RFP BOUNDARY CONDITION STUDIES ON TOKAPOLE II

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ABSTRACT

RFP Boundary Condition Studies on Tokapole II.* J.S. SARFF, J.C. SPROTT, L. TURNER**, University of Wisconsin-Madison-- It has been assumed that a reversed-field pinch (RFP) plasma requires a close fitting conducting shell for good stability and confinement. It is not known, however, the extent to which this boundary must be perfectly conducting. In order to form an RFP plasma bounded by a magnetic separatrix far from a conducting wall, we have operated the Tokapole II device, which is normally a four-node poloidal divertor tokamak, with a programmed-reversed toroidal field. We have obtained plasmas in which a reversal surface is formed far from a conducting wall up to 100 μsec. Coincident with reversal is a "quiet" period seen on various diagnostics sensitive to fluctuations. In addition, we present toroidal field profiles and flux plots determined by an analytic solution to $\nabla\times\underline{B}=\lambda\underline{B}$ with constant λ in a rectangular geometry with a perfectly conducting boundary including arbitrary, internal, filamentary currents. Our experiments show that, although there is current outside the separatrix, λ is smaller there than inside the separatrix, so that a constant-λ, force-free model does not hold for these plasmas.

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OUTLINE OF EXPERIMENTAL WORK:

J.S. SARFF and J.C. SPROTT

I. The TOKAPOLE II device.

II. The field, voltage, and current waveforms used in the "RFP mode" operation of Tokapole II.

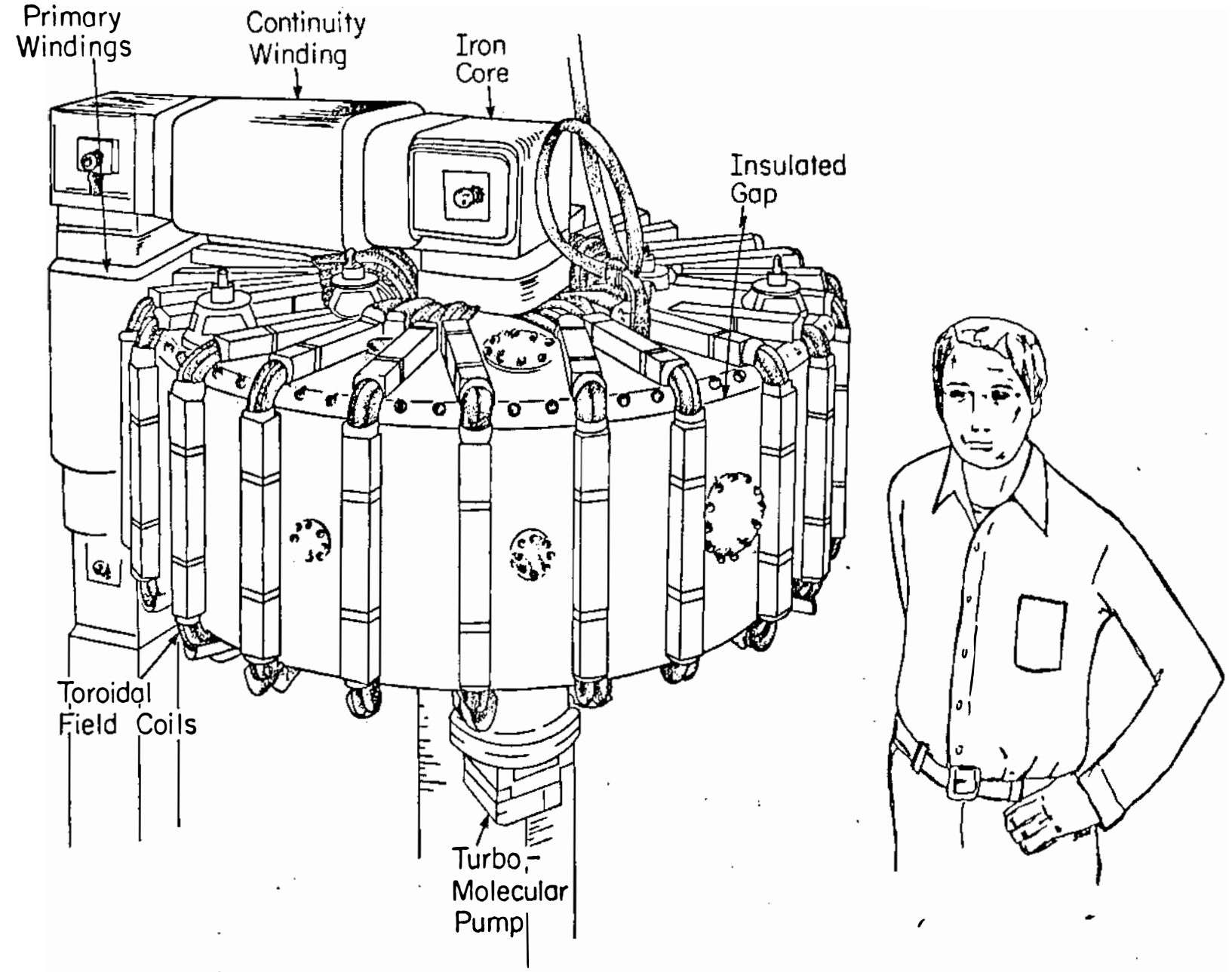
III. Our measured magnetic field and current density profiles.

