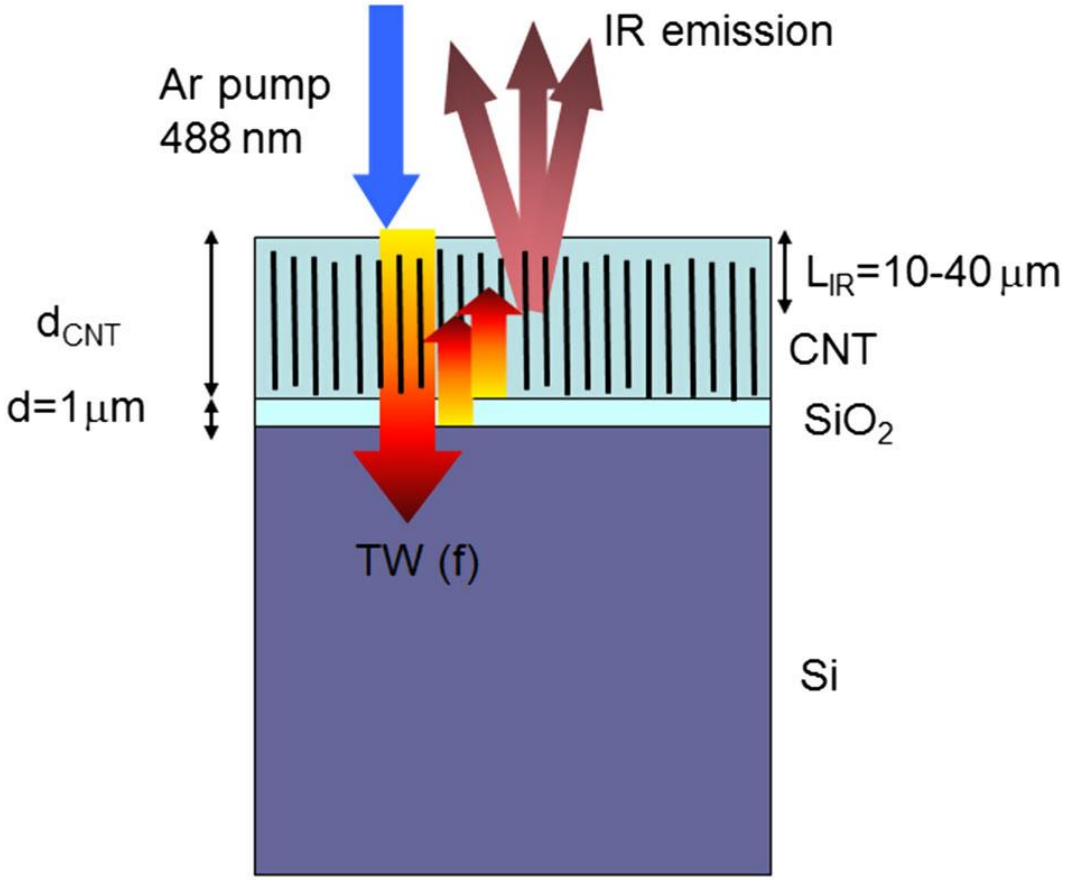
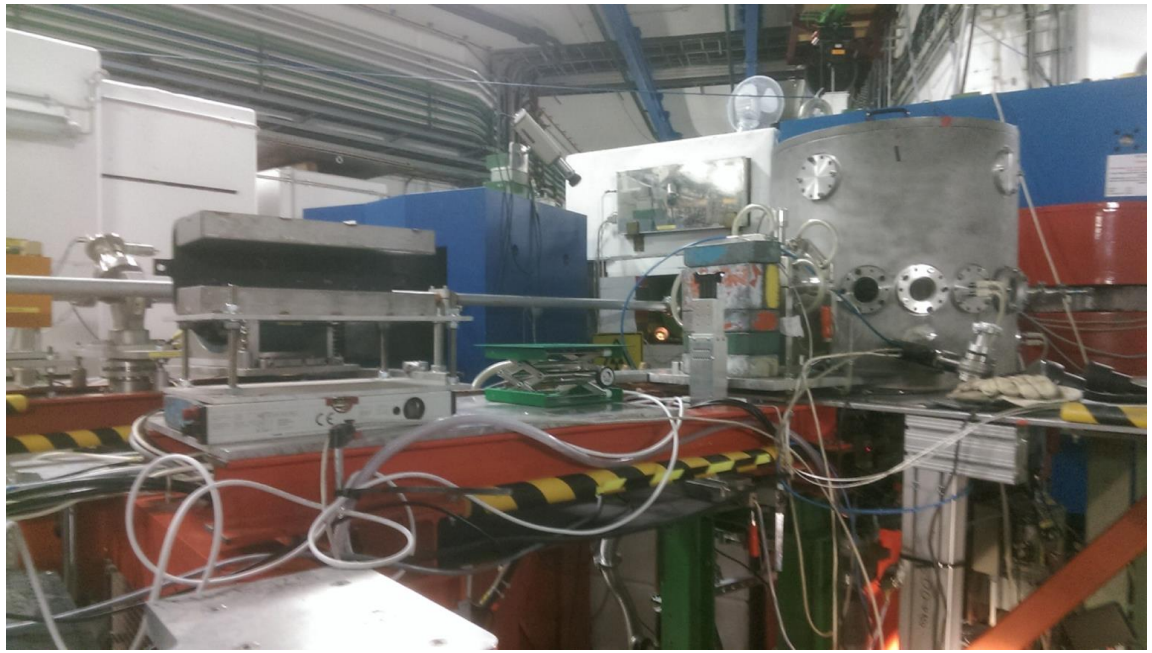


