

Initial Results of Magnetic Surface Mapping in the WEGA Stellarator

M. Otte, J. Lingertat

*Max-Planck-Institut für Plasmaphysik, Euratom Association, TI Greifswald,
Wendelsteinstraße 1, 17491 Greifswald / Germany*

Abstract

The vacuum configuration of magnetic flux surfaces in the WEGA stellarator has been studied using the fluorescence method. In the experiments the rotational transform ι was varied between 1/9 and 1 for a toroidal magnetic field strength of $B_t=87.5\text{mT}$. We have shown that the magnetic coil system of the WEGA generates good nested magnetic surfaces especially at low ι values. However, in the experiments non-natural islands have been observed caused by field perturbations which are still under investigation. The experimental results are compared with calculations obtained from the *Gourdon-* and *Werner-*code.

1. Introduction

The WEGA (Wendelstein Experiment in Greifswald für Ausbildung) is a classical stellarator and was established as an EURATOM collaboration between the Max-Planck-Institut für Plasmaphysik/Garching, the Institute C.E.N./Grenoble and the Institute ERM/Bruxelles [1]. The machine was originally built in the '70s in Grenoble/France as a tokamak with 40 field coils. Later the machine was converted to a stellarator by changing the torus (now $R=0.72\text{m}$ and $a=0.19\text{m}$) and adding 4 helical coil packets forming a $l=2$ and $n=5$ configuration. As a unique feature the WEGA torus can be easily separated into two halves without changes of the helix conductors. This is achieved by the introduction of so - called theta bridges, which at the ends of both half-tori return the current of each helical packet into two neighbouring packets.

After successful operation in Grenoble the WEGA was transferred via the Institut für Plasmaforschung, Stuttgart to the Max-Planck-Institut für Plasmaphysik, TI Greifswald in 2000 and rebuilt in a modernised version. The machine is used mainly for educational training, testing of new diagnostic equipment and for basic research in plasma physics. In July 2001 the first stellarator discharge was carried out in the new WEGA device. One of the first tasks performed on the WEGA device has been the evaluation of the magnetic field structure. The results are essential for the interpretation of data obtained by diagnostic equipment located at different toroidal and poloidal positions.

2. Experimental Set -Up

For the experimental mapping of the magnetic flux surfaces the well established fluorescent method was chosen [2, 3, 4]. A small electron gun (diameter = 6.5mm) emits a directed

electron beam with an intensity between 5 and 200 μ A and an energy between 20 and 300eV. Typically, a beam current of $\leq 30\mu$ A at 230eV was used. The diameter of the beam was restricted to ~ 1.5 mm at gun exit. The electron gun was positioned at the toroidal position $\varphi=252^\circ$ and was moveable by a vacuum manipulator in radial direction (Fig.1). For the visualisation of the magnetic flux surfaces a wire-ellipse was inserted at the toroidal positions $\varphi=72^\circ$ and $\varphi=144^\circ$, respectively. The wire-ellipse could be moved in radial direction scanning nearly the whole cross section of the torus within 15s. The wire with a diameter of 1.0mm was coated with fluorescent powder (ZnO:Zn). The fluorescent light generated by electrons striking the wire at the crossing points with the electron beam was recorded by a long-time integrating CCD-camera (Starlight-Xpress HX916) with a resolution of 1300x1030 pixel and a dynamic range of 16bit.

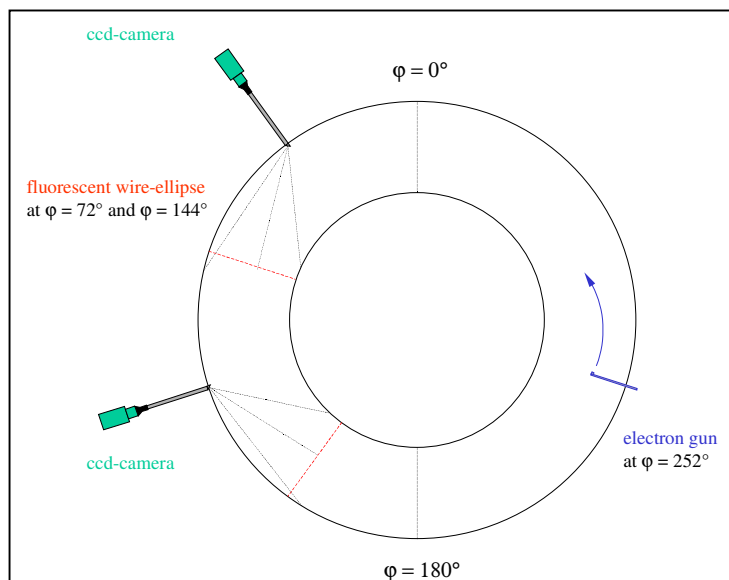


Fig. 1 Top view of experimental setup.

