NUKLEONIKA 2001;46(Supplement 1):S41–S43

PROCEEDINGS

Time-integrated diagnostics of X-ray emission from PALS and PF 1000 – preliminary results

Leszek Ryć, Josef Krása, Libor Juha, Jacek Kaczmarczyk, Marian Paduch, Piotr Parys, Krzysztof Tomaszewski, Marek Scholz

Abstract Thermoluminescent and semiconductor detectors operating in an integrating mode have been applied to the measurement of X-ray flashes of high intensity from large plasma facilities. A detection head of special kind has been developed to perform comparison measurements with the use of the detectors of both kinds.

Key words high-temperature plasma • semiconductor detector • thermoluminescent detector • X-ray diagnostics

Introduction

The knowledge of the total yield of X-ray radiation is essential for evaluation of a feature of produced plasma and for characterization of different X-ray sources constructed on the basis of plasma facilities. There are some difficulties encountered when dealing with measurements of high fluxes of X-rays from such great plasma facilities as a 1 kJ laser system PALS (Prague Asterix Laser System) and an 1 MJ Plasma Focus device PF1000 in Warsaw. The main problems that can arise are detector overloading, capturing the electric noise and the radiation from X-ray fluorescence or from the interaction of charged particles that can accompany the main X-ray flux.

Recently, investigations have been initiated at the PALS and the PF1000 with the aim at finding a proper equipment for the absolute measurements of X-ray output and checking out the boundary limits for overloading of several versions of X-ray detectors. Two types of detectors, the thermoluminescent (TLDs) [1–3] and semiconductor (SDs) ones, became objects of the tests. The TLDs are advantageous in being insensitive to noise, but they are rather cumbersome with reading out the collected doses. The output signals from SDs are easily accessible, but detectors of that kind can be sensitive to environmental noise. The quality of the used diagnostics can be evaluated from the mutual comparison of the results of measurements. Another means to check the proper behavior is recording the signals from a couple of detectors placed at different distances from the source and checking the $1/r^2$ law.

L. Ryć✉, J. Kaczmarczyk, M. Paduch, P. Parys, K. Tomaszewski, M. Scholz
Institute of Plasma Physics and Laser Microfusion (IPPLM), Hery 23, P.O. Box 49, 00-908 Warsaw, Poland,
Tel.: +4822/ 6859586, Fax: +4822/ 6668372,
e-mail: ryc@ifpilm.waw.pl

J. Krása, L. Juha
Institute of Physics,
Academy of Sciences of the Czech Republic,
Na Slovance 2, 182 21 Prague 8, Czech Republic

Received: 9 November 2000, Accepted: 4 January 2001

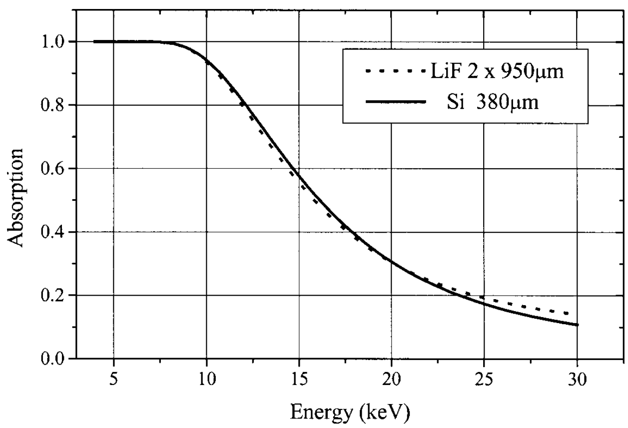

Fig. 1. X-ray absorption curves for two stacked LiF TLDs and Si SD (type FLM).

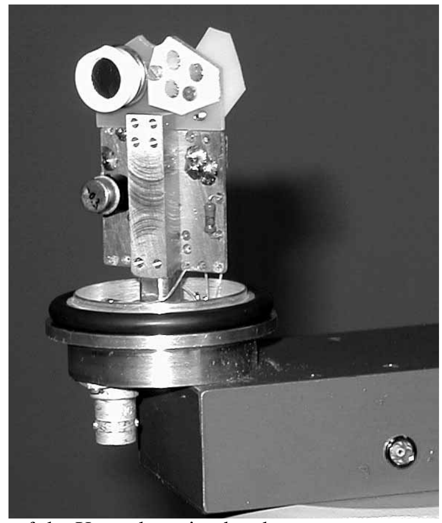

Fig. 2. Photo of the X-ray detection head.

In this paper we are describing details of the applied diagnostics and we are presenting some preliminary results of our investigation, which, at this stage, were carried out at the partial output energy of the exploited facilities.

