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ENERGY DEPOSITION EFFECTS OF THE X PHOTON BEAM ON THE MIRROR OF PLASMON-X EXPERIMENT AT LI2FE

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Abstract

LI2FE (Laboratorio Integrato Interdisciplinare con Fotoni ed Elettroni) is a test-facility in construction at the INFN Laboratori Nazionali di Frascati (LNF). The backbone of the the facility will be the 20-150 MeV in 2-5 ps electron beam from SPARC and the FLAME (Frascati Laser for Acceleration and Multidisciplinary Experiments) laser, a 800 nm, 6 J energy laser with 300 TW peak pulse in 20 fs and a repetition rate of 10 Hz.

The laser in under commissioning while the electron beam is already available for the SPARC FEL and THz experiment. Next year two additional beam lines will provide the electron beam to the PLASMON-X (where plasma acceleration experiment will be carried out, through theexternal injection of the electron beam into a plasma wave driven by the FLAME laser) and a Thomson backscattering X-ray Source.

A non perfect alignment of the electron beam can lead the scattered X photons to hit the mirror.

The effect of the X photon beam of 20 and 500 keV on the mirror, are investigated through the FLUKA code.

Under conservative hypotheses, no damage will occur to the mirror.

Work performed in the frame of the the FLUKA collaboration and SPARC activity

1 INTRODUCTION

LI2FE (Laboratorio Integrato Interdisciplinare con Fotoni ed Elettroni), will be a multidisciplinary laboratory at LNF Frascati, where electron and photon beams from the SPARC (Ref.1) accelerator and FEL experiment will be available.

Another photon source will be FLAME laser (Ref.2), and the X photons from Thomson scattering experiment, as shown in Fig.1.

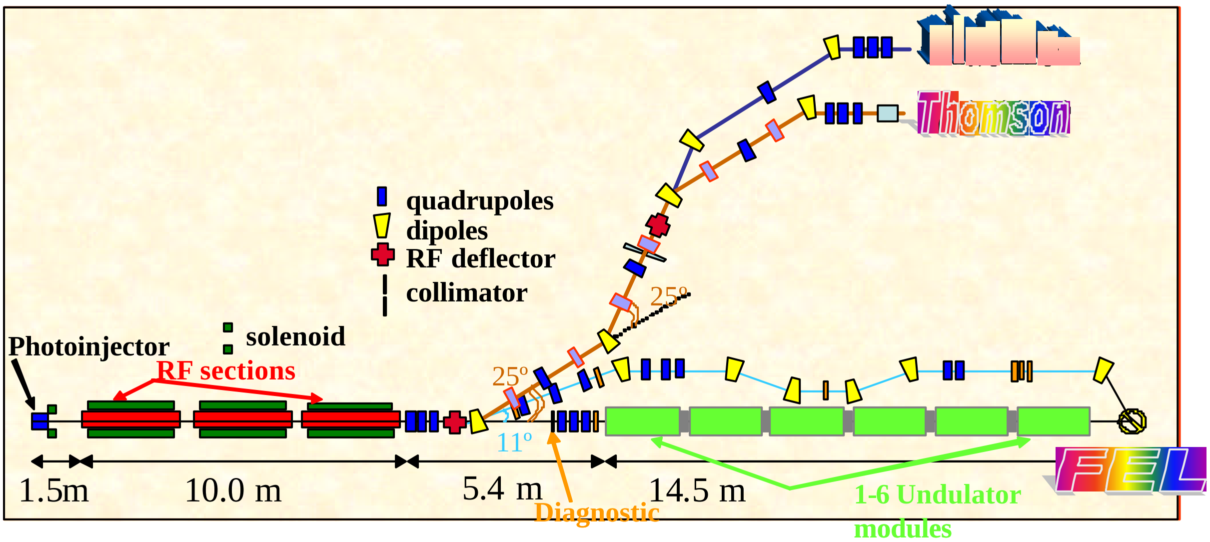

Fig.1 The SPARC/LIFE Facility

In Tab.1 the characteristics of the electron and photon beam are summarized.

