# SIMULATION OF THE THOMSON SCATTERING SYSTEM FOR THE BRAZILIAN SPHERICAL TOKAMAK ETE

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## 1. Introduction

The ETE ( Experimento Tokamak Esférico ) is a small-aspect-ratio tokamak ( R/a = 1.5, $I_p$ = 200kA - Initial phase, $B_t$ = 0.4T ) under construction at the Plasma Laboratory of the National Institute for Space Research ( LAP / INPE ) and its main objectives are to study the operation regimes and confinement properties of this type of compact tokamak [1]. The total height of ETE is 2.6 m and the diameter is 1.8 m. The vessel is made of Inconel that keeps eddy-current effects at low levels because of its high resistivity. The major radius of the machine is 30 cm and the minor radius is 20 cm. In the first stage of operation in ETE, densities of $5x10^{13}$ $cm^{-3}$ and temperatures of 500 eV during the 20 ms flat top plasma discharge are expected.

To measure the density and temperature profiles in this device, a Thomson Scattering system ( TS ) has been specified. In this paper we will show the general mechanical system features for the single pass injection system, the simulation for a multipass system and the expected performance of the collection optics .

## 2. Single Pass Injection Thomson Scattering System

The single pass injection system for the TS diagnostic is shown in Figure 1. The plasma will be probed by a 10 J ruby laser light ( $\lambda$ = 6943 Å ) of 30 ns pulse duration, focused in a 3 mm spot size in the plasma center, using a 3 m focal lens. The laser light will be injected through a steel flying tube of up to 1.3 m long. This tube contains special anodized aluminum inserts and baffles to prevent stray light. To dump the laser beam two blue glass plates that can easily be shifted during the alignment procedure will be used.

For the conditions described above ( $n = 5x10^{13}$ $cm^{-3}$ and $T_e$ = 500 eV ) we expect that $2x10^6$ photons will be scattered in the center of the plasma, in a solid angle of $\Omega$ = 0.018 sr.

## 3. Multipass Thomson Scattering System

The major difficulty of TS diagnostic lies mainly on the small ratio between scattered and incident laser power that, for tokamak plasmas is about $10^{-14}$. This problem can be minimized by using a multipass injection system that can help to increase the intensity of the scattered light profile. The multipass system that will be tested in ETE consists of two spherical mirrors ( $\phi$ = 10 cm, R = 1.3 m ), that force by multiple reflection the light to pass several times through the same plasma volume. This system has been already tested with good results in other machines [2,3]. Theoretically, it is possible to increase the gain by more than 15 times with 25 passes in a single pulse of laser.

To apply this multipass system in ETE it will be necessary to remove the flying tube and the dump propose in Section 2. In Figure 2, we show the results of the simulation performed with MATHEMATICA [4], using the same focusing lens of the previous system and the spherical mirrors ( $M_{1,2}$ ) described above. The access windows are represented by $W_{1,2}$ and the point C represents the plasma center. In the same figure, we show the cross-sections of the principal points of the laser pass. In this simulation, the system was optimized to obtain 40 passes through the plasma, generating a loss of spatial resolution as we can see in the plasma center cross section in Figure 2 .

## 4. Simulation of the Collection Optics

The collection system consists of a single channel computer driven mirror that collects light (F/6.3 ), shot by shot, for different plasma positions. Two plan-convex lenses of 50 cm focal length make a 1:1 image projection on the spectrometer slit ( 20x3 mm ). Since the scattered volume is in the horizontal position, two plan mirrors ( 10x10 cm ) are used to rotate the image by $90^{o}$ , matching the image with the vertical spectrometer slit. The signals will be registered by 4 or 5 EMI 9658R photomultipliers attached by optical fibers to the output slit of a Jobin Yvon spectrometer ( HR640, 1200lines/mm, 12Å/mm ).

The total scattered photons centered in the ruby wavelength ( 6943 Å ± 18Å ) in the 0.018 sr solid angle, considering a scattered angle from $75^{o}$ to $115^{o}$, a parabolic density and temperature profiles as a function of the position and a single pass injection system are represented by curve 1 ( solid circles ) in Figure 3. Curve 2 ( solid triangles ) represents the collected photons, considering an overall system transmission of less than 30% and 6% for detectors. The simulation also considers losses due to aberrations and bad image focusing of the scattered volume, for different plasma positions. We can verify two peaks in curve 2 that

represent the best focusing points of this system along the laser beam pass, where the maximum is near the plasma center with $3x10^4$ collected photons.

