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Optimizing Plasma Spectroscopy Diagnostic in the TCABR Tokamak: Simulating an Advanced Opto-Mechanical System for High Temporal and Spatial Resolution in Plasma Rotation Velocity Measurements

D.O. Novaes[1,2] , J.H.F. Severo [1], F.B. Rizzato[2] , F.A.F. Albuquerque [4], T. Fernandes[1]

(1) Plasma Physics Laboratory, Institute of Physics, University of São Paulo, Brazil; (2) Institute of Physics, Federal University of Rio Grande do Sul; (3) Faculty of Technology of São Paulo FATEC-SP

INTRODUCTION

Plasma rotation's significant role in enhancing confinement time and suppressing MHD instabilities in tokamaks has spurred interest in high-resolution diagnostic methods.

A novel method developed at the IFUSP Plasma Physics Laboratory detects Doppler displacement of plasma emission lines through high-temporal-resolution spectroscopy.

To support this, a new opto-mechanical system is being designed and simulated.

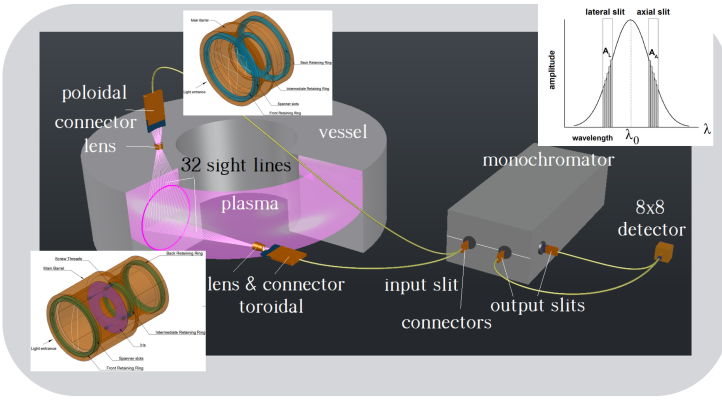
OBJECTIVE

Simulate a novel method with 16 lines of sight in both the toroidal and poloidal directions. This extended capability aims to enable comprehensive observations of the entire plasma column with high temporal resolution,

METHODOLOGY

The simulations were carried out in the Optic Studio Zemax/Ansys software working in Sequential Mode.

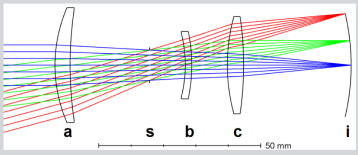
- Optical fiber NA = 0.12; Core diameter = 400 µm;
- Pupil diameter = 12.5 mm; Object Height = 6 mm.



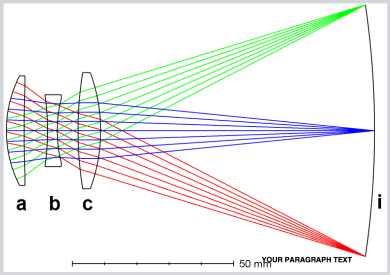
RESULTS

THE DESIGNED LAYOUTS OF THE TOROIDAL (Lt) AND POLOIDAL (Lp) LENSES

Each color of the light rays represents fields with parallel rays emitted from the source at various angles.

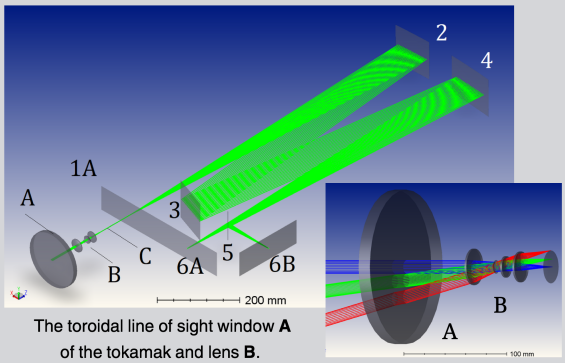


The plasma light undergoes refraction at elements **a**, **b**, and **c**, ultimately forming an image in the curved surface **i**, precisely at the entrances of the optical fibers.



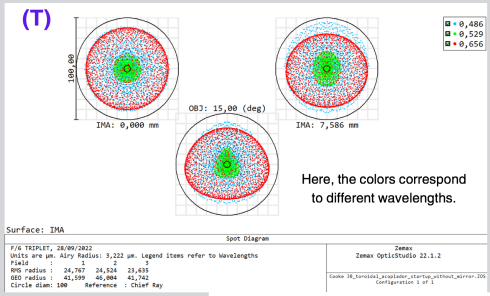
Notably, the toroidal configuration features the iris stop **s**, while the poloidal design incorporates the element **b** as a stop.

SHADED MODEL OF SEQUENTIAL MODE OPTICAL SYSTEM



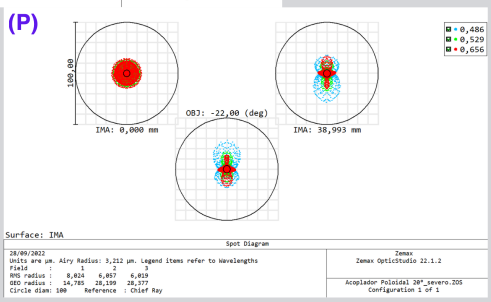
The toroidal line of sight window **A** of the tokamak and lens **B**.

SPOTS OF SIMULATED TOROIDAL (T) AND POLOIDAL (P) LENSES



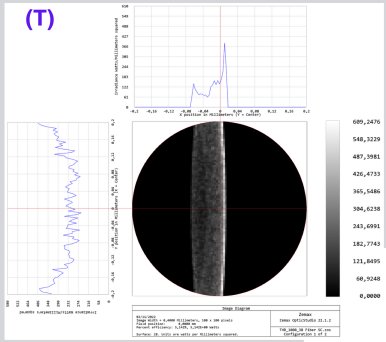
Here, the colors correspond to different wavelengths.

The spot diagrams at the entrances of the optical fibers localized in the *toroidal conector* **Ct** (at left) and *poloidal connector* **Cp** (below) of the optical system simulation in sequential mode.



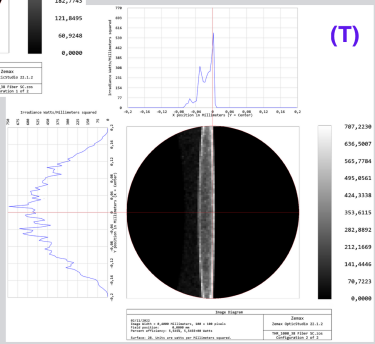
The simulated spots at 529 nm are ~10 times smaller than the 400 µm diameter of the optical fiber core.

IMAGE DIAGRAMS AND ENERGY DENSITY DISTRIBUTION



The image diagrams (black disks) at the entrances of the optical fibers in the *axial output slits* **FSa** (at left) and *lateral output slits* **FSl** (below) of the optical system simulation in sequential mode.

The energy density distribution is spread across the area where the optical fiber will be positioned. An efficiency slightly exceeding 5% of the radiance launched into the system is observed. These results take into account the effects of scattered and internally reflected rays. Without these effects, the efficiency could potentially reach around 60%.



CONCLUSIONS

The simulation enables us to observe the variation of light patterns across each optical system component. While the patterns over the entrance optical fiber are satisfactory, the image patterns exhibit pronounced astigmatism and coma.

These optical aberrations need to be mitigated in upcoming simulations prior to constructing the actual optical system.

ACKNOWLEDGMENT

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E-MAIL

douglas.novaes@ufrgs.br