Overview of the SCR-1 Stellarator

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TEC | Tecnológico de Costa Rica

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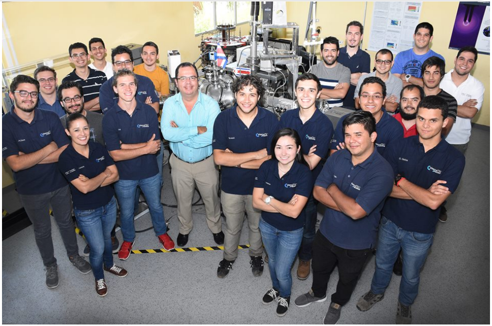
Outlines

Motivation

- Train human resources in fusion technology.
- Collaborate with international research centers in the pursuit of nuclear fusion energy.
- Strengthen the participation of Latin America in fusion research.
- Identify problems related to the design and construction of small modular stellarators

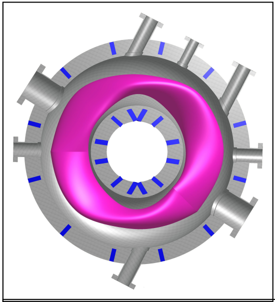
SCR-1 Stellarator

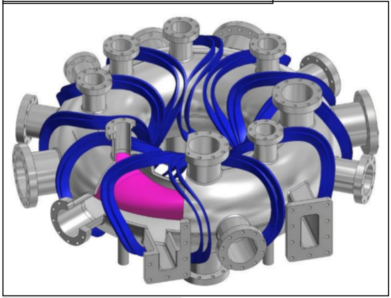


PlasmaTEC team

SCR-1 parameters

- **2-field period** modular stellarator.
- Aspect ratio $= 6.2$
- Major radius $R = 247.7\,\text{mm}$
- Low shear configuration
- $\iota_0 = 0.312$ and $\iota_a = 0.264$
- **6061-T6 aluminium** vacuum vessel
- ECRH power 2.45 GHz, second harmonic $(B = 43.8\,\text{mT})$, $\langle B \rangle = 41.99\,\text{mT}$.

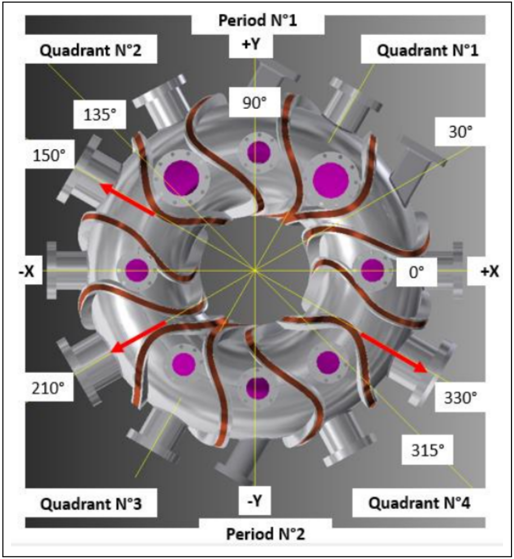




SCR-1 model

SCR-1 parameters

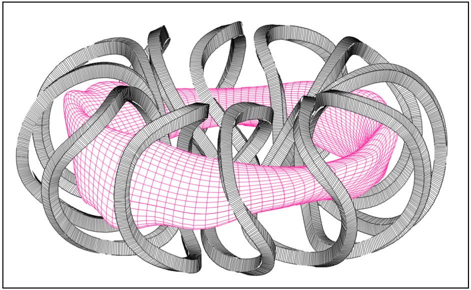
- Two magnetrons with a maximum output power of 2 kW and 3 kW.
- **12 modular coils** with **6 turns each**.
- 725 A per turn, providing a total toroidal field (TF) current of 4.35 kA – turn per coil.
- A bank of cell batteries of 120 V.
- Plasma pulse between 4 s to 10 s.



Schematic upper view of SCR-1 Stellarator

SCR-1 plasma parameters

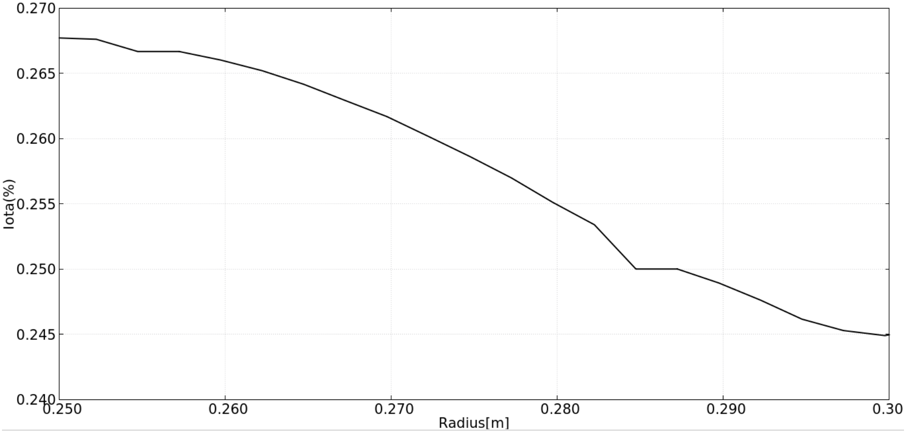
- Minor plasma radius = 39.95 mm.
- Estimated electron temperature = 10 eV.
- Electron density = $5 \times 10^{16}\,\mathrm{m}^{-3}$
- Estimated energy confinement time = 5.70×10^{-4} ms(of ISS04 [Ref.1]).
- Plasma density cut-off value of $7.45 \times 10^{16}\,\mathrm{m}^{-3}$.
- Plasma volume = 7.8 l($0.0078\,\mathrm{m}^3$)



