Overdense target development at the L2A2

Camilo Ruiz
Universidad de Santiago de Compostela.

Outline

- L2A2 @ Universidad de Santiago.
- Initial question.
- Target development at USC.
- Outlook

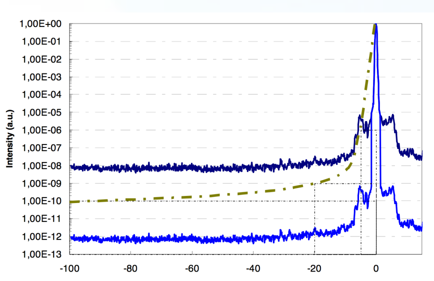
L2A2: Laser Laboratory for Acceleration and Applications at the USC

- A new laser facility for J and mJ short laser pulse generation.
    - Low energy particle acceleration in over dense media
    - Electron acceleration
    - X ray generation
    - Micromachining materials
    - Related facilities and equipment

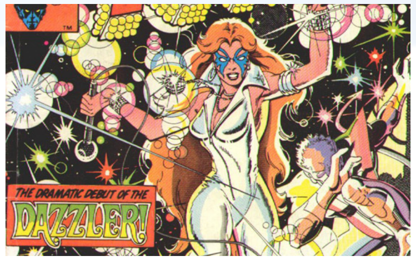
Laser system @ L2A2

Peak power	45 TW	30 GW
Nominal Energy	1.2 J	1 mJ
Pulse duration	<25 fs	<35 fs
Central wavelength	800 nm +- 10 nm	800 nm+-10 nm
Repetition rate	10 Hz	1 Khz

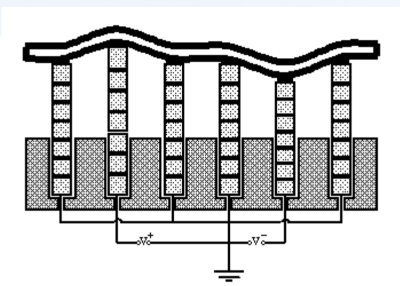
XPW: 10^{11} ps contrast



Dazzler: Spectral control



High power Adaptive Mirror

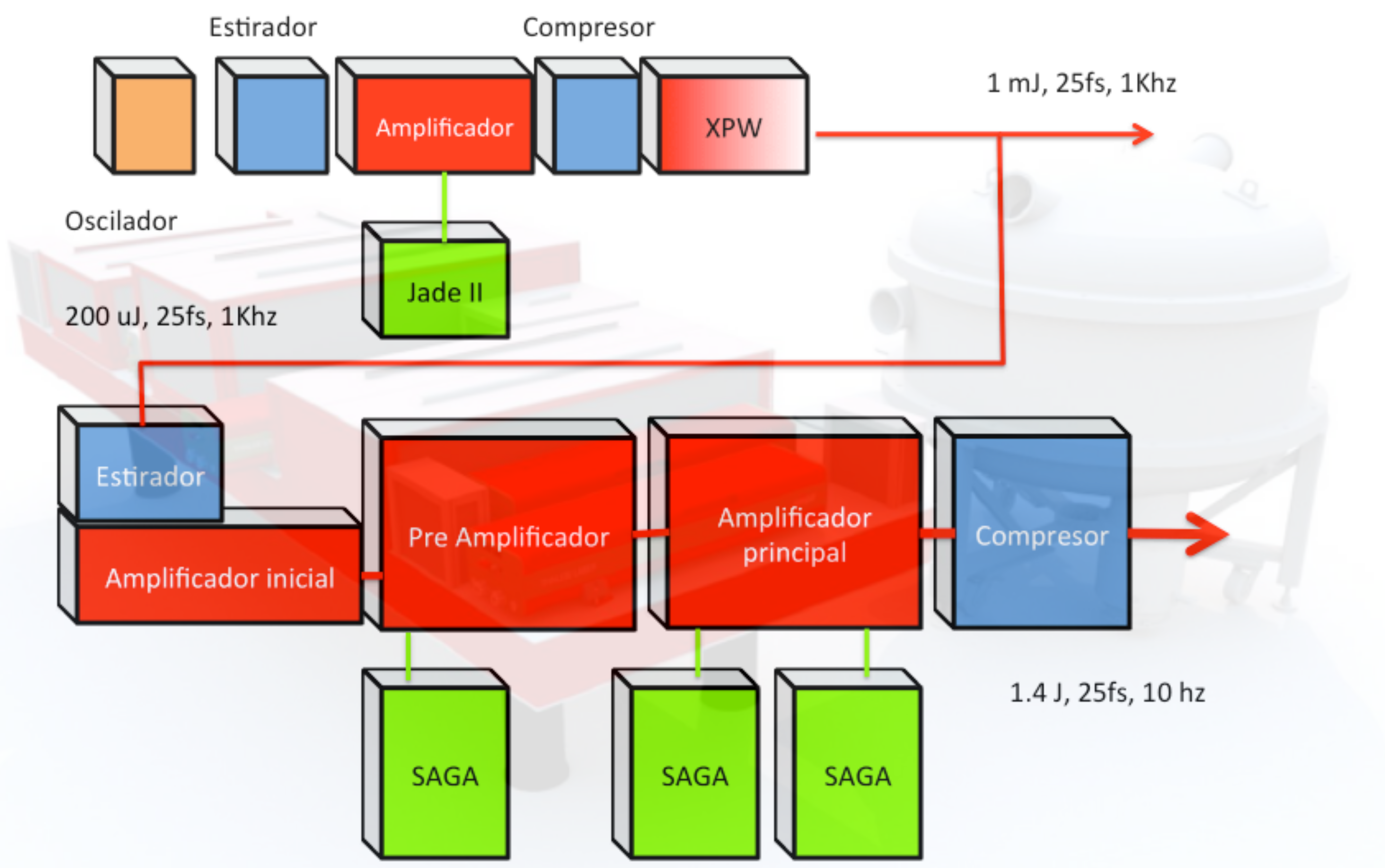


Beam pointing stability for underdense experiments

5μrad rms 500shots

Energy stability < 1.5 % rms
Strehl radio >0.6
Divergence 15 urad

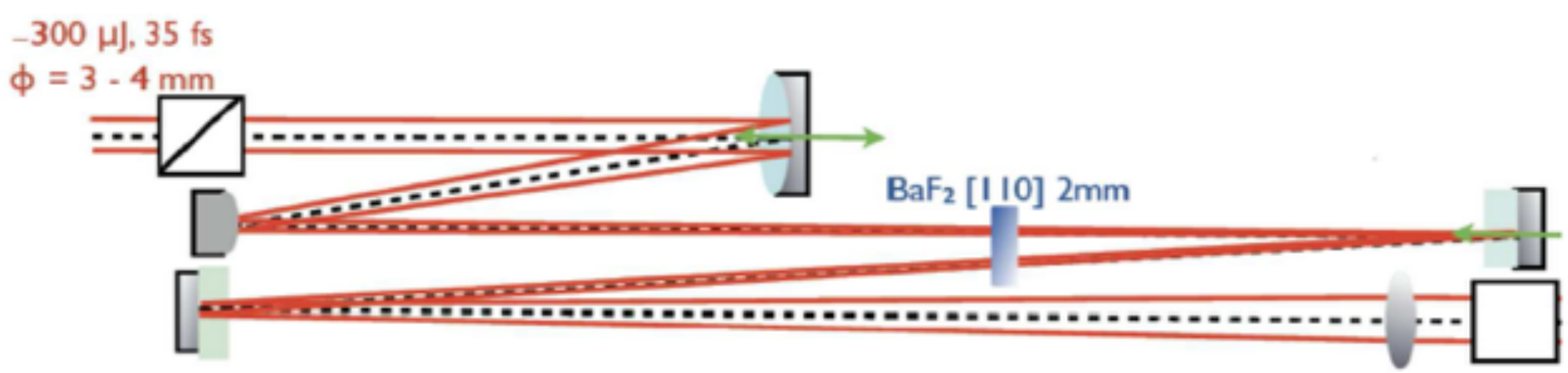
Laser system @ L2A2



Contrast management.