Fig. 1 Scanning electron micrographs of the "forest" CNT samples: (a) cross section, (b) outlook of sample surface, and (c) details of carbon nanotubes

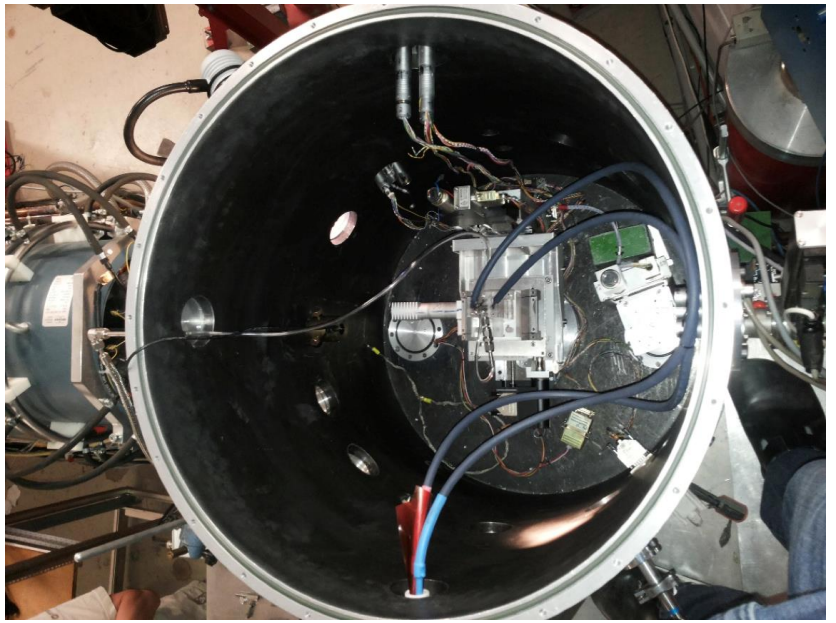


G. Leahu · R. Li Voti · M. C. Larciprete, C. Sibilia · M. Bertolotti · I. Nefedov · I. V. Anoshkin Thermal Characterization of Carbon Nanotubes by Photothermal Techniques, Int J Thermophys (2015) 36:1349–1357, DOI 10.1007/s10765-014-1804-0,

Irradiation tests at MAinzer MIcrotron facility (Mainz, D)



