TARGETS
Thermo-mechanical test for targets

INFN

Istituto Nazionale di Fisica Nucleare

Outline

- Introduction of the LEMMA project
- Features of the Positron beam
- Numerical simulation of the deposited energy onto the target
- Temperature behaviour of the thermal parameters of Beryllium and Carbon
- Temperature field after a single bunch – temperature temporal evolution
- Thermal stress and quality factors
- Future R&D Activity

Introduction of the LEMMA project

Low EMittance Muon Accelerator

INFN institutions involved: LNF, Roma1, Pd, Pi, Ts, Fe
Universities: Sapienza, Padova, Insubria
Contributions from: CERN, ESRF, LAL, SLAC

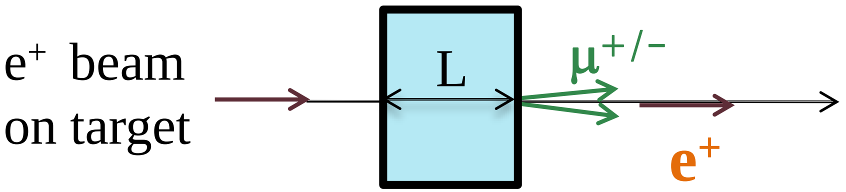
- A $\mu^+\mu^-$ collider offers an ideal technology to extend lepton high energy frontier in the multi-TeV range:
  - No synchrotron radiation (limit of e^+e^- circular colliders)
  - No beamstrahlung (limit of e^+e^- linear colliders)
  - but muon lifetime is 2.2 ms (at rest)

Muon source

e^+e^- annihilation - positron beam on target : very low emittance and no cooling needed, baseline for our proposal

e^+ on standard target (including crystals in channeling)
→ Need Positrons of ≈ 45 GeV

Ideally muons will *copy* the positron beam



(finite target length)

Material	Density $[g/cm^3]$	Length [m]	Length $[X_0]$	eff $[10^{-6}\mu/e^+]$
Be	1.85	0.106	0.3	1.3
C	2.27	0.057	0.3	1.0

Theoretical activity - Methodological approach

Deposited energy density

↓

Temperature field calculation (space/time)

