On the Confinement Properties of the Low-Shear Stellarator WIIb

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The confinement of low-ß plasmas in a stellarator magnetic field has been studied in the Wendelstein W IIb stellarator as a continuation of our previous work. This machine is d.c. operated, has a purely circular shape with major diameter of 1 m, avoids interruptions of the helical windings that generate an $\ell = 2$ helical field, and possesses five-fold rotational symmetry. The magnetic confining field has practically no shear but a small average magnetic well, 3-5% in depth. Barium plasma was produced by contact ionization on a radiation heated tantalum sphere located on or near the magnetic axis. Measurements of the steady state density distribution were performed for various values of the magnetic field, the angle of rotational transform and the magnitude of the input ion flux. The particle density was determined by Langmuir probes, resonance fluorescence of the Ba-ions and by microwave phase shift measurements. It has been previously reported [1] that the confinement time of this barium plasma showed rather close agreement with the predictions of the Pfirsch-Schlüter model. However, deviations from this model have been observed (1) for low values of the angle of rotational transform $\iota = \frac{L}{2\pi}$, and (2) for distinct and narrow ranges of L which seem to be connected with the fact whether or not the magnetic lines of force are closed upon themselves after a not too large number of revolutions around the machine.

As for (1), the value of the rotational transform must exceed a certain threshold value in order that the density builds up. As long as this threshold is not surpassed, the steady state density is far below the number calculated from the Pfirsch-Schlüter model. However, once the threshold is surpassed, a hysteresis is observed such that upon reducing the rotational transform below the threshold, the density still follows the theoretically predicted value. New experiments have been performed to study this effect. A tentative explanation considers the influence of collisions and the connection with either the method of plasma production or the mechanism of plasma confinement in the stellarator magnetic field. Residual deviations from the predicted n vs ϵ curves might find their explanation when estimating the effect of ion inertia and considering that the balancing mass flow in a stellarator cannot exceed the velocity of sound.

(2) Considering the appearance of deep minima of the mean particle life time for distinct values of ϵ, the condition of closure of the magnetic lines of force can be satisfied with a high degree of accuracy for an appreciable part of the plasma cross section simultaneously because of the particular construction of the helical windings (low shear). The occurrence of these minima in the confinement time has been studied in more detail making use of improved stabilization of the generator currents which produce the magnetic field components. Profiles of particle density and mean particle life times have been measured for either group of cases, good and bad confinement.

In view of the apparent plasma stability in this low shear stellarator (density fluctuations less than one percent) the question arises to what extent the shallow magnetic well might contribute to stability, for example, by suppressing resistive interchange modes. To study this question a new machine is under construction which has the same physical dimensions but will be equipped with a set of four helical conductors that allow to vary the depth of the magnetic well as well as the amount of shear in the magnetic confining field. A numerical programme has been started to investigate field configurations which result from varying the signs and magnitudes of the currents through these helical windings and from locally changing the pitch angles of these conductors. Results of the numerical calculations will be given and the merits of the various configurations discussed.

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[1] E. Berkl, D. Eckhartt, G. von Gierke, G. Grieger, E. Hinnov, K.U. von Hagenow, W. Ohlendorf
"Confinement of Contact-Ionized Barium Plasma in the Wendelstein Stellarator W II"
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