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Thomson scattering diagnostic in HL-2A Tokamak

Yuan Huang, Peng Zhang, Zhen Feng, Chunhua Liu , Peilan Shi,
Xuantong Ding, Yong Liu
Southwestern Institute of Physics, P O Box 432, Chengdu 610041, China

Thomson scattering is very powerful to measure Te and ne of magnetically confined plasmas, so that as a diagnostic tool which has been developed at many devices1-9, and now a multi-point TS measuring system is being built for the HL-2A tokamak. The main objective of this system is to provide routine measurements of HL-2A plasma temperature, and it can also be used to measure plasma density when accurately calibrated. In the 2006 experimental campaign, a one-point measurement TS system is successfully developed to measure core plasma Te and ne of HL-2A tokamak. This system includes the Nd:YAG laser, the collection optics, the equipments for spectral calibration and electronic gain calibration, filter polychromators, charge integrating ADC modules, and data acquisition hardware, etc. In future, about 20 points of spatial measurements are planned in the plasma region -40 cm < z < 20 cm. An outline of the system is shown in Fig.1.

The Nd:YAG laser is composed of one oscillator and three stage amplifiers. It can produce laser pulse with wavelength equal to 1064 nm, time duration about 10 ns and energy up to 4 J at the repetition rate of 10 Hz. The laser beam is expanded to 3 cm in diameter to avoid damage of optical components from dust. Its full angle divergence is less than 0.5 mrad and pointing stability is better than 50 μrad. The laser system is real-time controlled by a microprocessor, or indirectly controlled by the CAMAC that connects with the microprocessor via RS485 line. Through the control of the microprocessor or the CAMAC , a shutter can be steered into the cavity of the oscillator to prevent laser output just for safety, the number of laser pulse can be set, and the work mode of which is triggered by HL-2A central controller can be enabled, etc. At time a few seconds earlier than HL-2A plasma discharge, the laser is triggered to work to warm up the laser rods so that good quality beam is obtained for the Te and ne measurements.

We use a standard lamp-monochromator combination for the measurement of spectral responses. As shown in Fig. 2, the light was chopped by a slit wheel before entering into the entrance slit of the monochromator, and then transmitted into a 5-m long fiber bundle after leaving from the exit slit. The light power from the fiber bundle is measured with a standard detector, by sweeping the monochromator in the range 750 – 1200 nm with a step of 2 nm, and in this case the chopper does not work. Thus we get the power spectrum of the light source to be used for calibration. Then the carrier is moved on the rails, from the TS measurement position to the platform end. For the one-point calibration, the light source is placed as far as the scattering volume is optically to the collection lens, and is carefully adjusted to image into the 21-m long fiber bundle which transmits scattered light to polychromator. To locate the light source, a better mechanical supporter will be used to make it convenient for multipoint calibrations. In the range 750 – 1200 nm, after the monochromator is swept to a new wavelength, an electric pulse is sent to the control circuit of the calibration set, thus the circuit generates 30 electric pulses (because the 2250L ADC has 32 words of memory buffer in each channel) which are synchronizing with chopped light to enable the ADC to work. After that, we average the recorded data and divided it by the light output power of the calibration unit to obtain the spectral response. In this way, the spectral calibration is done automatically.

In 2006, the single-point Thomson scattering diagnostic system has provided routine measurements of HL-2A core plasma Te and ne. We use the lookup table method to calculate electron temperature by fitting the measured spectral data to Selden's formula10 of relativistic scattering spectrum. The Te value is used to calibrate the measurement of multi-channel ECE diagnostic, and their cross check is well consistent in temporal evolution, as shown in Fig.3 for shot05463. In this plasma discharge, the Bt = 2.29 T, Ip = 300 kA, the plasma is 68 GHz-ECW heated with Pw = 740 kW from 600 ms to 800 ms, and the TS system works at 5 Hz repetition rate. Because the TS intensity is proportional with electron density, thus electron density can be measured if we get the proportion coefficient by doing density calibration, such as Raman scattering or Rayleigh scattering experiments with high-pressure neutral gas filled in HL-2A vacuum. But we are not ready to do that in 2006, as an alternate, we utilize the line averaged ne data measured by HCN laser interferometer in some ohmic discharges to deduce the coefficient, so that the system also provides the measurement of electron density. One example is given in Fig. 4 for shot05898, in which the