↓

Stress calculation

↓

Von Mises criterion

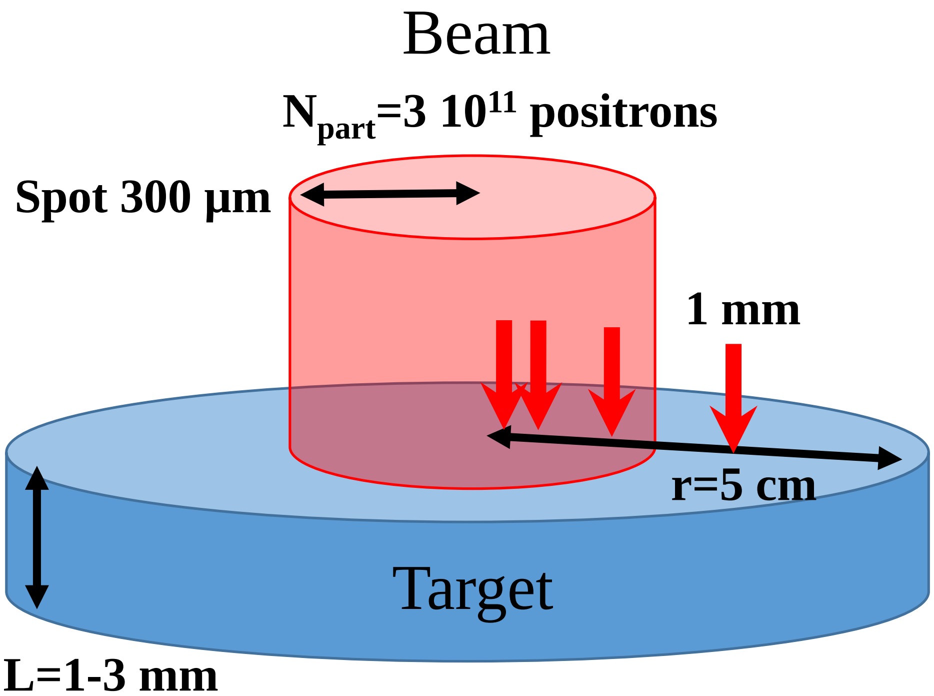
↓

Safety factors

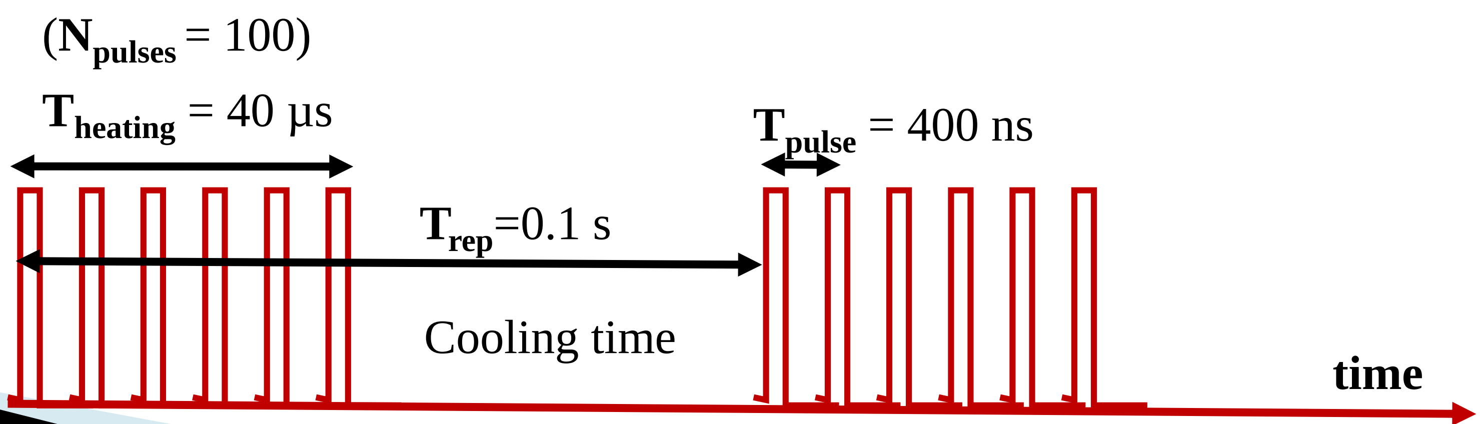
↓

Check of the safety thresholds

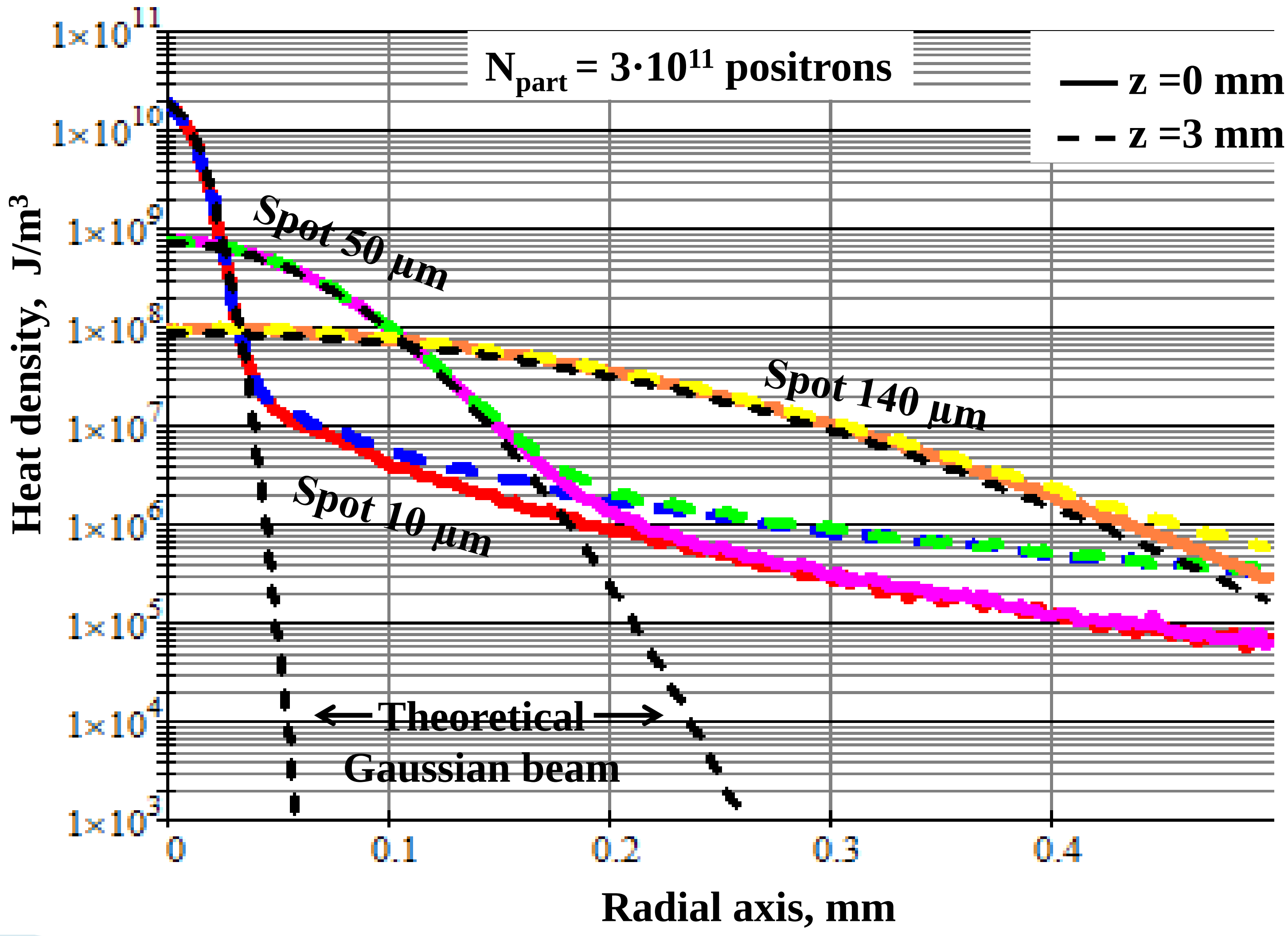
Positron source



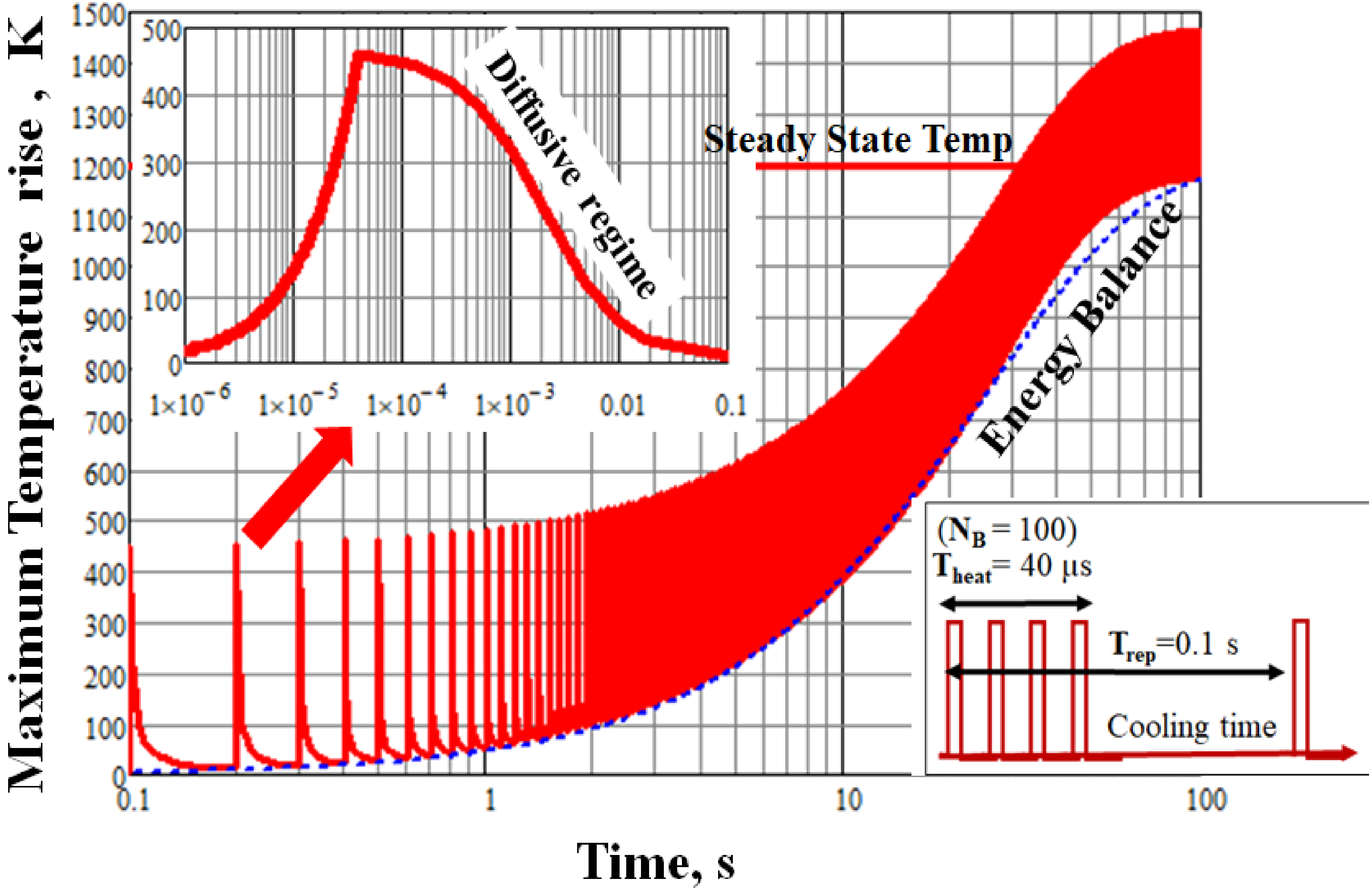
Symbol	Description	Reference Value
a	Gaussian beam spot size	300 µm
τ	bunch duration	10 ps
N_{part}	positron number	$3 \cdot 10^{11}$
N_{pulses}	number of consecutive bunches	100
T_{pulse}	time between two bunches	400 ns
$T_{heating}$	total time of N_{pulses}	40 µs
T_{rep}	repetition time of the N_{pulses} sequence	0.1 s