60 cm Vacuum chamber available



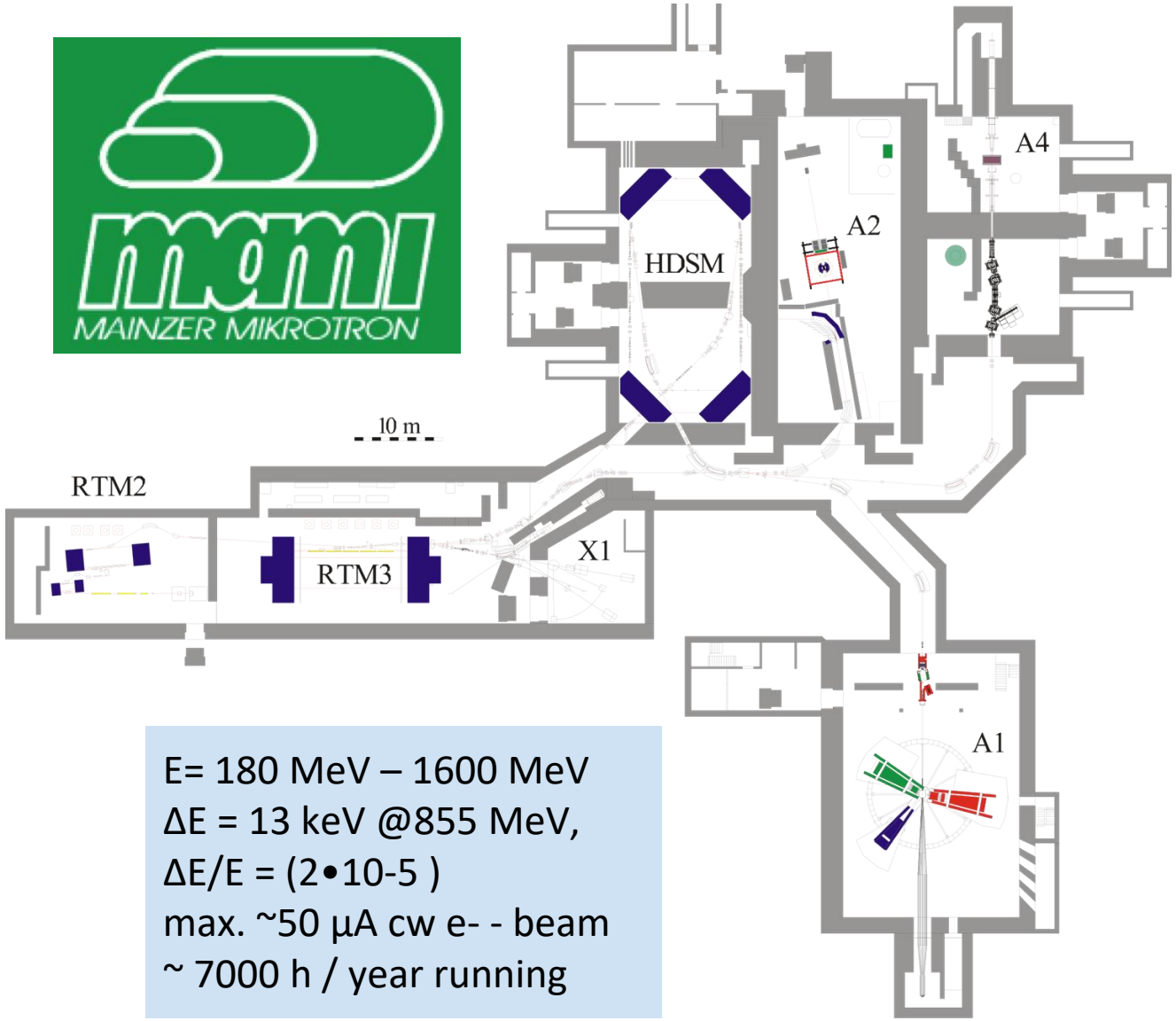
Experimental area:
- focused beam down to 10 µm
- intensities range: 1 nA -- 50 µA

investigating radiation dose in surroundings to use camera or thermocouple probes

First tests expected in the next 6 months:
- experimental setup mostly in place, need to be tested
- iterating with lab experts for setup specifications