IV. Other derived parameters: λ, F, Θ.

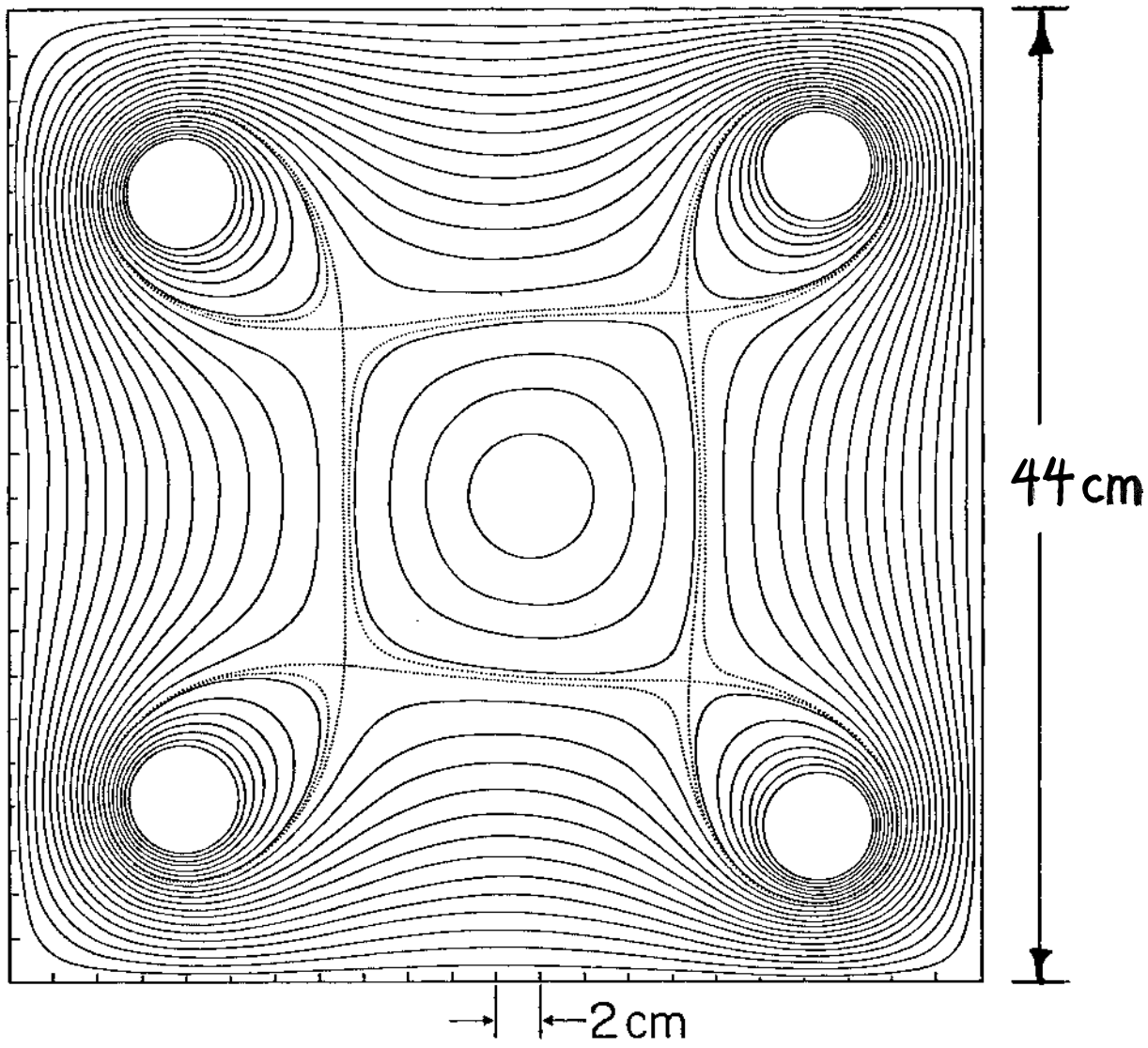
V. Plasma fluctuations.

VI. Summary.

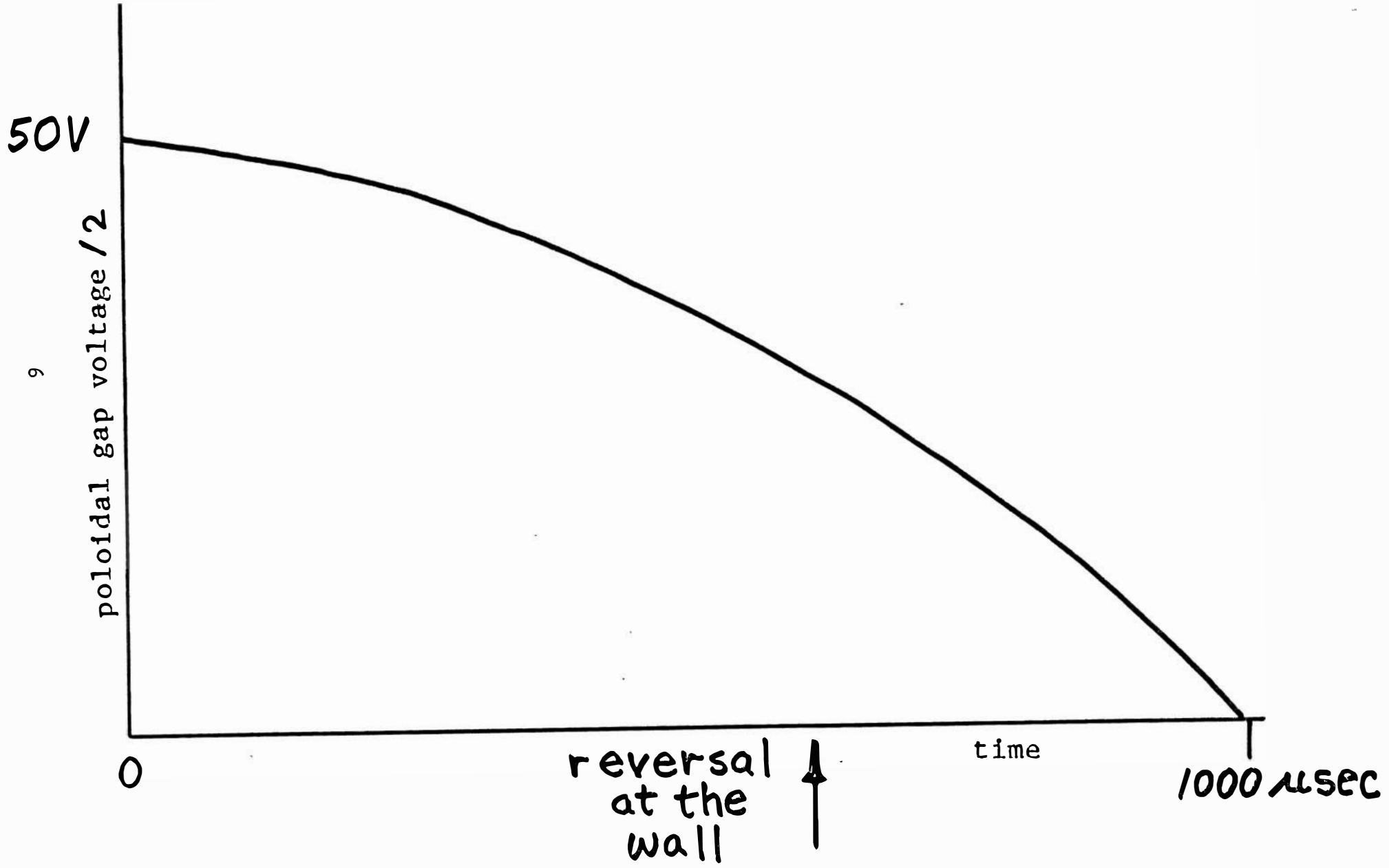
The TOKAPOLE II device which we have operated with a forced-reversed toroidal magnetic field.