Energy density deposited

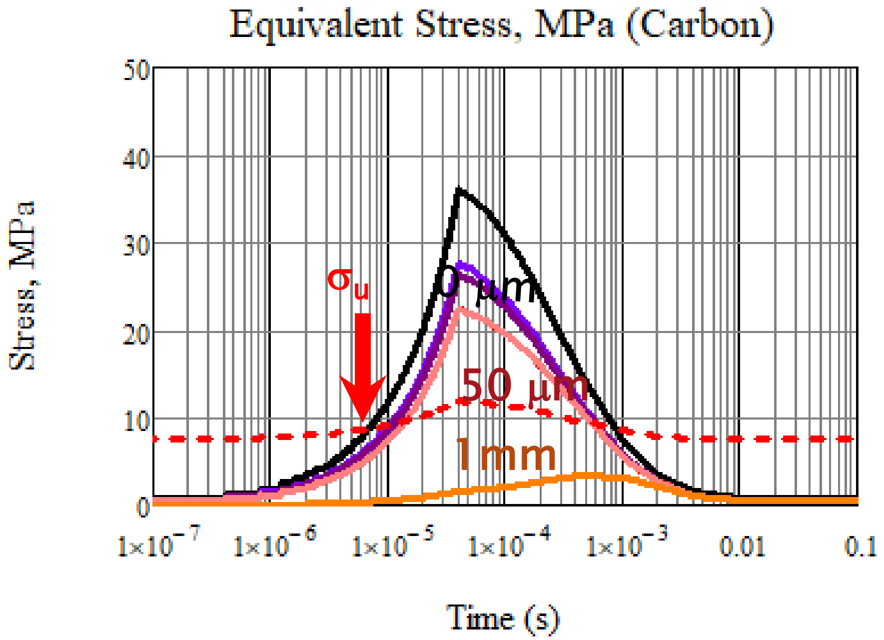


Numerical simulation- Maximum temperature rise in the Target

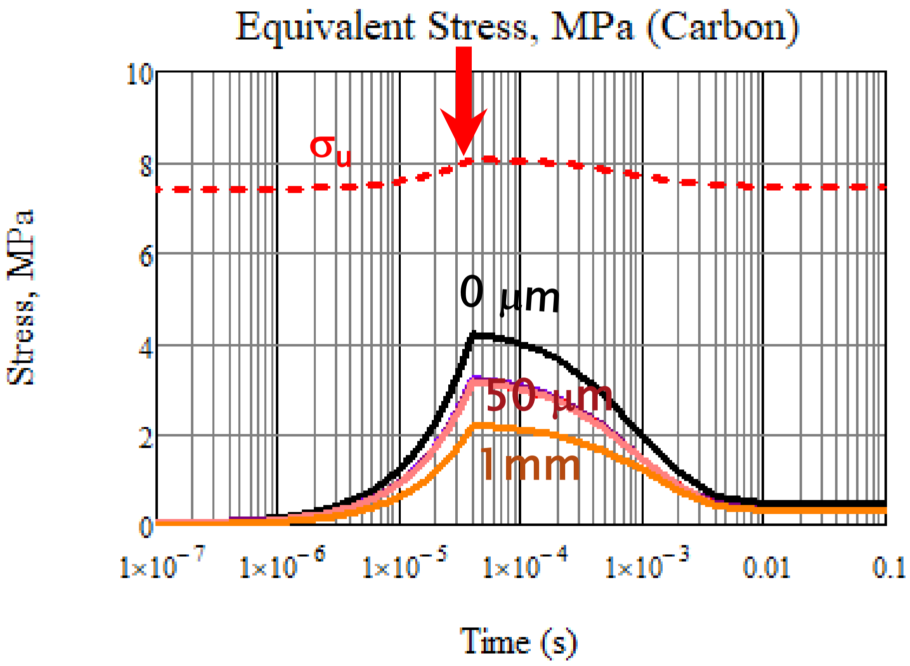


Stress and Safety factors – Carbon – Spot 0.3mm - 1mm

Spot 0.3mm



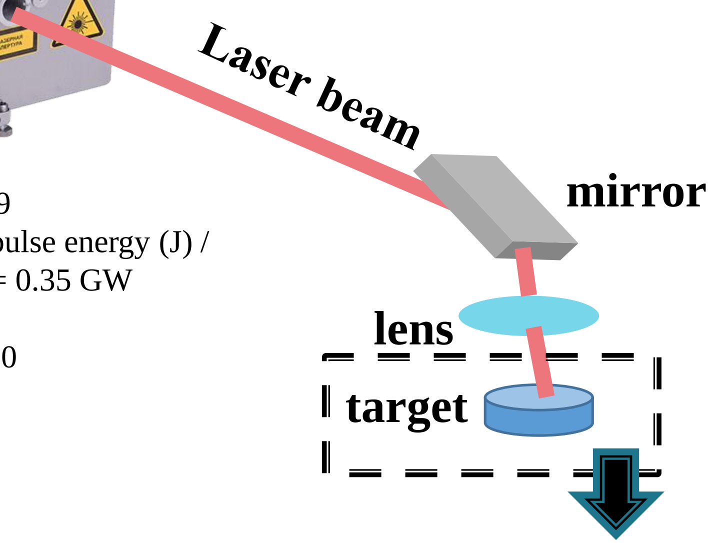
Spot 1mm



Future Activity: Target crash test with photons

Nd:YAG laser

MI Bicocca + RM1



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

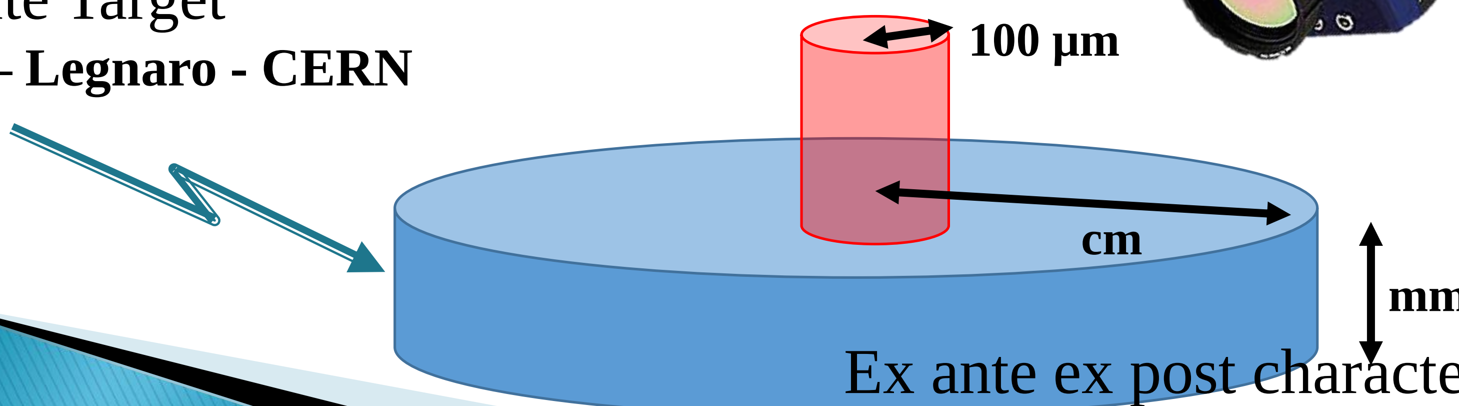
LNF

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

PoliTo – Legnaro - CERN



Ex ante ex post characterization

RM 3 + RM 1

LoI : Snowmass 2021 – AF7 6 AF4

Studies of target materials and layout for a low emittance muon source (LEMMA)

R. Li Voti[1,*], G. Cesarini[1], F. Anulli[1], M. Bauce[1], G. Cavoto[1], F. Collamati[1], S. Rosati[1], M. Antonelli[2], M.E. Biagini[2], M. Boscolo[2], P. Branchini[3], R. Di Nardo[3], A. Passeri[3], L. Tortora[3], V. Berandi[4], G. Catanesi[4], R. Spina[4], M. Bonesini[5], R. Benocci[5], L. Peroni[6], M. Scapin[6], L. Centofante[7], S. Corradetti[7], M. Manzolaro[7], A. Monetti[7], D. Scarpa[7], and N. Pastrone[8]

[1]INFN, Sezione di Roma e Università degli Studi di Roma "*Sapienza*"; *roberto.livoti@uniroma1.it
[2]INFN, Frascati National Laboratories, Frascati, Italy
[3]INFN Roma Tre e Università Roma Tre, Rome, Italy
[4]INFN Sezione di Bari e Università e Politecnico di Bari, Bari, Italy
[5]INFN Sezione di Milano Bicocca e Università di Milano Bicocca, Milano, Italy
[6]Department of Mechanical and Aerospace Engineering, Politecnico di Torino, Torino, Italy
