Development of laser produced plasma diagnostics for the Megajoule Laser facility and associated metrology

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Abstract. The goal of the Laser Megajoule (LMJ) will be to demonstrate ignition of a DT mixture and to validate theoretical models of laser-matter interaction and thermonuclear physics. This experimental validation on a complex installation such as the LMJ requires absolute measurements with as reduced as possible uncertainties. This LMJ experimental program involves specific developments of laser produced plasma diagnostics adapted to the complex experimental environment including nuclear background. In this paper we present a description of LMJ laser produced plasma diagnostics development program. We will briefly described present design and activation issues for X-ray imaging conducted at CEA/DAM since thirty years and neutron yield measurement devices by activation technics.

1. Introduction
The design (research and development), activation of this laser produced plasma diagnostics and validation of the simulation models render the rigorous metrology of the diagnostics essential before any experiments. Metrology can be carried out either on the complete measurement device or on some of its parts. Since, it is necessary to match up the metrology with expected working conditions of high intensity plasma and background; it requires a very intense radiation source such as a dedicated synchrotron radiation beam line.

2. LMJ laser produced plasma diagnostics development program and associated metrology
Various experimental studies are planned on the LMJ facility for example: laser matter interaction, matter equation of state at high temperature and/or high pressure, radiative hydrodynamic, Inertial Confinement Fusion (ICF indirect scheme) experiments.
On the LMJ, we have three diagnostic sets dedicated to:
- optical measurement: laser backscattering measurement system (DRED), VISAR,
- x-rays: spectrometers, imaging devices,
- nuclear fusion products: neutron imaging and spectrometry, gamma rays
The Figure 1 shows the LMJ diagnostic list, the LMJ diagnostics outlined in yellow will be used on the first experiments scheduled at the end of 2012.
### Diagnostic Family

| DIAGNOSTIC FAMILY | THEME | LMJ DIAGNOSTICS |
|-------------------|-------|-----------------|
| X RAY DIAGNOSTIC IMAGING SYSTEM | INITIAL CONDITIONS | IXDCM1t LARGE FoV |
| | | IXDCM2t MEDIUM FoV |
| | | IXMCM1t |
| | | IXMCM2t |
| | HYDRODYNAMIC | IXDCM1t (RX) |
| | RADIATIVE TRANSFER | IXMCM2t |
| | PRE-IGNITION | IXDHR1t SMALL FoV |
| | BURNING | IXDHR2t |
| OPTICAL DIAGNOSTICS | INITIAL CONDITIONS | 2 DRED RB Laser back scattering system |
| | | 2RED |
| | | 1 BEX1t 20pt |
| | | 1 BEX1t 20pt |
| | HYDRODYNAMIC | Pack UV VISAR |
| | IVCM1t |
| | IVH1t |
| X RAY DIAGNOSTIC SPECTROMETER | INITIAL CONDITIONS | DXRX1t Broad band spectrometer |
| | | DXRX2t |
| | HYDRODYNAMIC | SXHRS |
| | RADIATIVE TRANSFER | SXLBTD |
| | PRE-IGNITION / BURNING | SXHRS2 |
| NUCLEAR DIAGNOSTICS | PRE-IGNITION / BURNING | pack Ni |
| | | NiCuIn |
| | | NiSnSn Pct |
| | | GaCe1 |
| | | Ne/Si |
| | | Sn |
| | | In2DPe |

### Figure 1. Diagnostics for LMJ campaigns

LMJ diagnostics must be adapted into complex experimental environment and nuclear background. It is necessary to take account the diagnostic integration constraints in the experimental hall, the effect on the diagnostics and the measurement of the nuclear background, the non nuclear effect of x rays, electromagnetic field, shrapnel and debris [1].

For these goals various solutions must be used such as:

- radiative shields,
- enlarge the stand-off distance to the source of the diagnostic and the recording device,
- all devices must respect equipotential grounding rules,
- tritium contamination management,
- reduction of operators radiation exposure by remote handling (automated exchange of diagnostic in Diagnostic Inserters),
- new conception principle of measurement using fast phosphor, gated neutron imaging.