XPW filter

- Contrast enhancement > 10^4
- Output energy 30 μJ
- Bandwidth > 50 nm (FWHM)
- 2 cristals design



Better energy stability

Better spectrum stability

No Vacuum vessel needed

L2A2: New Building

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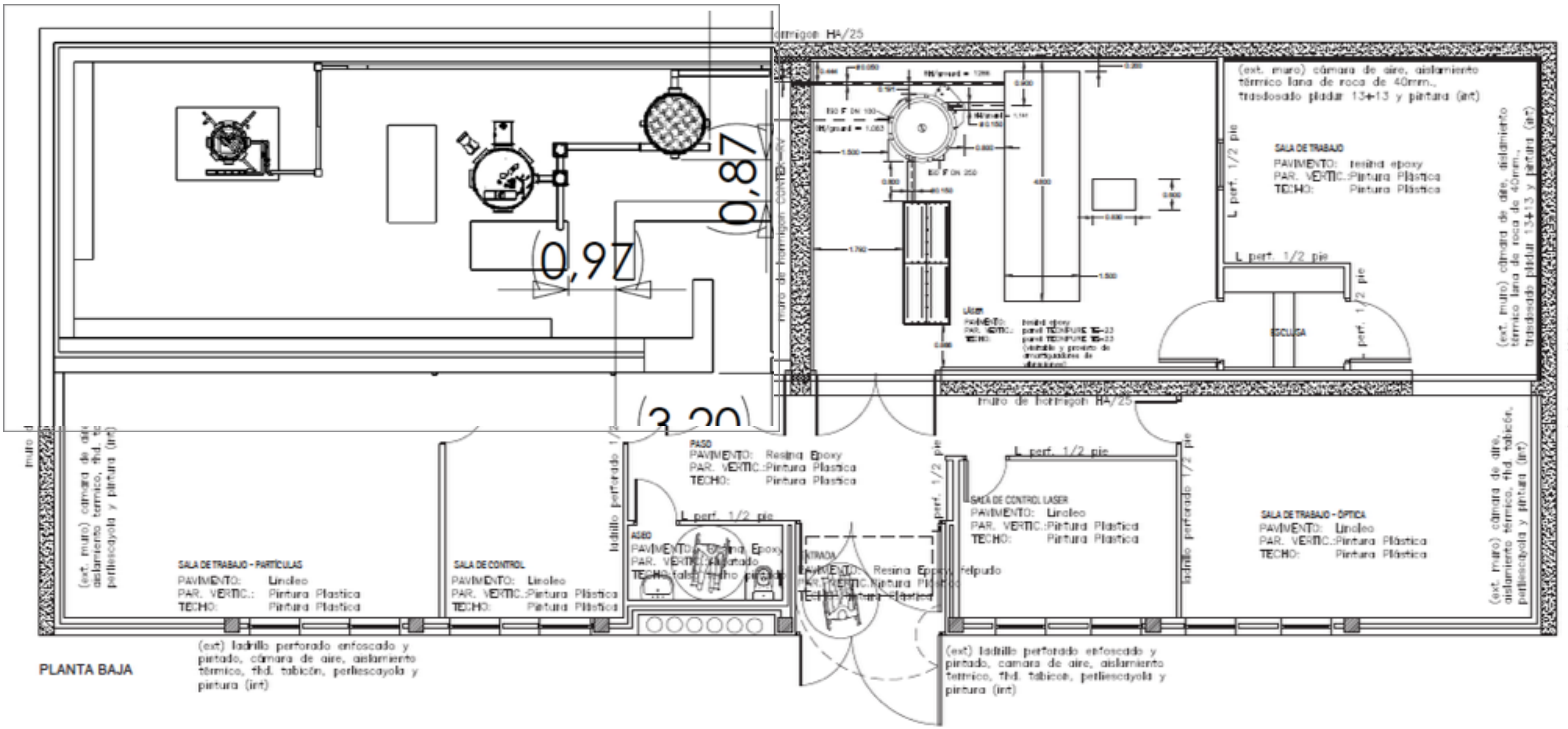
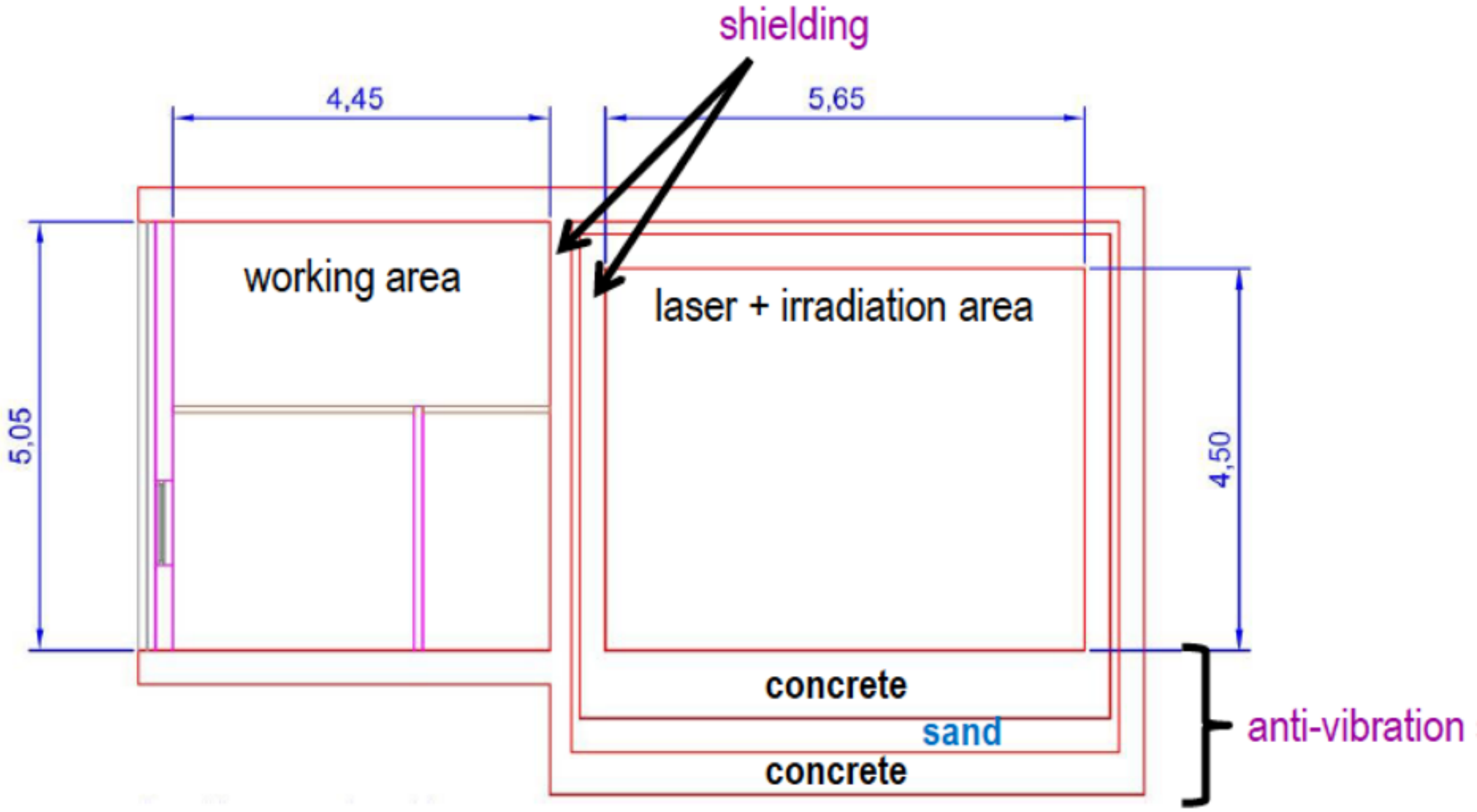
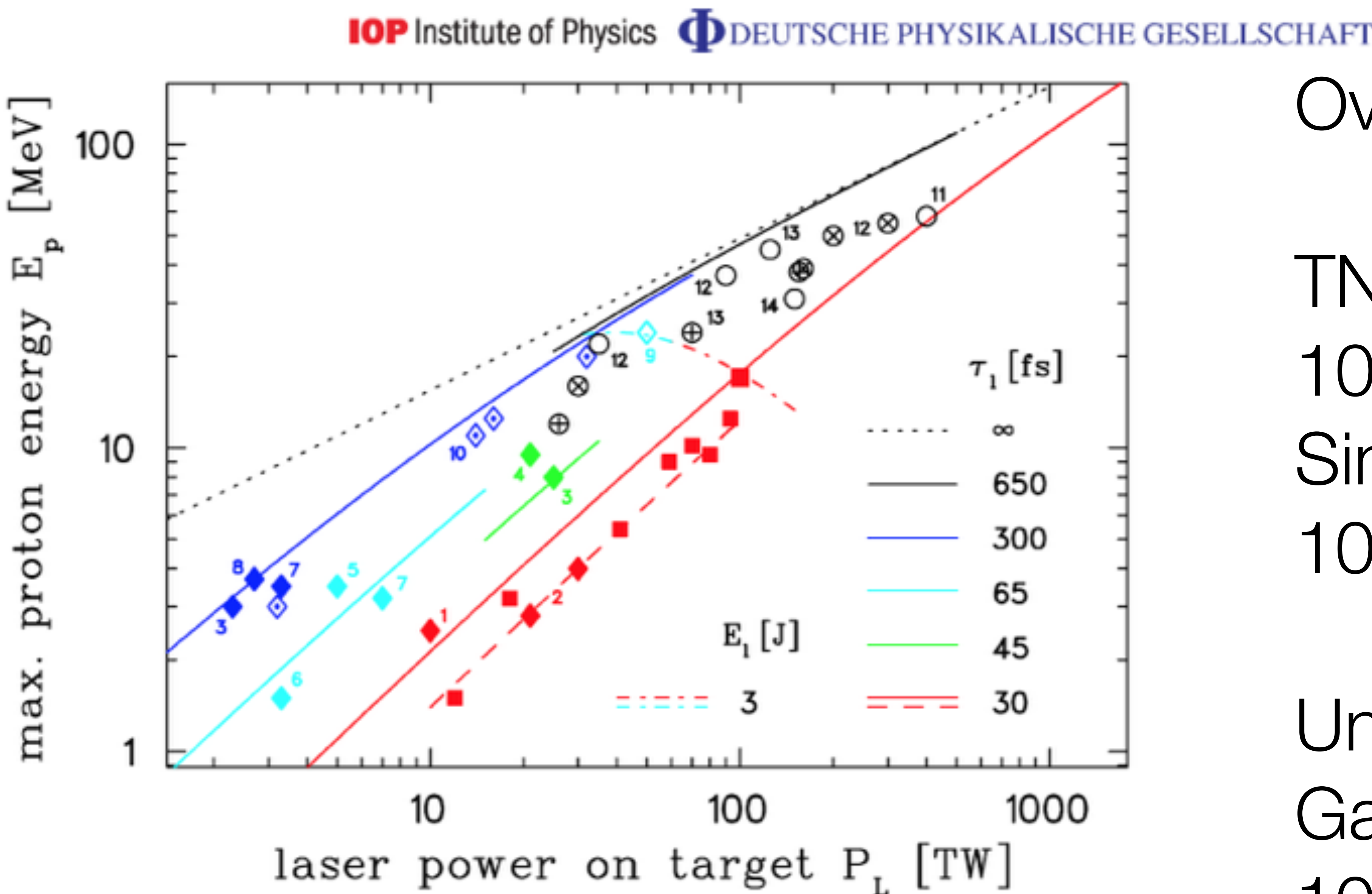