[7]INFN, Laboratori Nazionali di Legnaro - Legnaro (PD), Italy
[8]INFN sezione di Torino, Torino, Italy

Future

Future R&D: 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. This is a fundamental task because the real effective properties may differ from the reference literature values used in the numerical simulations.

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.

Future

Future R&D: experimental activity

4. 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*".

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

7. 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.

Future

Future R&D: theoretical activity

1. Numerical simulations for the evaluation of thermomechanical stresses on various muon collider architectures. The study can be extended to several targets (solids, liquids), several geometries, and eventually to other kind of particles.

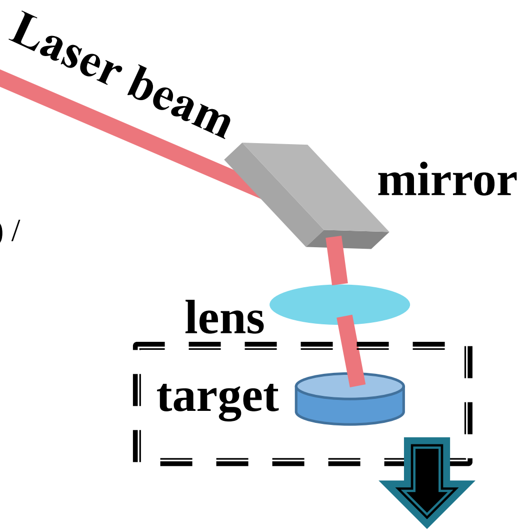
2. Theoretical-experimental fit for the determination of the thermal and elastic parameters of the targets. This activity should be performed together with the experimental activity for the nondestructive testing of materials.

This work will be pursued within the newly formed International Muon Collider collaboration.

Future Activity: Target crash test with photons

Nd:YAG laser
Bicocca + Roma1

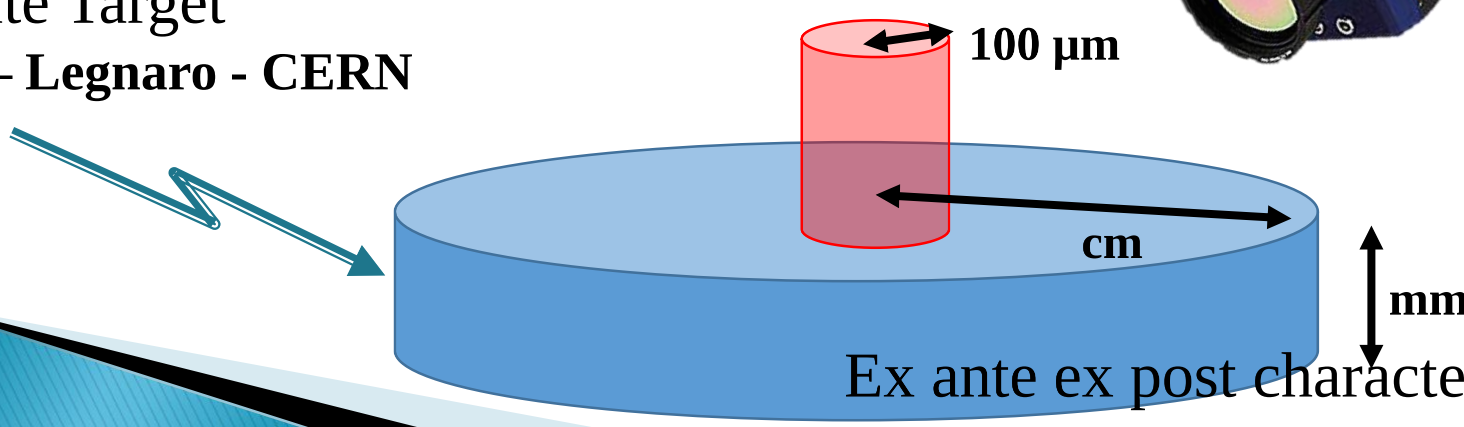
Lunghezza_d'onda (nm) 1064
Laser output pulse energy (J) 0.69
Peak power (mW) STIMATO = pulse energy (J) / Pulse width (s) = 0.69 / 5.7 GW = 0.35 GW
Average power (mW) 6900
Pulse repetition frequency (Hz) 10
Pulse width (s) 5.7ns



