JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS Vol. 10, No. 8, August 2008, p. 2092 - 2094

Super-heated fluid detectors for neutron measurements at JET

M. GHERENDI[a*], V. KIPTILY[b], V. ZOITA[a], S. CONROY[c], T. EDLINGTON[b], D. FALIE[a], A MURARI[d], A. PANTEA[a], S. POPOVICHEV[b], M. SANTALA[e], S. SOARE[f] AND JET-EFDA CONTRIBUTORS[#]
[a]*Association EURATOM-MEdC, National Institute for Laser, Plasma and Radiation Physics, Bucharest, Romania*
[b]*Association EURATOM-UKAEA, Culham Science Centre, Abingdon, UK*
[c]*Association EURATOM-VR, Uppsala University, Uppsala, Sweden*
[d]*Association EURATOM-ENEA, RFX, Padova, Italy*
[e]*Association EURATOM-Tekes, Helsinki University of Technology, Finland*
[f]Association *EURATOM-MEdC, National Institute for Cryogenics and Isotopic Technologies, Rm. Valcea, Romania*
[#] *See Appendix of M.L. Watkins et al., Fusion Energy 2006 (Proc. 21st Int. Conf. Chengdu, 2006), IAEA, 2006*

In this work we report the results of a first series of neutron measurements carried out at JET during the last experimental campaigns (C17-C19) using super-heated fluid detectors (SHFD's). The SHFD's were located in the neutron beam propagating along a collimated vertical line-of-sight, above the TOFOR neutron time-of-flight spectrometer (KM11 diagnostics). The radial distribution of the neutron fluence in the neutron beam was obtained with less than one cm spatial resolution. The neutron spectrum in the neutron beam was obtained over a broad energy range (six energy bins, from 10 keV to 20 MeV).

(Received March 1, 2008; accepted June 30, 2008)

Keywords: Tokamak plasma, Plasma diagnostics, Neutron diagnostics

1. Introduction

Neutron diagnostics techniques based on a new type of detector (the super-heated fluid detector – SHFD) have been evaluated and found to be of particular interest for the characterisation of the neutron emission from the JET tokamak. The proposal for the development of SHFD technique for tokamak devices followed from the successful application of this method on pulsed plasma devices [1-3].

The super-heated fluid detectors (also known as "bubble detectors") have been very successfully developed as neutron dosimeters due to their particular characteristics: immediate, visible response; high neutron efficiency (about 3%); (practically) zero gamma sensitivity; lightweight, rugged and compact; broad energy range spectrometric capability.

2. Principle of operation of the SHFD's

Super-heated fluid detectors are suspensions of metastable droplets which readily vaporise into bubbles when they are nucleated by radiation interactions. The active detecting medium (Fig.1) is in the form of microscopic (20-50 μm) droplets suspended within an elastic polymer [4].

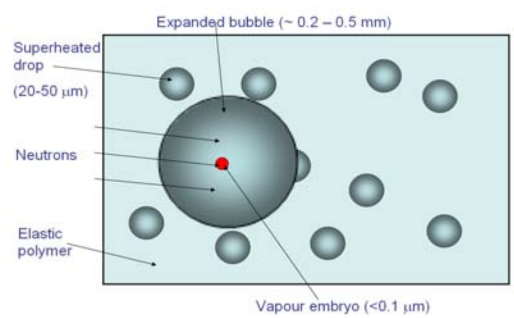
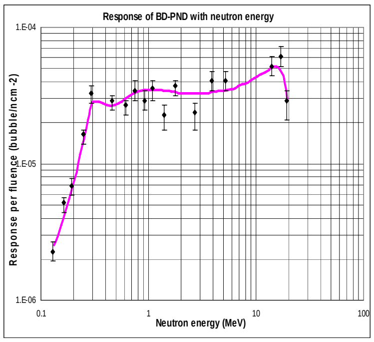