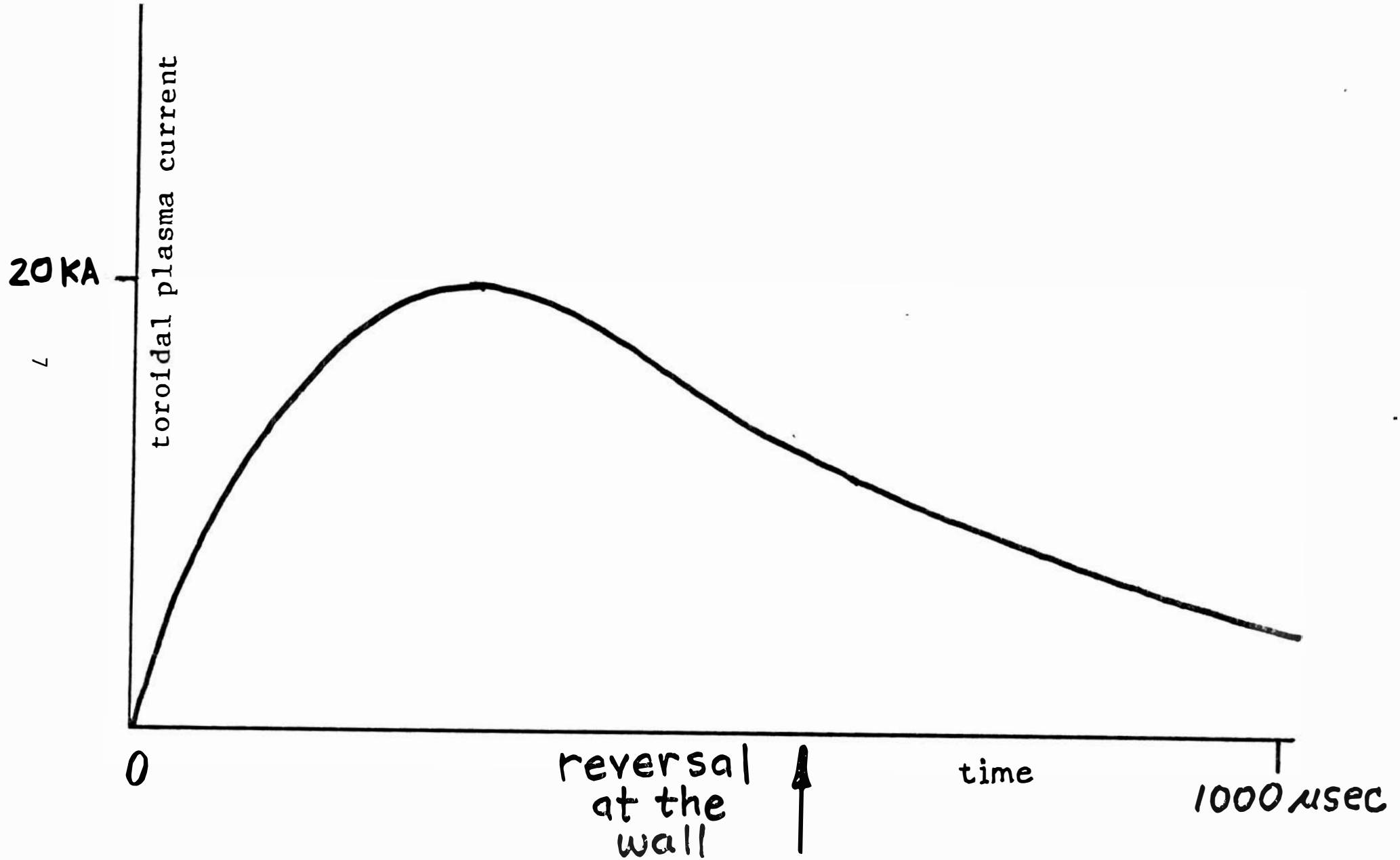
Tokapole II has four internal copper hoops which are inductively driven along with the plasma current forming a flux plot with a magnetic separatrix.