Last Closed Magnetic Surface in SCR-1 Plasma

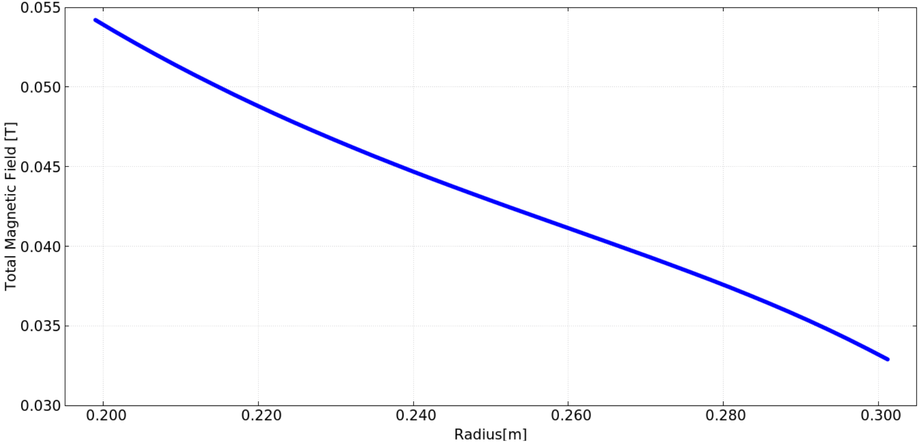
[1]Yamada H. et al., Nucl. Fusion 45, 1684 (2005).

Rotational Transform Profile using VMEC code



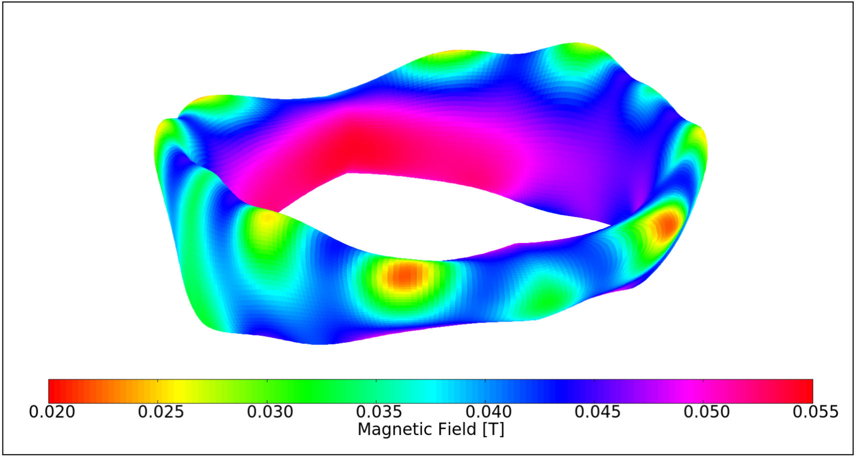
Rotational transform profile for SCR-1 stellarator at 0° toroidal angle

Magnetic Field Calculations using VMEC code



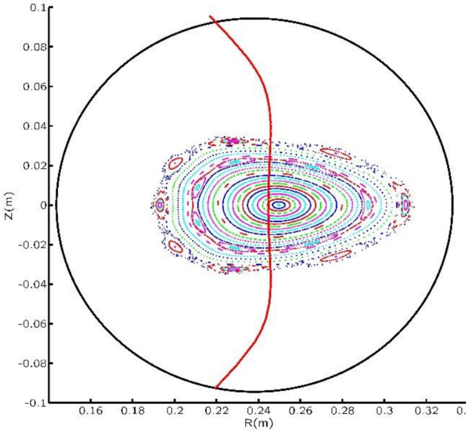
Magnetic field Module at 0° toroidal angle

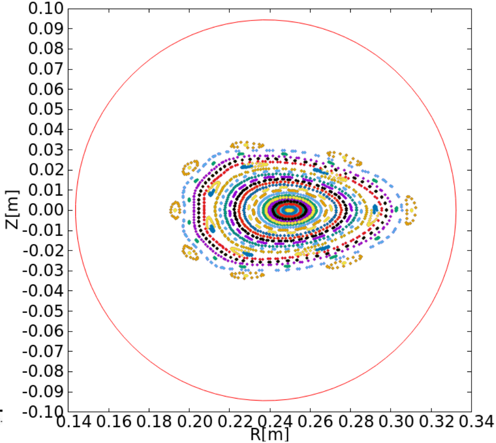
Magnetic Field Calculations using VMEC code



