ESRF | The European Synchrotron

The High Power Laser Facility at ESRF: an update on the commissioning of the 15J Front End laser

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OUTLINE

I. Historical background: why a high power laser facility at ESRF?

II. The commissioning of the Front End (2018)

III. The HPLF facility at the EBS restart (2020)

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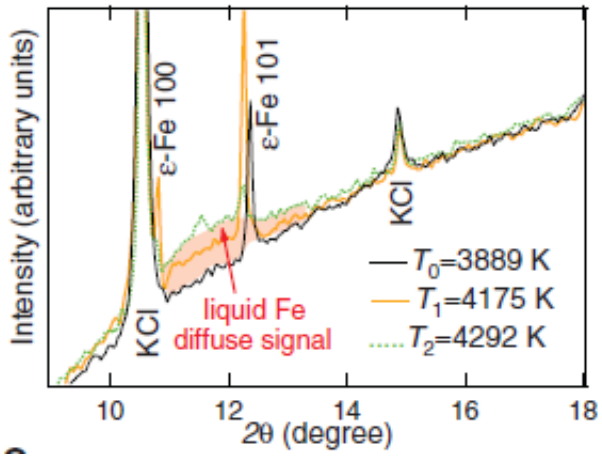
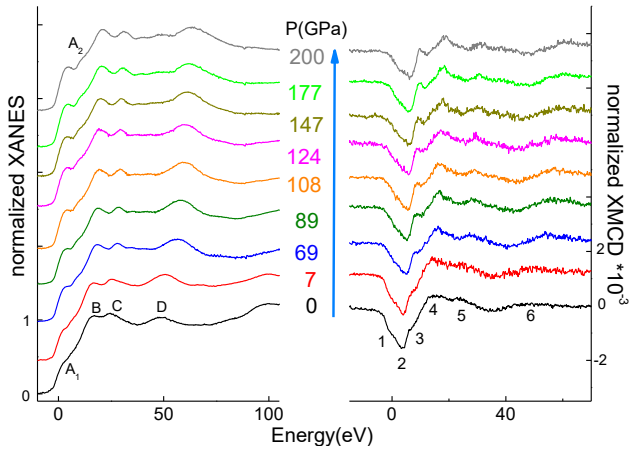
STATIC COMPRESSION AT SYNCHROTRONS TODAY

XRD 1.3 Mbar 4300K



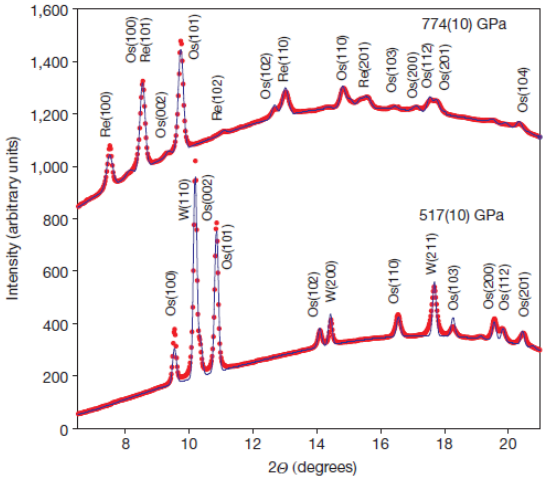
Anzellini Science 2013

XMCD 2 Mbar



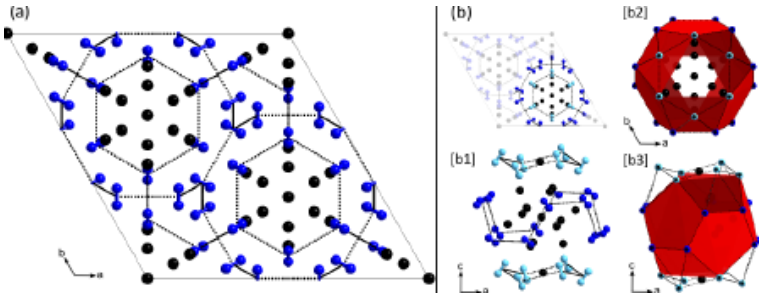
Torchio PRL 2011

XRD 7 Mbar



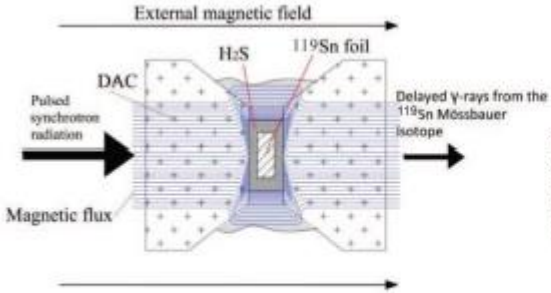
Dubrovinsky Nature 2015

Single Crystal XRD

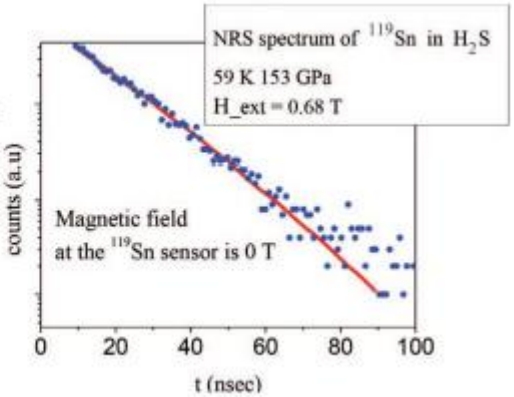


Spaulding Nature Comm. 2014

Nuclear Resonance Scattering



Troyan Science 2016



PUSHING THE FRONTIERS OF HIGH PRESSURE RESEARCH ….

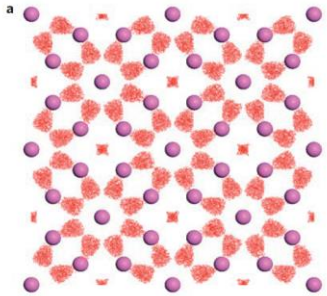
❑ Go more extreme → TPa & eV

Conditions beyond those existing in our planet → Input for planetary models

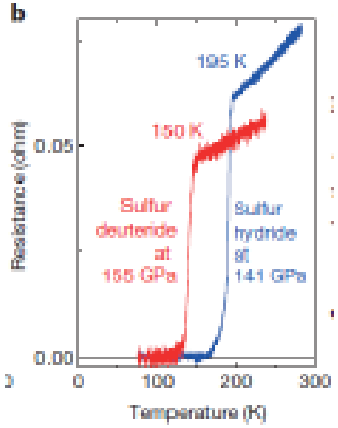
Synthesis of novel materials

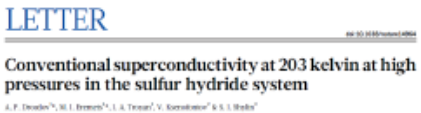
Reveal new physical chemistry

Al @ 1TPa

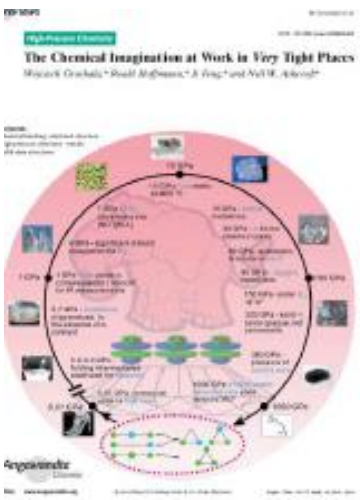


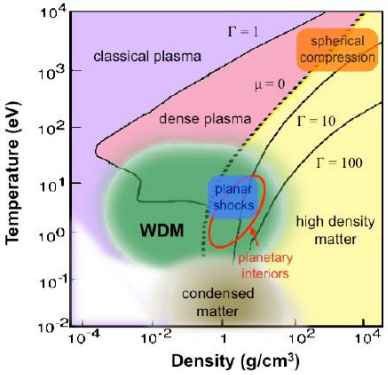
Pickard and Needs 2010




LETTER

Conventional superconductivity at 203 kelvin at high pressures in the sulfur hydride system





Particle ejection

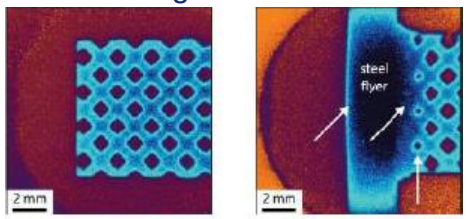
ENSMA Poitiers

❑ Explore the time scale of high pressure phenomena → ns

Dynamic behavior of matter and materials under high strain rates

- Mechanisms and nucleation of phase transitions
- Yield strength (dynamics of dislocations)
- Nanostructuration, amorphisation, metastable phases