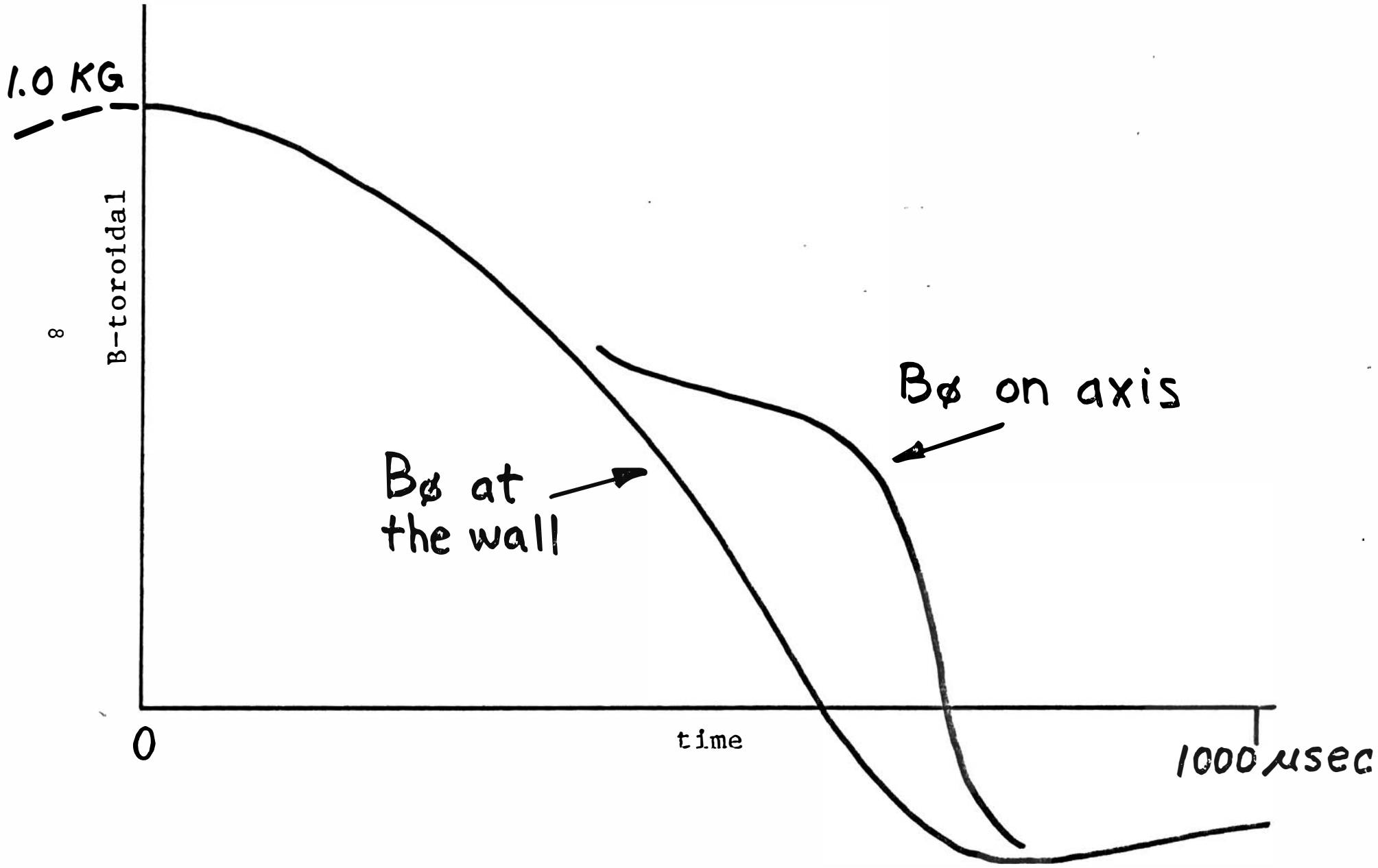
The toroidal voltage seen by the plasma is roughly one-half the total applied. The remaining half drives the hoops.



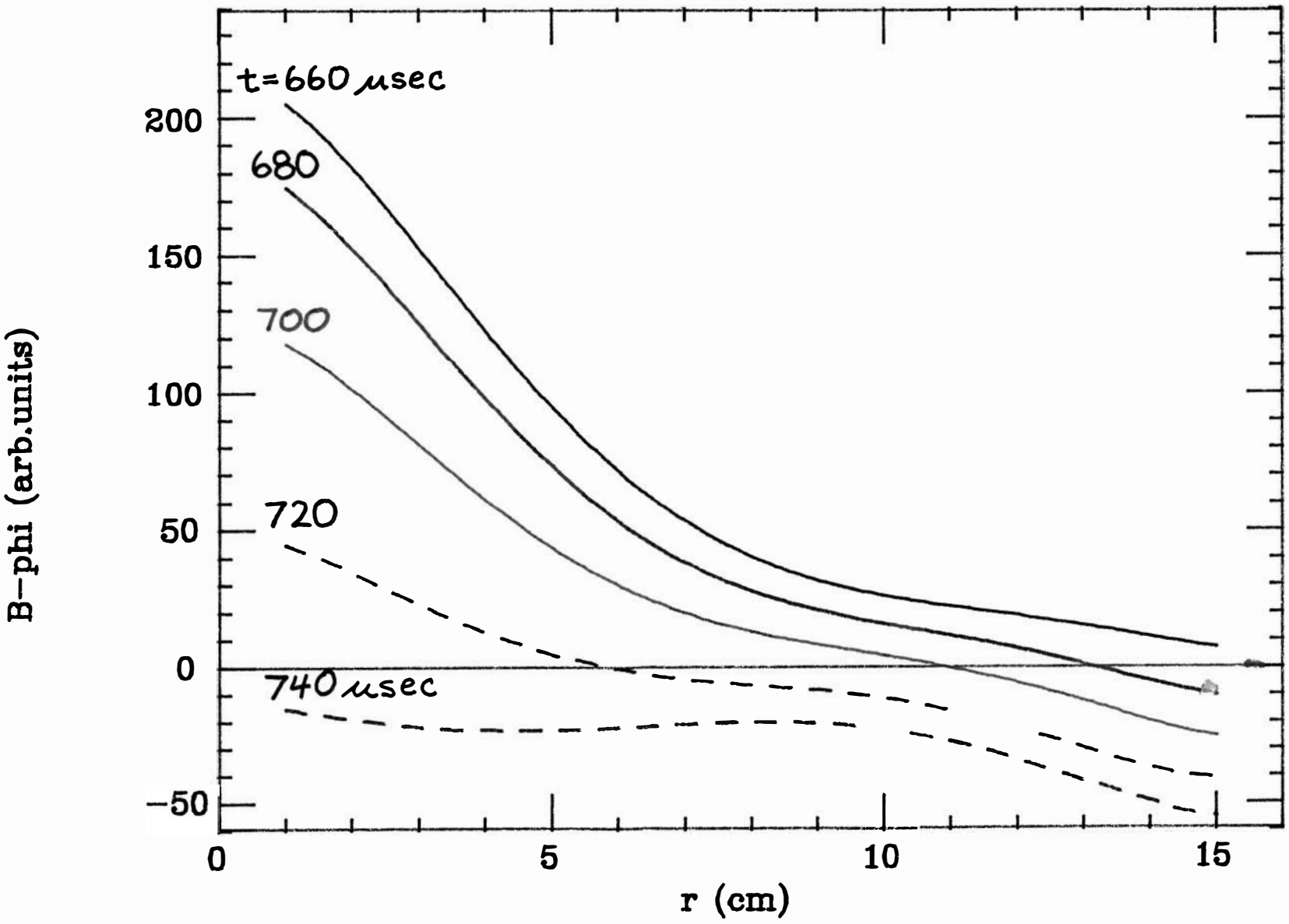
The toroidal plasma current resulting from the above applied voltage.