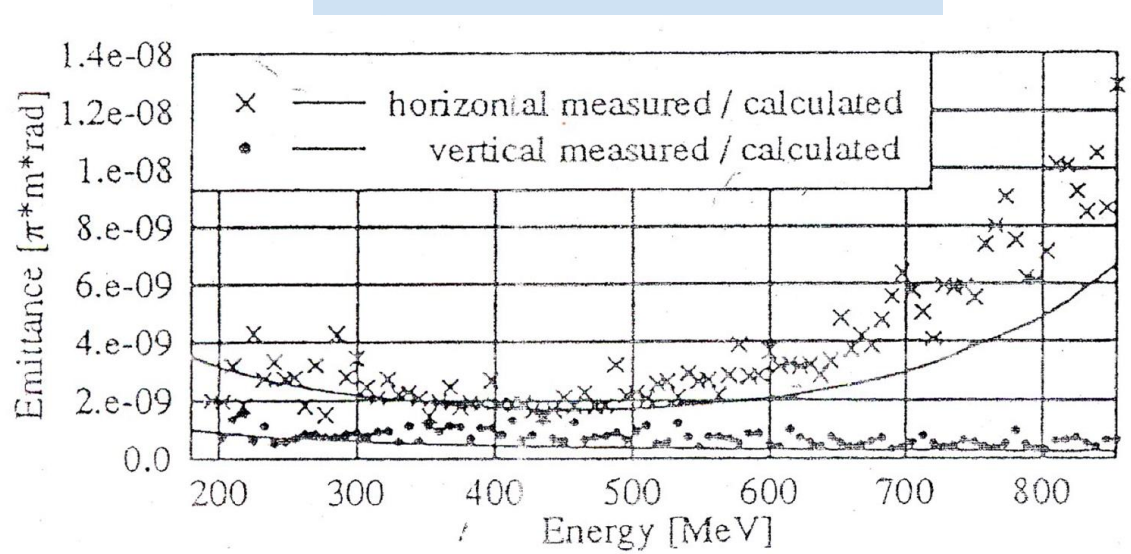
Crucial step to validate model predictions with experimental data.

Irradiation tests at MAinzer MIcrotron facility (Mainz, D)



E= 180 MeV – 1600 MeV
ΔE = 13 keV @855 MeV,
ΔE/E = (2•10-5)
max. ~50 µA cw e- - beam
~ 7000 h / year running

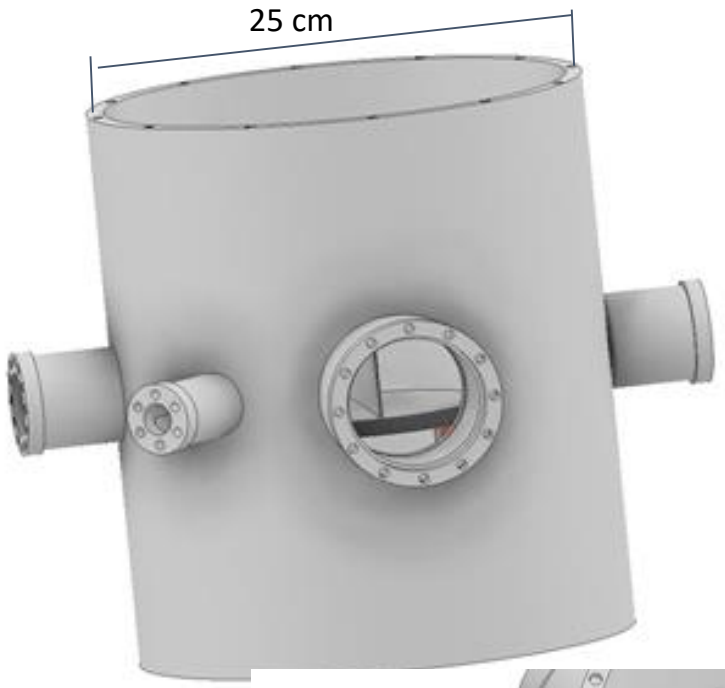
Emittance:
Vertical : εy=8 nm rad
Horizontal: εx=8 nm rad