L2A2: New Building



Initial experiments



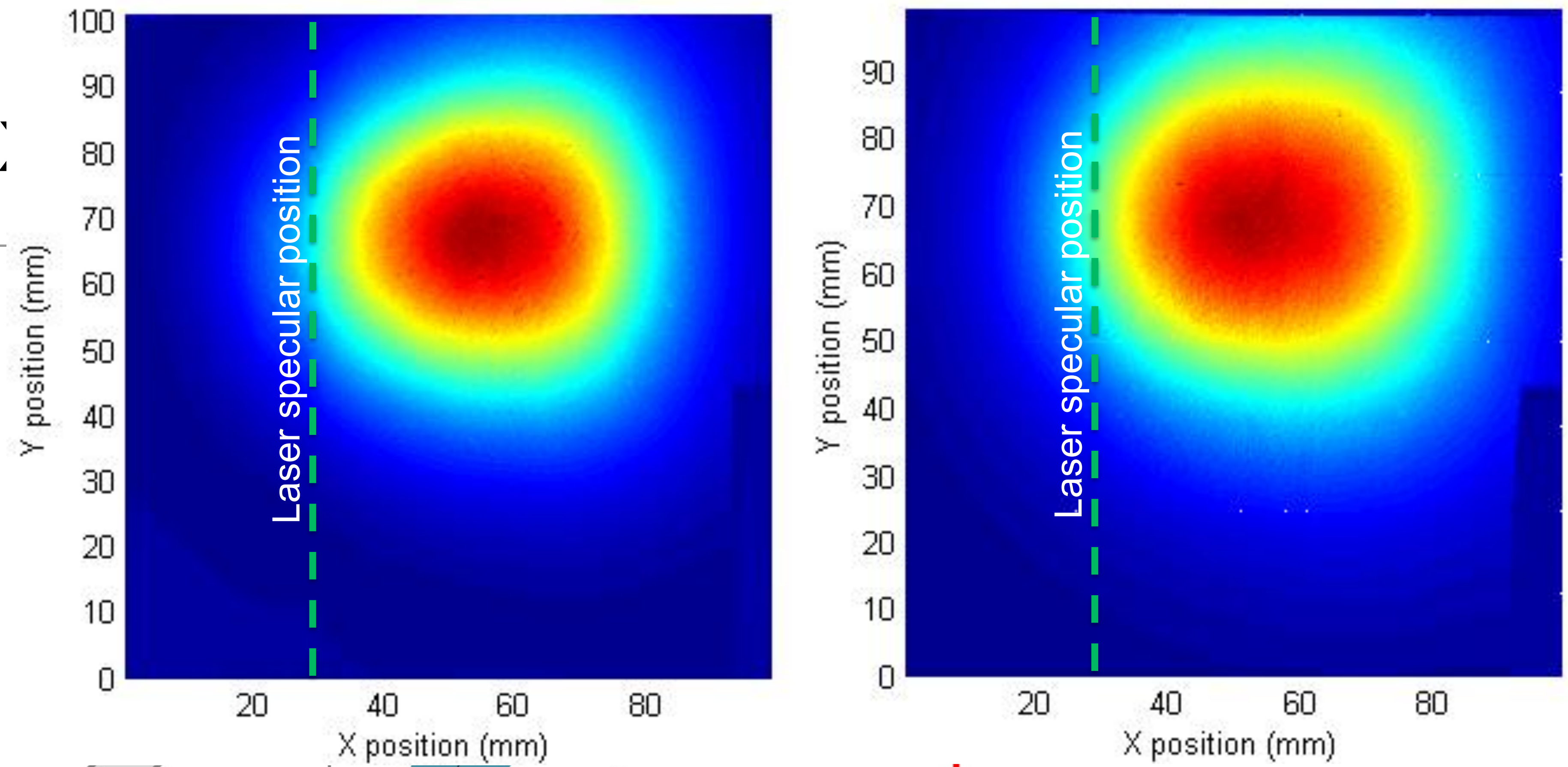
Overdense.

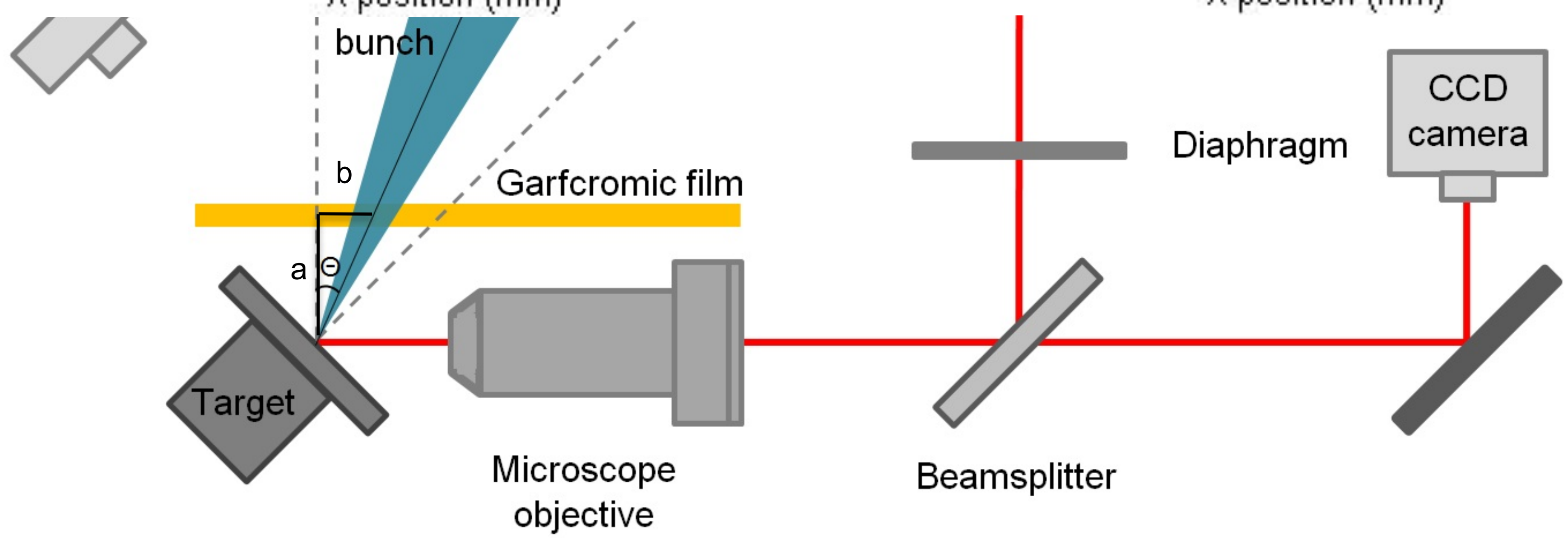
TNSA
10 um Al foils
Single shot
10 MeV protons

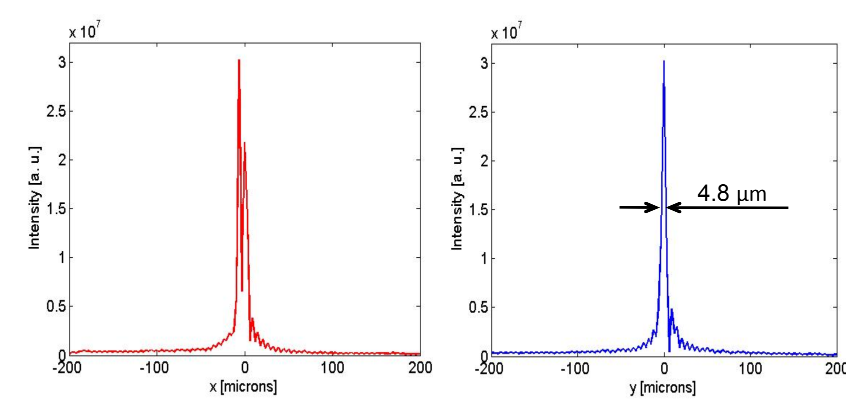
Underdense
Gas jet
100 MeV

High rep rate :

E	0.8 mJ
τ	120 fs
ν	1 kHz
f	15 mm
Spot (r)	2.4 μm
I	10^{16} W/cm^2
Incidence Angle	45 (deg)
45λx9λ^2	405λ^3