Tab.1

ELECTRON BEAM (SPARC)	
Electron Beam Energy (MeV)	20-150
Bunch Charge (nC)	0.1-1
Rep rate (Hz)	1-10
Rms norm. transverse emitt. @ Linac exit (mm.mrad)	< 2
Rms longitudinal emittance (deg.keV)	1000
Rms total correlated energy spread (%)	0.2
Rms beam spot size @ Linac exit (mm)	0.4
Rms bunch length @ Linac exit (mm)	0.05-1
LASER BEAM (FLAME)	
Wavelength (nm)	800
Pulse Energy (J)	6
Pulse duration (FWHM) (fs)	25-5000
Repetition rate (Hz)	10

The Thomson scattering occurs with an head on electron-photon interaction, to this aim the photon beam is reflected by an off-axis parabola mirror with a hole in its center in order to allow the passing through of the scattered radiation ad of the electron beam. The scheme of the interaction is shown in Fig.2.

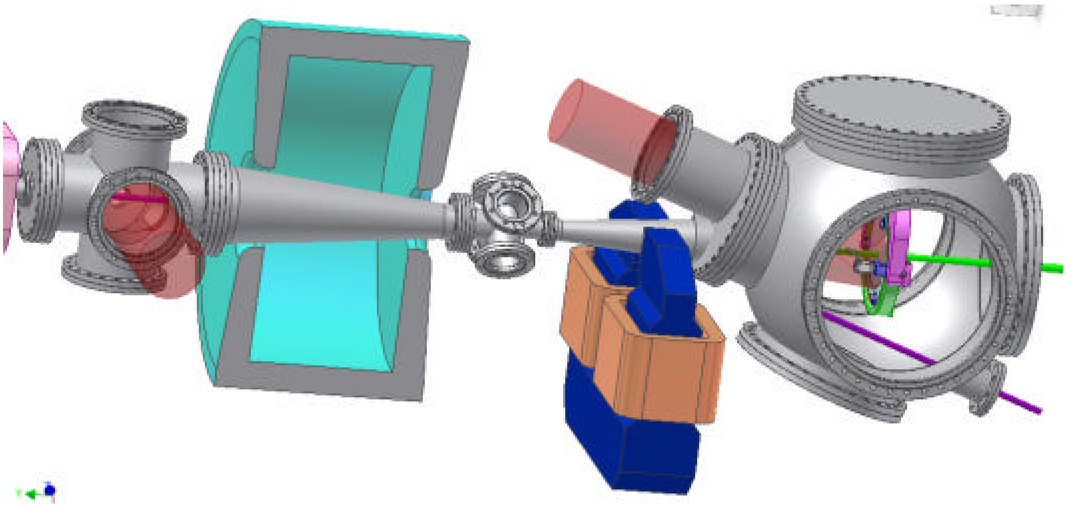

Fig.2 The PLASMONX interaction scheme.

Any misalignment on the photon beam can drive it on the mirror.

The effect of the energy deposition of the photon beam on the mirror has been evaluated with the FLUKA code (Ref. 3,4), showing that no damage can occur at the mirror (either at the gold coating or at the glass bulk).

2 FLUKA GEOMETRY AND PARAMETERS

The drawing of the PLASMON-X mirror is shown in Fig.3. The electron beam comes from the right and makes a head on collision with the laser beam in the focus.

Then the beam (purple color in fig.2) is bent by a dipole to the beam dump in order not to hit the mirror, while the X-ray beam goes through the hole in the mirror (green color in fig.2). To evaluate possible misalignment effects and/or the effects of X-ray beam halos hitting the mirror, we calculated the interaction with the mirror as if the mirror had no hole and the X-ray beam would be intercepted completely by the mirror.

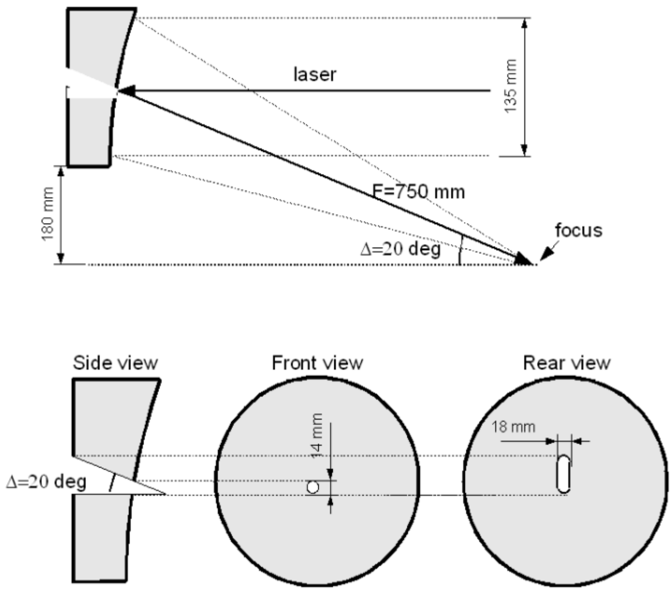

Fig.3 The PLASMONX mirror.