Magnetic field of the last closed magnetic surface for the SCR-1 Plasma

Magnetic Flux Surfaces at 0°



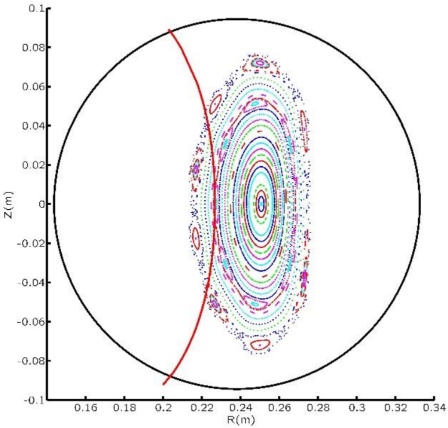


BSOLCTRA code

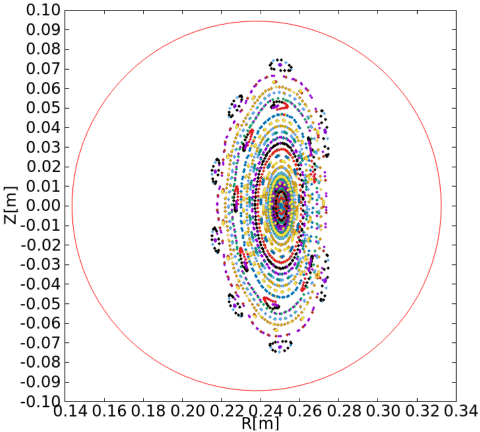
POINCARE code

Biot - Savart Solver for Compute and Trace Magnetic Fields)