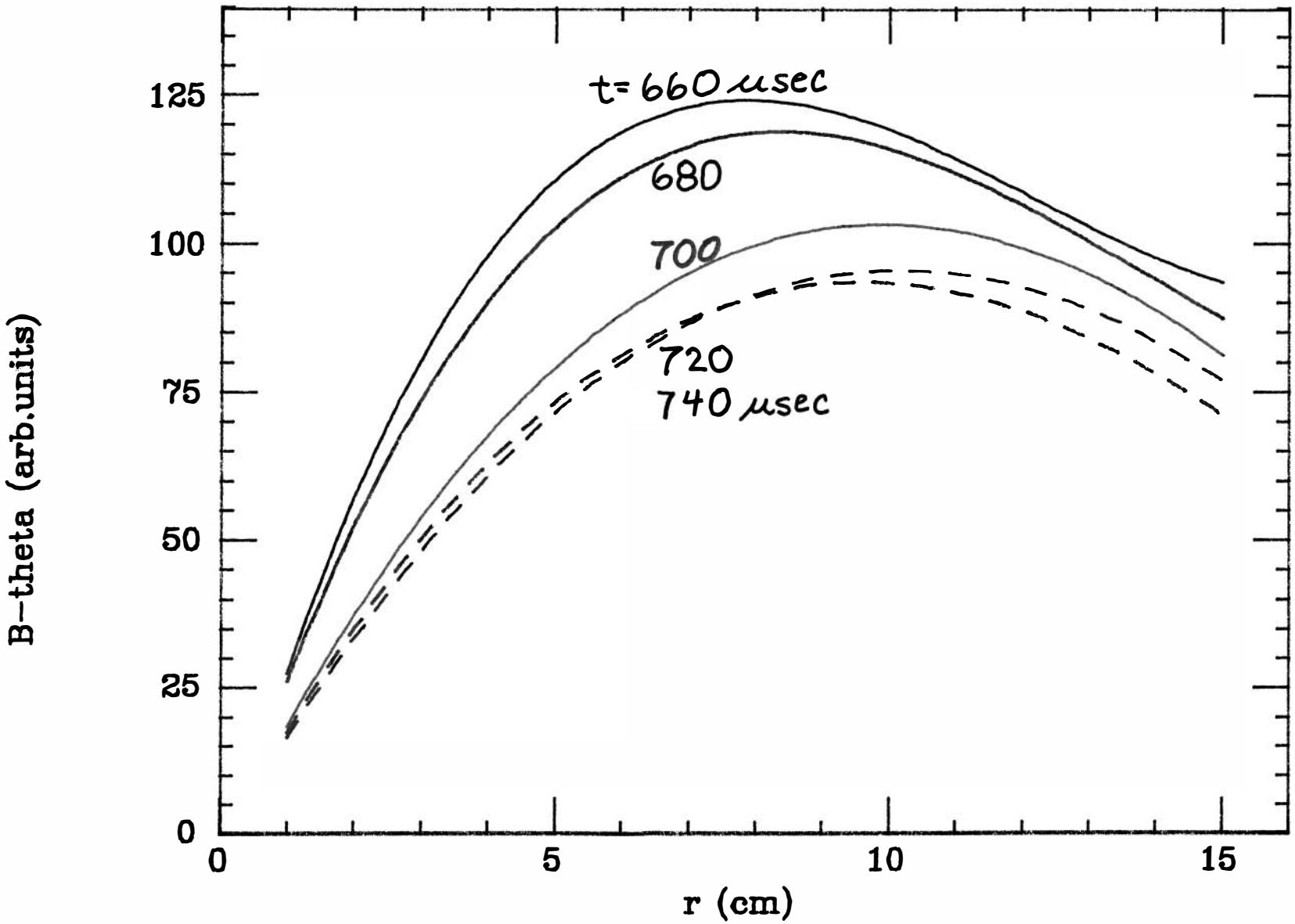
The toroidal field is reversed by reversing the winding current. Plotted below is the toroidal field waveform seen at the wall and at the magnetic axis.



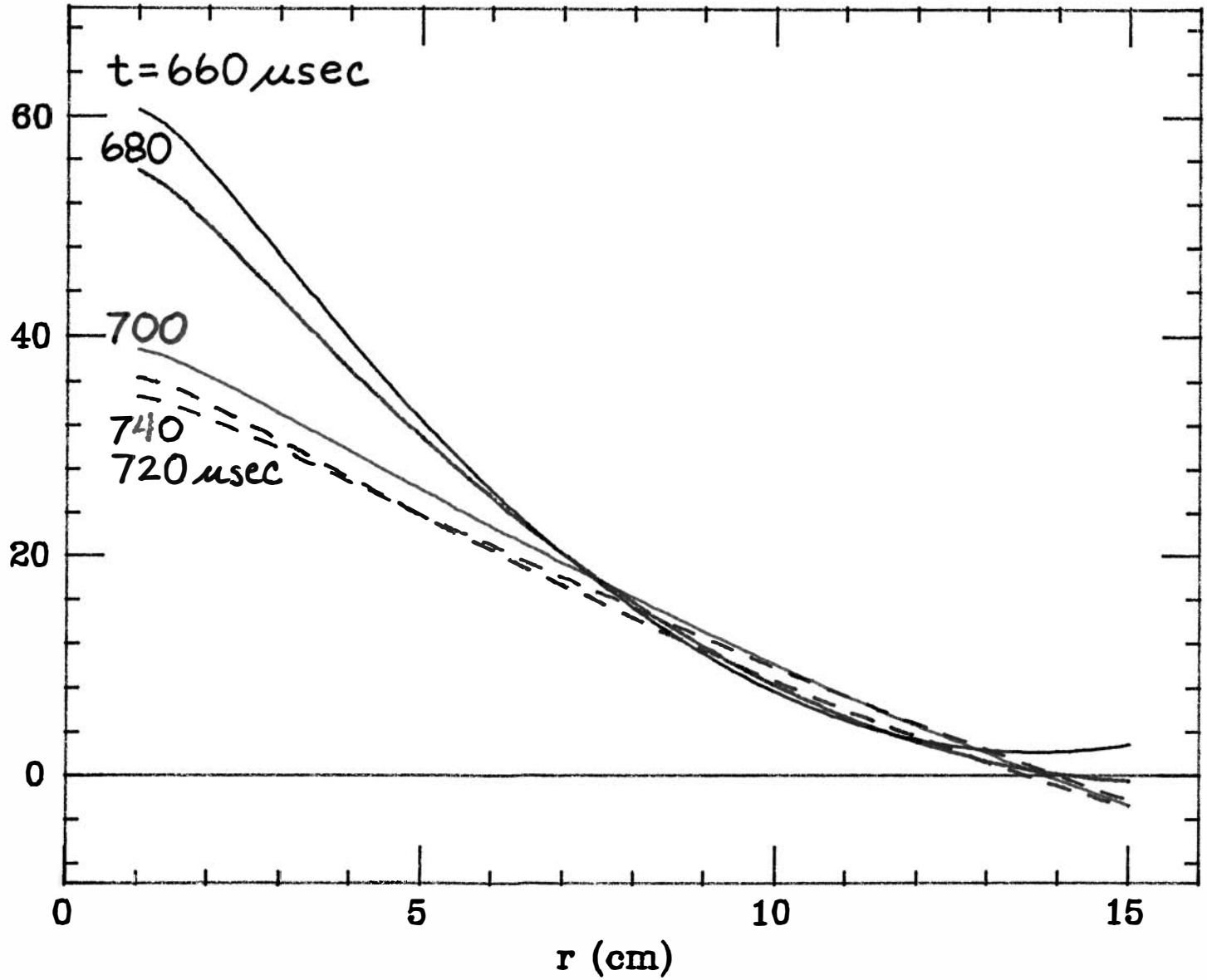
Profiles of the toroidal field taken with a magnetic ($\dot{B}$) probe.