The schematization of the geometry used for the FLUKA simulation is shown in Fig. 4. The interaction occurs in a stainless steel chamber in vacuum, the mirror is located at about 70 cm from the interaction point, where the laser light (red), is downscattered (blue) by the electron bunch (grey).

The mirror is a Zerodur® bulk with a gold coating of about 20 µm thickness.

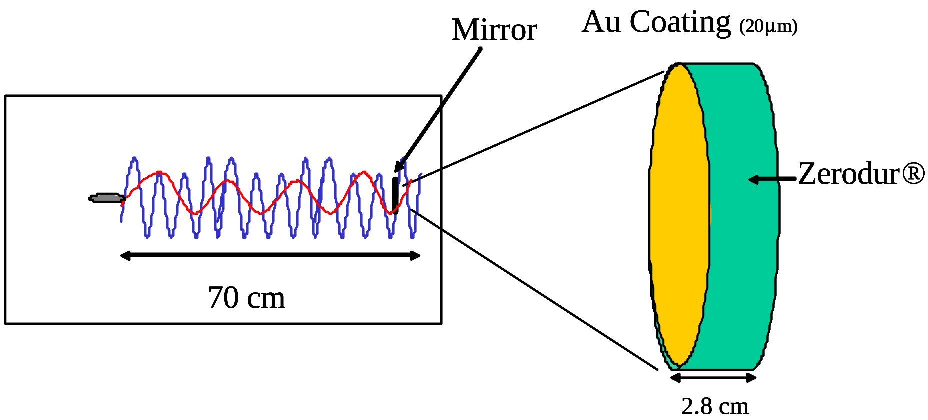

Fig.4 The FLUKA modelling of the interaction chamber.
The electron beam (grey), backscatter the incident laser light (red), the resulting radiation is shown in blue. At the right is the enlargement of the mirror.

The photon beam has a spot of 10 µm at the interaction point (z=0) with a divergence of 28.56 mrad, leading to a beam spot of about 2 cm at the mirror (z=70 cm). The transport cut-off were set at 2 eV. No energy spread is considered.

The composition of the Zerodur® bulk material listed in Tab.2 (Ref.5).

Tab.2.

ZERODUR®		
	Composition	
	wt (%)	mol (%)
SiO_2	55.4	63.9
Al_2O_3	25.4	17.2
Li_2O	3.7	8.5
Na_2O	0.2	0.2
K_2O	0.6	0.5
MgO	1.0	1.7
ZnO	1.6	1.3
P_2O_5	7.2	3.5
TiO_2	2.3	2.0
ZrO_2	1.8	1.0
As_2O_3	0.6	0.2

Different photon energies have been considered (20 and 500 keV).
The beam impinges normally on the mirror.

3 SIMULATION RESULTS

The results are obtained from 10 independent runs with 10^7 primary photon each.

3.1 Energy Deposition

In Fig. 6 the energy deposition map in the mirror is shown for the photon beam energy of 20 keV.

The coating is just the first slab of the mirror and it cannot be seen on these scales.

The bin volume is 0.04x0.04x0.028 cm^3.