Detectors and detection heads

The TLD and SD detectors used in the work were selected so that the X-ray absorption characteristics for each type could differ as little as possible. It was found that the shape of the X-ray absorption curve for two stacked standard TLD chips made from LiF (TLD100 or GR200A), each 920 μm thick, is almost the same as the one for a (single) silicon SD, type FLM (ITE, Warsaw), 380 μm thick (Fig. 1). Such a good matching of the detector characteristics had given the possibility of a prompt comparison of absolute values of recordings from both types of detectors independently of the spectral shape of X-ray emission. The detectors of both types are suitable to operate approximately in the range of 1–20 keV that is determined by the thickness of detectors and the thickness of the used entrance filter (18 μm Al).

A few special X-ray detection heads equipped with SDs (active surface 4.6×4.6 mm^2), each prepared for inserting three chips of TLD dosimeters (diameter 4.5 mm), have been designed and fabricated (Fig. 2). The Si detectors were accompanied by simple electronic circuits (Fig. 3), each equipped with an integrating capacitor C* (from the range of 500–2000 pF), which determines sensitivity and an IC buffer (LH0002, voltage gain 0.97 when unloaded, and 0.48 when loaded with a 50 Ω resistance). Battery biasing was applied to make the head more resistant to noise. The doses absorbed by TLDs were measured with the use of a Harshaw TLD reading system.

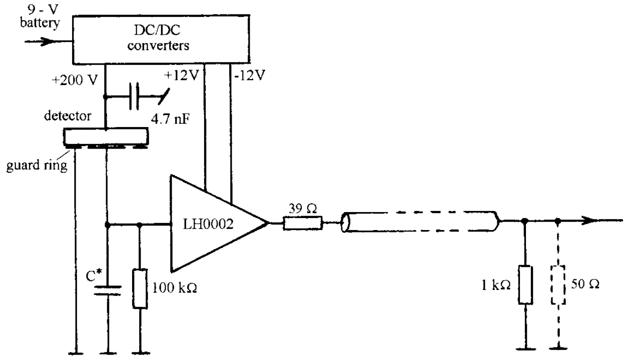

Fig. 3. Electronic circuit of the X-ray detection head.

Measurements of X-ray emission

Preliminary tests of the overall behavior of the detection heads were performed by the use of a pulsed, cold-cathode X-ray lamp (Dina 1, Russian production). 1.3 V output pulses were obtained (at integrating capacitance of 1500 pF and at a distance from the X-ray source of 28.7 cm). This corresponds to the charge of 1.95×10^{-9} C collected from the detector. The heads occurred to be resistant to intensive noise generated by the lamp. The results from SDs were in agreement with the data obtained from TLDs. The good resistance against noise was confirmed with the PF1000 Plasma Focus device as well. The head could operate without any special demands concerning the shielding of the output cable and loaded with the high-resistance of 1 kΩ

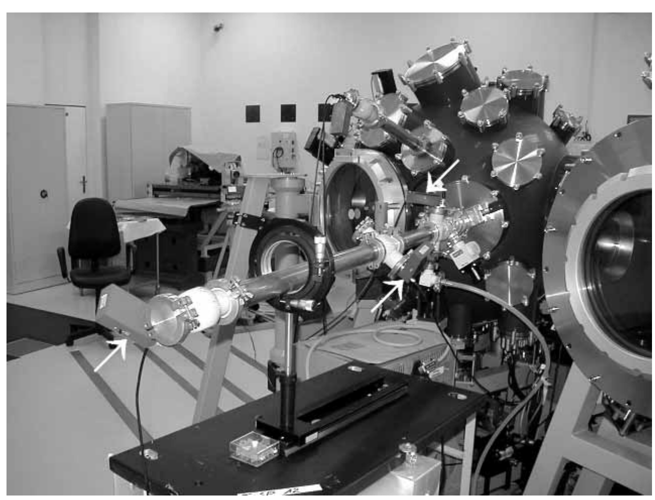

Fig. 4. X-ray detection heads installed in the experimental chamber of the PALS.

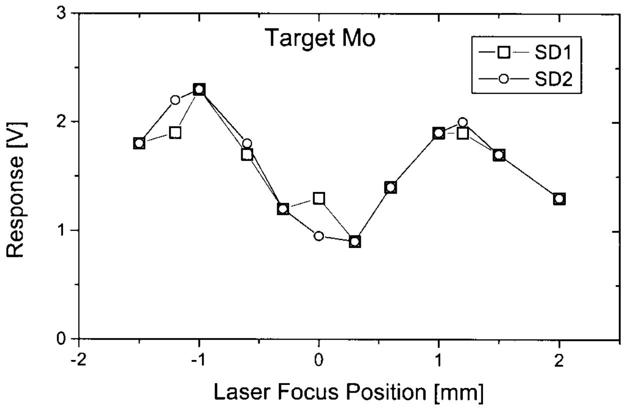

Fig. 5. X-ray emission from Mo target as a function of laser focus position, measured by two detection heads of different, particularly chosen sensitivities (at 15 J of laser energy, data are from SDs).