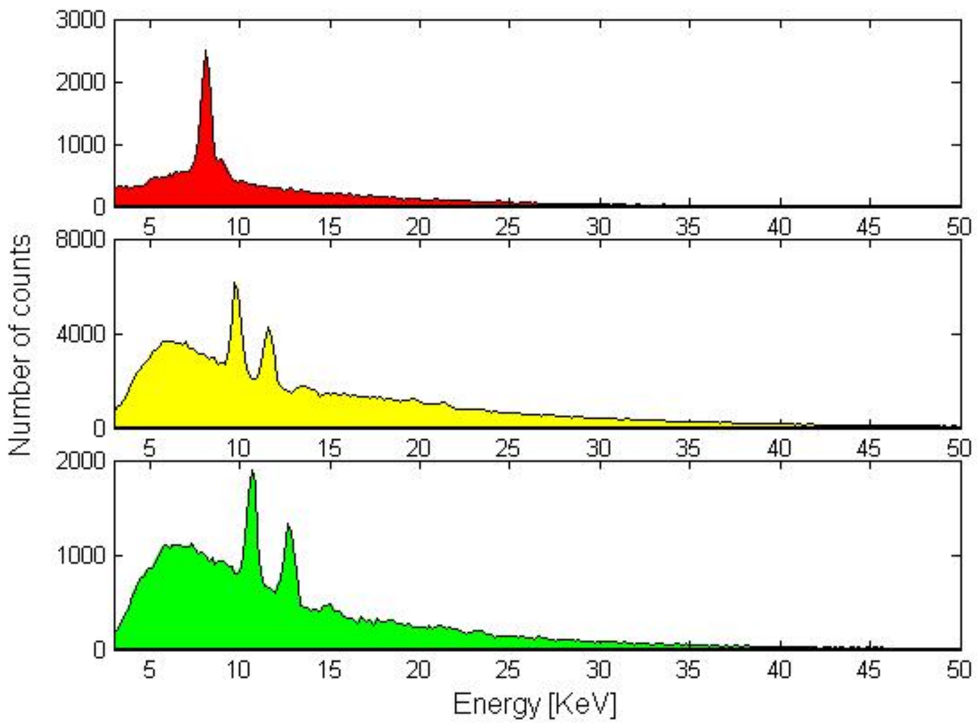






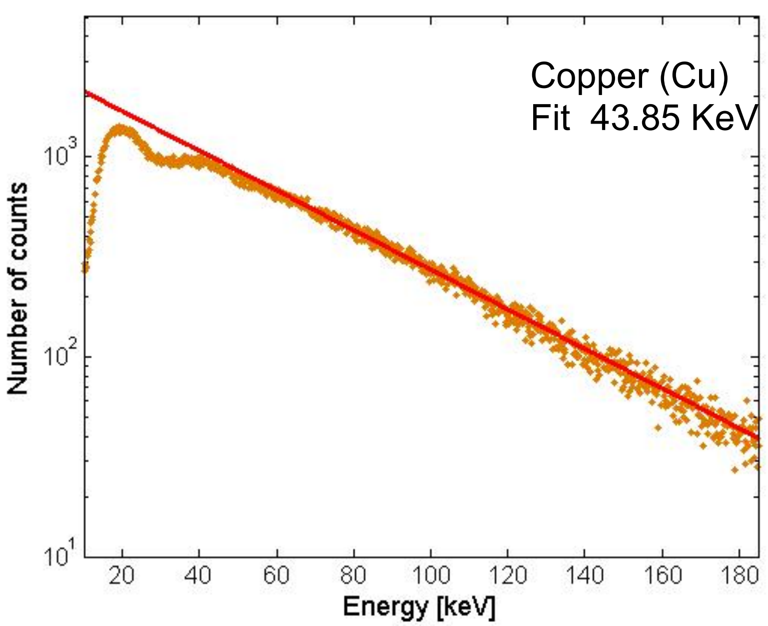
$$Dosis(u.a) = 0.994D_{e,13.8keV} + 2.583 \times 10^{-3} D_{e,60keV} + 3.019 \times 10^{-3} D_{\gamma,9keV}$$

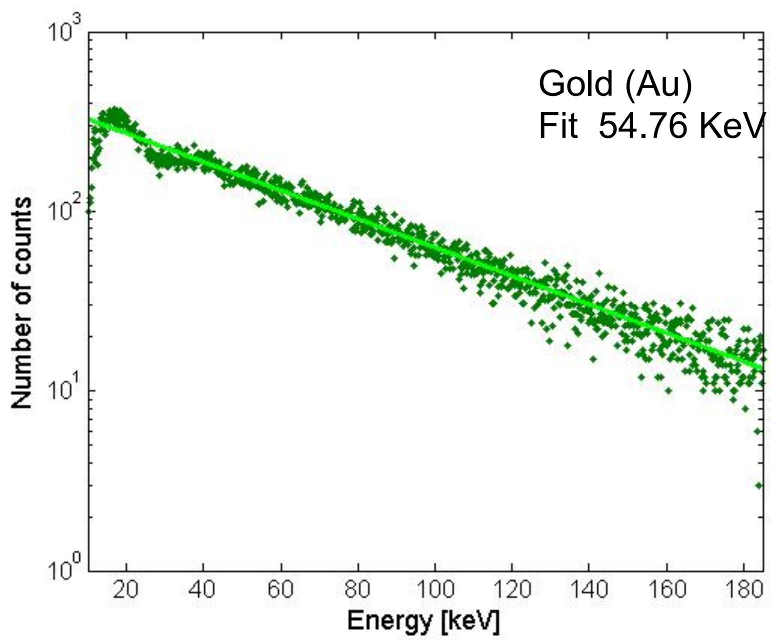
X ray source.

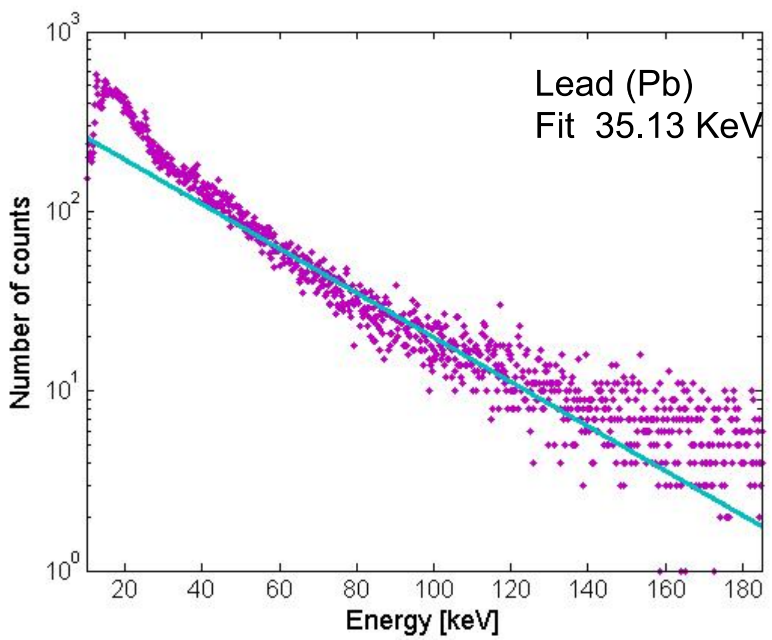


ELEMENT	Z	ELECTRON COLD TEMP.	ELECTRON HOT TEMP.
Cu	29	10.8 keV	43.9 KeV
Au	79	11.1 keV	54.8 KeV
Pb	82	8.5 keV	35.1 KeV

ELEMENT	Copper (Cu)	Gold (Au)		Lead (Pb)	
LINE	Kα 8.05 keV	Lα 9,6 keV	Lβ 11,5 keV	Lα 10,6 keV	Lβ 12,6 keV
EFICIENCY	3.81e-7	1.65e-9	1.54e-9	5.63e-10	4.84e-10







Non linear propagation in air.

$$\frac{\partial \varepsilon}{\partial z} = \frac{i}{2k}\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\varepsilon - i\frac{k''}{2}\frac{\partial^2 \varepsilon}{\partial t^2} + N(|\varepsilon|^2,\rho)\varepsilon$$

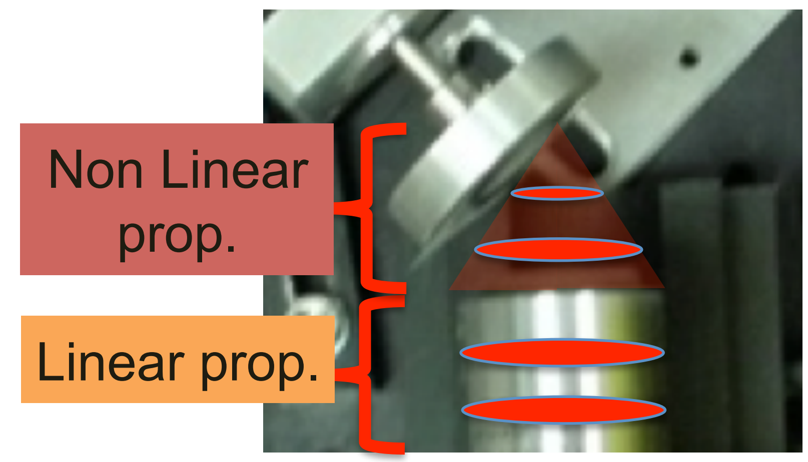
Field equation

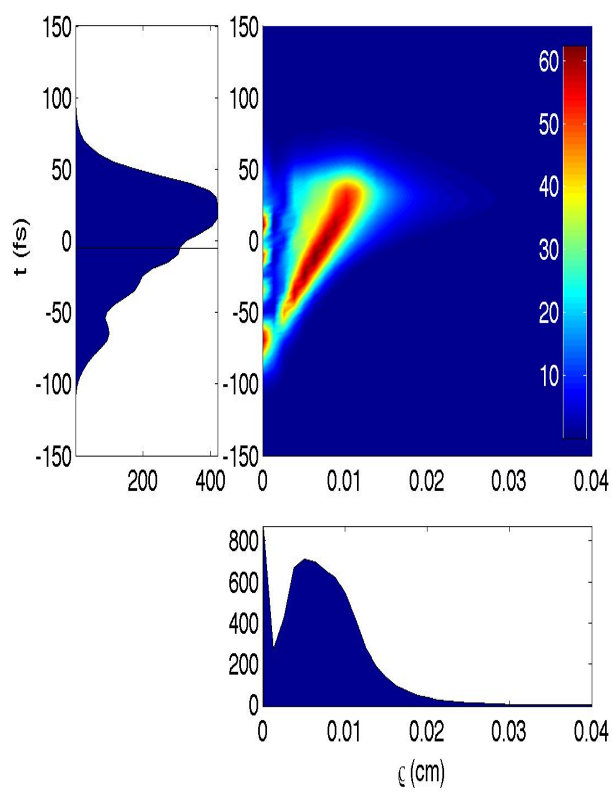
$$N\left(|\varepsilon|^2,\rho\right) = N_{Kerr}\left(|\varepsilon|^2\right) + N_{Plasma}(\rho) + N_{MPA}\left(|\varepsilon|^2\right)$$