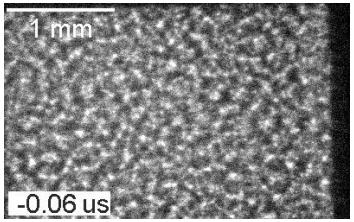
Heterogeneous media



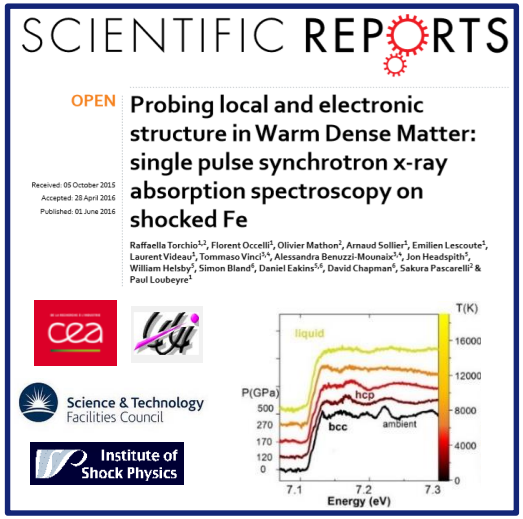
Pre-shot 2.4 µs

ISP Imperial London

A SYNERGETIC APPROACH TO DYNAMIC COMPRESSION AT ESRF

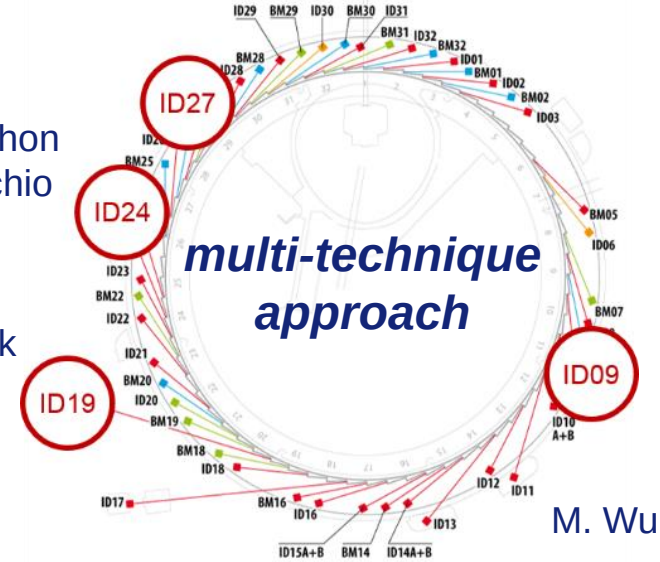


Olbinado J. Phys D 2018

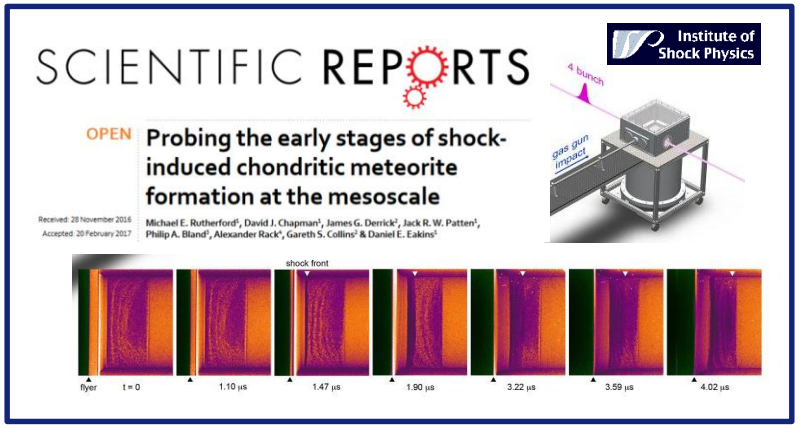


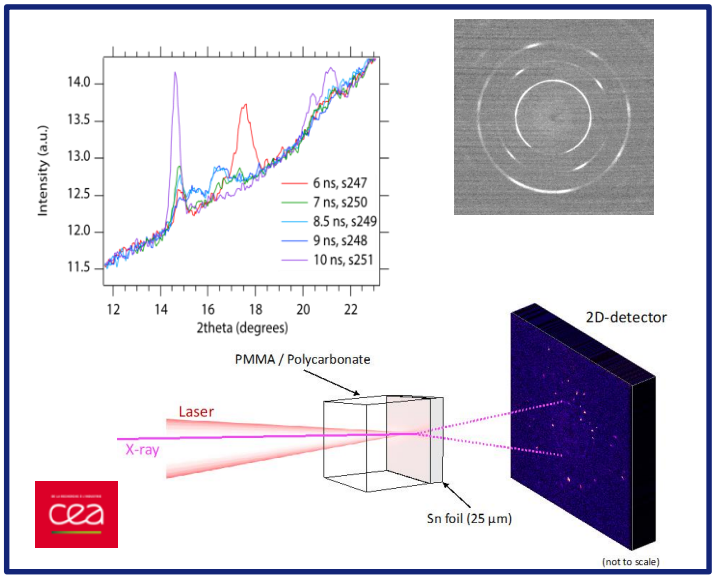
O. Mathon
R. Torchio

A. Rack

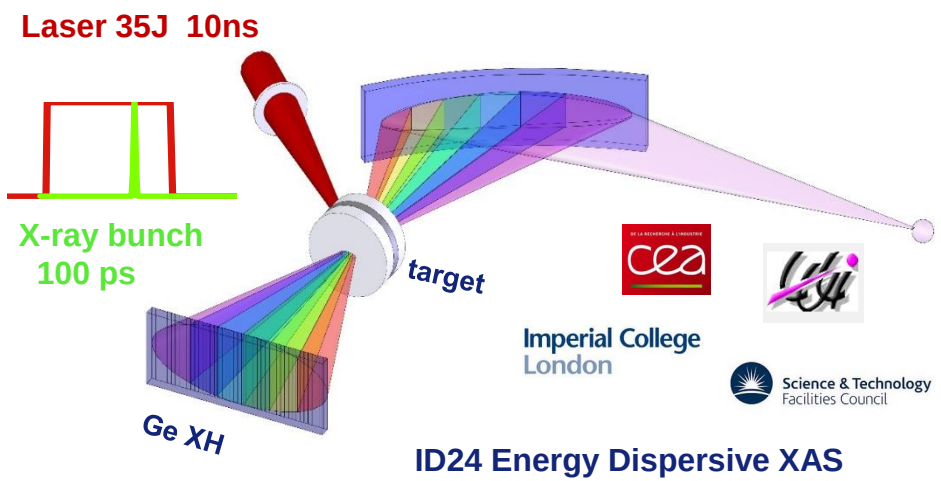


M. Wulff





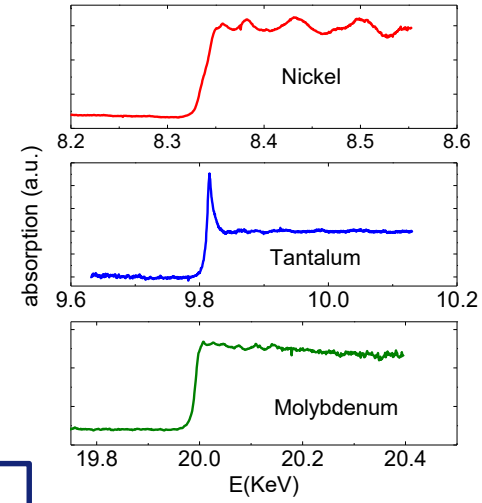
FIRST EXPERIMENTS ON ID24 (2014-2016)



ID24 Energy Dispersive XAS

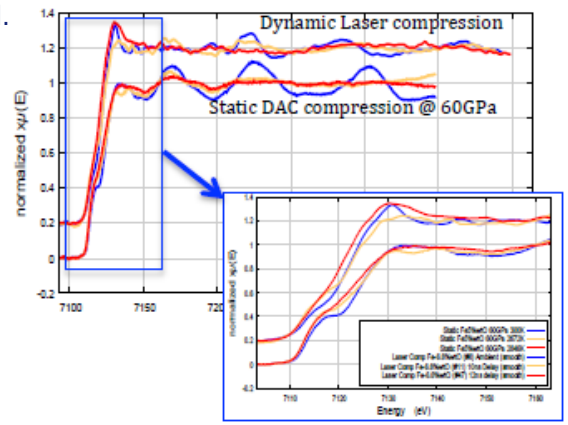
Single bunch XAS at Ni, Ta and Mo

O. Mathon et al., HPR 36, 404 (2016)



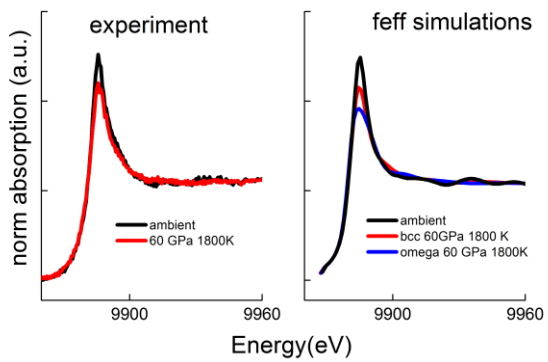
Local structure of laser shocked Fe-6.6%wtO