Magnetic Flux Surfaces at 90°

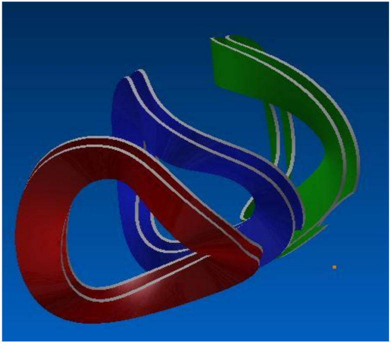


BSOLCTRA code



POINCARE code

Modular Coils



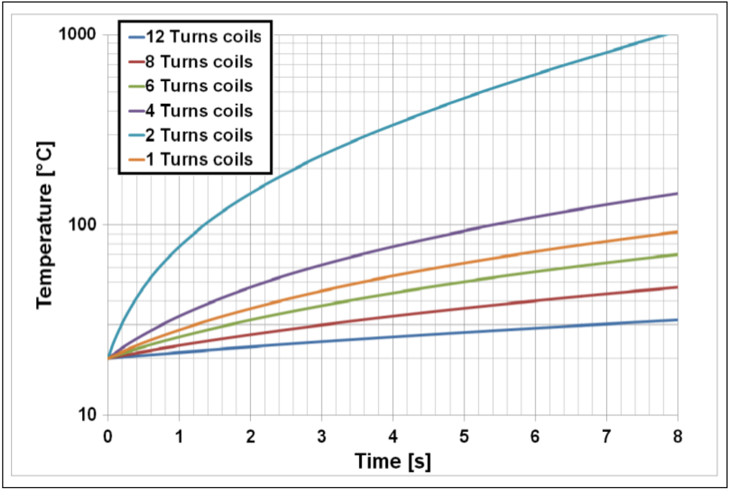
Helical coils design

AWG4 Wire

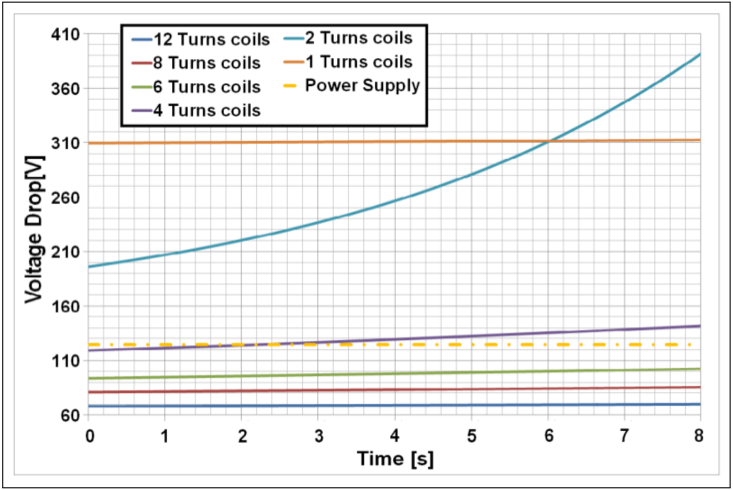
Modular Coils

Upper view of SCR-1

Modular Coils



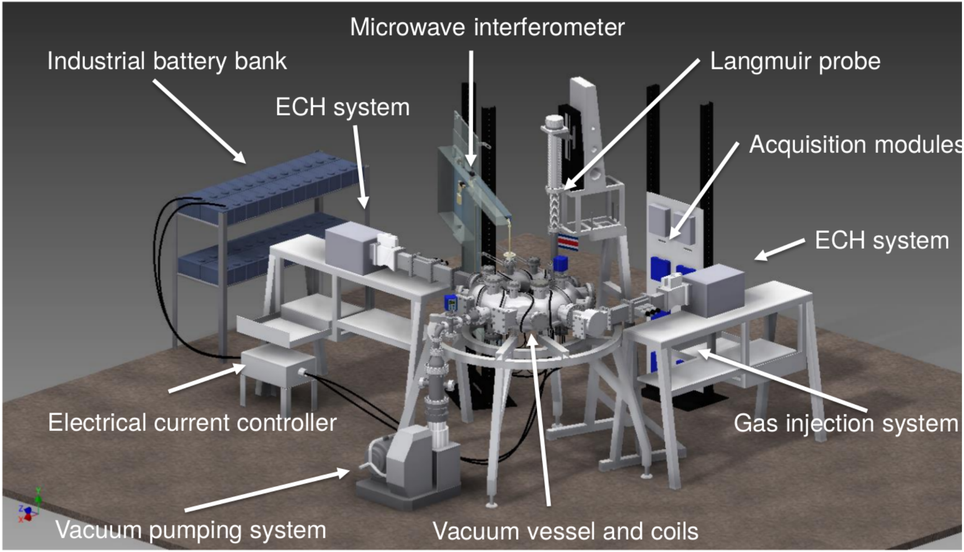
Simulation of temperature comparison between different wire configurations.[Ref 2]



Simulation of voltage-drop vs time for the battery bank of the SCR-1. [Ref. 2]

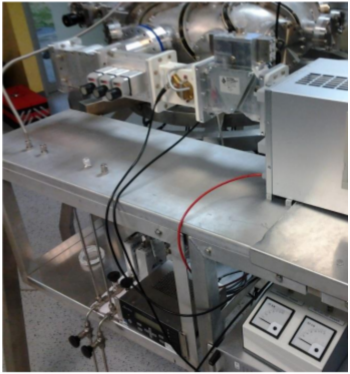
[2]Vargas, V. I., et al. 2013. "Engineering issues to the stellerator of Costa Rica 1". 1-6.