The images were taken through an endoscope with a nearly perpendicular view of the poloidal plane to be mapped as can be seen in Fig. 1. For each position of the electron gun we obtained a single magnetic surface. Due to the small diameter of the electron beam and the high intensity of the fluorescent signal up to 20 flux surfaces could be superimposed using a step width of 0.5cm of the electron gun.

3. Results

The experiments have been carried out scanning a wide ι range from $1/9 \leq \iota \leq 1$ by changing the current in the helical field coils at a constant toroidal field $B_t = 87.5$ mT. For some configurations up to 40 single striking points each representing one toroidal turn of the

electron beam could be distinguished experimentally. The experiments show a good agreement with the calculations in the existence of closed nested magnetic field surfaces as well as the position of the magnetic axis which is shifted inwards by approximately 1.5cm. Also, as can be seen from Fig. 2a and Fig. 3a, the magnetic surfaces at $\iota = 1/7$ and $\iota = 1/3$ are disturbed by non-natural islands caused by unwanted error fields. In fact all islands for $\iota = (n = 1) / m$ with $m = 7, \dots, 3$ have been distinguished experimentally.

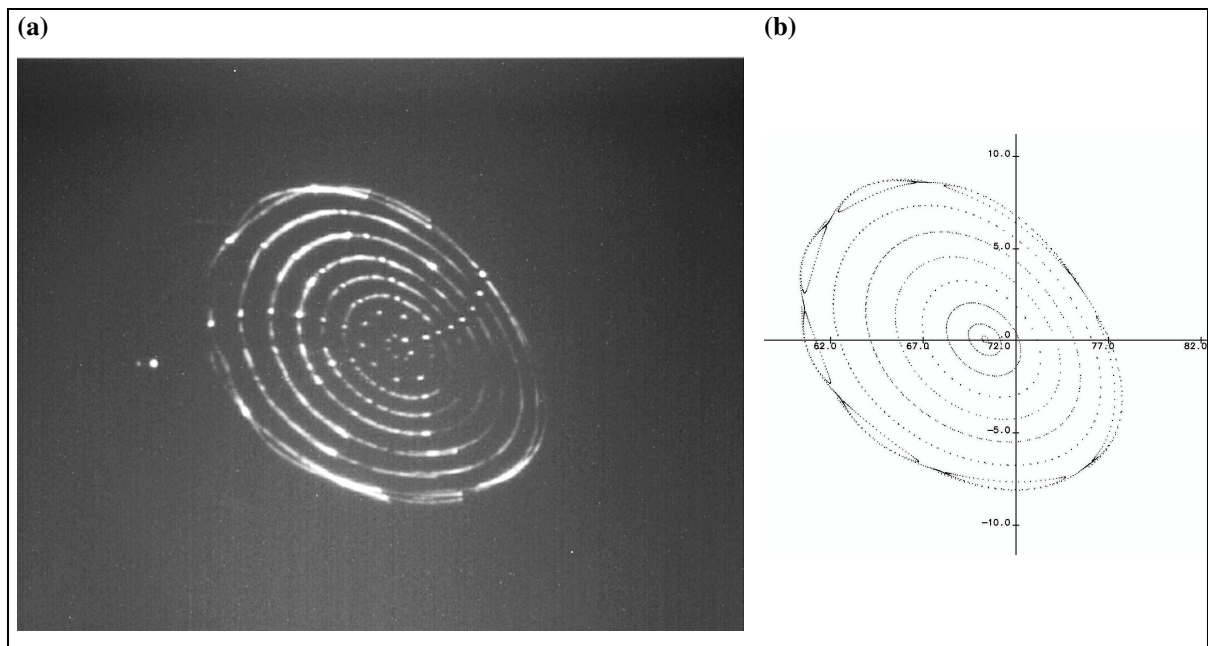


Fig. 2 Measured (a) and computed (b) magnetic surfaces for $\iota = 1/7$ at $\phi = 72^\circ$.