Bt = 2.29 T, Ip = 300 kA, the plasma is ECW heated with Pw = 1300 kW from 800 ms to 1200 ms, and the TS system works at 10 Hz repetition rate. During ECRH duration, the "pump-out" effect11 of core plasma density is observed.

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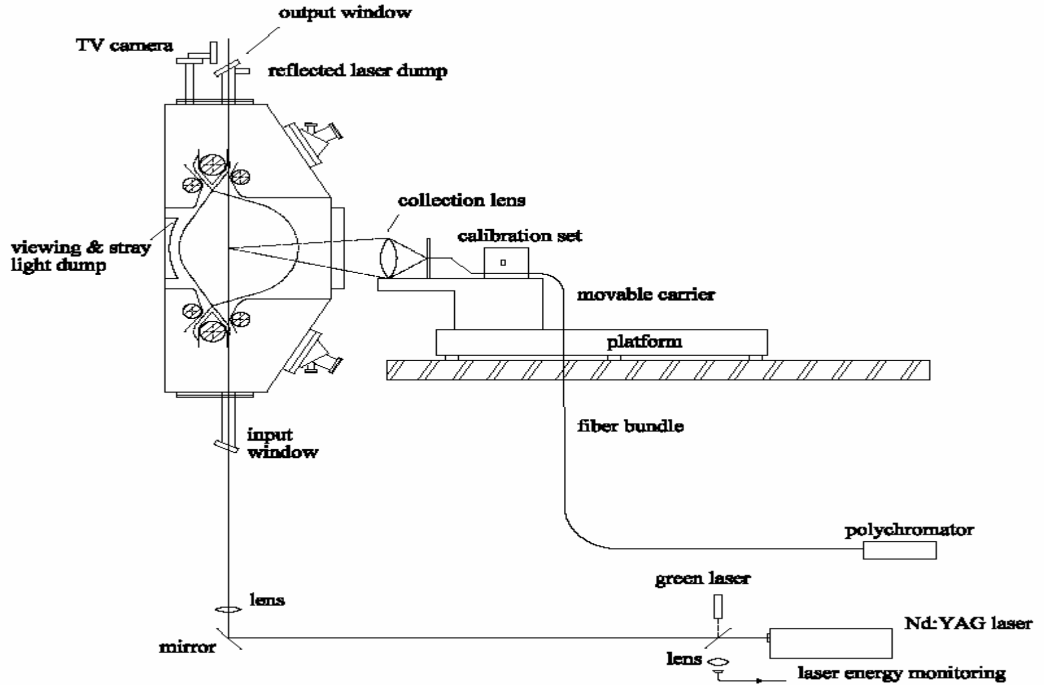

Fig.1, Schematic layout of the HL-2A Thomson scattering system. The distance from the laser head to the plasma is about 20 m. After imaged by the collection lens, the scattered light is transmitted through 21 m long fiber bundles to polychromators.