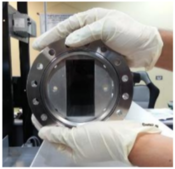
Support Structure

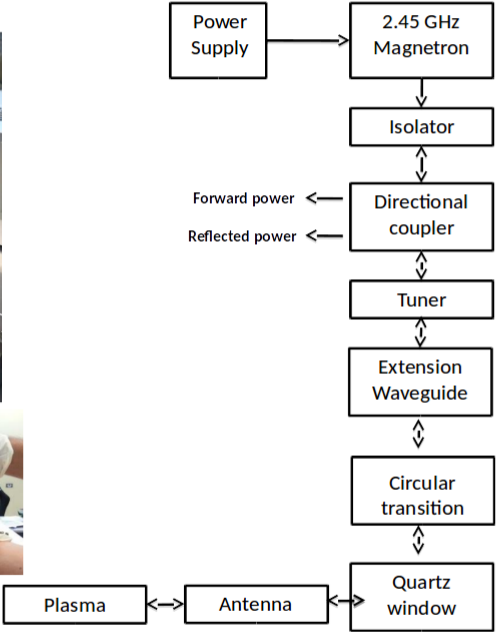


Set of equipments attached to the SCR-1 stellarator

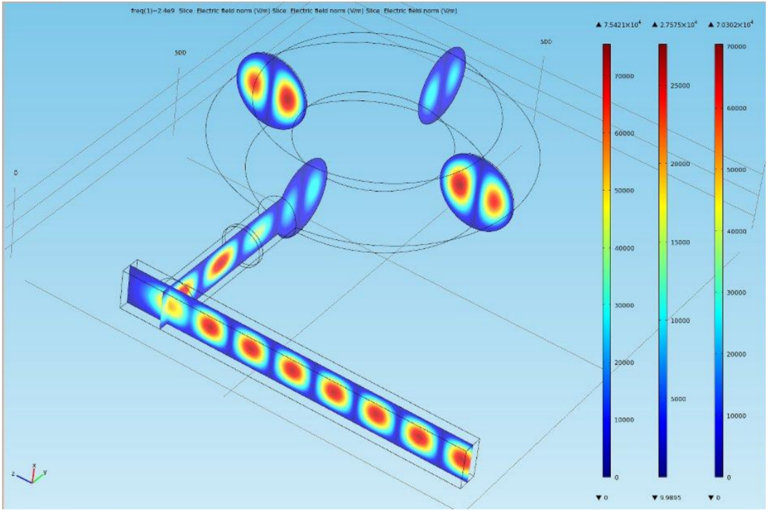
ECR Heating System





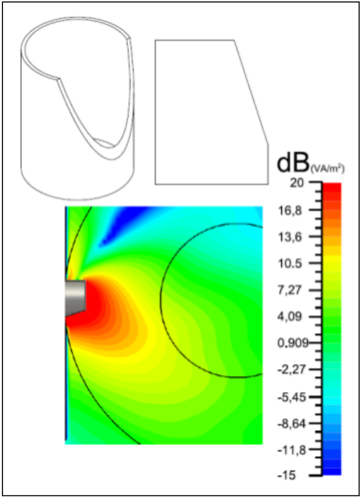


ECR Heating System

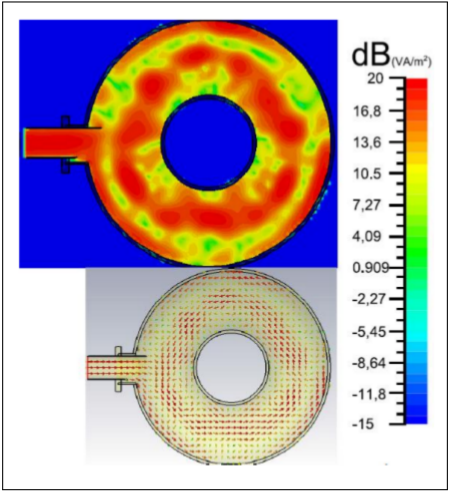


Simulations of electric field norm

Antenna for improving the plasma heating

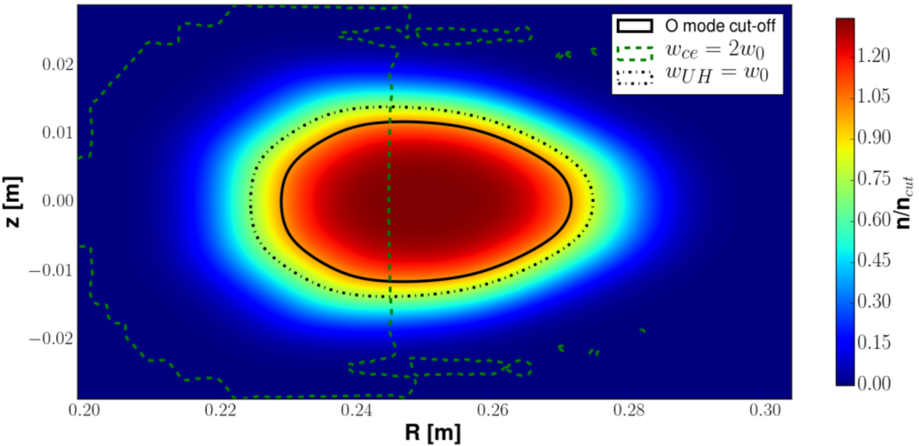


Design of the Vlasov antenna



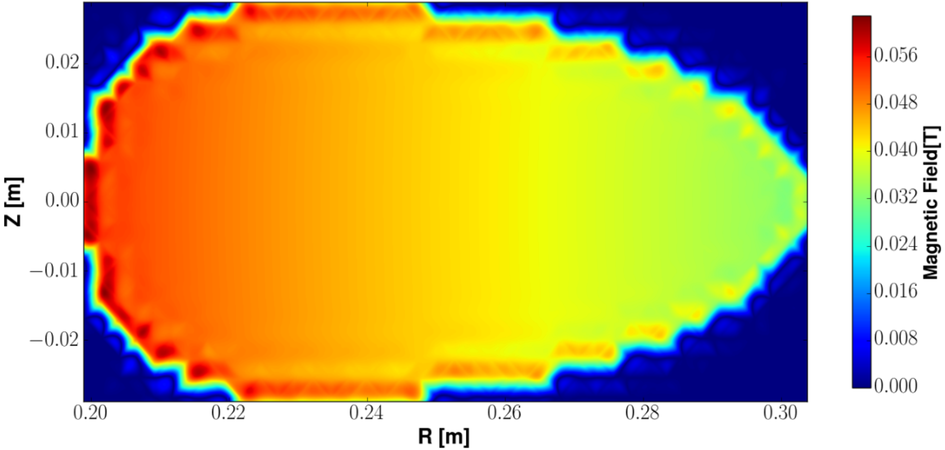
Microwave scenario

Full wave simulations using IPF-FDMC code



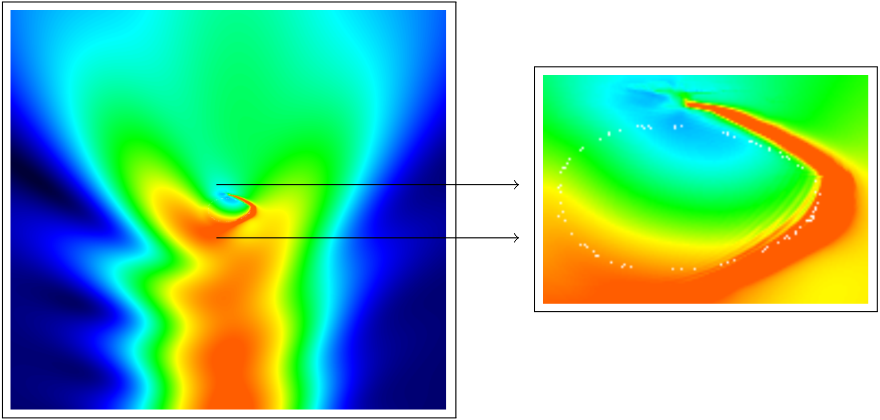
Contour map of electron density and frequencies at 0°