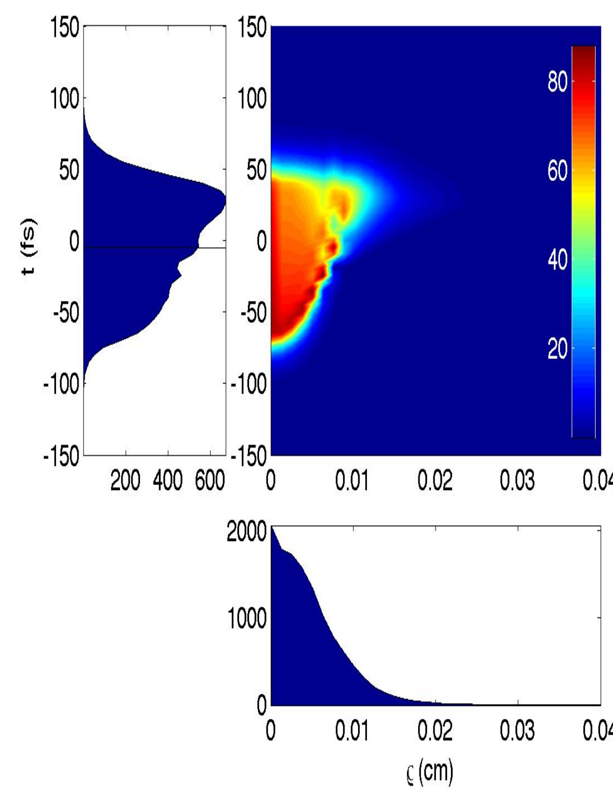
Non linear term

$$\frac{\partial \rho}{\partial t} = W\left(|\varepsilon|^2\right)(\rho_{at}-\rho)$$

Plasma source

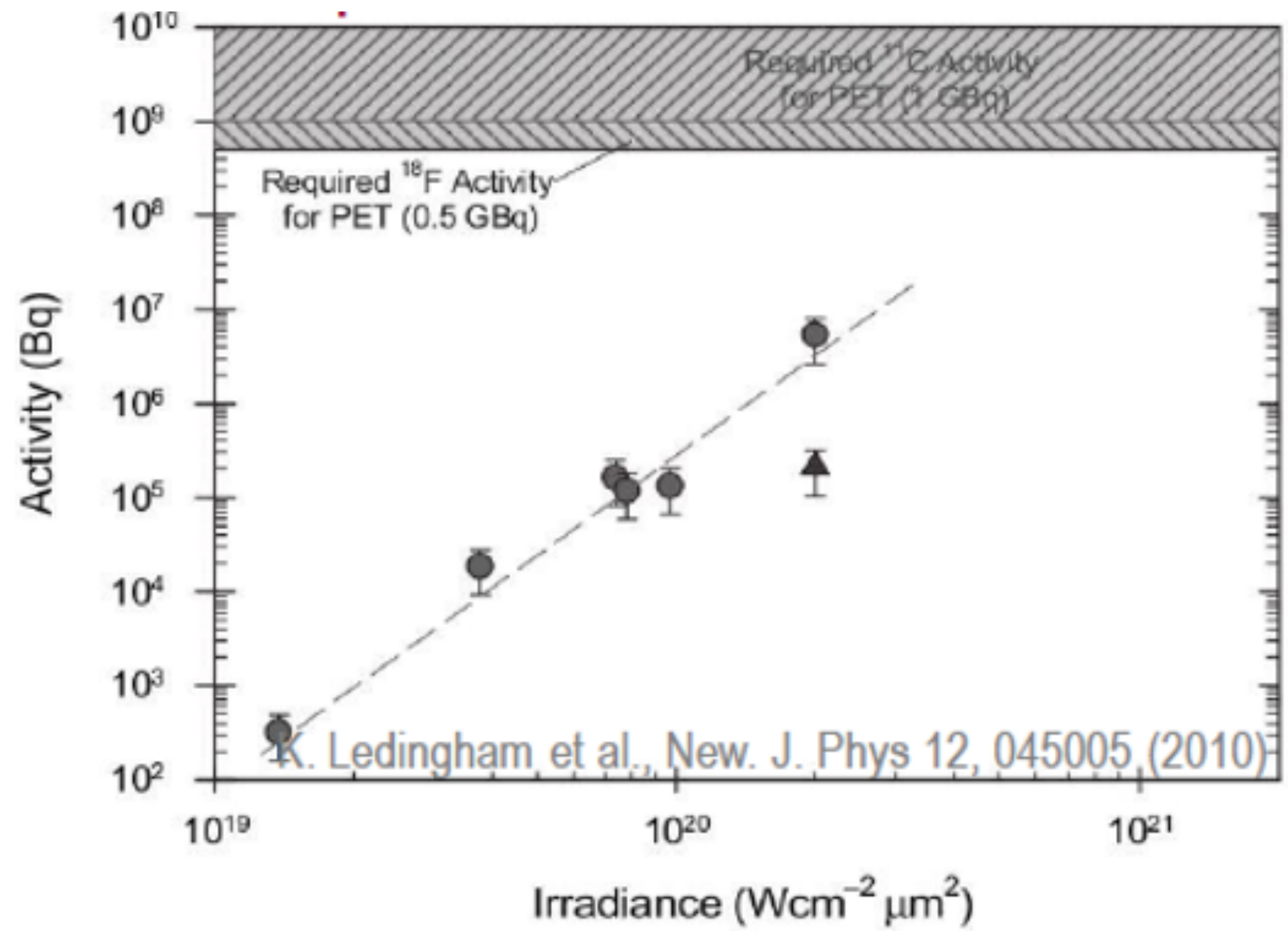






The initial question:
Activation by laser produced protons

- 120 J, ~1 ps (10^{20} W/cm^2), CR ~10^6
  ^{11}C activity/shot ~ 200 kBq
  I. Spencer et al., NIMB 183, 449 (2001)
- 20-30 J, 0.3 – 0.8 ps (1-6 10^{19} W/cm^2), CR <10^6
  ^{11}C activity/shot ~ 1 MBq
  J. Fuchs et al., PRL 94, 045004 (2005)
- 0.8 J, 40 fs (6 10^{19} W/cm^2), CR <10^6
  ^{11}C activity/shot ~ 1.2 kBq
  S. Fritzler et al., App. Phys. Lett. 83, 3039 (2003)



K. Ledingham et al., New. J. Phys 12, 045005 (2010)

The initial question:
Almost 10 years after this estimation what has changed?

JOURNAL OF APPLIED PHYSICS **100**, 113308 (2006)

Numerical simulation of isotope production for positron emission tomography with laser-accelerated ions

Erik Lefebvre[a)]
Département de Physique Théorique et Appliquée, CEA/DAM Ile-de-France, BP 12, 91680 Bruyères-le-Châtel, France

Emmanuel d'Humières
Département de Physique Théorique et Appliquée, CEA/DAM Ile-de-France, BP 12, 91680 Bruyères-le-Châtel, France and National Terawatt Facility, MS-372, University of Nevada, Reno, Nevada 89557

Sven Fritzler
Siemens Medical Solutions, Vacuum Technology, 91052 Erlangen, Germany

Victor Malka
Laboratoire d'Optique Appliquée, ENSTA, UMR 7639 CNRS/Ecole Polytechnique, 91761 Palaiseau, France

$I = 10^{20} W/cm^2$

^{11}C	1.1×10^8	per shot	94.8 Gbq 1Khz 1hr
^{18}F	3.1×10^7	per shot	9.7 Gbq 1Khz 1hr

$I = 4 \times 10^{20} W/cm^2$

^{18}F	104 Gb (2.8 Ci) 1Khz 1hr

The initial question:
Almost 10 years after this estimation what has changed?