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
PoliTo – Legnaro - CERN



Ex ante ex post characterization
Roma 3 + Roma 1

Studio e test dell’opzione multitarget

- Si vuole iniziare un programma di studi per testare le varie configurazioni di targhette
- L’apparato sperimentale da realizzare dovra` quindi essere *upgradabile* e facilmente trasportabile
  - test presso il LINAC di DAFNE il primo anno
  - successivamente opzioni da esplorare

- **Richieste per il 2020**
- Acquisto targhette Be o C — **15 kEuro**
- Meccanica motorizzata con controllo remoto per posizionamento bersagli — **15 kEuro**
- Camera a vuoto con passaggi di acquisizione e finestra per infrarossi — **10 kEuro**
- Camera a infrarossi — **30 kEuro(*)**
- Sistema di termocoppie e di acquisizione dei dati — **10 kEuro**

Totale: 80 kEuro(*)

(*) L’acquisto della termocamera puo` andare sub judice, poiche’ vogliamo esplorare possibilita` diverse dall’acquisto, o differire l’acquisto all’anno successivo

FLIR X6901- Features

FLIR X6901sc SLS

P/N: 29421-201

Copyright

Document identity

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Website

http://www.flir.com

Customer support

http://support.flir.com

Disclaimer

Specifications subject to change without further notice. Camera models and accessories subject to regional market considerations. License procedures may apply. Products described herein may be subject to US Export Regulations. Please refer to exportquestions@flir.com with any questions.

Detector data	
Detector Type	Strained-Layer Superlattice
Spectral Range	7.5 µm (lower), 11.5-12.5 µm (upper)
Resolution	640 x 512
Detector Pitch	25 µm
Thermal Sensitivity/NETD	≤ 45 mK (≤ 40 mK typical)
Well Capacity	11.0 M electrons
Operability	≥ 98% (≥ 99% typical)
Sensor Cooling	Closed cycle rotary
Electronics	
Readout Type	Snapshot
Readout Modes	Asynchronous integrate while read Asynchronous integrate then read
Synchronization Modes	Genlock, Sync-in, Sync-out
Image Time Stamp	Internal IRIG-B decoder clock TSPI accurate time stamp
Integration Time	270 ns to 687 sec
Pixel Clock	355 MHz
Frame Rate (Full Window)	Programmable; 0.0015 Hz to 1004 Hz
Subwindow Mode	Flexible windowing down to 32 x 4 (steps of 32 columns, 4 rows)
Dynamic Range	14-bit
On-Camera Image Storage	RAM (volatile): 16 GB, up to 26000 frames, full frame SSD (non-volatile): >4 TB
Radiometric Data Streaming	Simultaneous Gigabit Ethernet (GigE Vision), Camera Link, CoaXPress (CXP)
Standard Video	HDMI, SDI, NTSC, PAL
Command and Control	GigE, USB, RS-232, Camera Link, CXP (GeniCam protocol supported over GigE or CXP)

TERMOCAMERA LWIR SLS AD ALTE PRESTAZIONI

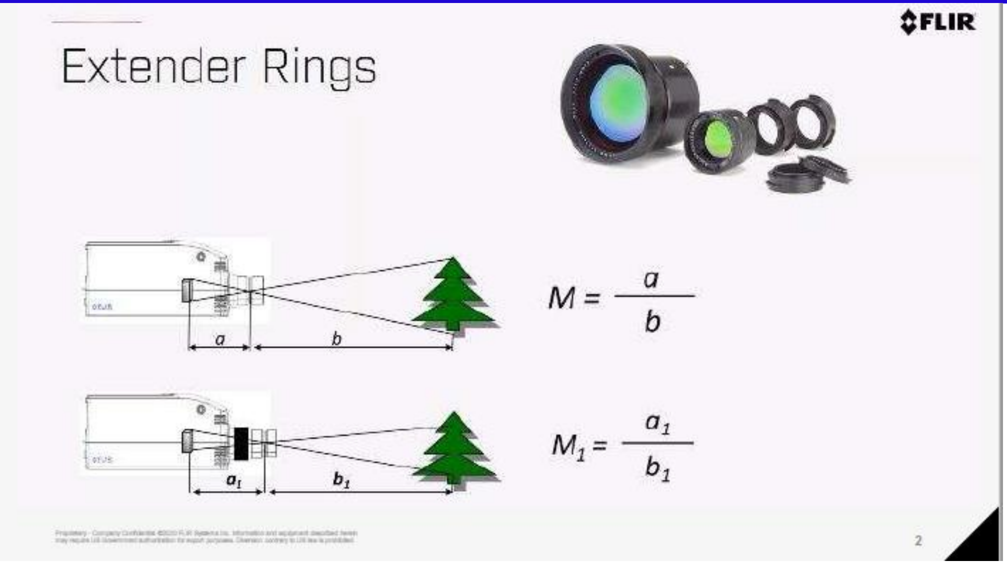
FLIR X6900sc SLS

MODELLO: FLIR X6900SC SLS LWIR

Vai alla pagina di supporto »

La FLIR X6900sc SLS è una termocamera LWIR straordinariamente veloce e ad elevata sensibilità progettata per scienziati, ricercatori e ingegneri. Il sensore strained layer superlattice (SLS) offre velocità di integrazione più brevi, bande di temperatura più ampie e una migliore uniformità rispetto alle attuali alternative LWIR o MWIR. Dotata di funzioni di triggering avanzate, registrazione su RAM/SSD e di una ruota portafiltri motorizzata a quattro posizioni, questa termocamera è perfetta per effettuare fermi immagine di eventi ad alta velocità, sia in laboratorio che sul campo di prova.