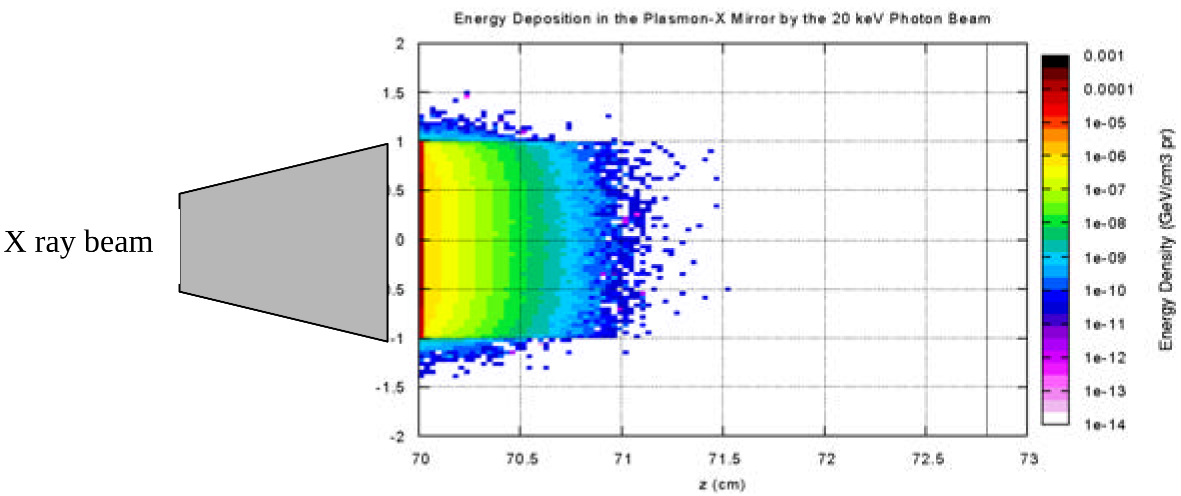

Fig.6. Energy deposition map in the mirror maps for 20 keV electron beam (bin dimensions = 0.04 x 0.04 x 0.028 cm^3).

In Fig 7 the energy deposition map in the mirror, as in Fig 6, is shown for photon beam energy of 500 keV

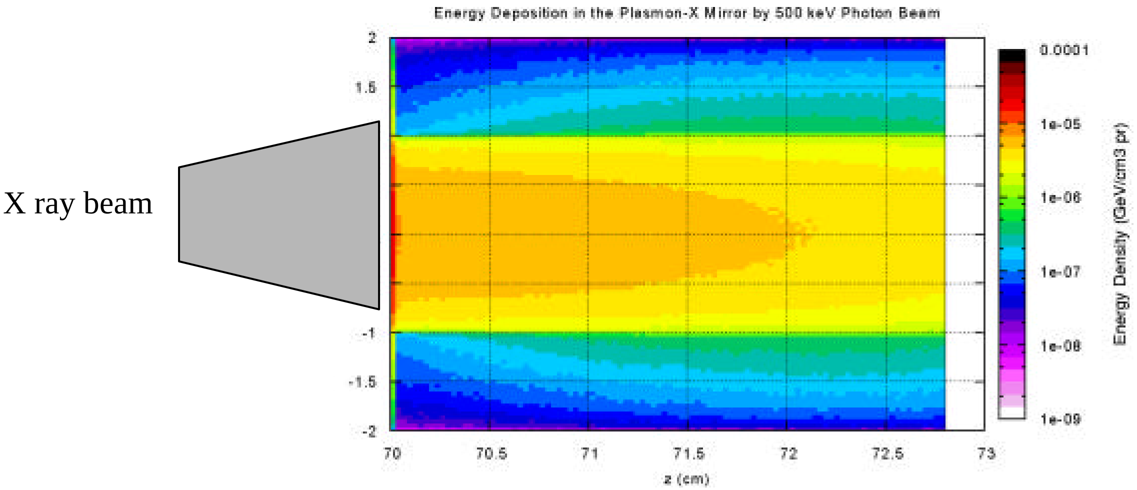

Fig.7. Energy deposition map in the mirror maps for 500 keV electron beam (bin dimensions = 0.04 x 0.04 x 0.028 cm^3).

In Fig. 8 and 9 the energy deposition maps just in the gold coating slab is shown for 20 keV and 500 keV photon beam respectively.

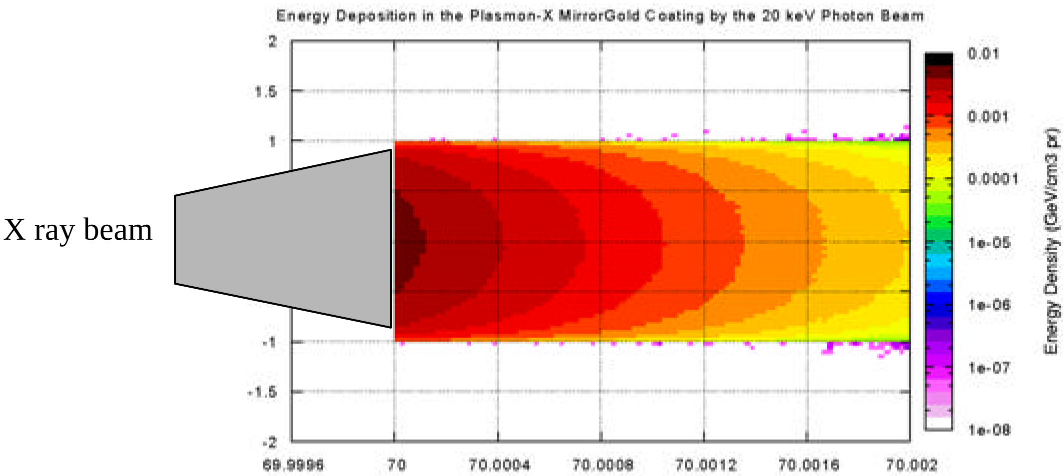

Fig.8. Energy deposition map in the gold coating for 20 keV electron beam hitting the mirror. The bin dimensions are the same as in Fig .6 and 7