## 5. Conclusions

A TS diagnostic is been specified for the spherical tokamak ETE and its principal features were shown in this work. We are also verifying the possibilities to apply a multipass injection system in order to obtain the profiles of low density regions and also to study better its performance. The collection system were simulated and a maximum of $3x10^4$ photons were achieved for the plasma center. We also verified by simulation that this system presents a maximum photon collection spot near the plasma center which capability rapidly falls because of the lens focusing. It is expected to obtain a flatter collection profile using fibers but with higher losses.

## References


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[3] D.O. Campos, et al.: Jpn. J. Appl. Phys. **35**, 6273 (1996).

[4] Mathematica of the Wolfram Research, Inc. ( OPTICA package)


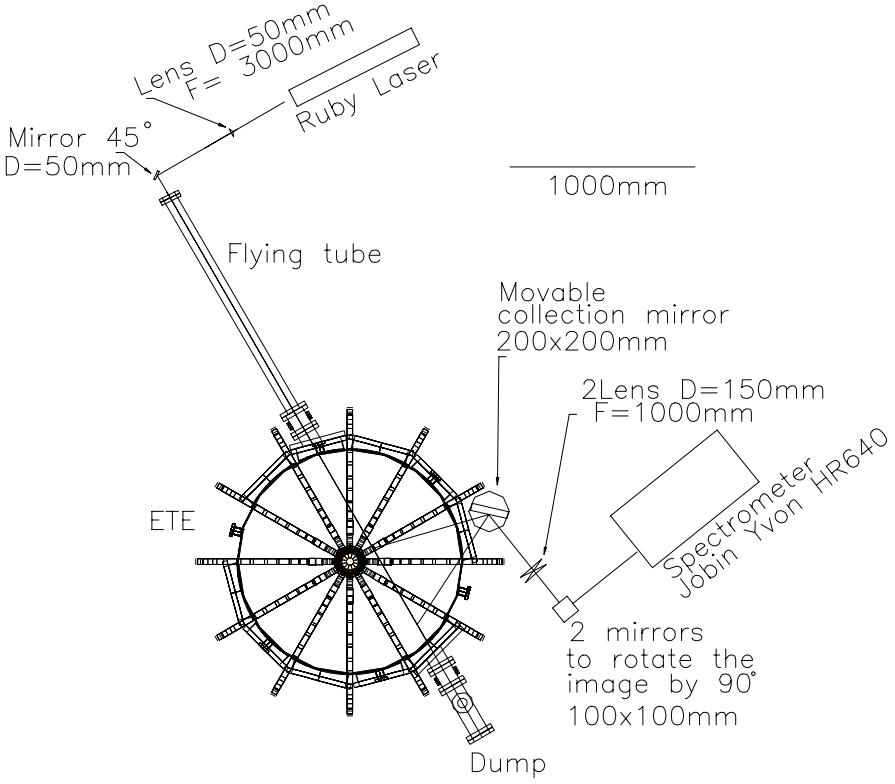


**Figure 1.** Top view diagram of the ETE Thomson scattering system.

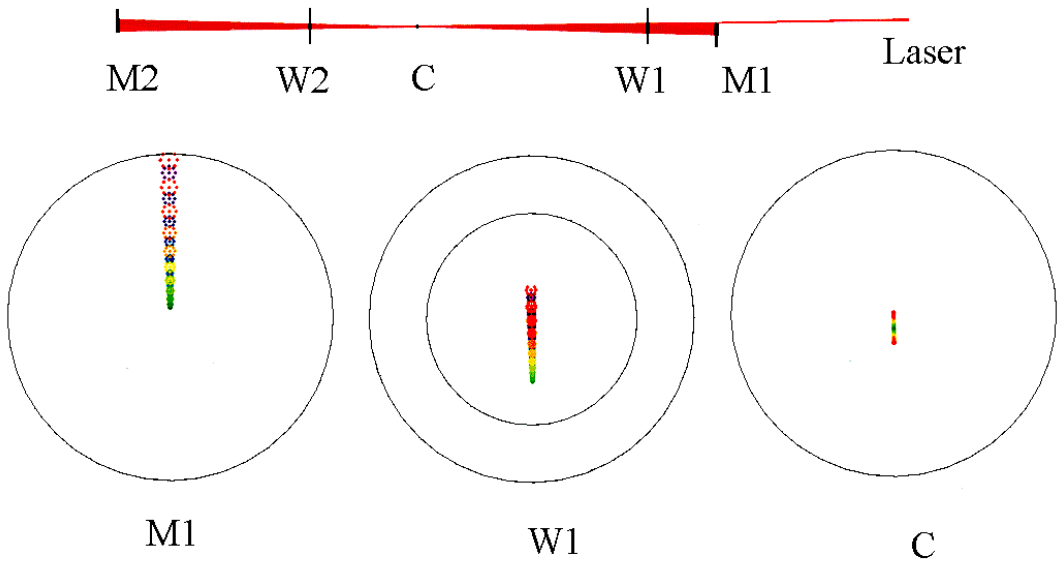


**Figure 2.** Simulation of the ETE multipass injection system (high )with cross sections ( low ) of the first mirror ( M1 ), window (W1 ) and plasma center ( C ).

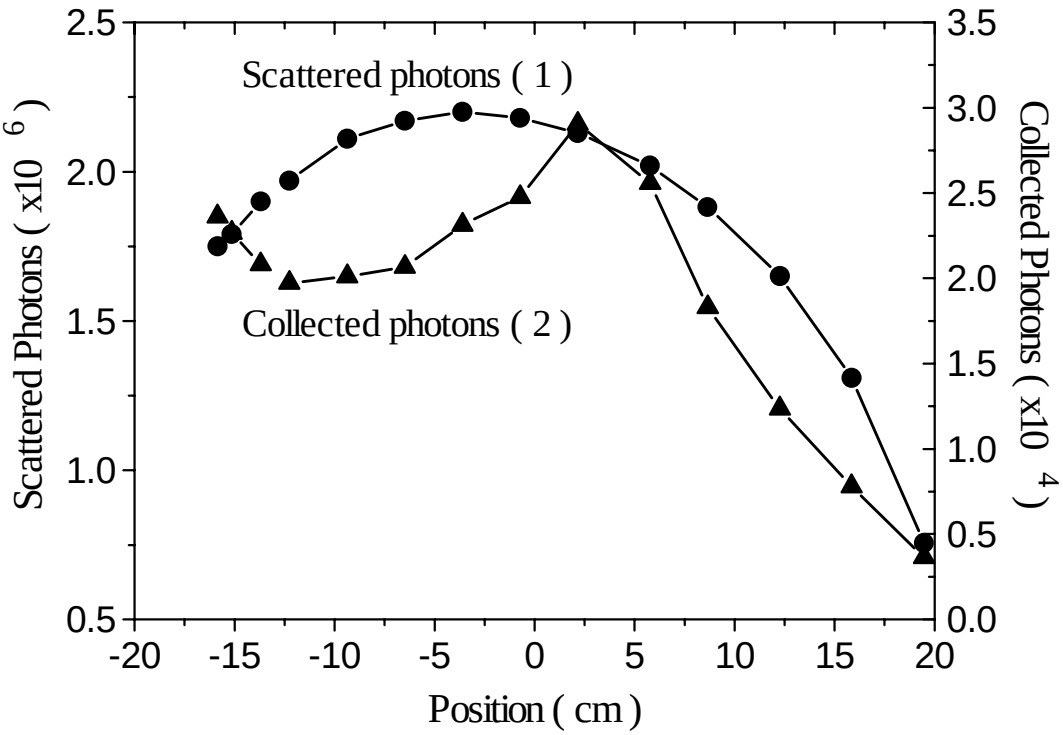


**Figure 3.** Simulation of the collected photons by the system ( curve 2 - solid circles ) compared with the plasma scattered photons ( curve 1 - solid triangles ).