M. Harmand et al.



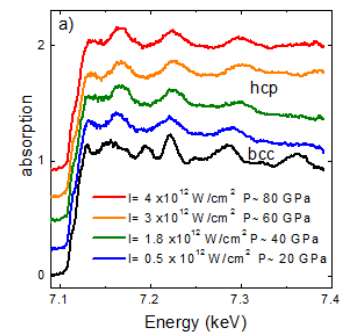
Local structure of laser shocked Ta

A. Sollier et al



Local and electronic structure in warm dense Fe

R. Torchio et al. Sci. Rep. 2016

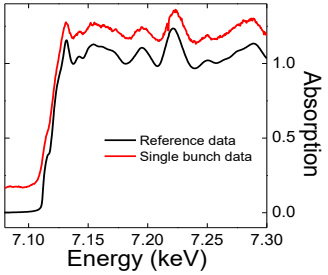


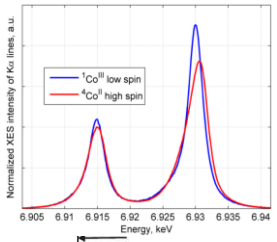
THE HIGH POWER LASER FACILITY AT THE ESRF

HPLF-I (2018-2021)

Couple a 100 J (upgradable to 200 J) ns-shaped laser to XAS on ID24

In Construction

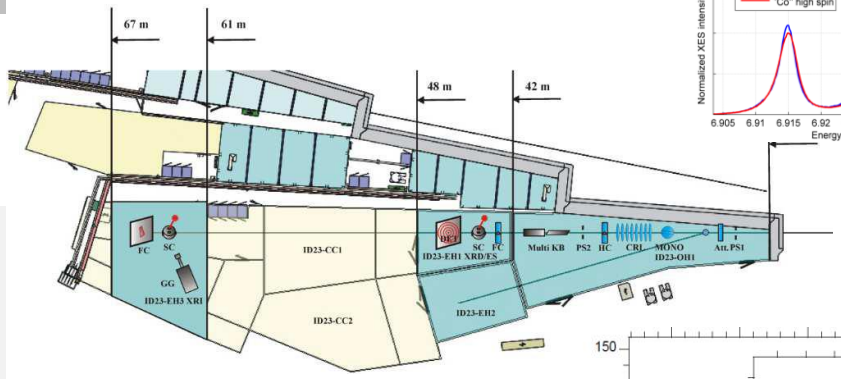


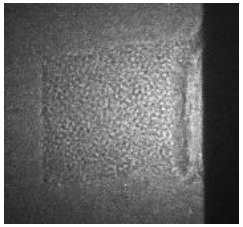


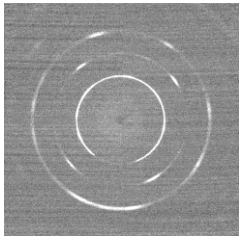
HPLF-II (from 2023)

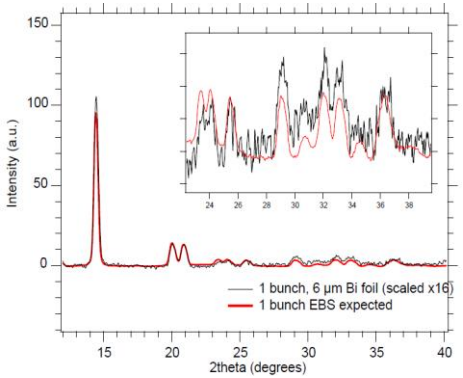
Extend to XRD, XRI, XES on ID23
Laser upgrade