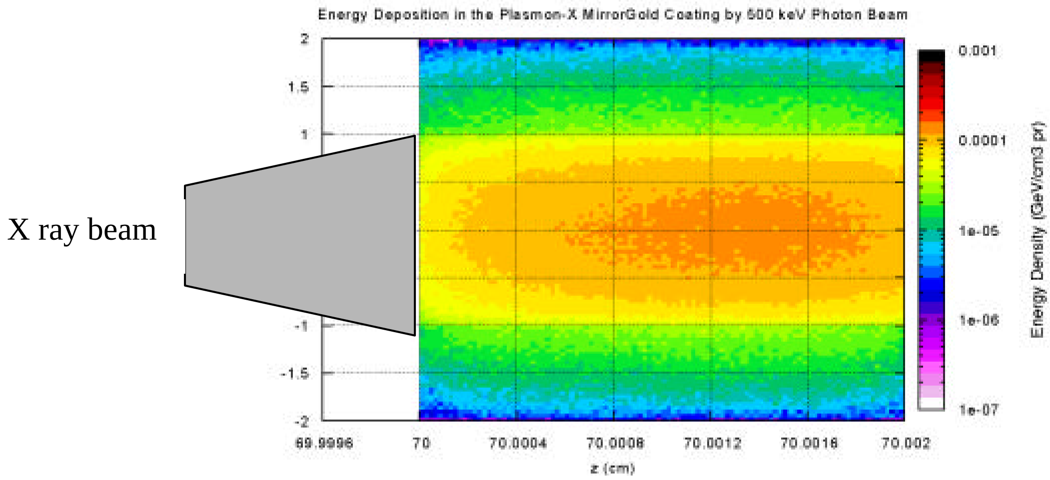

Fig.9. Energy deposition map in the gold coating for 500 keV electron beam hitting the mirror. The bin dimensions are the same as in Fig .6 and 7

In the following table the amount of energy deposed in the mirror coating and bulk is summarized for the examined cases.

Case	Energy Deposed (GeV/pr)	
	Gold	Zerodur®
20 keV	1.9E-5 ± 4.0E-3%	1.0E-6 ± 0.08%
500 keV	1.7E-6 ± 0.08%	9.8E-5 ± 0.02%

3.2 Temperature Increase

The temperature increase is conservatively evaluated by considering the region where the energy is deposed as a fully adiabatic one.

So the temperature variation under a flux of 10^{10} photons per second of in the gold coating is given by:

$$\Delta T_{Au} = \frac{Q}{mc_p} = \frac{1.9 \cdot 10^{-5} \cdot 10^{10}}{p\left(1 \cdot 10^{-2}\right)^2 \cdot 20 \cdot 10^{-6} \cdot 19.32 \cdot 10^3 \cdot 0.128 \cdot 10^3} = 0.002°$$

Being 19.32 g/cm^3 Au density

0.128 x 10^3 J deg Kg^{-1} Au specific heat

The temperature increase in the Zerodur®, even considering the energy deposistion concentrated in the first centimeter, as results from Fig. 6, is negligible.

4 CONCLUSIONS

The simulations show that no danger will occur at the PLASMON-X mirror in case of hitting of the x photon beam on the mirror.

The data refers to flux of 10^{10} photons per second.

Zerodur® is used in astronomy and astronautics because of its good thermal properties (low thermal expansion) (Ref.6), so no optical degradation of the mirror and of the whole PLASMON-X optics, due to thermal expansion, should be expected.

In space applications the radiation environment is quite harder and with characteristics ((X,γ rays and hadrons too) stronger, in term of Linear Energy Transfer and damage, than the low energy photons wich we are dealing with, so non damage is foreseen for an accidental hit of the PLASMON-X photon beam on the mirror.

5 REFERENCES

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