Conversion of electrostatic Bernstein waves in the SCR-1 Stellarator using a full wave code

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MOTIVATION

The Stellarator of Costa Rica 1 (SCR-1) was designed, constructed and implemented at TEC, with the main goal to carry out engineering and physics research in small magnetic confinement devices [1]. Other aims are:

- To identify problems related to the design and construction of small modular stellarators.
- To train human resources in fusion technology and physics.
- To collaborate with international research centers in the pursuit of nuclear fusion energy.
- To strengthen the participation of Latin America in fusion research.

This work presents new computational results related with single O-X pass conversion with microwave heating scenarios. The BS-SOLCTRA(Biot-Savart Solver for Computing and Tracing magnetic fields) code also has been improved with a better visualization quality and parallel execution that turns into an easy, high performance computing platform. Vacuum magnetic flux surfaces measurements are compared with the BS-SOLCTRA code calculations to verify the design and correct position of the coils.

SCR-1 parameters

- 2-field period modular Stellarator
- Major radius R= 247.7 mm
- Aspect ratio = 6.2
- Low shear configuration
- ι_o=0.312 and ι_a=0.264
- 6061-T6 aluminum vacuum vessel
- ECH power 5 kW (2.45 GHz), second harmonic (B = 43.8 mT), $\langle \boldsymbol{B} \rangle$ = 41.99 mT
- 12 modular coils with 6 turns each
- 725 A per turn, providing a total toroidal field (TF) current of 4.35 kA-turn per coil
- The coils will be supplied by a bank of cell batteries of 120 V
- Plasma pulse between 4 s to 10 s

SCR-1 plasma parameters

- Minor plasma radius: 39.95 mm
- Line averaged electron density: 5 $\times 10^{16}$ m^{-3}
- Plasma density cut-off value of 7.45 $\times 10^{16}$ m^{-3}
- Estimated energy confinement time: 5.70 $\times 10^{-4}$ ms (of ISS04 [Ref.2])
- Plasma volume: 7.8 liters (0.0078 m^3)
- β_{Total}=0.001 %
- Electron temperature: 6 - 14 eV

Conclusions

- Microwave heating scenarios proved the existence of UHR layer with a O-X conversion between 10%-12% (previous results).
- The BS-SOLCTRA code took its first steps to turn into a full-scale simulation–visualization infrastructure with the option of to generate better visualization quality of magnetic flux surfaces and it was parallelized to enhance performance demands.
- The magnetic mapping experiment confirmed the correct positioning of the modular coils in SCR-1.