EBS Beamline program









HPLF – I : PLANNING

2018: Delivery & commissioning of the 15J laser front end

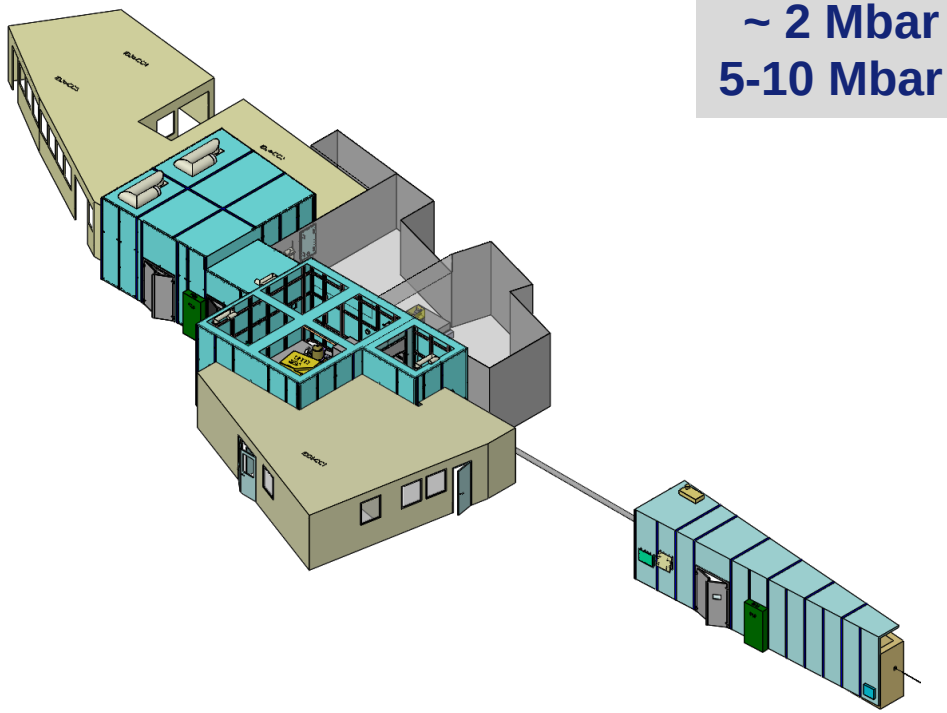
2019: EBS shutdown

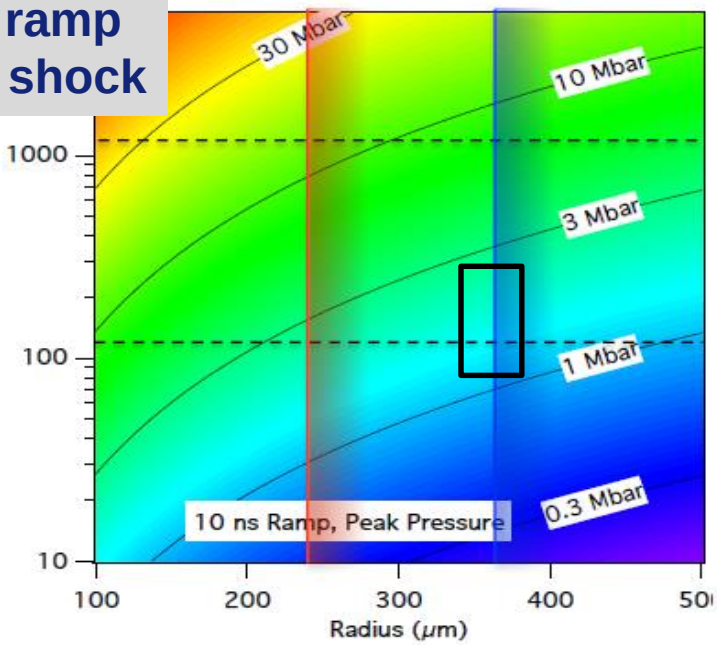
2020: 100J laser delivery

2021: User operation

15J, 10ns
40-200 GPa

100J, 6ns
~ 2 Mbar in ramp
5-10 Mbar in shock





Fratanduono 2011

OUTLINE

I. Historical background: why a high power laser facility at ESRF?

II. The commissioning of the Front End (2018)

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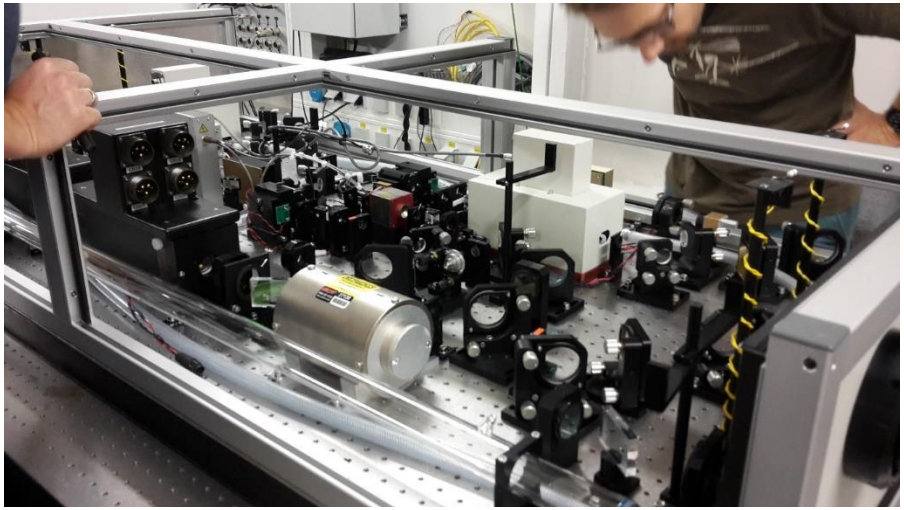
INSTALLATION OF FRONT END ON ID24: SEPTEMBER 4TH 2018



LASER CHARACTERISTICS

LASER provided by *Amplitude Laser Group (Lisses, Fr. and San Jose, USA)*

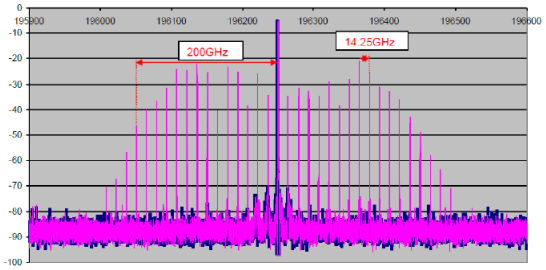
FRONT-END
15J @ 1053 nm
2-15 ns
Pulse shaped

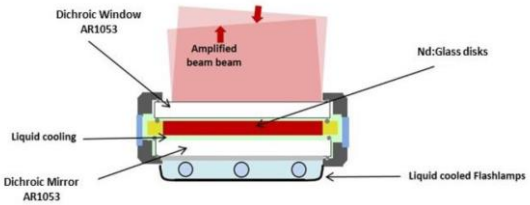
→ Power Amplifier
Disk Amplifier
Head (DAH)

→ 3 DAH: 108J @ 1053 nm, 4-15 ns
→ 5 DAH: 200J @ 1053 nm, 6-15 ns
→ Green option

Front-end

- Pulse generation (CW laser)
- Pulse shaping
- Spectral broadening
- Pre-amplification stages



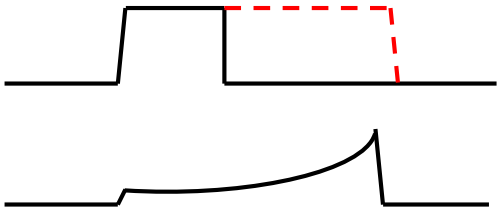


Amplification chain

- Nd:Glass DAH
- Liquid cooled amplifiers
- Pumped by flash lamps
- 3 DAHs for HPLF-I
- Compatible 5 DAHs (upgrade)

Output

- 1-100 J adjustable
- Top-hat spatial profile N>8
- Adjustable temporal profile
  flat top variable (2-15ns)
  ramps t^2, t^3, t^4
- 1 shot every 4 minutes
- Jitter < 26 ps rms



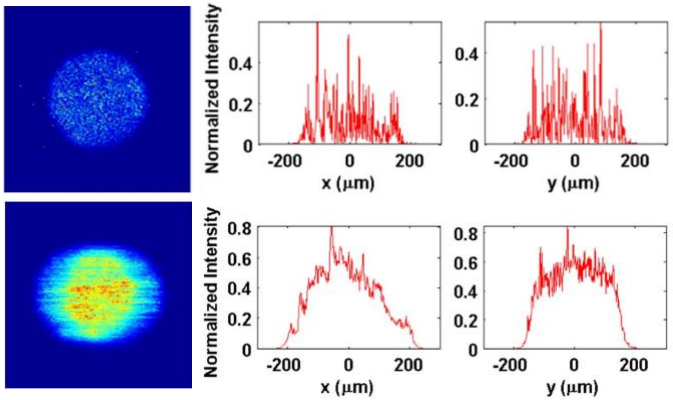
LASER CHARACTERISTICS: FRONT-END

LASER provided by *Amplitude Laser Group (Lisses, Fr. and San Jose, USA)*

Shape control: 0.25 ns step
Jitter < 26 ps
Rising edge: 0.25ns 20-80%
Modulation < 3% rms
Shot-to-shot stability < 2% rms
Contrast > 10^5

No SSD

SSD

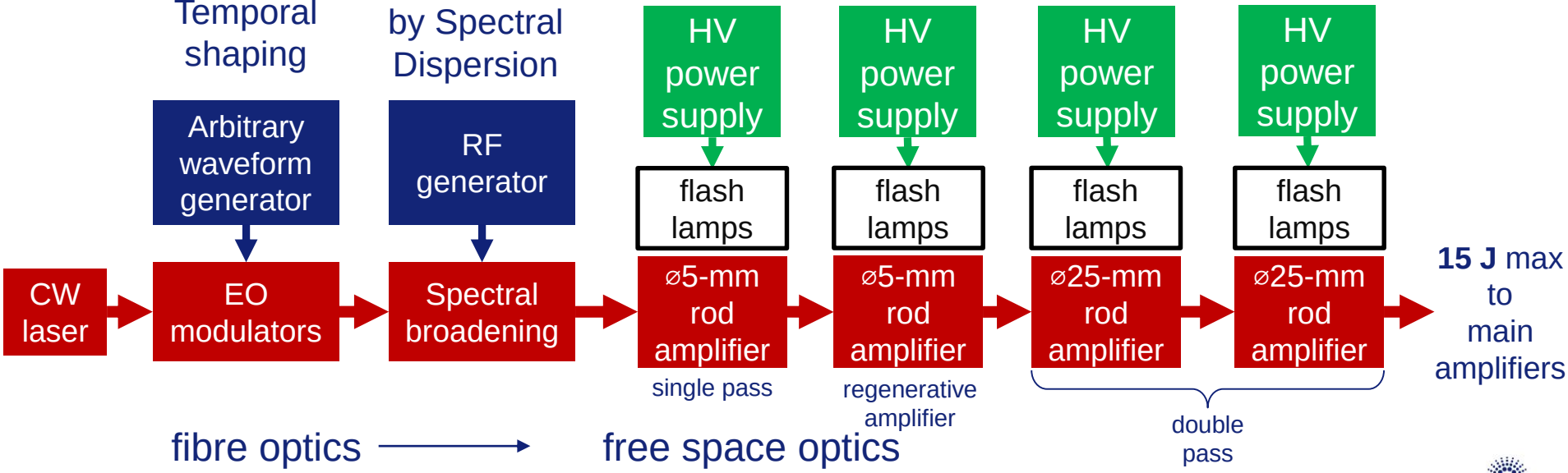


From Jiang et al., J. Opt. Soc. Am. A (2013)

Temporal shaping

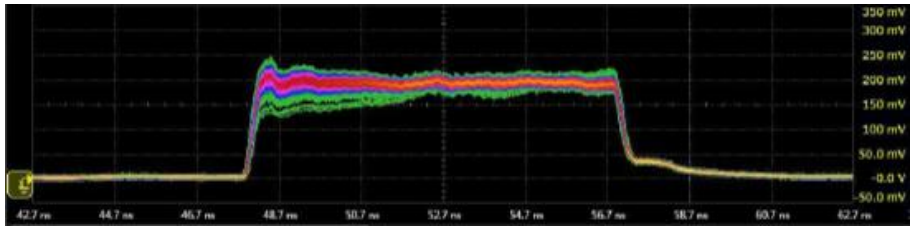
Smoothing by Spectral Dispersion

Energy amplification



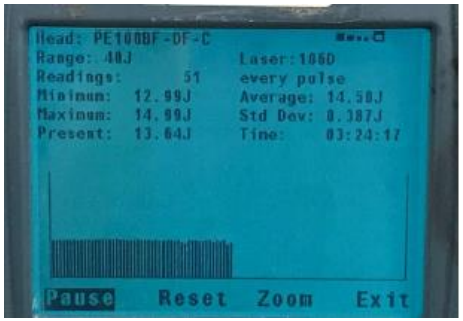
2018 Commissioning: Evaluation of Front End characteristics