### 3. Plasma diagnostics metrology

These calibrations are performed on dedicated facilities. For 14 MeV neutrons we use D+ Ion accelerator on tritiated target and for the X-ray diagnostics (imaging system, spectrometer) we use X-ray tube associated with spectro-goniometer and synchrotron facility beam line. Due to the temporal, high brightness, polarization and spectral characteristics of its radiation, the synchrotron is an ideal source for X-UV calibration. This calibration must be performed on a specific beam line where it is possible to optimize the intensity, the spectral purity and the size of the analysis beam. Our laboratory
participate in the design on specific beam lines dedicated for X-ray calibration measurement on SOLEIL synchrotron source at Saclay France [2].

The figure 2 presents the beam line configuration on SOLEIL synchrotron facility dedicated to X UV calibration of plasma diagnostic. We use only two parts of the beam line which enable to calibrate the plasma diagnostics in the energy range 30 to 28000 eV (41 - 0.044 nm).

| Beam line Part | Energy Range | Wavelength |
|----------------|--------------|------------|
| Hard X-ray part | 100 - 28000 eV + white beam | 12.4 - 0.044 nm |
| XUV part | 30 - 2000 eV | 0.62 - 41 nm |
| VUV part | 4 - 100 eV | 12.4 - 310 nm |

**Figure 2.** Beam line configuration on SOLEIL facility dedicated for X-UV metrology of plasma diagnostics

### 4. X-ray imaging diagnostic

Many X-ray imaging diagnostics have been developed for thirty years at CEA. The design of these microscopes depends on the studied spectral band; for photons energies higher than 1 keV, the most used instruments are pinhole cameras, Kirkpatrick-Baez microscopes and Wolter microscopes [3]. All X-ray imaging diagnostic are used in Diagnostic Inserters System (SID). The microscope includes an alignment system unit consisting of four optical pointers (laser diode with fibre and a focusing lens). All streak or framing cameras will be located in to an air box inserted by the SID. For yields $Y_n > 5 \times 10^{15}$ neutrons main imagers are shielded and we study to transfer very quickly (in less than 100 ns) the image via an optical transport device to protected areas (LMJ bunkers). The figure 3 shows the layout of optical transports and LMJ measurement bunkers around the LMJ Chamber. For high energy and spatial resolution imaging diagnostics, the design consists in three toroidal aperiodic multilayers (Si/W) mirrors needed to achieve 5 µm (resolution) over a 500 µm FoV for spectral range between 8 and 14 keV. A prototype of such High Resolution Imager HRI will be commissioned at the end of 2007.

### 5. Neutron activation and radiochemistry diagnostics

Activation of copper or indium sample is a standard technique for neutron yield measurements. After sample activation by the neutron flux, we measure the nuclear radiations emitted by the sample by gamma counting measurement. But it is necessary to transfer promptly the active sample to the analysis laboratory. In the LMJ, we have reserved two positions for activation and radiochemistry measurements at the equator plane. The sample is transferred from the equator plane to the sample analysis laboratory at first level by using pneumatic transportation device in less than 10 minutes.

For activation measurement, Tritium contamination of the sample is avoided by use of protection pipe inside the LMJ chamber.
The Figure 4 presents the pneumatic transport network for neutron activation and radiochemistry measurement.

![Figure 3. layout of optical transports and LMJ Bunkers around the LMJ chamber](image1)

![Figure 4. Pneumatic transportation network for neutron activation radiochemistry.](image2)

6. Conclusion

LMJ experimental program requires specific development of laser produced plasma diagnostics adapted to the complex experimental environment including nuclear background. These diagnostics shall be carefully calibrated to provide the experimental data needed by the validation of simulation models.

Various facilities including synchrotron beam line will be used to test the design optics and provide rigorous calibration data.

The first diagnostics (imaging system, broad band spectrometer) are in the conceptual design phase until the middle of 2008 for LMJ activation at the end of 2012.

As the same time we develop calibration facility on the French synchrotron source (SOLEIL). A dedicated beam line for plasma diagnostics metrology should be commissioned in 2008.

7. References

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