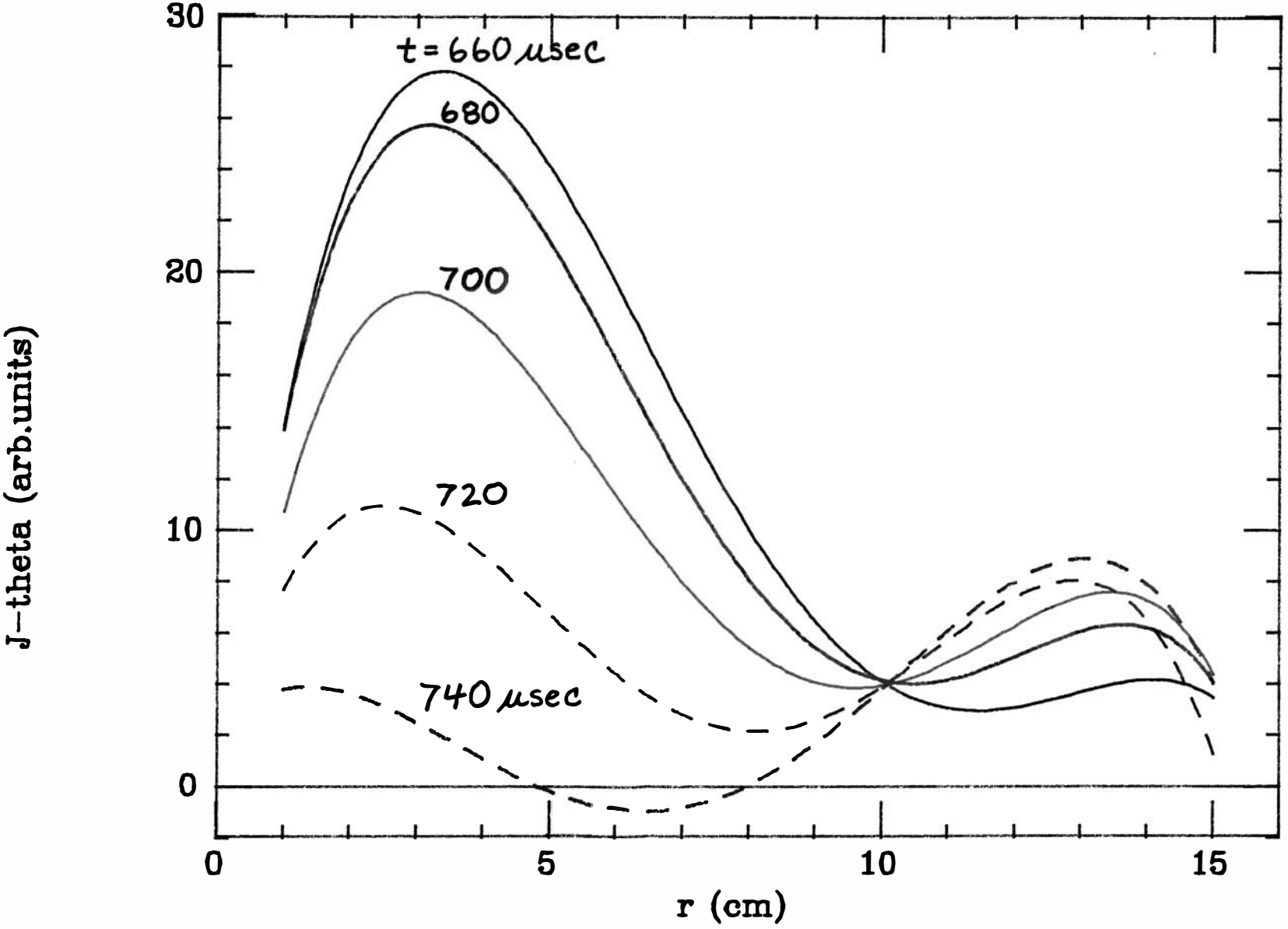
Profiles of the poloidal field taken with a magnetic ($\dot{B}$) probe.