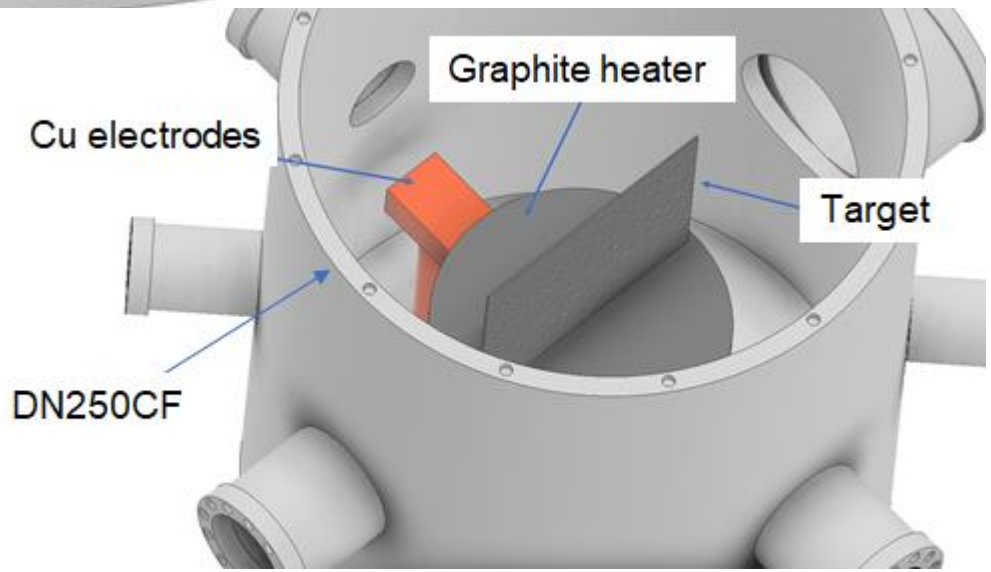


Beam intensities close to the benchmark considered in the published paper (~10^{-1} smaller)

funded also with separate MAT grant from INFN (M. Bauce)

Custom HV chamber





Preventivo IonVac per camera a vuoto con scaldatore a effetto Joule (max T=1000°C)

Doppia camera coassiale in acciaio inox DN250CF_UHV "Ultra High Vacuum" tenute da vuoto metalliche (standard 250CF Conflat). Raffreddamento a liquido, Ports per diagnostiche di processo 4X DN40CF, 1xDN16CF, 1XDN100CF. Flangia base con n.2 ports DN40CF adatti ad alloggiare passanti elettrici da vuoto. Flangia superiore adatta ad ospitare oblò di ispezione DN100, 1XDN40CF. Piedini di supporto su tavolo.	18.500,00 €
Sistema portacampioni in grafite diametro circa 102mm termoregolabile ad effetto Joule fino a 1000°C. Schermi e Break termici, passanti da vuoto alta corrente raffreddati ad acqua. Sistema meccanico con squadrette ortogonali al riscaldatore per il posizionamento del campione ruotato di 90°.	7.000,00 €
Unità di potenza alta corrente a stato solido con sistema di termoregolazione Gestita da microprocessore PID.Sensori di temperatura termocoppia (campione e riscaldatore) completi di passanti da vuoto. Eventualmente con sistema pirometrico feedback da Voi fornito.	9.000,00 €
TOTALE camera a vuoto - IVA esclusa	**34.500,00 €**
con IVA	**42.090,00 €**

Stima costi per pompe scroll + turbomolecolare (in base a precedenti acquisti)

Scroll pump (vuoto ~10^-2 mbar)	2.800,00 €
Pompa turbomolecolare (10^-10 mbar) + alimentatore + air cooling e accessori	4.500,00 €
Sensore di misura dell'alto vuoto Pirani/Penning	900,00 €
TOTALE pompe di vuoto - IVA esclusa	**8.200,00 €**
con IVA	**10.004,00 €**
TOTALE da impegnare	**52.094,00 €**

Attività RD_MUCOL a LNL

2021:

- We completed the purchase of 4 different types of graphite Toyo Tanso, after a selection of the desired properties
- Each type came as cylinders with 3 different sizes (100 mm, 40 mm and 20 mm diameter)
- The cylinders will soon undergo cutting (either in the LNL mechanical workshop or in an external company)
- We hope to have soon a student (mechanical engineering) to do the thermal characterization tests starting in October

Producer		s_t/MOR (Mpa)	E (Gpa)	a ($10^{-6}K^{-1}$)	k ($Wm^{-1}K^{-1}$)	RTS (Wm^{-1})
TOYO TANSO	IG-43	37	10,8	4,8	140	99923
TOYO TANSO	IG-45	40	12,0	4,9	140	95238
TOYO TANSO	TTK-4	49	10,9	5,0	90	80917
TOYO TANSO	HPG-59	74	12,7	5,7	95	97113

2022:

- We asked for 5 k€ of consumables to both buy new graphite types (depending on the characterization of IG-43, IG-45, TTK-4 and HPG-59 undergoing this winter) and components to perform the measurements and to upgrade our thermal and mechanical characterization device (crucible, mechanical and electrical parts)

Preventivi 2022

Toyo Tanso Europe S.p.A.

Via Leonardo da Vinci, 5 20877 Roncello (MB)
Tel: +39 039 62784 1 Fax: +39 039 695202 Mail: info@tteurope.it
Pec: pecmail@pec.toyotansoeurope.com - Codice destinatario SDI: A4707H7
Reg. imprese Monza-Brianza R.E.A. 1867882 - C.F. 00749030151 - P.IVA 02667560961
Capitale sociale 500.000€ I.V. - Soc. unico socio
Soggetto che esercita attività di Direzione e coordinamento: Toyo Tanso Co., Ltd.