Fig. 1. The basic operation of Super-heated Fluid Detectors

The phenomenon of neutron detection by a SHFD is a mixture of nuclear interactions (neutron collisions with nuclei of the active medium), thermodynamic behaviour of the detecting medium (the super-heated fluid), and the mechanical response of the embedding elastic polymer. If sufficient energy is transferred from the colliding neutron to the nucleus of one of the elements in the composition of the active medium, the recoil nucleus will initiate the generation of a vapour embryo of sub-micron dimensions. Under proper conditions (that depend on the thermodynamics of the active medium) the vapour embryo will lead to the vaporisation of the super-heated droplet with the subsequent expansion into a macroscopic (0.2 – 0.5 mm) bubble. The bubbles generated in the detector are counted by various means: eye counting for up to a few tens of bubbles per detector, automatic counting through processing of the detector image, acoustical detection of the bubble formation. The number of bubbles generated within a given volume of the detector is simply and directly related to the neutron fluence (neutrons per unit area).

The SHFD's have a threshold-type energy response (Fig. 2) with the threshold energy depending on: droplet composition, detector operating temperature, and detector operating pressure.



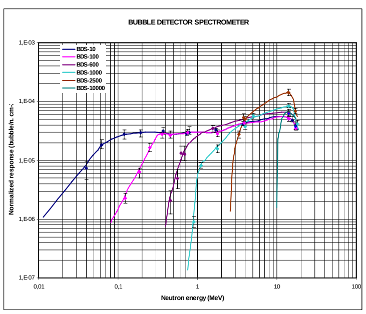


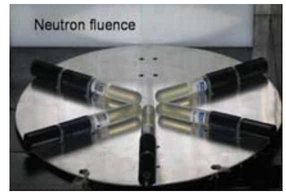
Fig. 2. Energy response of type BD-PND and BDS detectors

For a standard bubble detector like the BD-PND(†) type, the energy response is approximately flat within the range 0.3-10 MeV.

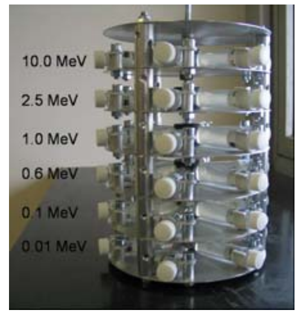
Using detectors with different energy thresholds, a bubble detector spectrometer (BDS(†)) is obtained. The BDS covers a broad energy range (0.01-20 MeV) and provides six energy thresholds in that range.

3. Experimental set-up on the JET tokamak

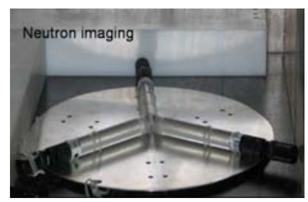
Three types of SHFD's (BD-PND, BDS and DEFENDER(†)) (Fig. 3) have been used for neutron measurements at JET during the last experimental campaigns (C17-C19). Standard bubble detector of the BD-PND type have been used on the JET tokamak for neutron fluence measurements, while high sensitivity DEFENDER-type detectors have been used for neutron beam imaging.



a)



b)



c)

Fig. 3. (a) BD-PND-type detectors for neutron fluence measurements; (b) BDS-type detectors; (c) DEFENDER-type detectors for neutron imaging.

The detectors (82 detectors) and the associated equipment (automatic detector reader, detector compression chamber, spectrometer frame, PC with dedicated interface and software) have been provided on loan to JET by the EURATOM-MEdC Association (Fig. 4).

a)

b)

Fig. 4. Equipment for neutron measurements at JET: (a) detector reader unit; (b) detector recompression Chamber.

All measurements for this series of experiments at JET have been done at the end of the KM11 diagnostics line-of sight, above the TOFOR neutron time-of-flight spectrometer (Fig. 5). The SHFD detectors have been placed in front of the vertical NaI(Tl) gamma-ray spectrometer.

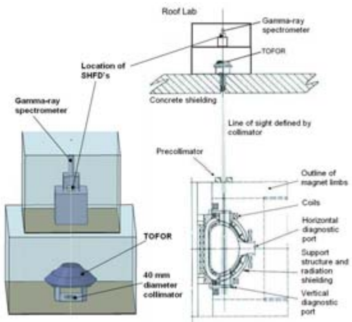


Fig. 5. Experimental setup for SHFD neutron measurements along the JET KM11 line-of-sight.