SCR-1 Stellarator

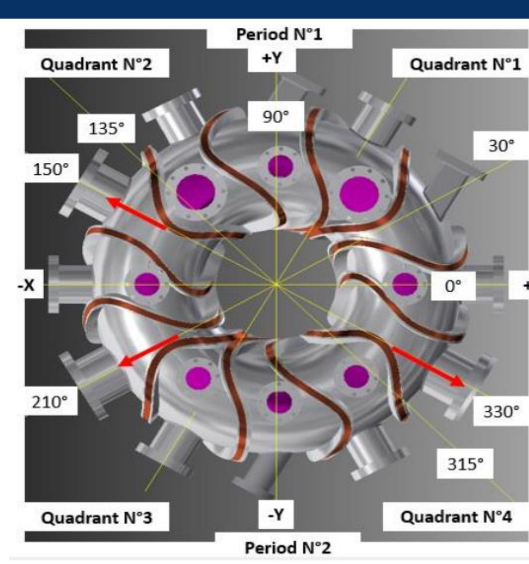

Figure 1. Schematic upper view of SCR-1 Stellarator

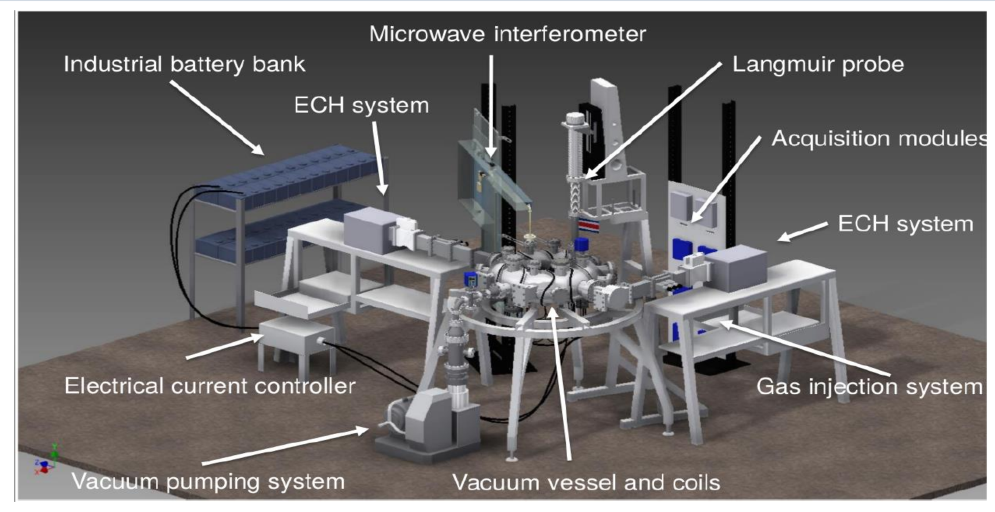

Figure 2. SCR-1 Main Components.

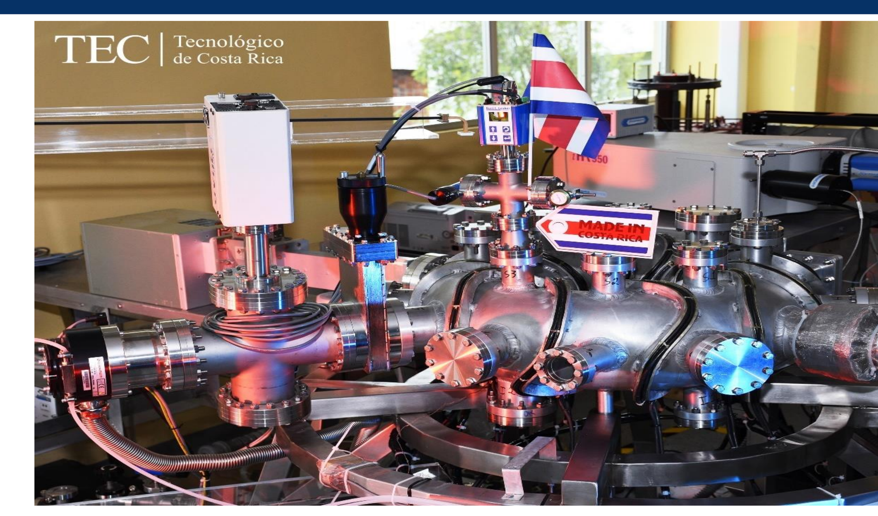

Figure 3. SCR-1 at Instituto Tecnológico de Costa Rica.

Microwave Heating Scenarios

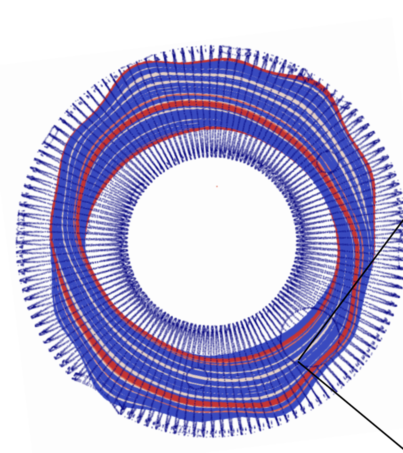

Figure 4. Last closed magnetic flux Surface in 3 Dimension generated by BS-SOLCTRA code.