FLIR – APPLICATIONS FOR MICROSCOPY

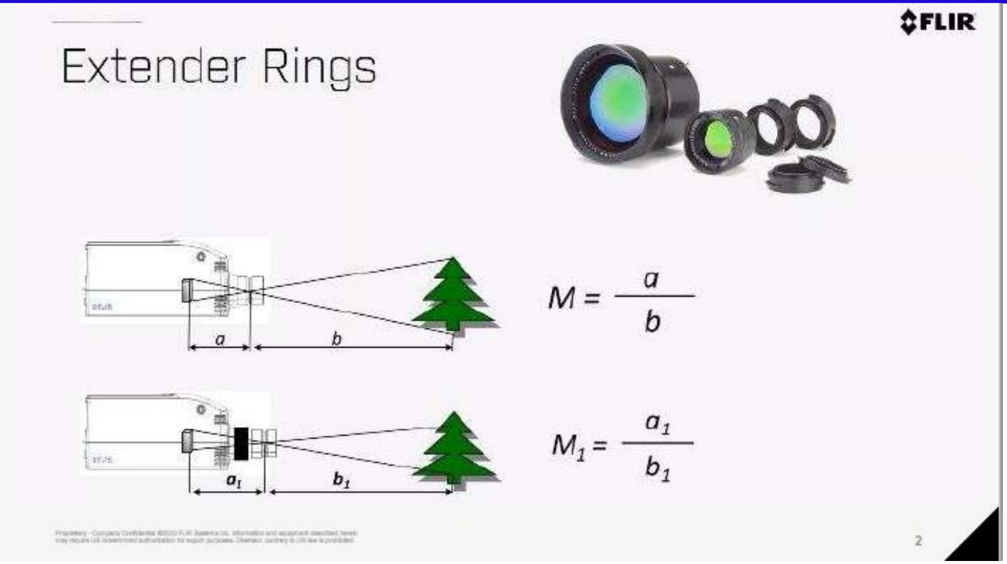


OPZIONE A: Ottica microscopica competa di stativo

1x Microscope LWIR lens (7.5 - 12.0µm), f/2.5	8.265,00 €
LWIR Microscope Thermographic Calibration for -10°C to +350°C	2.580,00 €
Stima costi di importazione e spedizione	1.500,00 €
Microscope Stand Mounting Accessory for Niceville cooled cameras	4.500,00 €
Microscopic Stand for infrared camera. Lens mounting part to be added	5.429,00 €
TOTALE	22.274,00 €

Training course
Thermography Course for remote sensing + lock-in thermography (2days) 3.500 +IVA
Totale complessivo = 25.774 + IVA

FLIR – APPLICATIONS FOR MICROSCOPY

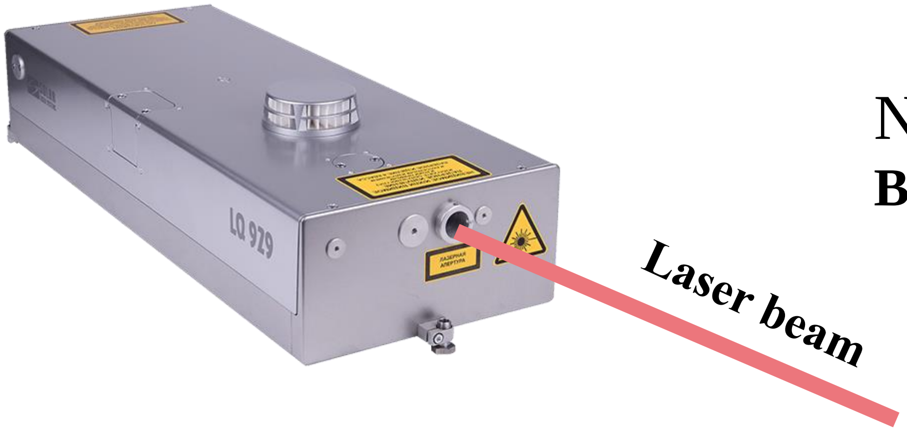


OPZIONE B: Anelli e nuova ottica

Extender Ring Set, 4 Rings 0.25", 0.50", 0.75", & 1.00" (HDC Bayonet)	713,00 €
100mm LWIR lens (7.5 - 12.0µm), f/2.5 (HDC Bayonet)	8.888,00 €
LWIR Thermographic Calibration for -20°C to +650°C	1.843,00 €
Stima costi di importazione e spedizione	1.500,00 €
TOTALE	12.944,00 €

Training course
Thermography Course for remote sensing + lock-in thermography (2days) 3.500 +IVA
Totale complessivo = 16.444 + IVA

Nd: YAG laser for inducing equivalent stress with photons



Nd:YAG laser
Bicocca + Roma1

Lunghezza_d’onda (nm) 1064
Modalità di emissione Repetitevely pulsed
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