TOYO TANSO

Indirizzo di fatturazione

xxx ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratorio di Legnaro (PD)
Viale dell'Universita' n. 2
35020 Legnaro PD
Italia

Offerta

Nr.	Data Documento	Vs. riferimento	Banca di Canalizzazione	Pagina
OFC-210112	30/06/2021	CIG ZEA3237DD7		3/3

Cliente	Contatto	Termini di pagamento	Causale del trasporto
C01964	Mr. Stefano Corradetti Ph.D.	30 GG. D.F. F.M.	VENDITA
	E-mail: stefano.corradetti@lnl.infn.it	Metodo di pagamento: BONIFICO	

Partita IVA	Incoterm	Data Validità Offerta	Valuta
Codice fiscale: 84001850589	FRANCO DESTINO	30/09/2021	EUR
	Vettore		

Nr.	Descrizione	Quantità	U.M.	Prezzo Unitario	Sc. %	Importo	Data Consegna	IVA

Importo Minimo Fatturabile €250,00

Data scadenza	Importo	Codice IVA	% IVA	Descrizione	Sc. fatt.	Imponibile	Importo
31/07/2021	2.178,92	22	22	Iva 22%		1.786,00	392,92

Totale	Sconto fattura	Totale Imponibile	Totale IVA	Totale documento
1.786,00	0,00	1.786,00	392,92	**2.178,92 EUR**

1) Se non riceviamo nulla entro due giorni dal ricevimento dell'ordine, quanto indicato si considera accettato dalla Vs. azienda 2) Salvo diversa indicazione, la tolleranza accettata sulle consegne sarà del +/- 3% della quantità ordinata 3) Altre condizioni come al solito Per le nostre condizioni generali di vendita consultare il nostro sito web

	Contatto Interno	Approvata da
	Elena Wiget	

Graphite targets

EUROGRAFITE
PRODOTTI IN GRAFITE E REFRATTARI

Offerta / Offer

Numero / Number	Del / Date
17/00202	26/07/2017

Pagamento / Payment: Bonifico Bancario 30 gg df fm

Pagamento / Payment to:
CASSA RISPARMIO DEL VENETO - Ag.di Bassano del Grappa (VI)
IBAN: IT 58 F 06225 60166 100000006910
SWIFT: IBSPIT2PXXX

Spett.le
INFN - Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro Viale dell'Università, 2
35020 LEGNARO PD
ITALIA

Partita IVA / Customer VAT reg.	Prev. Consegna / Estimated Deliv
04430461006	26/07/2017

Ns. riferimento / Our Ref.	Vs. riferimento / Your Ref.	Telefono / Phone	Fax	Divisa
Elisa		049 8068311	049 8068350	€uro

Gentile Dott. Menzolaro, La ringrazio per la nuova richiesta di quotazione. Di seguito ci pregiamo di sottoporLe la ns. migliore offerta per i particolari richiesti:

Codice / Code	Descrizione / Description	UM Mes	Quantità Quantity	Val.Unitario Unit Price	Consegna Delivery
	C2) ST_PIS_04_002_Support Chamber Ø42x76mm	NR	5,00	163,00	26/07/2017
	C3) ST_PIS_04_003_Closing Nut Ø46x7,5mm	NR	5,00	49,50	26/07/2017
	C4) ST_PIS_04_004_Centering Bolt dim.5x5x12mm	NR	5,00	19,60	26/07/2017
	D) THERMAL CONDUCTIVITY				
	D1) ST_HTA_01_001_Crogiolo dim.12x50x240mm realizzato in grafite POKO EDM3 da noi fornita	NR	5,00	217,00	26/07/2017
	*** *** *** *** ***				
	CONDIZIONI DI VENDITA TEMPI DI CONSEGNA: 4 settimane data ordine ALTRE CONDIZIONI: solite in uso con Voi *** *** *** *** ***				

Spese di spedizione / Freight Charges	Altre condizioni / Other terms of sale	Distinti Saluti / Yours Sincerely
AL COSTO / AT COST	SOLITE IN USO / AS USUAL	EUROGRAFITE SRL Zanchetta Elisa

EUROGRAFITE S.R.L.

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Example of components for the characterization furnace