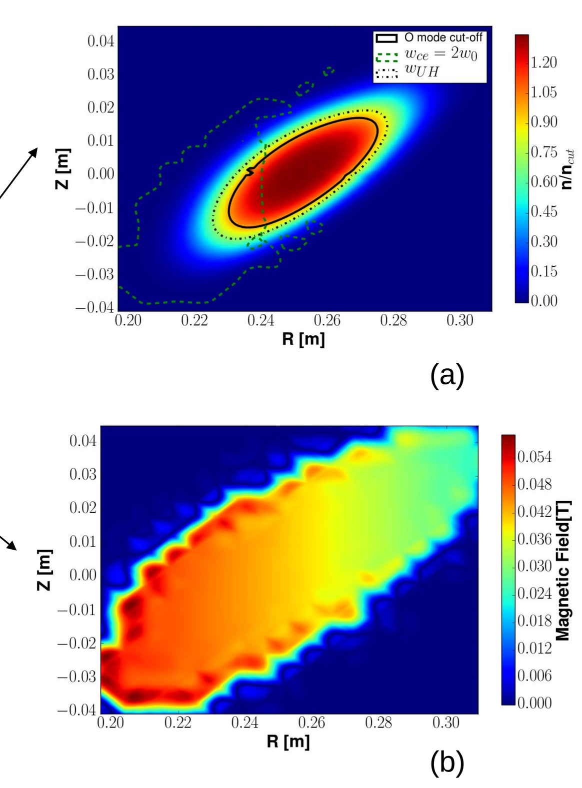

Figure 5. (a) Electron density and (b) magnetic field strength contour map for the toroidal position at 330°.

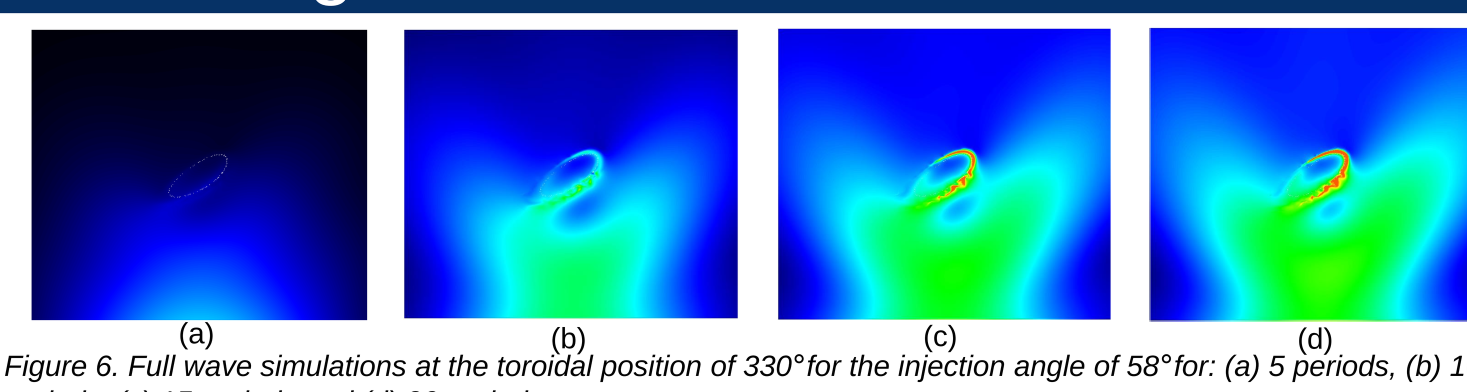

Figure 6. Full wave simulations at the toroidal position of 330° for the injection angle of 58° for: (a) 5 periods, (b) 10 periods, (c) 15 periods and (d) 20 periods.