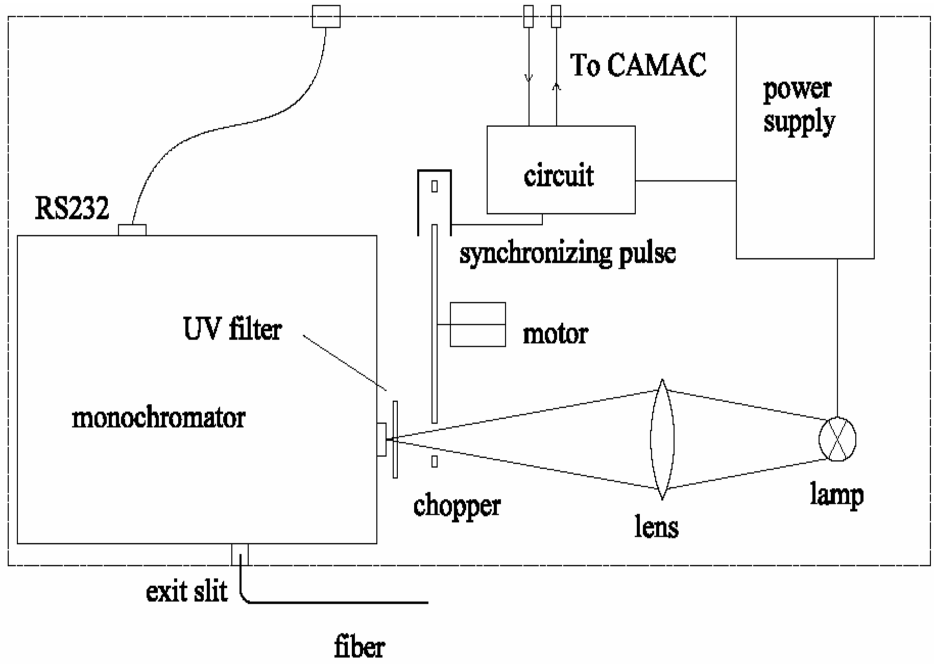

Fig.2, The standard lamp-monochromator spectral combination unit for calibrating the responsibilities of polychromators.

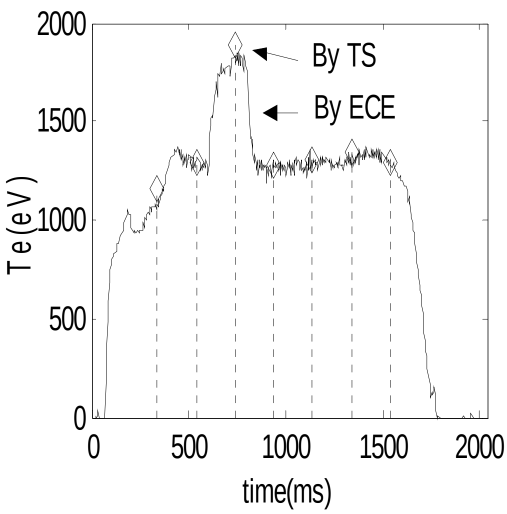

Fig.3, The temporal evolution comparison of Te values measured by TS and ECE diagnostics. In this case, the plasma is ECRH heated from 600 ms to 800 ms.

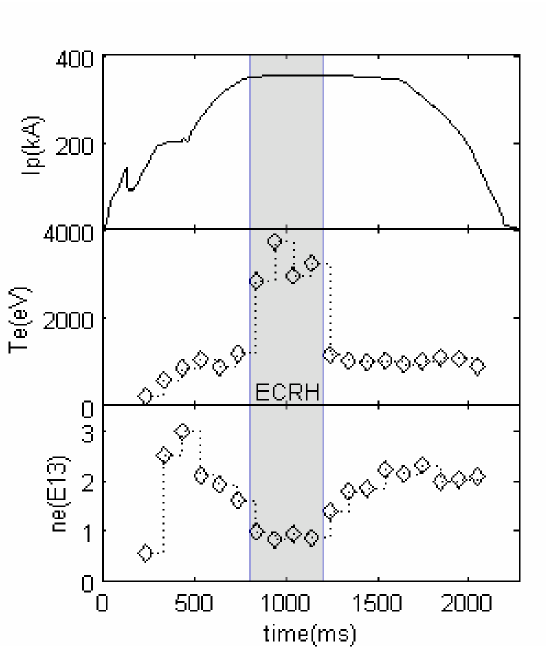

Fig.4, An example of Te and ne measurements in shot05898 plasma discharge with ECRH from 800 ms to 1200 ms.