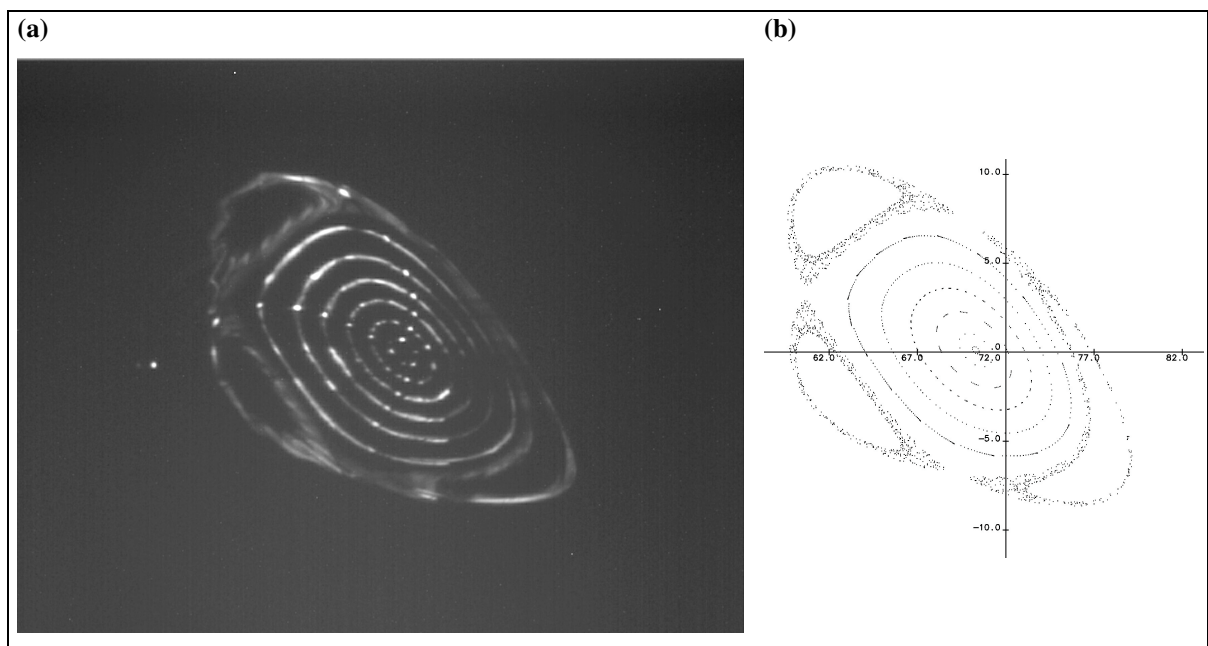


Fig. 3 Measured (a) and computed (b) magnetic surfaces for $\iota = 1/3$ at $\phi = 72^\circ$.

The observed error fields could be caused by a small displacement of the helix windings relative to the toroidal field [2] or an inaccurate position of the helix conductors in the theta bridges. In Fig. 2b and 3b the results of calculations using the *Gourdon*- [5, 6] and the *Werner*-code [7] adapted to the configuration of the WEGA are shown. In order to obtain a similar shape and position of the experimentally observed islands an artificial horizontal homogeneous magnetic field of $B_x = 0.2\text{mT}$ and $B_y = -0.2\text{mT}$ was superimposed and the helical field current was lowered to approximately 95.5%. The same result is obtained by allowing a horizontal shift of approximately 1mm between the axis of the toroidal and helical field coils.

Summary

The recent experimental investigations of the magnetic flux surfaces of the WEGA stellarator have shown the existence of closed nested flux surfaces in a wide ι range. However, the magnetic surfaces are disturbed by an error field of the order $n=1$. The experimental results are in good agreement with calculations based on the *Gourdon*- and *Werner*-code if additional error-fields are assumed. With the knowledge of the size and shape of the islands for the various configurations we are now in a position to investigate transport properties of magnetic islands.

References

1. R. Fritsch et al., Technological aspects of the WEGA stellarator, Proc. 9th Symposium Fusion Technology, Pergamon Press 1976.
2. H. Hailer et al., Max-Planck-Institut für Plasmaphysik, Garching, Annual Report (1987), 191-193.
3. R. Jaenicke et al., Nuclear Fusion 33 (1993) 687.
4. E. Ascasibar et al., J. Plasma Fusion Res. Series, 1 (1998), 183.
5. C. Gourdon, Programme optimise de calcul numerique dans le configurations magnetique toroidales, DPH-PFC-EUR-CEA-FC 449, Janvier 1968.
6. K. Schwörer, Institut für Plasmaphysik, Stuttgart, private communication.
7. A. Werner, Max-Planck-Institut für Plasmaphysik, private communication.