§20. Improvement of Collimator of Compact CsI(Tl) Scintillation Detector for Hard X-ray Energy Spectrum Measurement in LHD

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Effect of suprathermal electrons on electron cyclotron resonance heating (ECRH) has been intensively investigated in ECRH plasmas of LHD[1)]. Lately, magnetohydrodynamic (MHD) instabilities associated with suprathermal electrons have been recognized in LHD[2)], providing a good opportunity to obtain deeper understanding of excitation mechanism of fast-particle-driven MHD instabilities in magnetically confined fusion plasmas. To clarify role of suprathermal electrons in physics above mentioned, hard X-ray diagnostic is indispensable. In LHD, a germanium semiconductor detector has been employed to measure hard X-ray of which energy is up to ~300 keV[3)]. Because there has been clear sings of the presence of HX of which energy is over 300 keV in low-density 2nd harmonic ECRH plasmas, two compact CsI(Tl) scintillation detectors coupled with a photodiode were installed on the lower diagnostic port of LHD at the vertically elongated cross section in 2011. This detector can measure hard X-ray of which energy is up to MeV range. One of primary advantages of CsI(Tl) scintillator is that because the wavelength of scintillation light (540 nm) is the longest among high Z inorganic scintillators[4)], a photodiode can be used for pulse height analysis. Normally, a photomultiplier tube (PMT) is used to detect scintillation light for other high Z scintillator as NaI(Tl) and BGO and it is well known that the operation of PMT is affected by magnetic field. Unlike those scintillation detectors, the CsI(Tl) detector used in LHD can work in a magnetic field environment because of the use of photodiode. For this reason, this detector can be set anywhere near the machine without magnetic shield.

In 2011, the CsI(Tl) detector provided time-resolved pulse height distributions due to hard X-ray emitted from suprathermal electrons. However, the detector was not applicable to low-density ECRH plasmas (n_e<0.5x10^{19} m^{-3}). This is because the counting rate often exceeded the maximum counting rate capability of the detector and as a result of it, we suffered from pile up issues due to huge flux of hard X-ray. Because of this, the detectable maximum energy of hard X-ray was limited to ~300 keV. To overcome this situation, the collimator for CsI(Tl) detector was improved in 2012. The collimator in 2011 was made of only stainless steel having the cylindrical opening of 3 mm in diameter. In 2012, the lead block having the cylindrical opening of 1 mm in diameter was partially installed. Fig. 1 shows hard X-ray energy spectra measured in 2nd harmonic ECRH plasmas without neutral beam injection. The detector is now applicable to fairly low-density ECRH plasmas (n_e~0.1x10^{19} m^{-3}). As seen in Fig. 1, hard X-ray of which energy is up to ~600 keV can be measured. The measurements indicated that energy and flux of hard X-ray depends on electron density as expected. Those values tend to increase as electron density decreases.

In JET, the CsI(Tl) scintillation detector array, so-called γ-ray camera, has been used to study confinement characteristics of MeV ions accelerated by ion cyclotron resonance heating[5,6)]. So far, the γ-ray camera in JET has succeeded in visualization of orbits of energetic banana ions through the measurement of γ-ray spectrum. In addition to contribution to ongoing LHD experiments, this work is being conducted as a part of fundamental examination toward γ-ray diagnostics in deuterium experiment planned in LHD in order to obtain experience and knowledge of handling of compact CsI(Tl) scintillator coupled with a photodiode in the actual LHD environment.

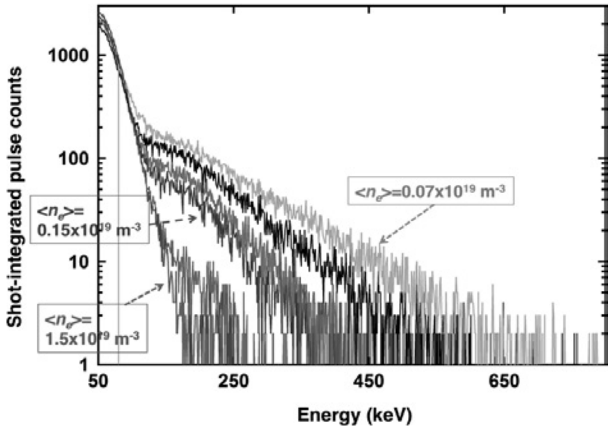

Fig. 1. Hard X-ray energy spectra measured with the CsI(Tl) scintillation detector in 2nd harmonic ECRH plasmas without neutral beam injection for various electron density cases. These data were taken in shot numbers 114713, 114733, 114735-114737, and 114746.

1) Kubo, S. et al.: J. Plasma Fusion Res. SERIES, **8** (2009) 1095.
2) Isobe, M. et al.: Proc. of 12th IAEA Technical Meeting on Energetic Particles in Magnetic Confinement System, Sep.7-10, 2011 Austin, Texas, USA. **O-20**.
3) Muto, S. et al.: Rev. Sci. Instrum. **74** (2003) 1993.
4) Knoll, G.F.: “Radiation detection and measurement”, the Nikkan Kogyo Shinbun Ltd.
5) Kiptily, V.G. et al.: Nucl. Fusion **42** (2002) 999.
6) Kiptily, V.G. et al.: Plasma Phys. Control. Fusion **48** (2006) R59.