Full wave simulations using IPF-FDMC code



Contour map of the magnetic field at 0°

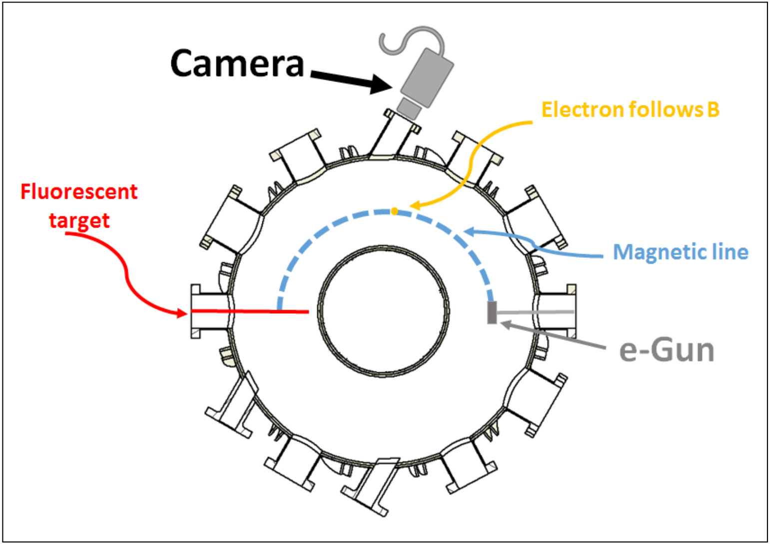
IPF-FDMC Full wave code



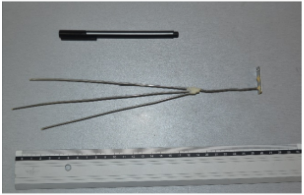
Simulations of the rms-value of the wave electric field in O- mode configuration

- O-X-B conversion
- Angle of the antenna in the toroidal direction $= 40^{\circ}$

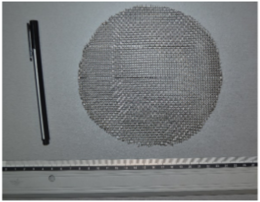
Magnetic mapping experiment



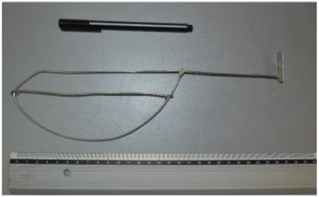
Magnetic mapping experiment methods



Oscillating Rod

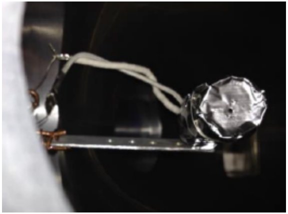


Mesh



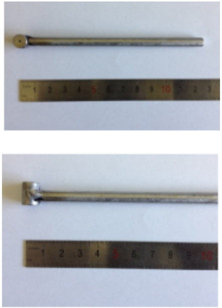
"Cuchillo de mantequilla"