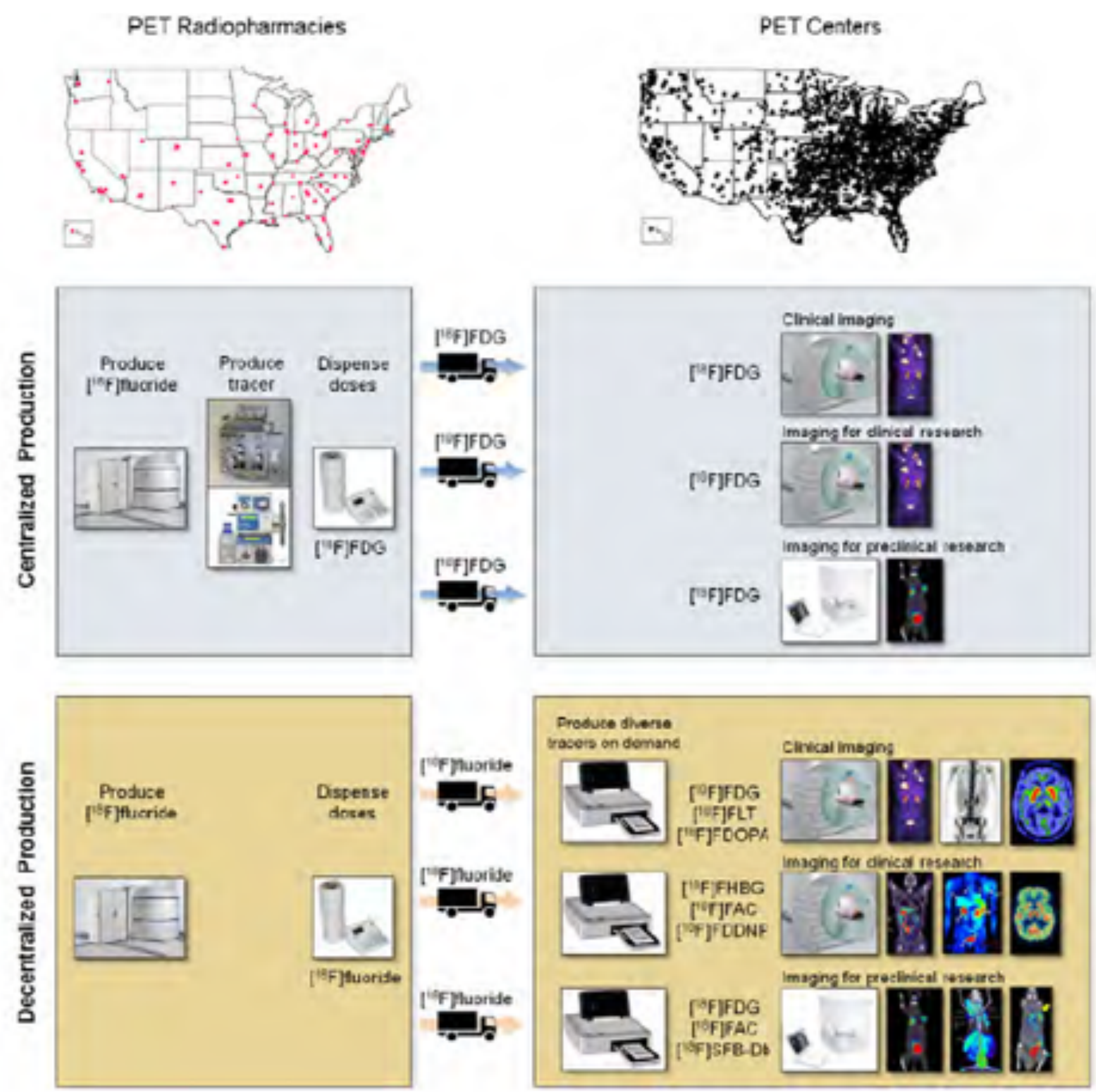


Fig. 1. Centralized and decentralized models of PET tracer production.

Radionuclide	Half-live	reaction	E_{min} (MeV)	E_{beam} (MeV)
^{11}C	20.3 min.	$^{14}N(p,\alpha)$ $^{11}B(p,n)$ $^{10}B(d,n)$	3.13 3.02 0	11-19 10 10
^{13}N	9.97 min.	$^{16}O(p,\alpha)$ $^{13}C(p,n)$	5.55 3.23	19 11
^{15}O	2.03 min.	$^{15}N(p,n)$ $^{14}N(d,2n)$ $^{16}O(p,pn)$	3.77 0 14.28	11 6 >26
^{18}F	110 min.	$^{18}O(p,n)$ $^{20}Ne(d,\alpha)$	2.57 0	11-17 8-14
^{64}Cu	12.7 h	$^{64}Ni(p,n)$ $^{68}Zn(p,\alpha n)$ $^{nat}Zn(d,\alpha xn)$	2.49 8.65 9.31	15 30 19
^{124}I	4.14 d	$^{124}Te(p,n)$ $^{125}Te(d,2n)$	3.97	13 25

Emerging Technologies for Decentralized Production of PET Tracers

Pei Yuin Keng[1], Melissa Esterby[1,2] and R. Michael van Dam[1]
[1]*Crump Institute for Molecular Imaging, Department of Molecular & Medical Pharmacology, David Geffen School of Medicine, University of California, Los Angeles*
[2]*Sofie Biosciences, Inc.*
USA

The initial question:
Almost 10 years after this estimation what has changed?

- Decentralized approach:

  - Integrated quality control

The initial question:What has changed?

- Can the laser proton replace the cyclotron: No!
- 150 Mbq for preclinical images.

50 TW laser
1.4 J 25 fs 10 Hz
800 nm

10 MeV cut off

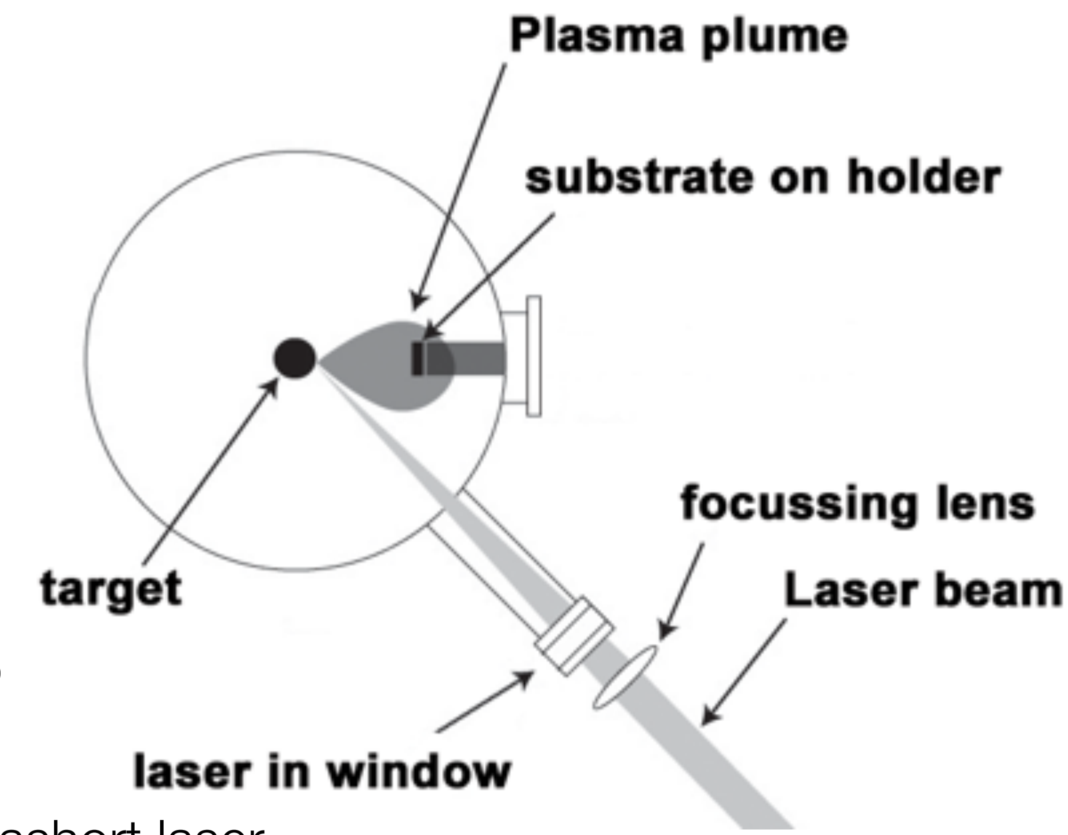
^{11}C, ^{13}N, ^{15}O

Positron Emission Tomography

PET image

Structured targets activities @ USC

- Pulsed laser deposition (PLD)

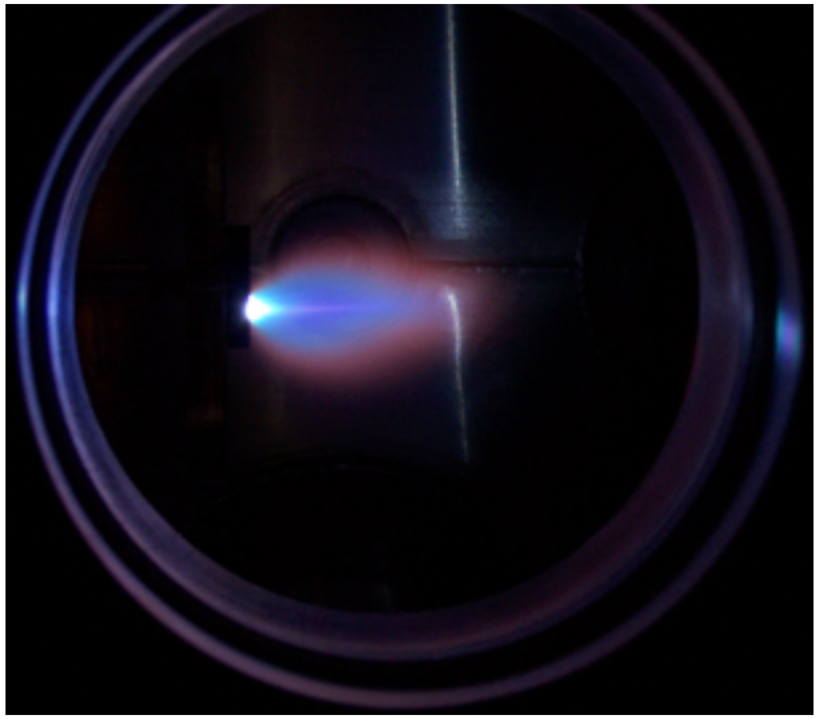


Passoni, et al (2014). Energetic ions at moderate laser intensities using foam-based multi-layered targets. Plasma Physics and Controlled Fusion, 56(4), 045001.