MIB -
Lavorazione meccaniche 5.000 Euro
Refurbishing laser 4.000 Euro

Roma 3 Unit

Instruments at LASR3

3D Stylus Profilometer

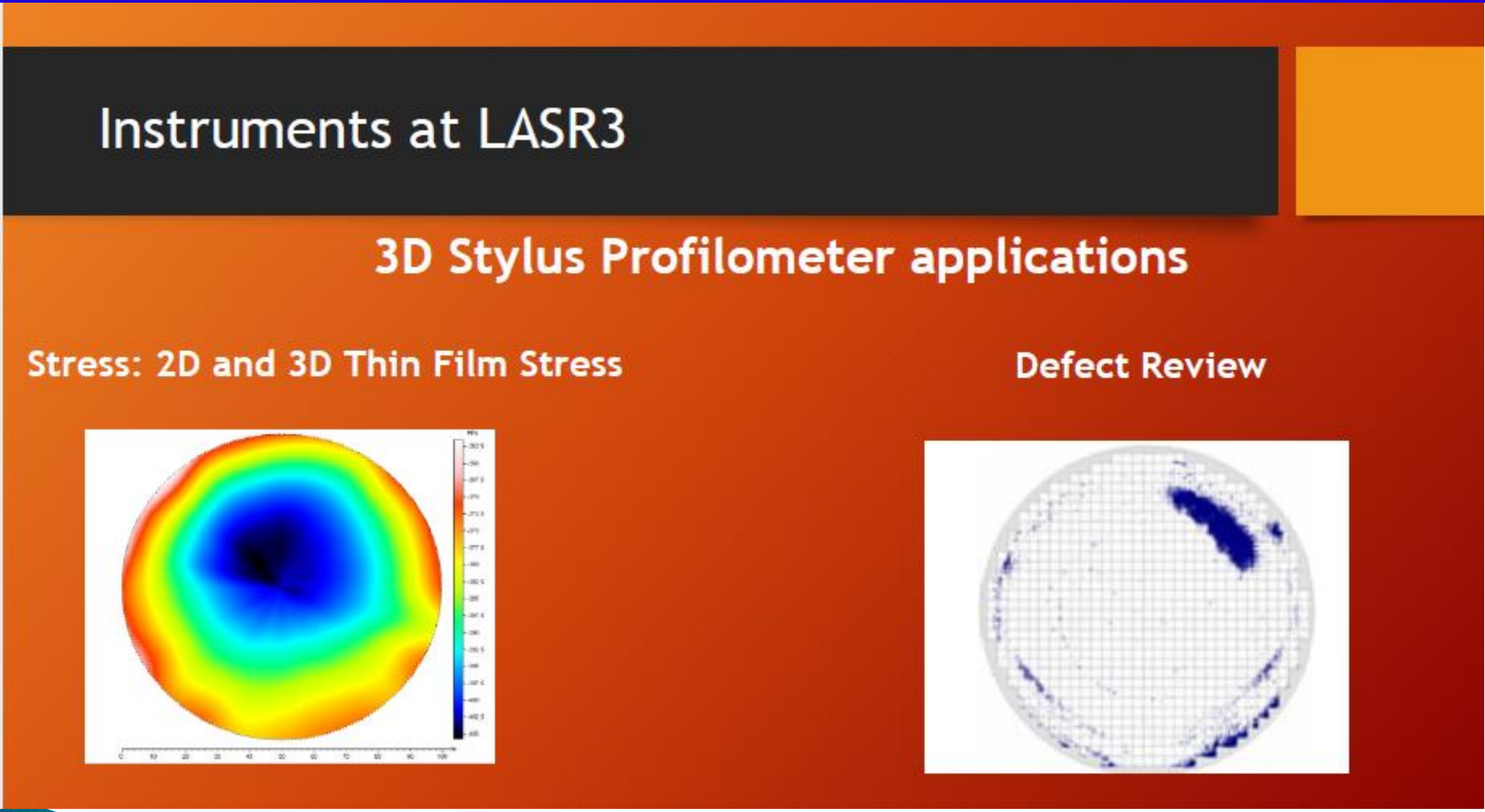
Stylus Profiling

The precision scan stage design enables high quality scans over the entire 150 mm sample stage area with up to 150 mm scan length and 1 mm Z range. This design ensures the highest quality 2D and 3D scans resulting in a higher level of metrology quality.

Step Height Repeatability

A step height repeatability of 4 Å, one-sigma or better on samples up to 1 µm tall offers the best measurement precision in the research field. This performance is ensured with ultra-low-noise electronics, and a low mass, low inertia capacitive sensor with sub-Angstrom resolution, and superior scan flatness.

Roma 3 Unit



RM3-
Integrazione per 3D Stylus : 4.500 Euro

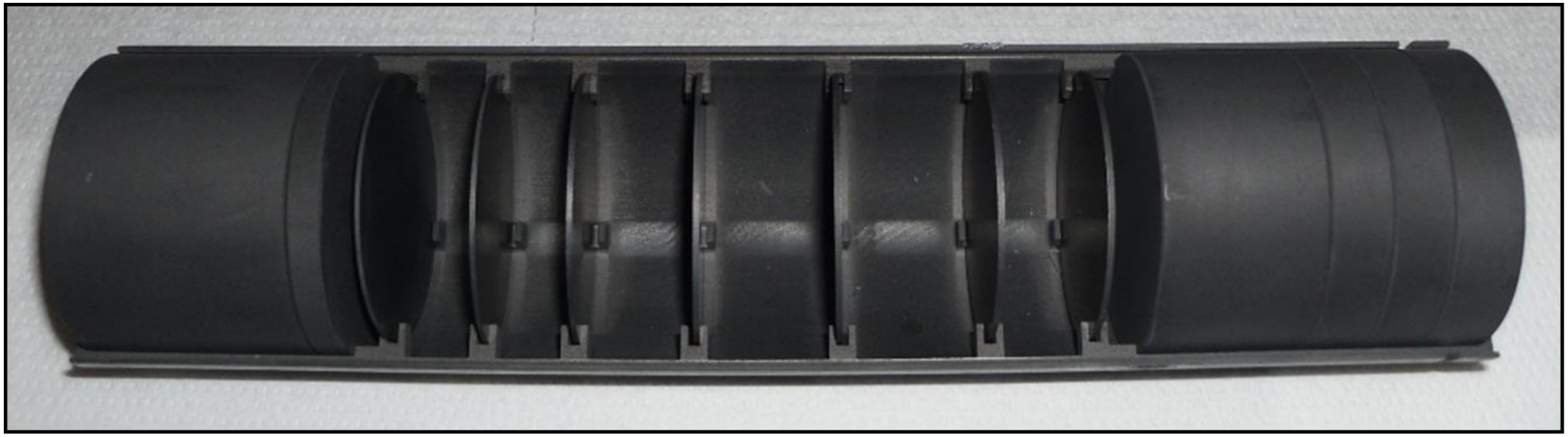
PoliTo Unit

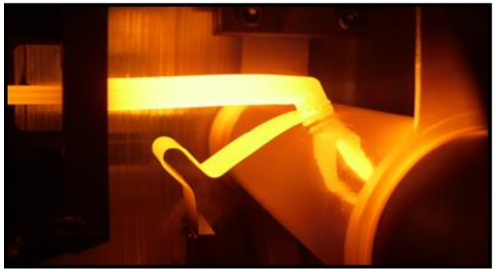
DYNLAB

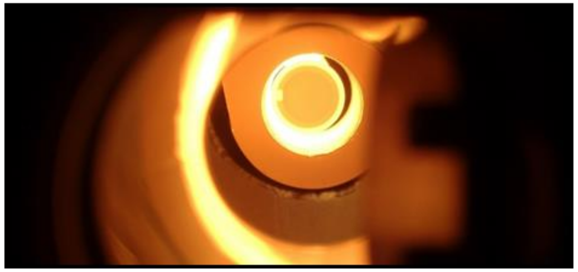
Materials testing in extreme loading conditions