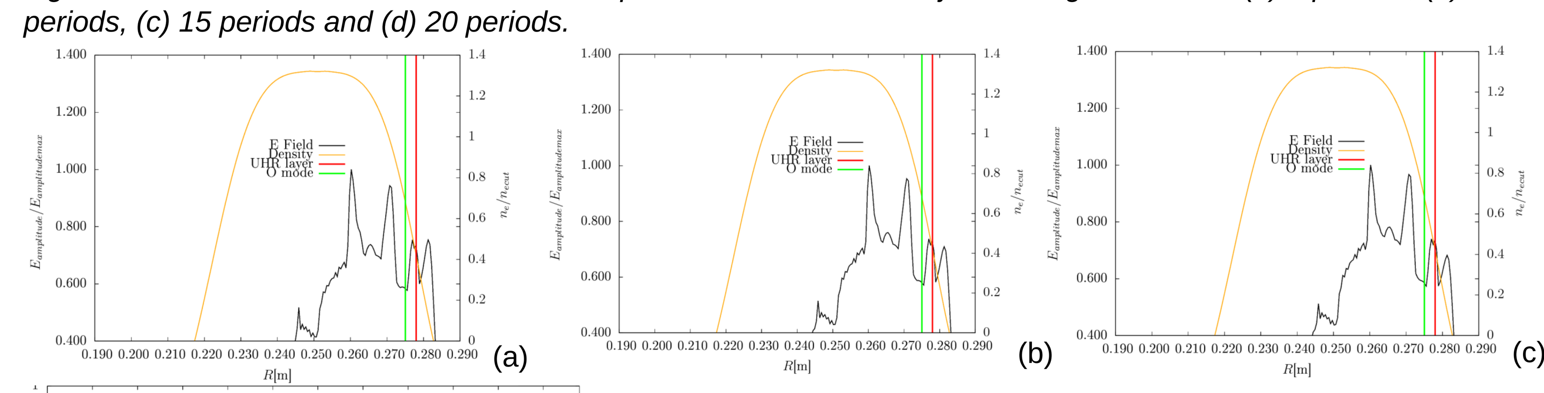

Figure 7. Amplitude variations of the electric field of the electromagnetic wave for (a) 1.1w$_0$, (b) 1.5w$_0$ and (c) 1.9w$_0$

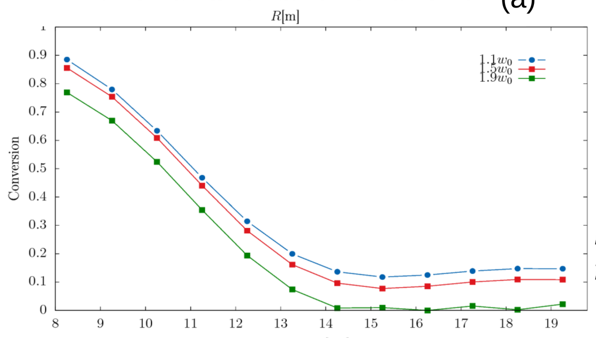

Figure 8. Percentage of single pass conversion from O mode to X mode for different beam sizes.

The BS-SOLCTRA code

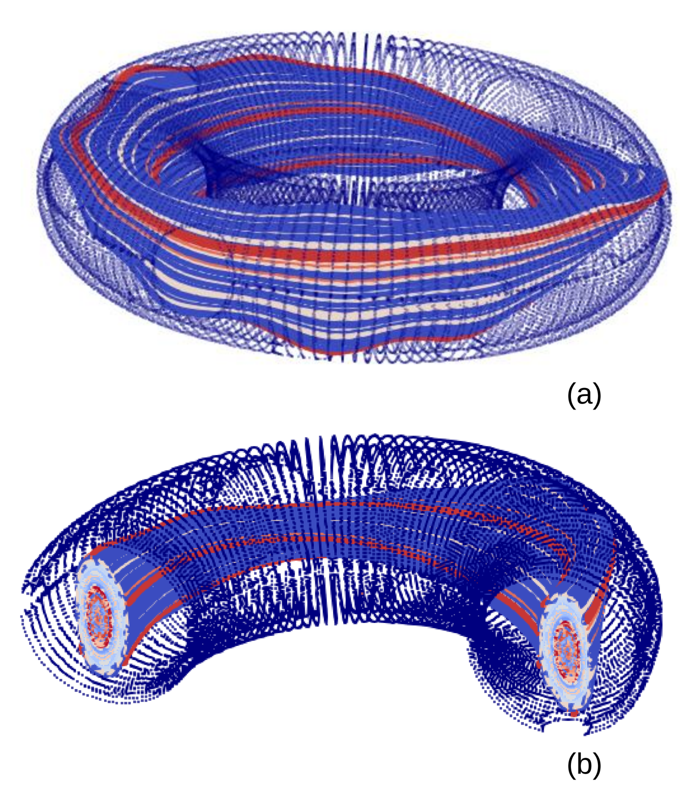

Figure 9 Last closed magnetic flux Surface in 3 Dimension generated by BS-SOLCTRA code for (a) an half cut and (b) lateral view