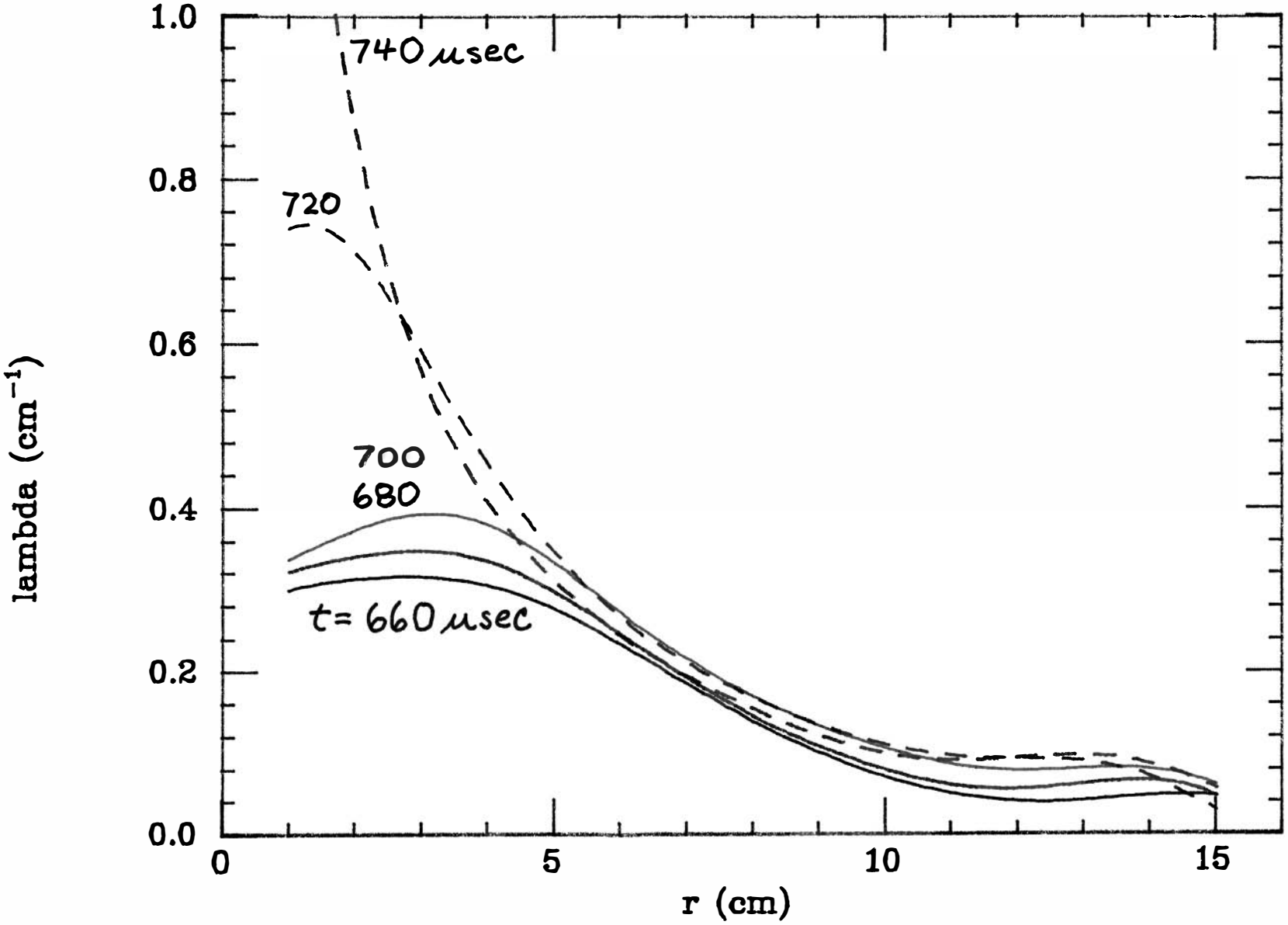
Profiles of the toroidal current density obtained from the poloidal field profiles.



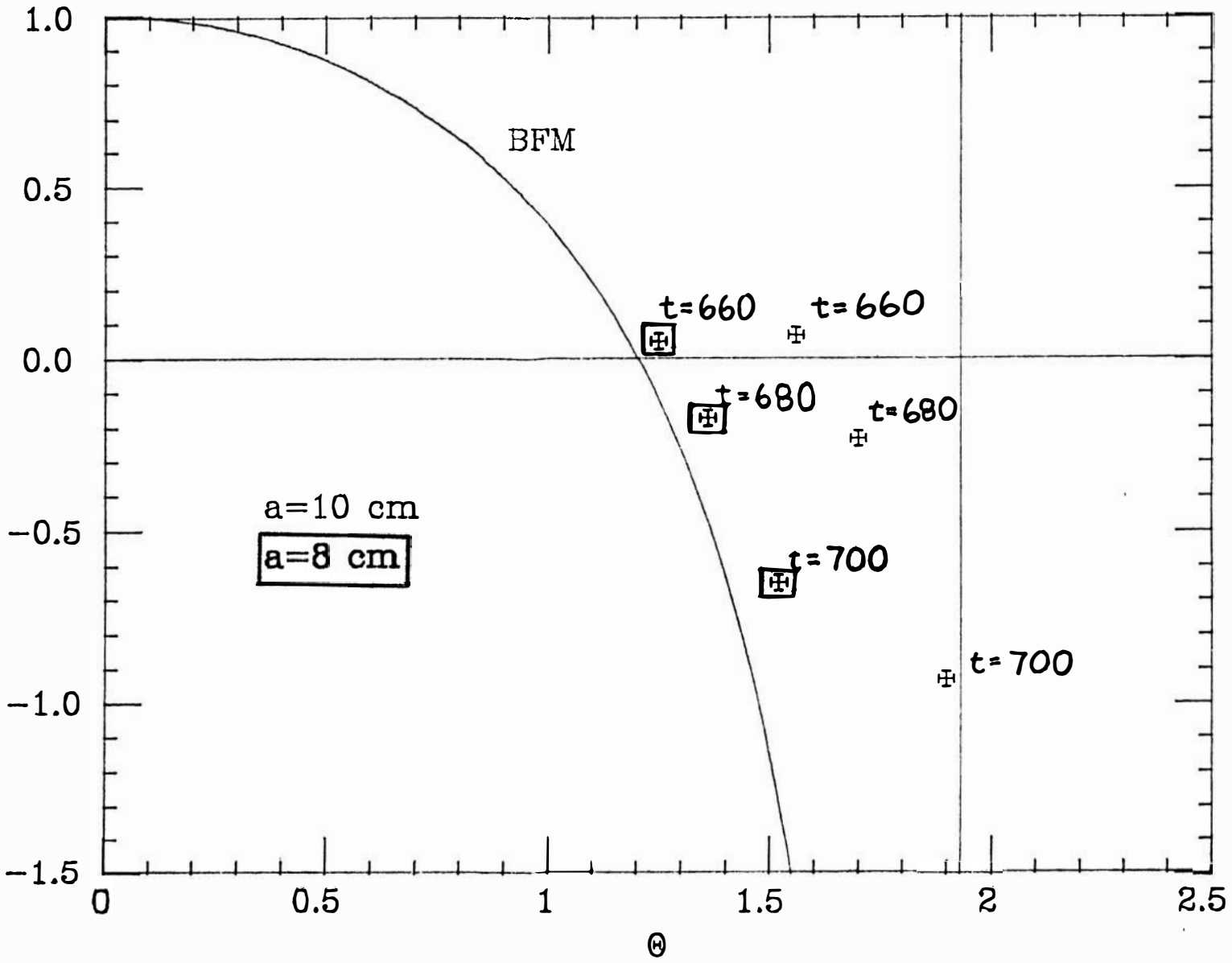
Profiles of the poloidal current density obtained from the toroidal field profiles.