Temporal shape over time



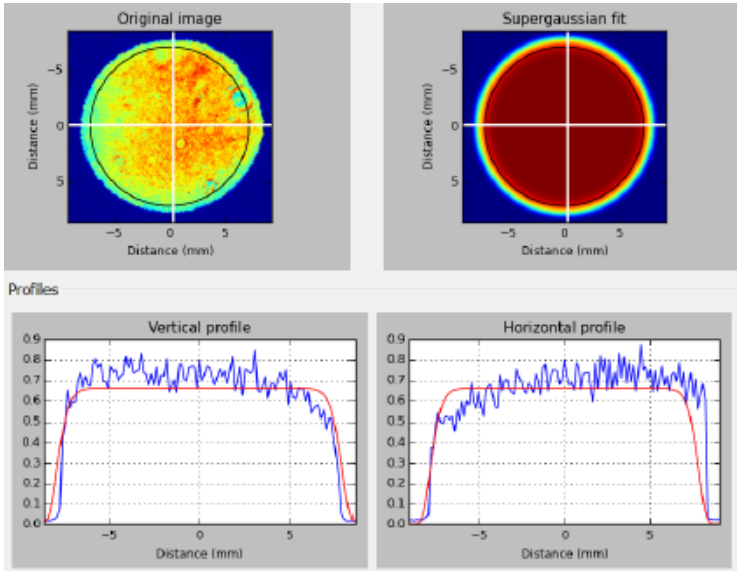
rise time of 240 ps and 350 ps fall time. Timing jitter of 22 ps rms

Energy stability



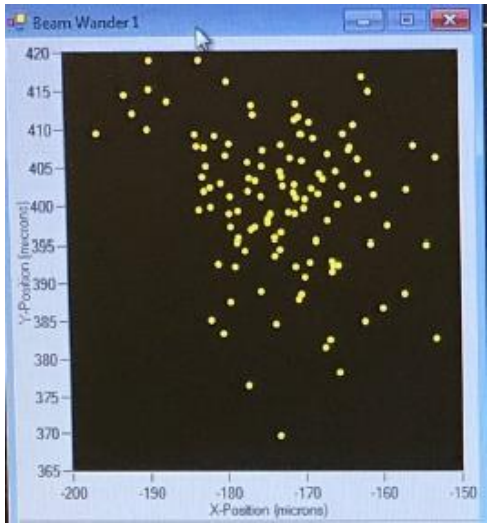
2.7% rms over 3h 24min
at 1 shot every 4 min = 51 shots

Spatial distribution



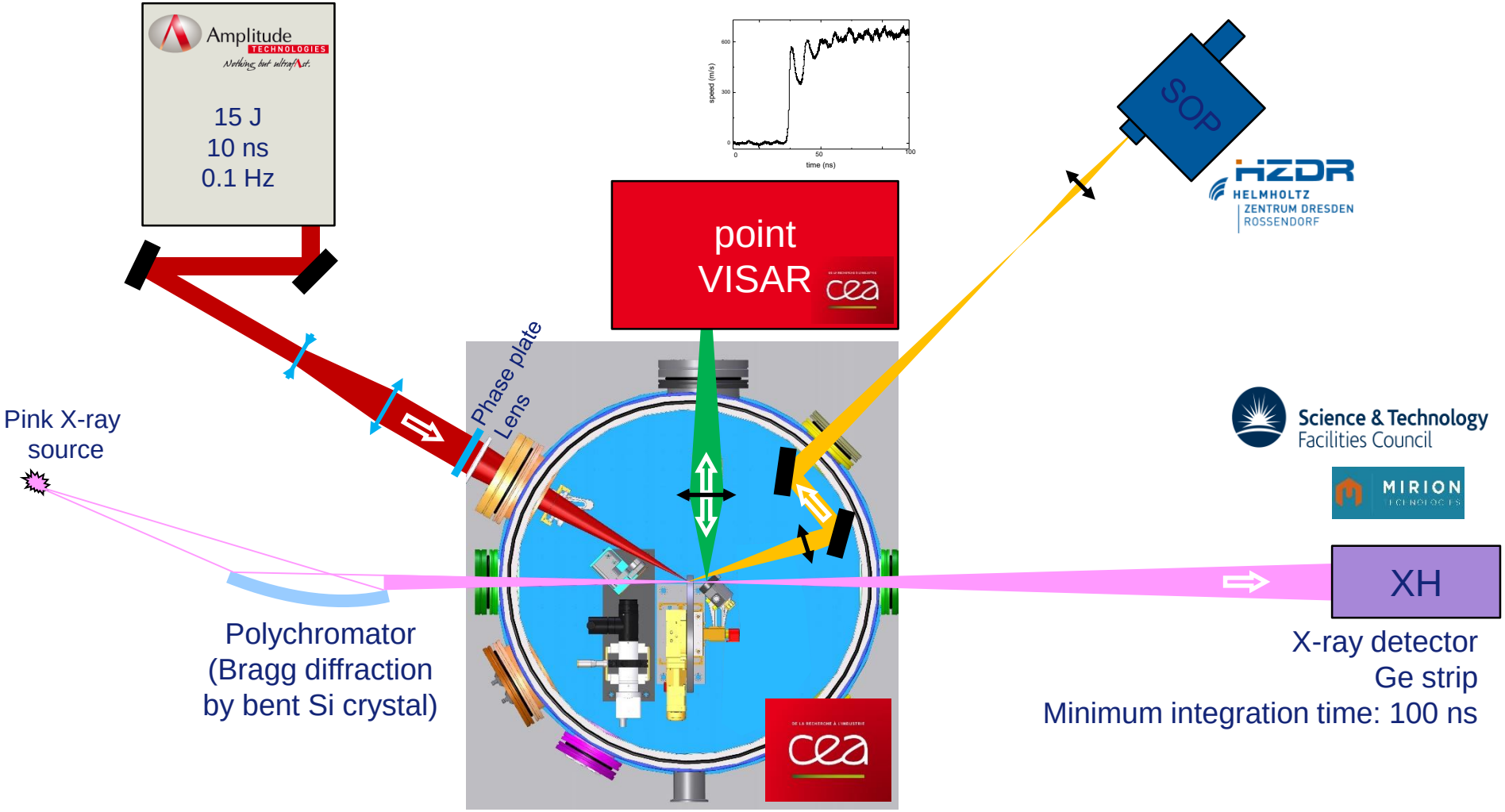
Supergaussian order 20; modulations on plateau level 13% rms
Ellipticity 95%.