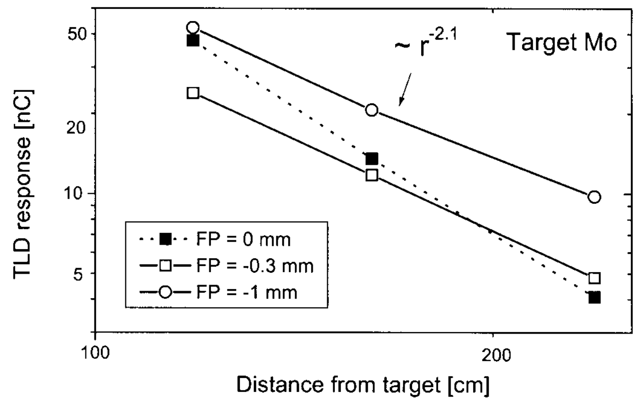

Fig. 6. X-ray emission, measured with the use of TLDs placed at different distances from the target (log-log plot).

(instead of the usual 50 Ω). The charge up to 1.7×10^{-8} C was recorded when the head was set at 118.5 cm from the plasma focus and the discharge energy was ~650 kJ.

More detailed measurements with the heads were done using the PALS, as the plasma produced there is of very low dimensions, so it can be treated as a point source and checking of the $1/r^2$ law is possible. The emission from Al and Mo targets was measured. The heads were placed at three different distances (118, 162, and 238 cm) from the target (Fig. 4). The sensitivities of the heads were properly adjusted (by changing C*) to the descending level of radiation in order to obtain from all of them the same level of the output signal. For these experiments two laser energy levels – 15 and 70 J – were used, while the laser pulse duration 0.3 ns was constant. Filtering trough an 18 μm Al foil resulted in the occurrence of two ranges of good sensitivity: 1–1.56 keV and 3–15 keV. In practice, the output signals were from the first, softer range, because the contribution of the harder component is usually minor in the case of radiation from plasma. The linear response could be proved for most shots, at different levels of the laser energy up to 70 J, and at different positions of the target in relation to the position of the optical focus, but with the exception of the best (sharp) focusing. It can be seen from Fig. 5 where the responses from two heads, placed at the distances of 118 and 162 cm, are presented (data are from SDs, SD1 and SD2, respectively). The sharp focusing is at the position of 0 mm. The same effect was obtained from TLDs as it is seen from Fig. 6. There is a different slope of the line at sharp focusing. As it was observed, at low levels of X-ray emission as well, it could not be the result of overloading. We suppose it is due to the disturbance caused by the excess of highly energetic electrons and/or ions that produce an additional flux of X-rays from the shielding filters and from the walls of the experimental chamber. From the observation it follows that special measures for stopping charged particles (and better collimating) must be taken in the future experiments.

From all the correct recordings (except the ones with the mentioned odd effect) we conclude that the FLM SD is linear at least up to the level of 1.8×10^{-8} C of the charge produced inside the active layer (the charge at which the detector becomes nonlinear has not been reached yet). This corresponds to an X-ray energy dose of 6.7×10^{-8} J delivered to the detector (surface density of 3.2×10^{-9} J/mm^2). It must be noted that the condition of detector overloading by soft X-ray radiation (when interaction takes place at the very surface) may be different from the one for overloading by hard X-rays (when the whole volume of a detector is enlightened).

Summary and conclusions

An idea of equipment for the comparison of X-ray responses from TLD and SD detectors has been invented. SDs are operating in an integrating mode. The thickness of detectors of both kinds was properly chosen to obtain the same X-ray absorption characteristics. The detection head containing both kinds of detectors was fabricated and then tested at different pulsed plasma sources. Linearity of both types of detectors up to the level of an X-ray flux of 3.2×10^{-9} J/mm^2 was proved. Further investigations are foreseen to check the detectors at higher loading. Some modification must be introduced to the measuring system in order to avoid the disturbance from the charged particles.

Acknowledgments The authors are thankful to A. Cejnarová for assistance during measurements with the PALS and to J. Król for the help along designing the detection heads. This work was realized, in part, within the framework of the HPRI-CT-1999-00053 (PALS 0007) project of the Improving Human Potential EU (5th FP) programme and, in part, within the framework of the grant LA055, INGO, from the Czech Ministry of Education.

References

1. Fárniková M, Krása J, Juha L, Ryć L (1996) Thermoluminescent dosimetry of X-ray radiation emitted from a laser-produced plasma. J Phys D, Appl Phys 29:2119–2123
2. Fárniková M, Juha L, Krása J, Parys P, Ryć L, Wołowski J, Woryna E (1996) Absolute brightness measurement of X-ray emission from laser-produced plasma using thermoluminescent dosimeters. Nucl Instrum Meth A 36:484–487
3. Krása J, Fárniková M, Juha L, Cejnarová A (2001) Limitation of thermoluminescent dosimeters in soft X-ray diagnostics of pulsed plasma. Nukleonika, Suppl 46;1:S49–S51