4. Experimental results

The radial distribution of the neutron fluence in the neutron beam at a distance of about 3 m from the exit of the 40 mm diameter KM11 collimator was obtained with a spatial resolution of less than one centimetre (Fig. 6). A better alignment of the vertical NaI(Tl) gamma-ray spectrometer was obtained as an immediate effect of these measurements. The cross-section of the neutron beam is determined by the diameter of the floor collimating hole. The FWHM of the beam profile is approximately 40 mm.

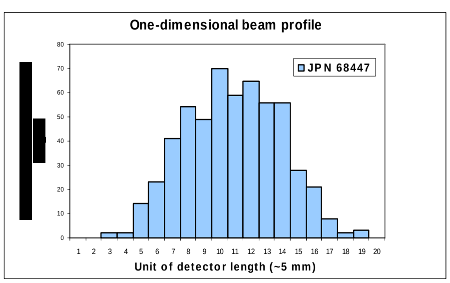


Fig. 6. One-dimensional neutron beam profile for JPN 68447

The neutron energy distribution at the end of the KM11 line-of-sight was obtained over a broad energy range (Fig. 7) (six energy bins, defined by the energy thresholds: 0.01; 0.1; 0.6; 1.0; 2.5; 10.0 MeV). The measurement was done during a Ripple H-mode Study session (JET pulse numbers: 70656-70660). The energy distribution shows an energy component around the 2.5 MeV value (DD fusion neutrons) and a large low energy component, most probably generated by the scattering of the fusion neutrons in the collimating structures.

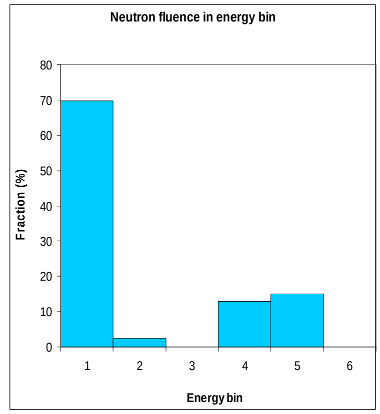


Fig. 7. Neutron energy distribution determined by bubble detector spectrometer (BDS).

5. Conclusions

A neutron diagnostics technique based on the super-heated fluid detectors (SHFD's or "bubble detectors") has been successfully tested at JET on various types of discharges during Campaigns C17-C19. It provided new information about the following characteristics of the neutron field at the end of the KM11 line-of-sight: fluence, beam profile, broad-band energy distribution.

The results (although very encouraging) are of preliminary nature and they should be checked and confirmed in better defined and suitably controlled measurements during Campaigns C20-C25.

(†) All detectors used in this work were manufactured by Bubble Technology Industries, Chalk River, Canada

References

[1] V. Zoita, "Plasma focus neutron diagnostics - methods and devices", International Symposium PLASMA-2001 on "Research and Applications of Plasmas", Warsaw, Poland, September 19-21, 2001.

[2] V. Zoita, M. Scholz, H. Schmidt, A. Patran, F. Rocchi, S. Vitulli, "First results on the use of bubble detectors for neutron yield measurements on the PF-1000 installation", 12th Conference on Plasma Physics and Applications, Iassy, Romania, September 1-3, 2003.

[3] V. Zoita, A. Patran, A. Pantea, G. Craciun, E. Grigore, M. Scholz, K. Tomaszewski, S. Jednorog, P. Strzyzewski, P. Lee, S. Vitulli, "Development of new neutron diagnostics for the PF1000 plasma focus installation", International Conference on Plasma Science, Monterey, California, June 19-23, 2005.

[4] F. d'Enrico and M. Matzke, Rad. Prot. Dosimetry, Vol. 107, pp. 111-124 (2003).

*Corresponding author: mihaela_gherendi@yahoo.com