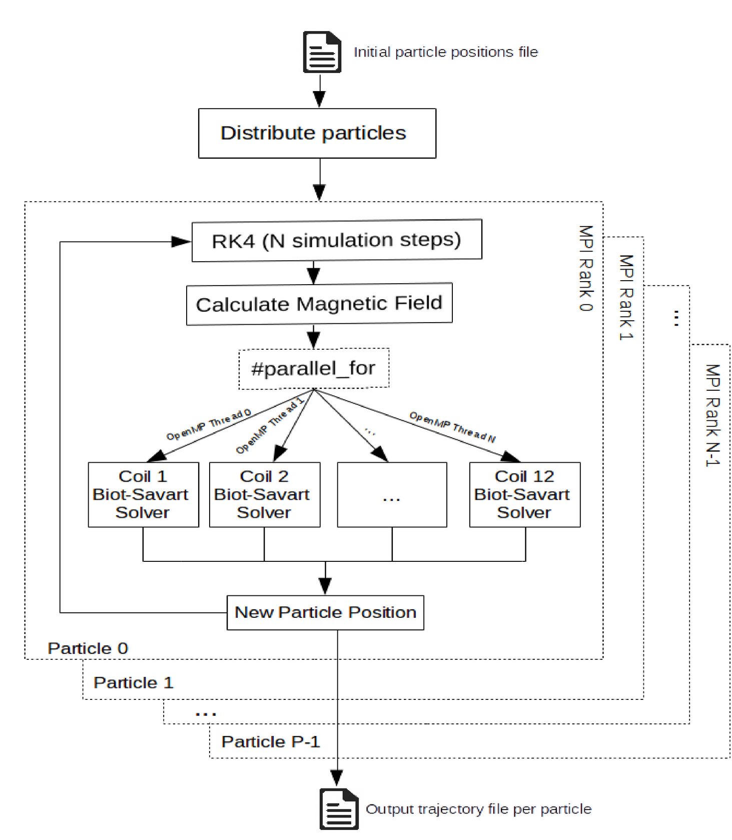

Figure 10. Flowchart of the parallel BS-SOLCTRA implementation

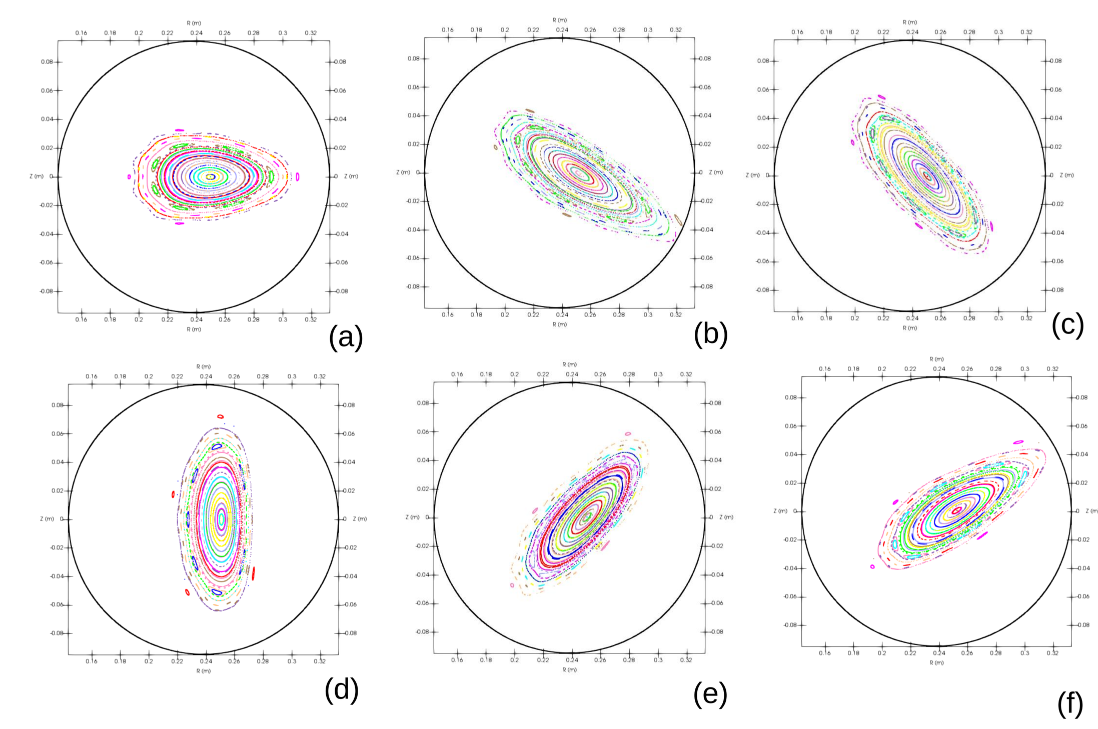

Figure 11. Vacuum magnetic flux surfaces at toroidal positions of: (a) 0°, (b) 30°, (c) 45°, (d) 90°, (e) 135° and (f)150°