Electron Gun prototypes



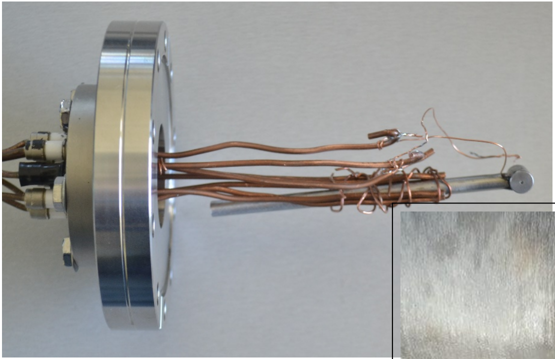
First e-gun tested

Second e-gun tested

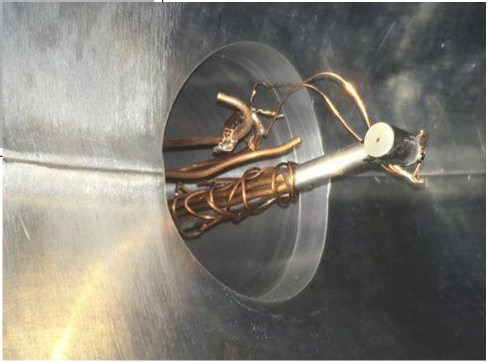


Final e-gun

Electron gun mounted

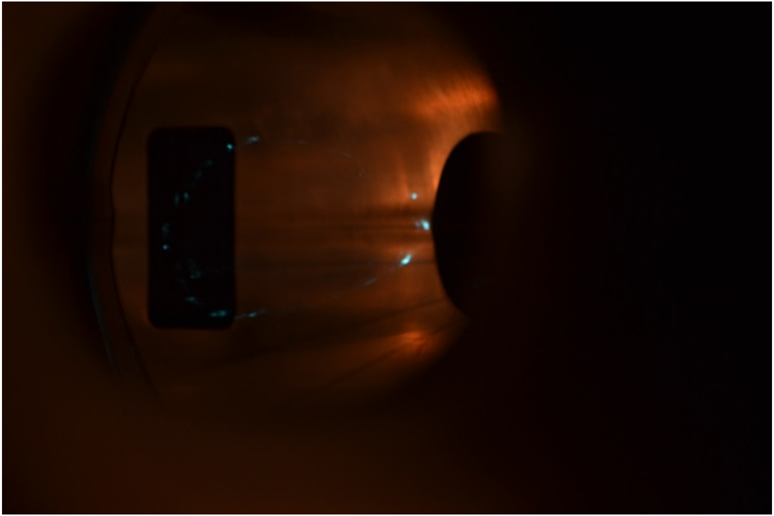


Electron gun



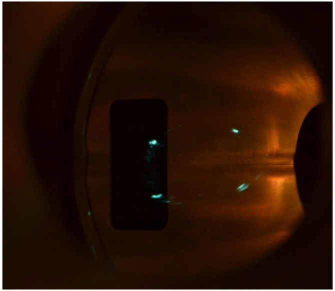
E-gun mounted inside the vacuum vessel

Results of the magnetic mapping experiment

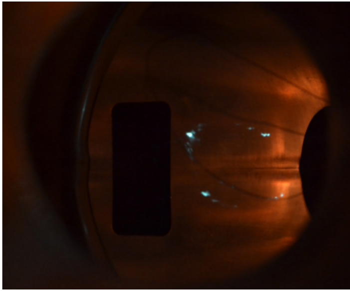


Results of the magnetic mapping experiment

Mesh

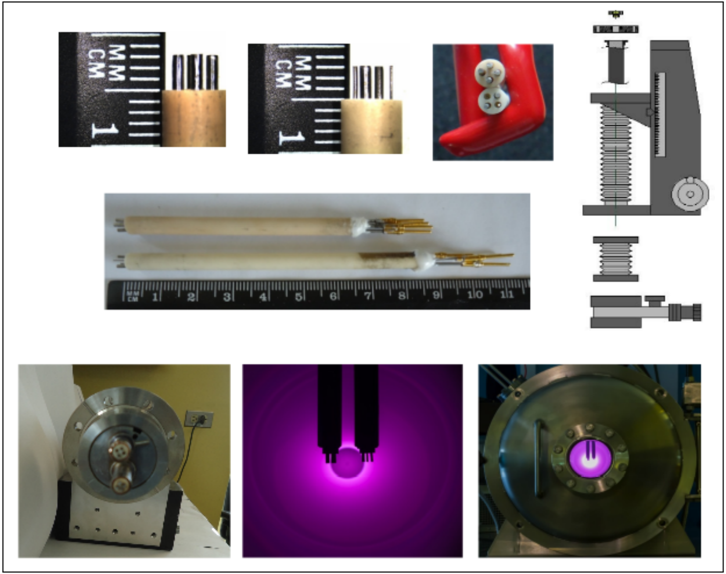


Oscillating rod



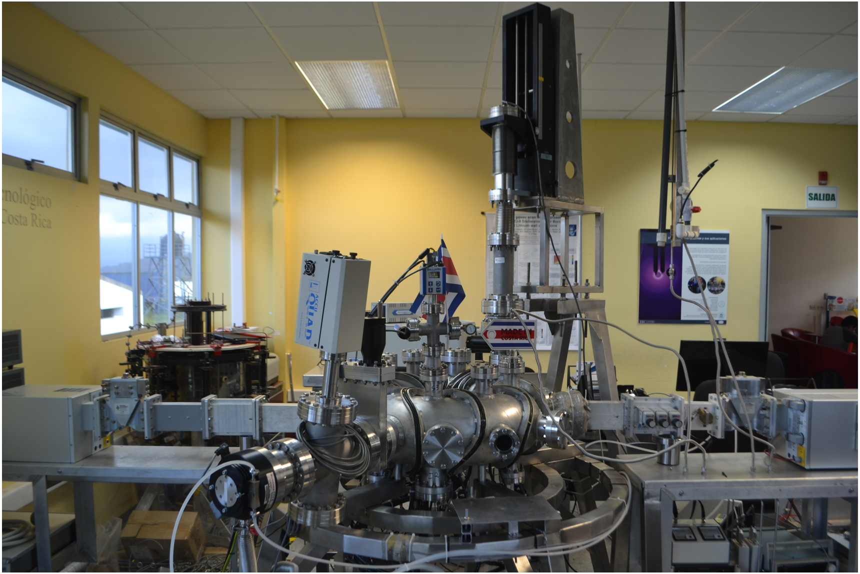
"Cuchillo de mantequilla"