Pointing stability

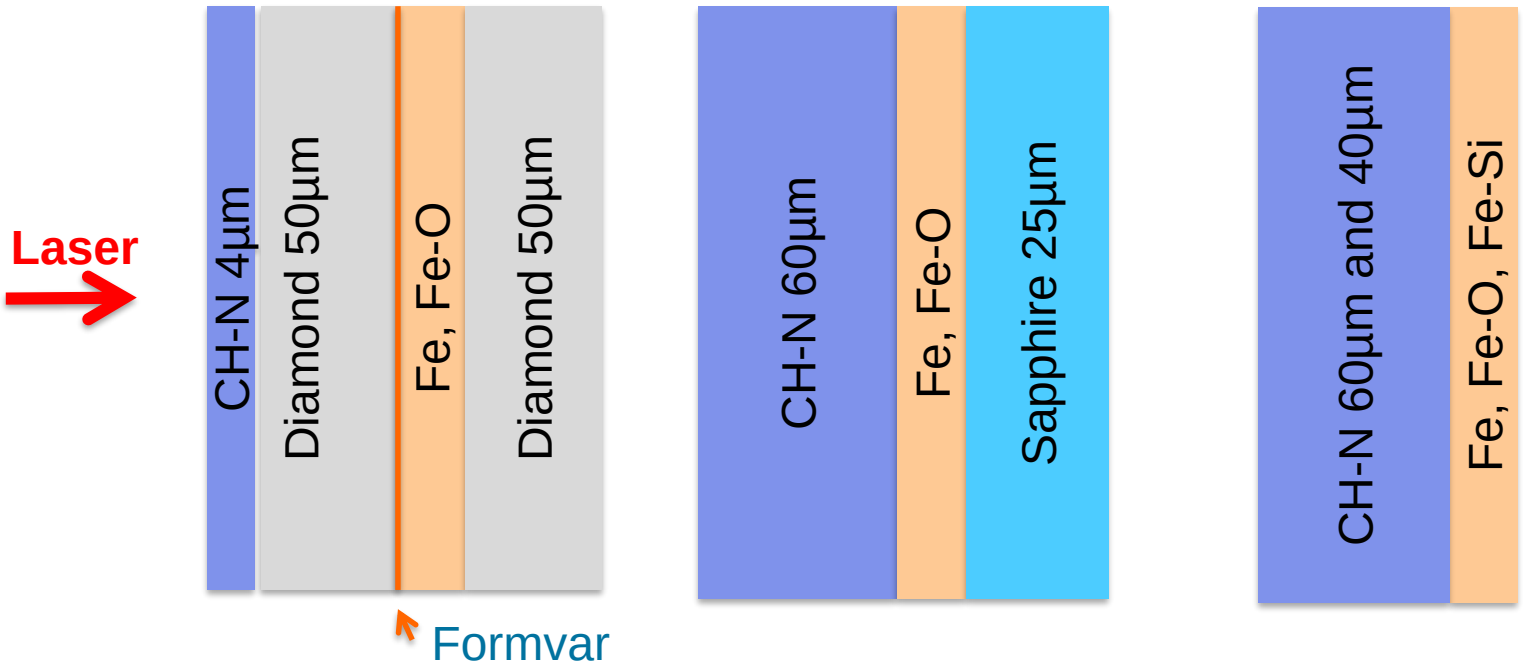


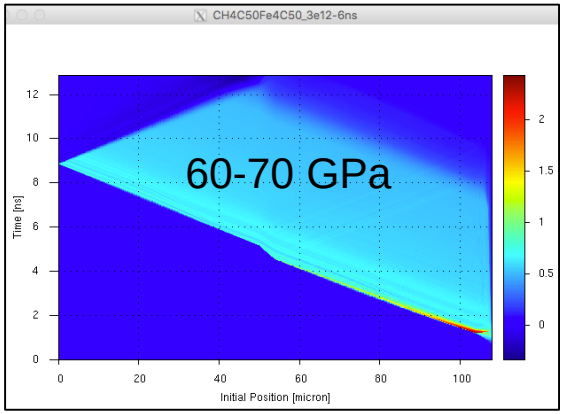
Standard Deviation < 10 µrad over 100 shots

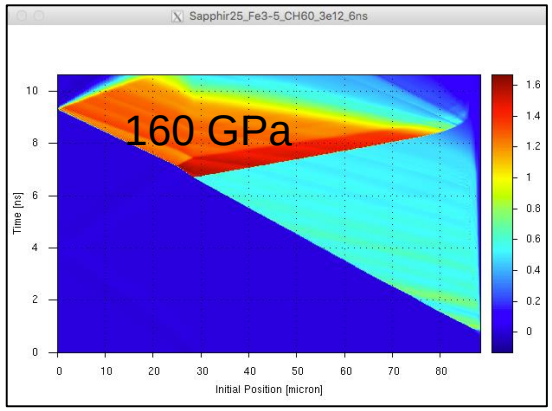
2018 Commissioning: Experimental Layout



2018 Commissioning: Target Design

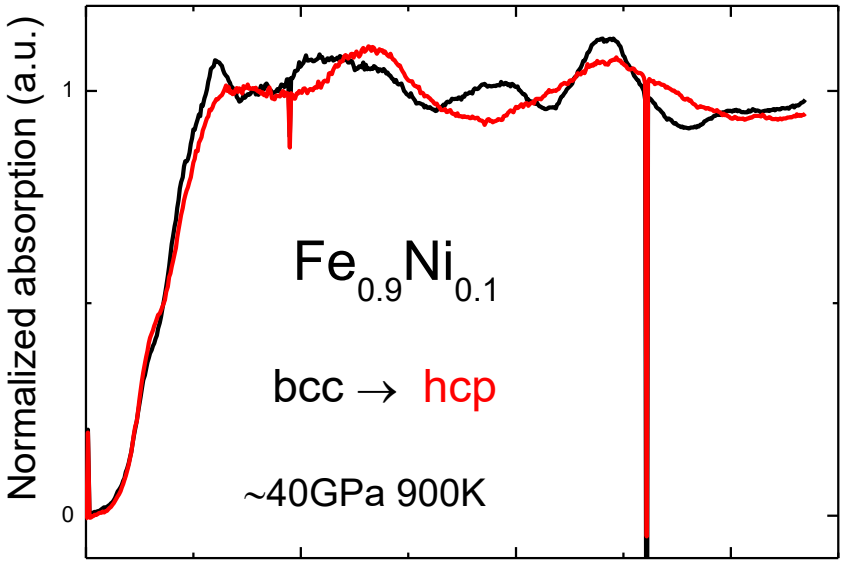


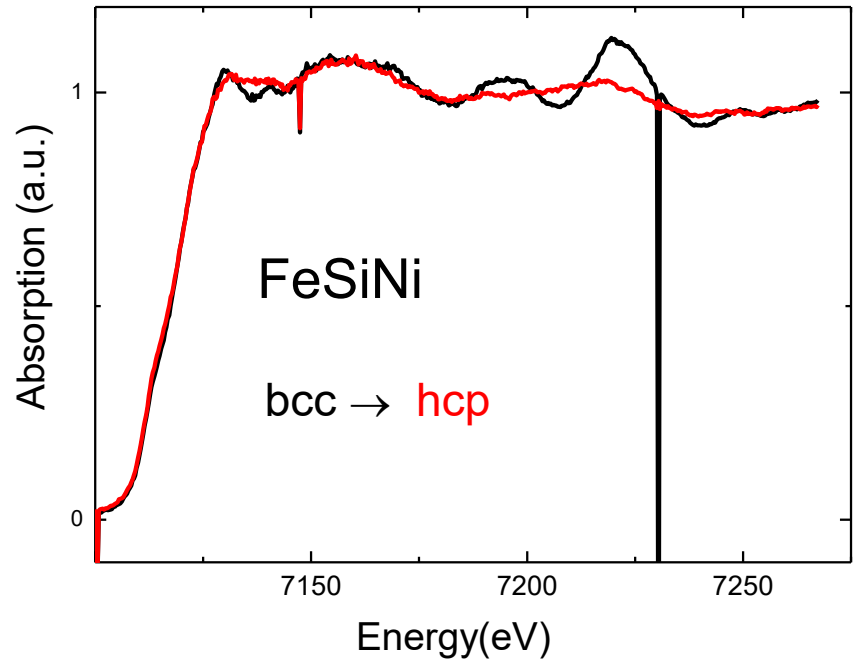


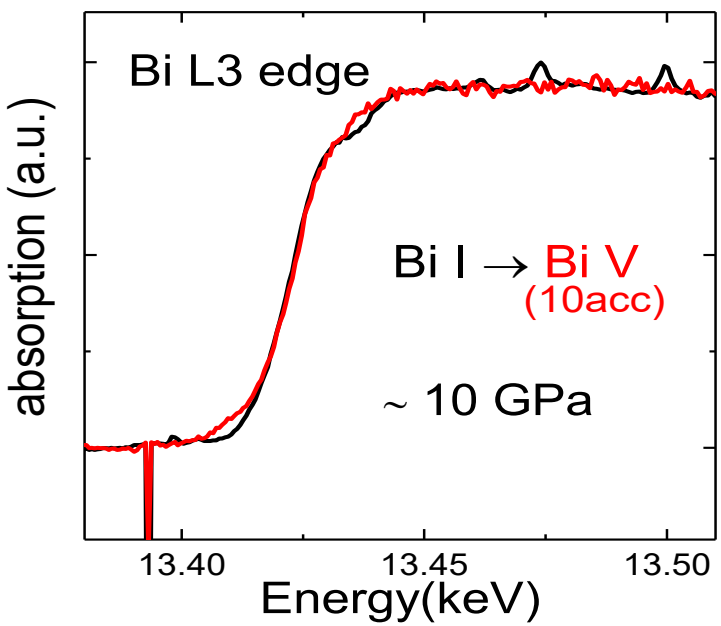


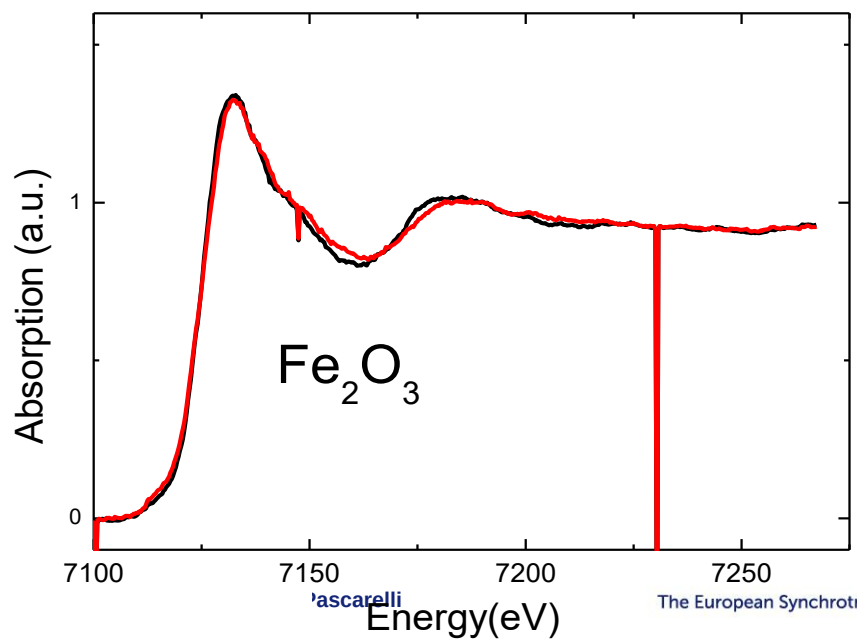
- Fe
- Fe-10%wtO
- Fe_2O_3
- FeNi, FeSiNi