Zigler, A., et al. (2011). 5.5–7.5 MeV Proton Generation by a Moderate-Intensity Ultrashort-Pulse Laser Interaction with H2O Nanowire Targets. Physical review letters, 106(13), 134801.

Zigler, A., et al (2013). Enhanced proton acceleration by an ultrashort laser interaction with structured dynamic plasma targets. Physical review letters, 110(21), 215004.

Sgattoni, A., Londrillo, P., Macchi, A., & Passoni, M. (2012). Laser ion acceleration using a solid target coupled with a low-density layer. Physical Review E, 85(3), 036405.



Structured targets @ USC

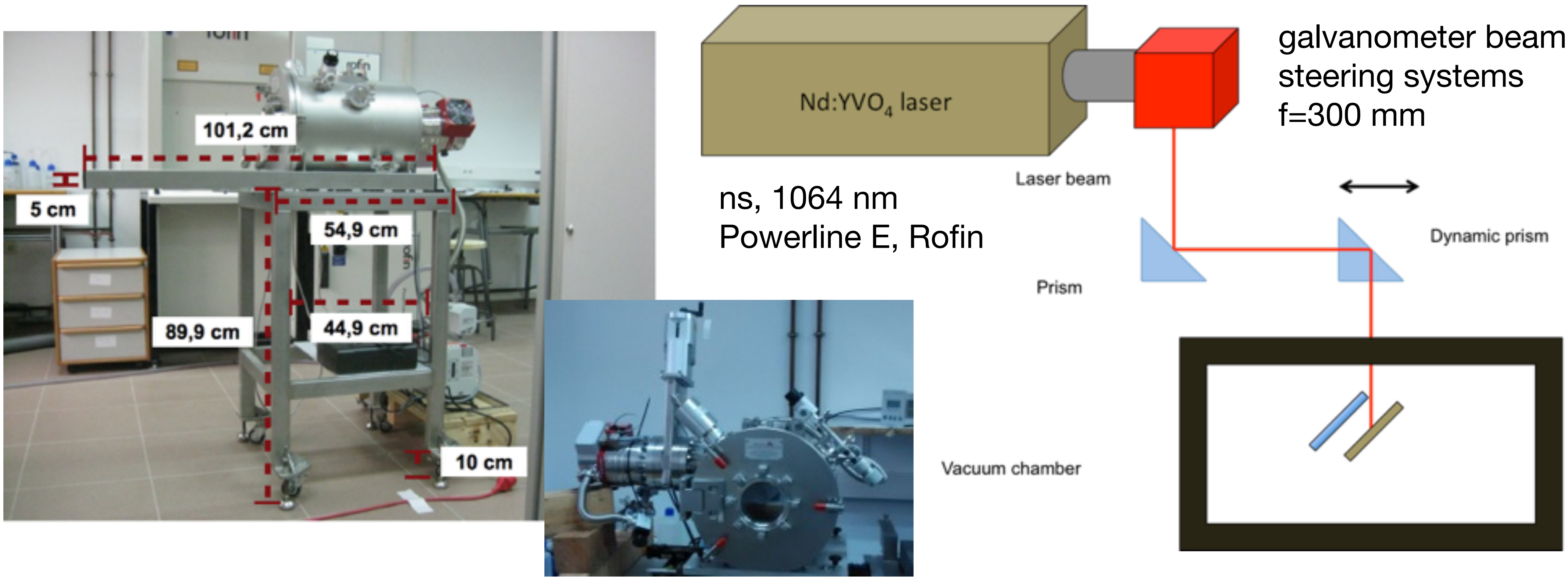
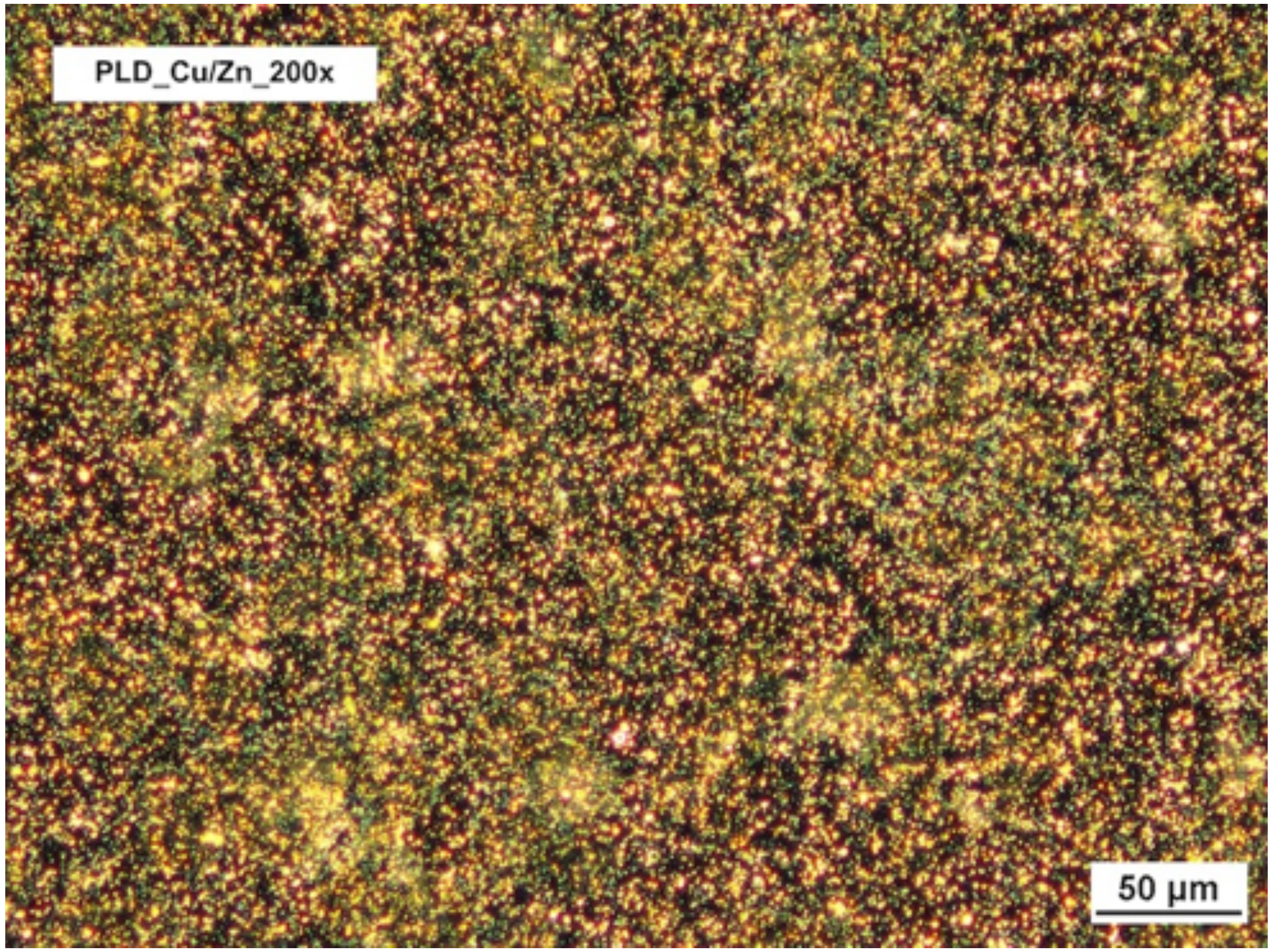


Table 1: PLD optimal laser parameters applied for aluminum (Al) and brass (Cu/Zn).