Langmuir Probe



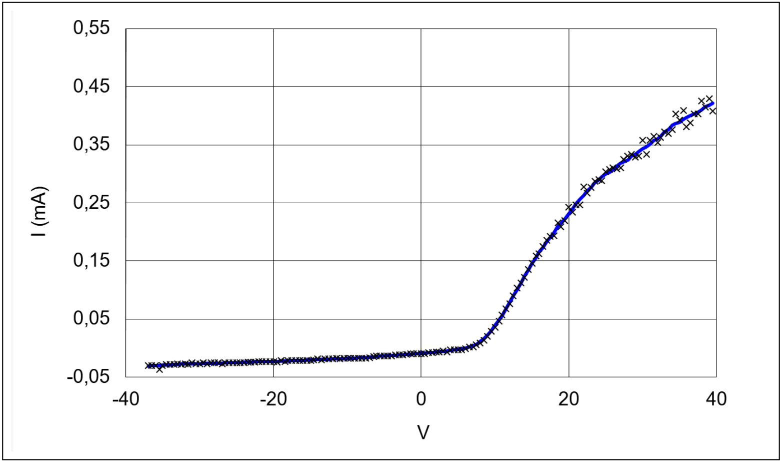
Langmuir probe set and different parts

Langmuir probe at SCR-1 Stellarator



Langmuir probe at SCR-1

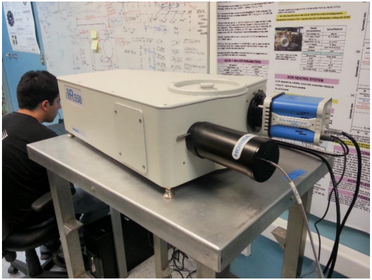
Langmuir probe results



- Electron temperature 5.29 eV.
- Electron density $5 \times 10^{14}\,\mathrm{m}^{-3}$.
- Nominal power 784 W.

Optical Spectrometer

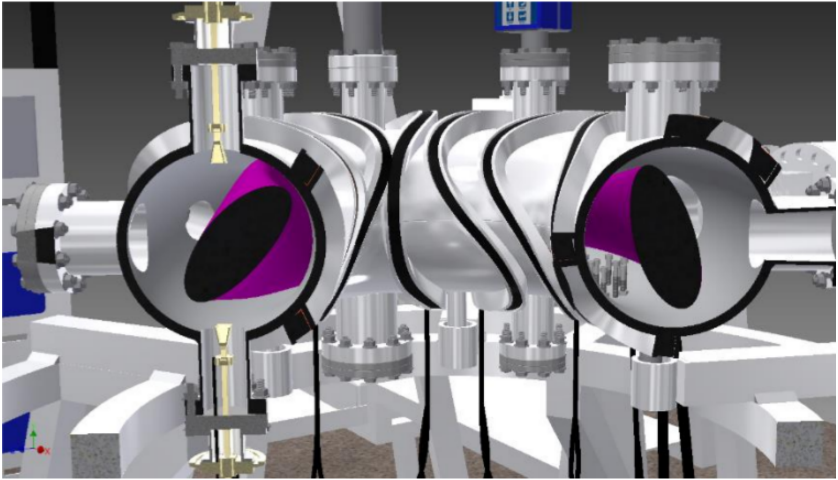
Focal Length	550 mm
Aperture	f/6.4
Spectral Range	150 to 1500 nm with 1200 g/mm
Resolution with exit slit and PMT	0.025 nm
Wavelength accuracy	±0.20 nm
Repeatibility	±0.075 nm
Spectral Dispersion	1.34 nm/mm



iHR550 optical spectrometer

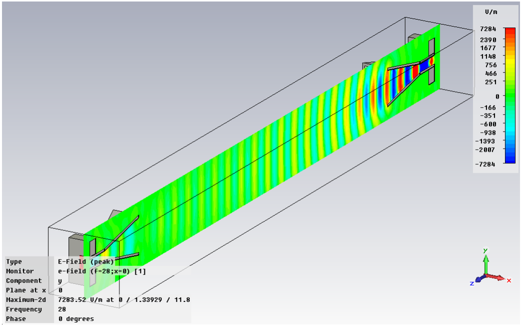
Colimator and focusing lens

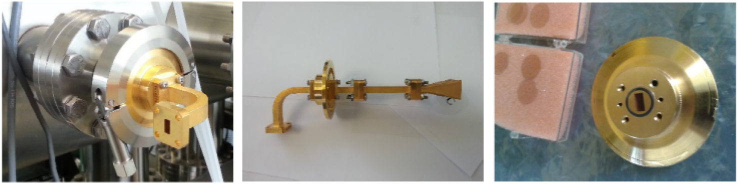
Microwave Heterodyne Interferometer



Microwave heterodyne interferometer in SCR-1 stellarator

Microwave Heterodyne Interferometer





Electric field simulation of the incident wave and CF to KF adapter and feedthroughs

Summary and Conclusions

- A small modular stellarator was designed, constructed and implemented at the Instituto Tecnológico de Costa Rica.
- The main goal is to provide a tool to carry out engineering and physics research of small-size confinement magnetic devices.
- Results of POINCARE and BSOLCTRA codes are in concordance with each other.
- Microwave scenario at $0°$ toroidal angle shows a variation of the wave electrical field that can be significant for the conversion to the Electric Bernstein Waves. Nevertheless, we have to explore more scenarios.
- The electron temperature and density for the plasma in SCR-1 is approximately 5 eV and 10^{14} m^{-3} for a nominal power of 732 W.
- The magnetic mapping experiment and the magnetic flux surface at $0°$ toroidal angle, calculated by Poincare and BSOLCTRA are similar with the magnetic mapping methods.

Next steps

- To measure the electron density and temperature profiles in the SCR-1 Stellarator.
- To simulate scenarios for an Electron Bernstein Heating System in the SCR-1 Stellarator (experience of TJ-K) with the IPF-FDMC full wave code taking into account the geometry of the vacuum vessel.
- To start the design of SCR-2 Stellarator using the STELLE configuration and VMEC for obtaining the MHD equilibrium.