2018 COMMISSIONING: FIRST DATA









OUTLINE

I. Historical background: why a high power laser facility at ESRF?

II. The commissioning of the Front End (2018)

III. The HPLF facility at the EBS restart (2020)

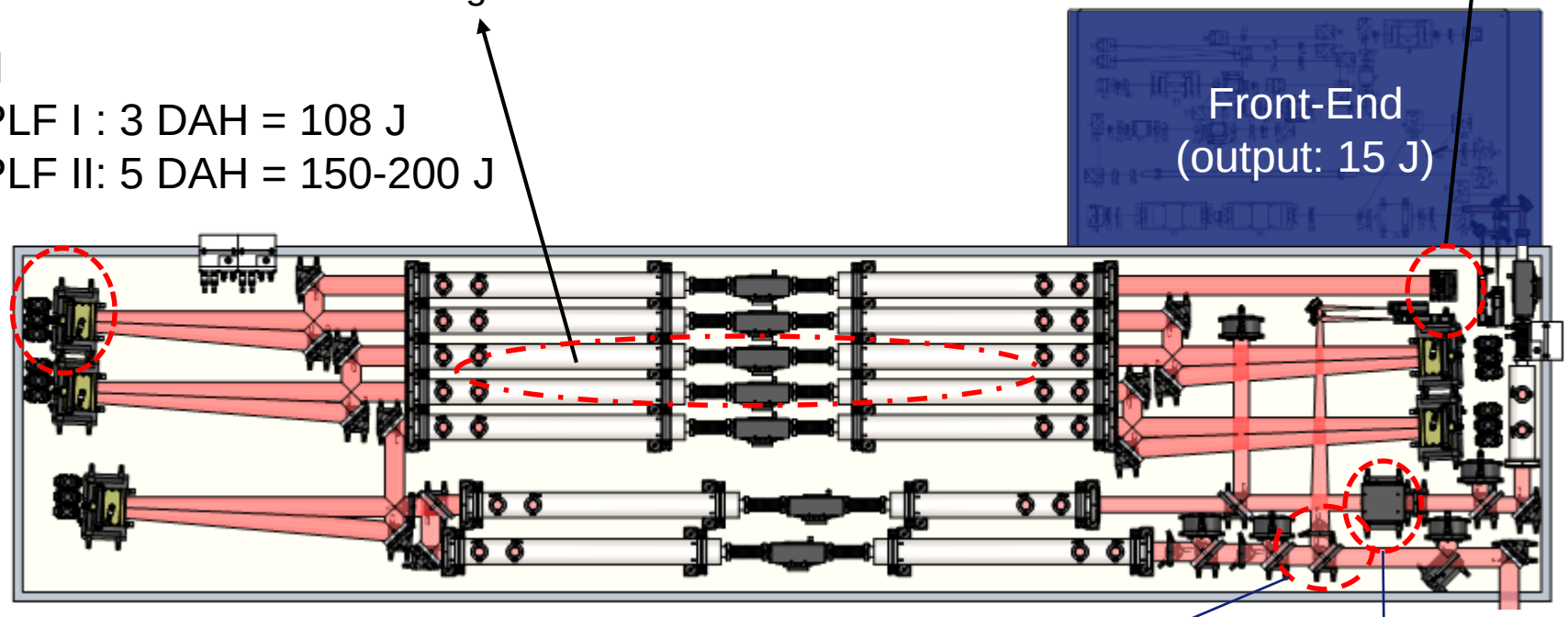
LASER CHARACTERISTICS: AMPLIFICATION

LASER provided by *Amplitude Laser Group (Lisses, Fr. and San Jose, USA)*

Relay imaging propagation
- Optimum beam quality on critical components
- Safer for optical elements
- Less sensitive to misalignment and thermal effect