The Laboratory

Design of High Temperature ISOL Targets







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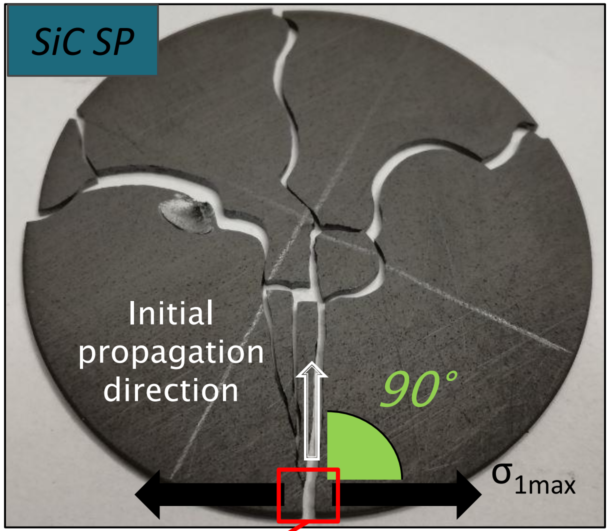
Mainly taken from M. Manzolaro presentation at the HPTW 2018

Università degli Studi di Padova

S. Corradetti, M. Manzolaro, D. Scarpa, A. Monetti, L. Centofante

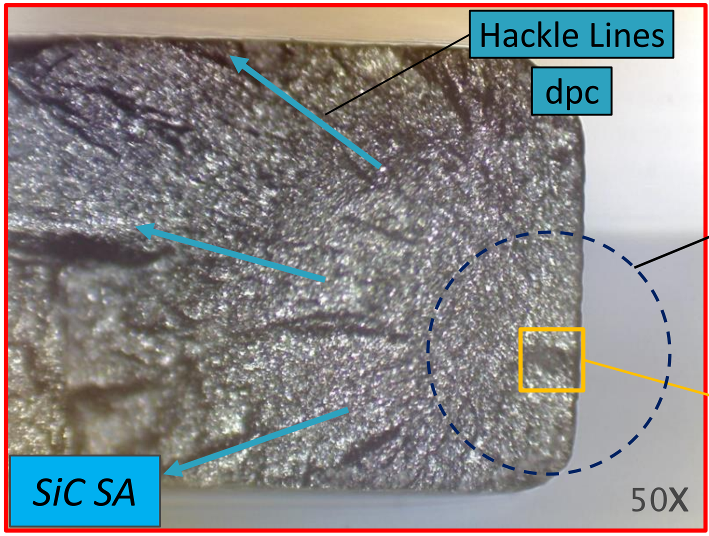
Target material characterization @ HT

Peculiar fracture shape



Defect

Fracture surface morphology



G.D. Quinn, *Fractography of Ceramics and Glasses*, NIST Recommended Practice Guide, 2016

Mirror

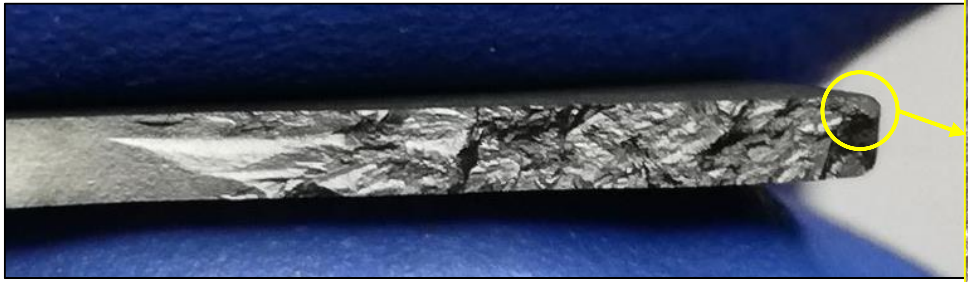
V_{pc}=1500 m/s

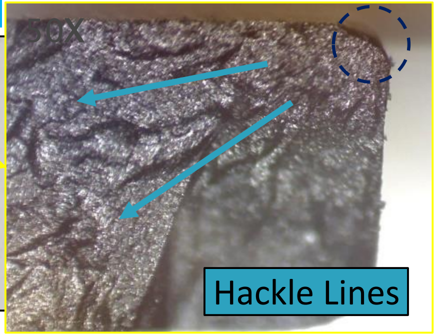
Defect

V_{pc}=0 m/s

Silicon Carbide Hexoloy SA

Mirror





Legnaro

Materiali grafite : 5.000 Euro

Roma 1 Unit

Photoacoustic and Photothermal Lab @Sapienza

Dipartimento di Scienze di Base e Applicate per l'Ingegneria - Sapienza Università di Roma, Italy

DIPARTIMENTO DI SCIENZE
DI BASE E APPLICATE
PER L'INGEGNERIA

SAPIENZA
UNIVERSITÀ DI ROMA

RM1-
Integrazione per misure termomeccaniche: 2.000 Euro

Email: roberto.livoti@uniroma1.it

Photoacoustic & Photothermal Techniques – Sapienza Lab

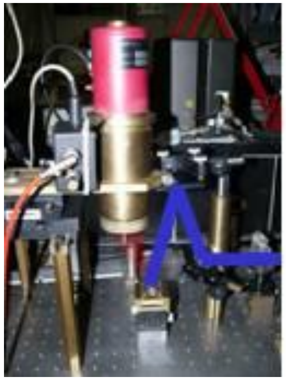
Applications

Measurement of thermal conductivity and diffusivity of materials
Non Destructive Evaluation and Testing of materials
Detection of surface and subsurface cracks and defects
Surface roughness characterization
Nanoscale heat transfer and heat management
Trace gas analysis and sensors
IR filters design and characterizarion

Photothermal and Photoacoustic spectroscopy

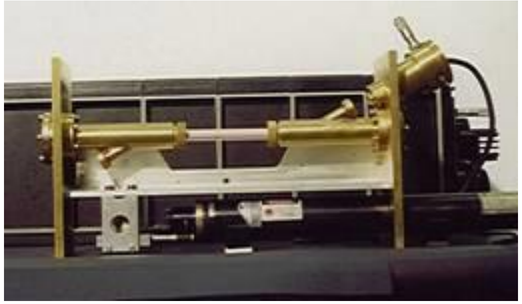
New Industrial Applications

- *Noncontact merasurement of the hardeness of steels– AVIO (General Electric)*
- *Nonconctact measurement of the surface roughness*
- *Design and Realization of new Photovoltaic Cells – Regional project*
- *IR filters for the reduction of the IR Signature*
- *Design of IR nanoantennas*
- *Applications in agro food*


Photothermal Radiometry and Thermography

Collaboration with Universities and Industries

- *Hokkaido University, Sapporo*
- *Tokyo Institute of Technology, Tokyo*
- *Toronto University*
- *Università di Leuven,*
- *IOFFE Institute of S.Petersburg*
- *ICMM Madrid*
- *CNRS Network on Nanophononics*
- *ENEA*
- *AVIO S.p.A*
- *MDM Metrosoft*
- *BIFRANGI*


Trace Gas Analysis