Magnetic Mapping

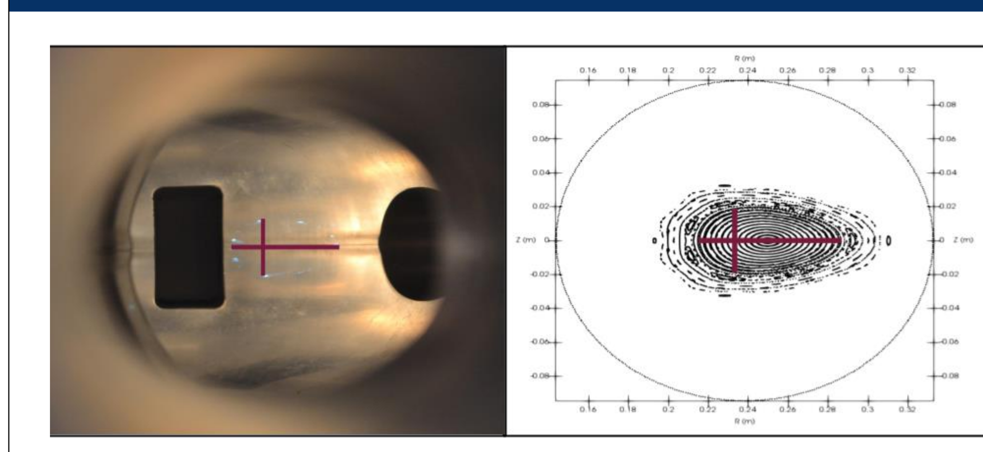

Figure 12. Comparision between (a) points where the hits on the oscillating rod, obtained using a high speed camera and (b) Poincare diagram at the toroidal position of 0° using modified BS-SOLCTRA code.

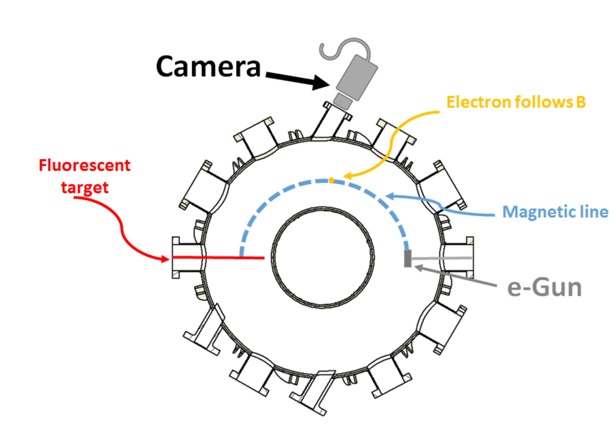

Figure 13. Experimental scheme of the magnetic mapping experiment

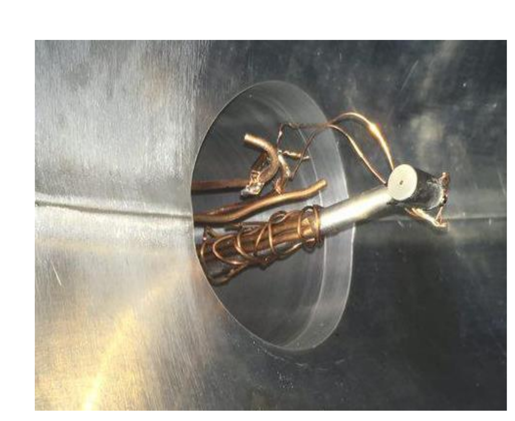

Figure 14. e-gun installed at SCR-1 stellarator vacuum vessel

References

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[2] Yamada H. et al., Nucl. Fusion 45, 1684 (2005).
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