HPLF-II: Deformable mirror

DAH
- HPLF I : 3 DAH = 108 J
- HPLF II: 5 DAH = 150-200 J

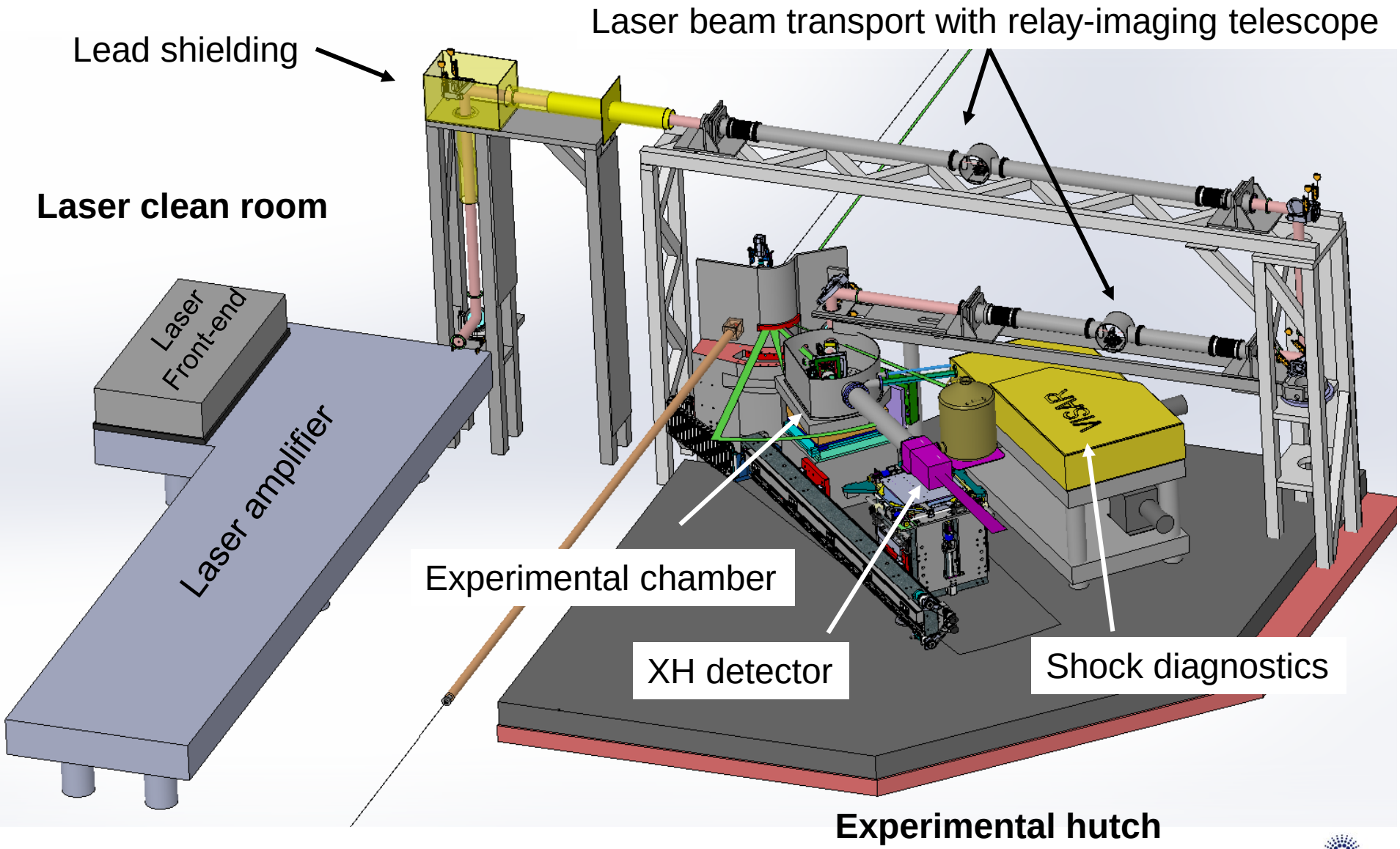


6.5 m

Backstop pockels

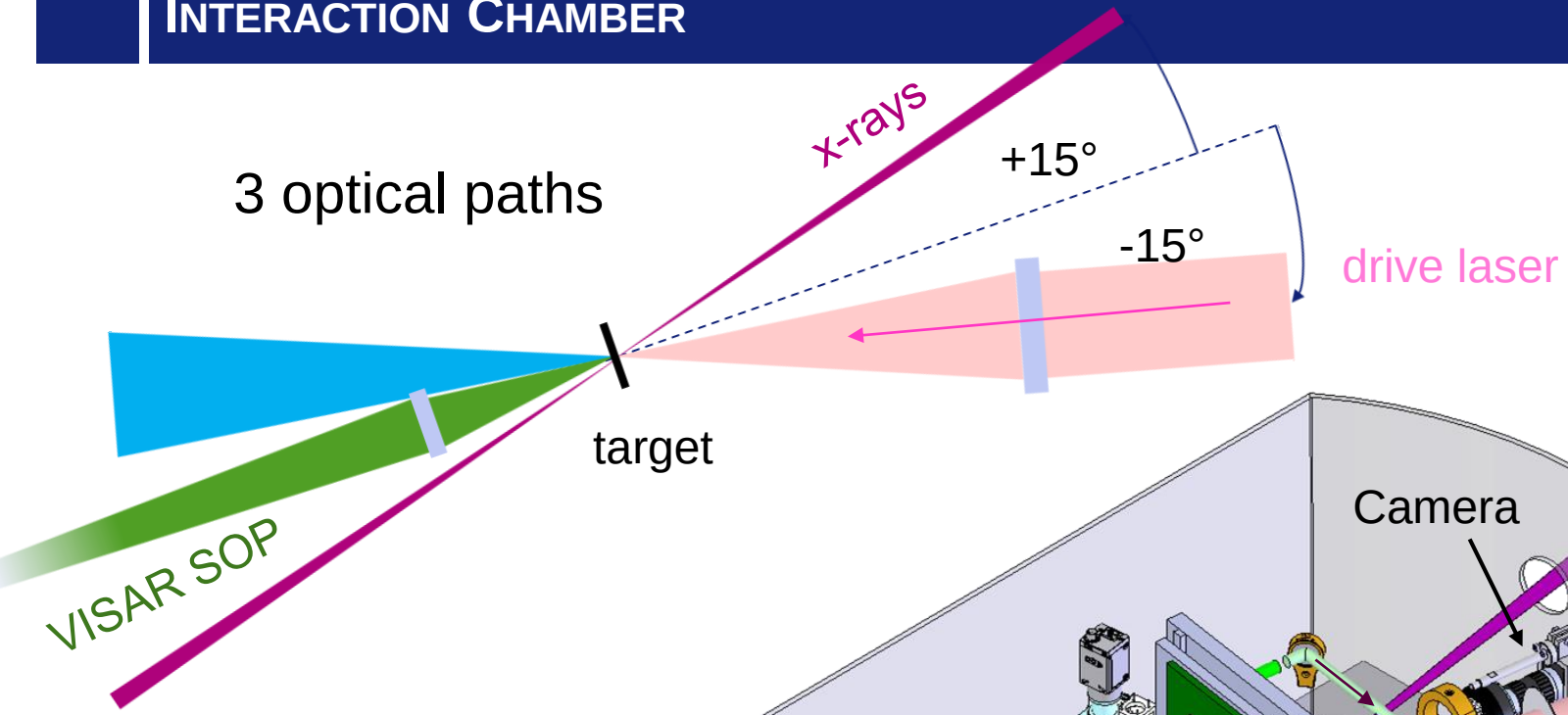
Shot-to-shot characterization
Spatial and temporal profile

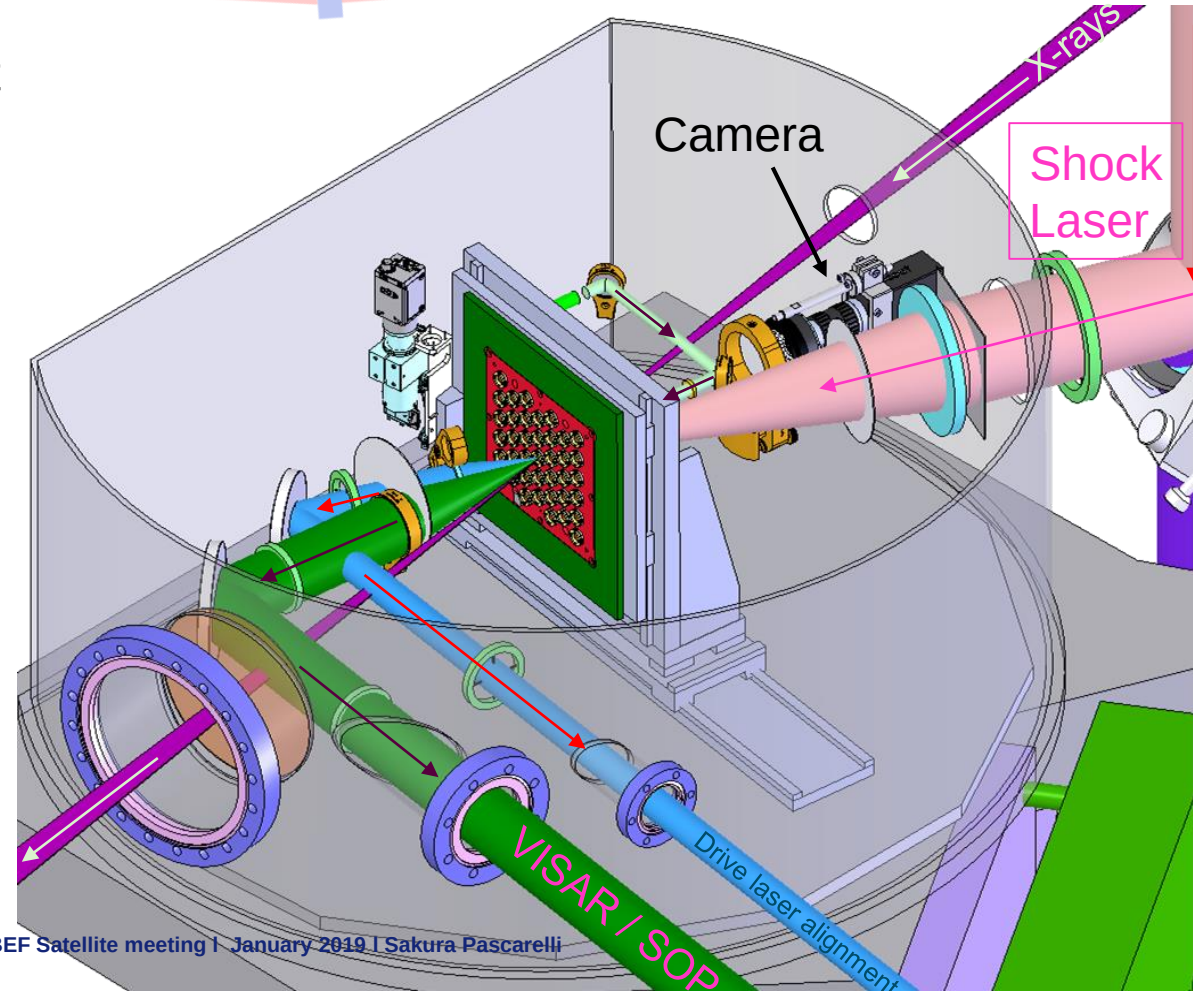
LASER ENVIRONMENT AND TRANSPORT



Interaction Chamber

3 optical paths





X-rays: local structure (XAS)
VISAR/SOP: measure P, T
Drive laser: extreme P, T
Alignment: drive laser

target holder EUCALL

Studies of Laser excited extreme states of matter by X-rays

fs ps ns ms

Out-of-equilibrium
Isochoric heating, ultra fast phase transitions, electronic excitations, cold melting, laser processes, laser-plasma interactions, quantum states of matter…

At local thermal equilibrium
dynamic compression, dynamic phase diagrams, thermal melting, WDM, kinetics, nucleation, electronic transitions, synthesis of new materials, fragmentation, ejecta …

HED | **HED & HPLF**

- two complementary facilities covering timescales from fs to static → a unique offer worldwide
- very dynamic and expert user community, including (new) groups from optical laser facilities that need high quality X-ray probes

→ exploit synergies
→ develop strong collaborations
→ most efficient scientific exploitation

The best path to

EXCELLENT SCIENCE

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THANKS

Thank you for your attention