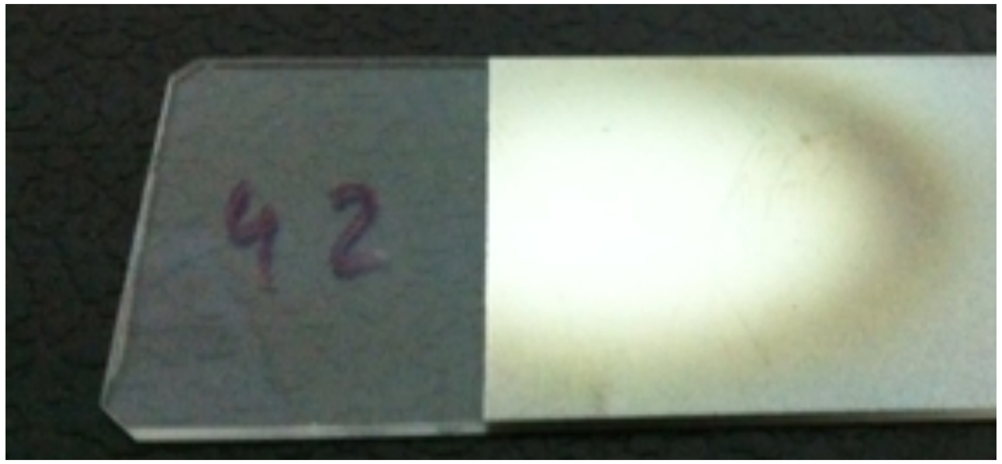
Metal	Irradiance (W/cm^2)	Frequency (kHz)	Marking Speed (mm/sec)	Translation Speed (mm/sec)	Working Pressure (mbar)
Al	$4{,}13 \times 10^{10}$	10	300	1	$8{,}7 \times 10^{-7}$
Cu/Zn	$5{,}44 \times 10^{10}$	2	50	0.5	$8{,}2 \times 10^{-7}$

Structured targets @ USC



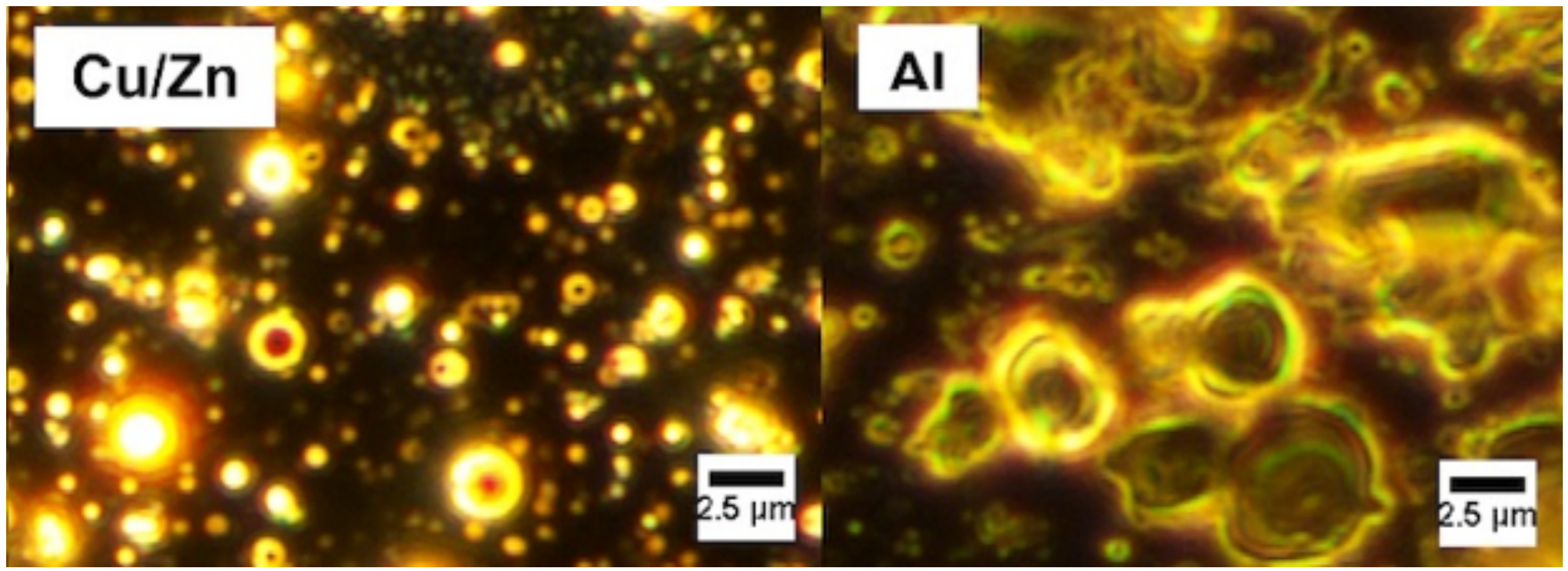
PLD with brass

Brass



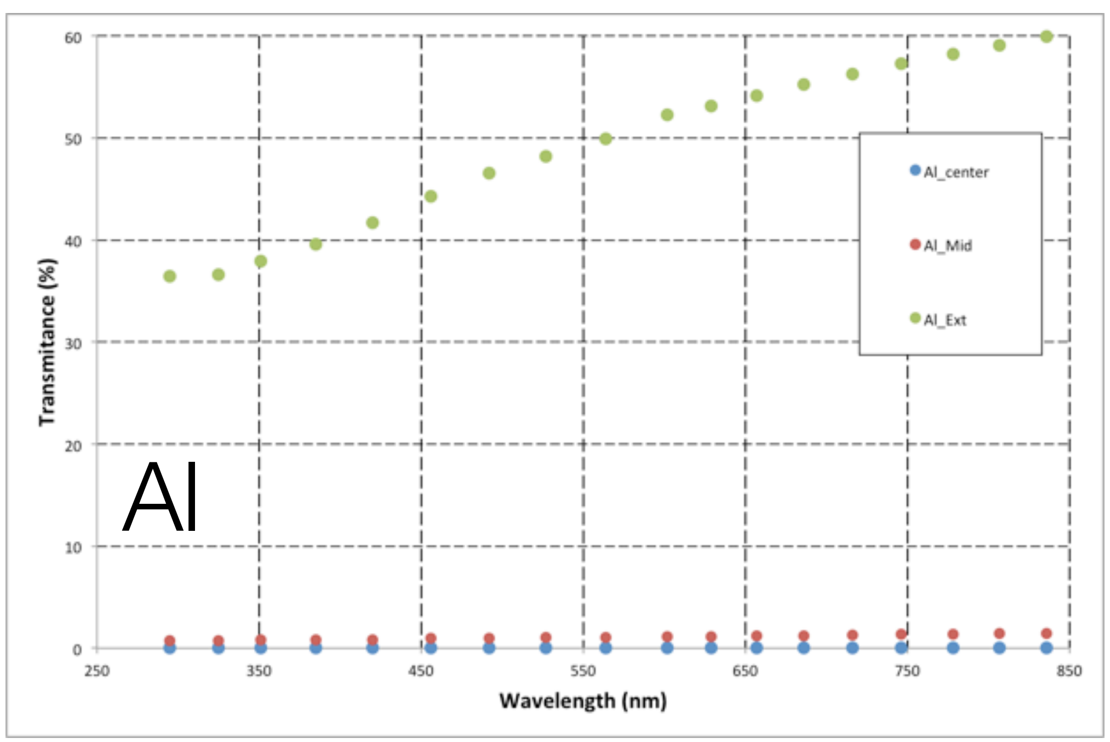
Aluminium

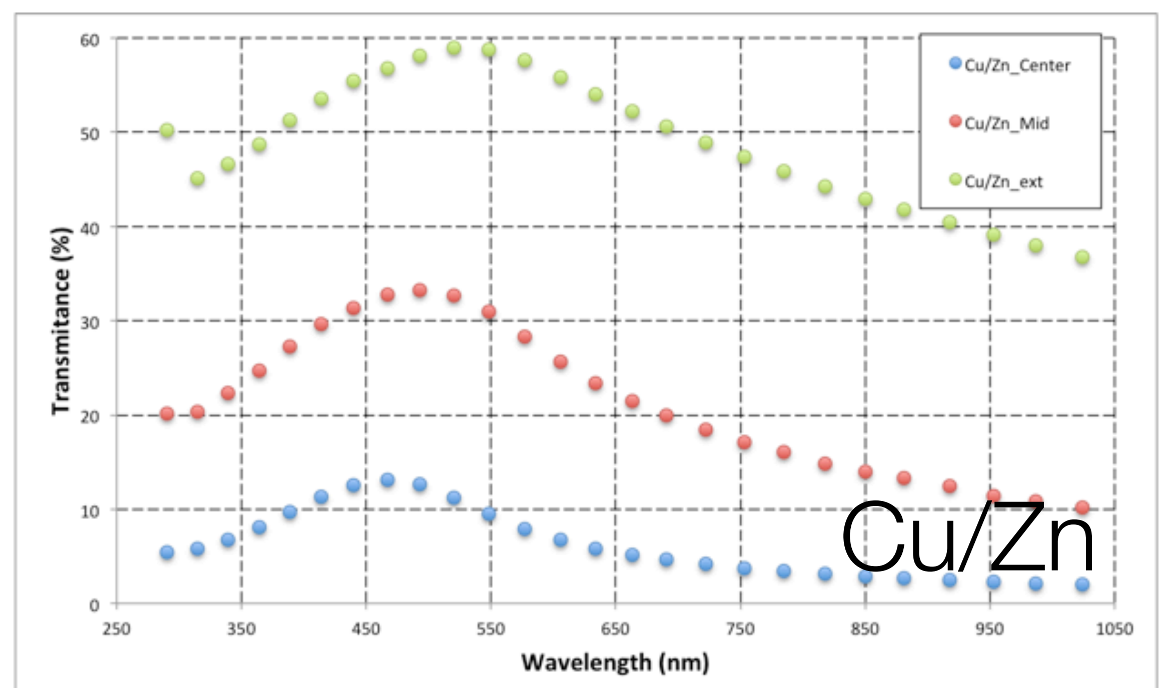
Structured targets @ USC



Calculated density (g/cm^3): 8.93

Calculated density (g/cm^3): 2.71





Transmitance for different regions

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