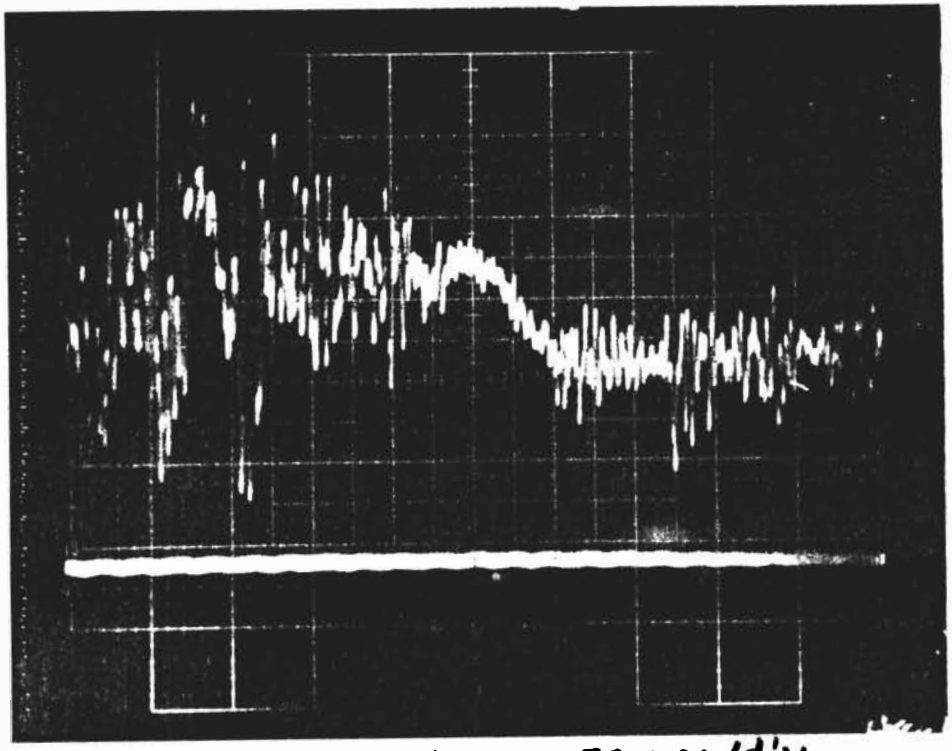
Profiles of the λ parameter for the force-free magnetic field ($\nabla \times \underline{B} = \lambda \underline{B}$) calculated from the field and current profiles.



The field reversal parameter (F) and the pinch parameter (Θ) are determined from the toroidal magnetic profile and the λ profile ($\Theta = a\lambda/2$). We have used a=8 cm corresponding to the position of the separatrix and a=10 cm corresponding to where the poloidal current density goes to "zero".



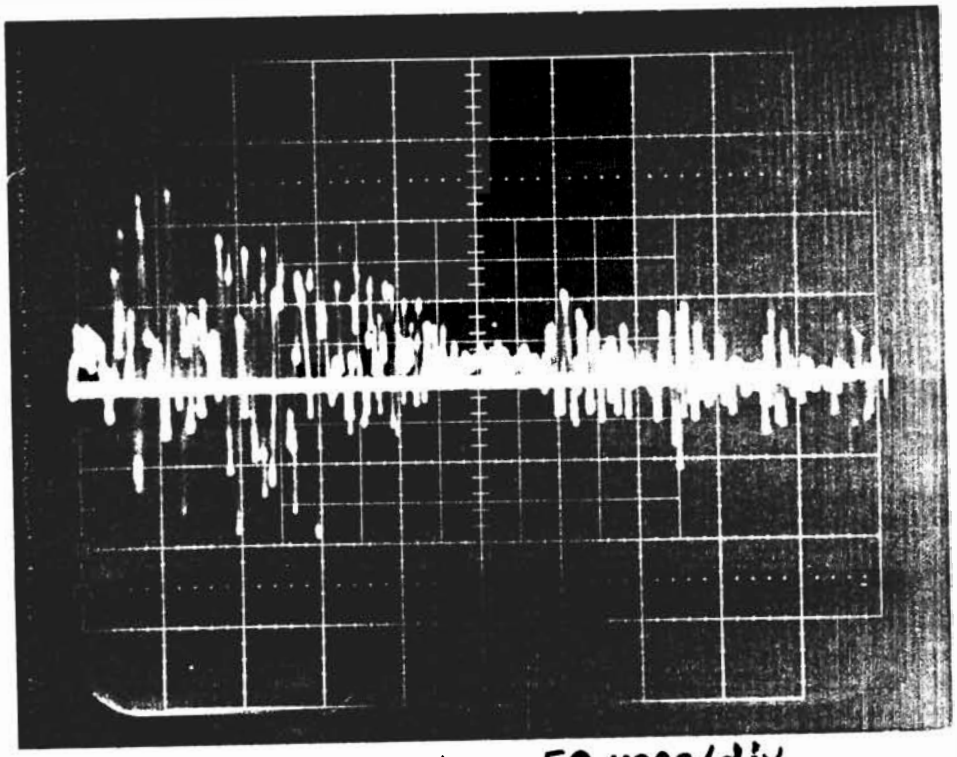
Plasma fluctuations seen on a magnetic ($\dot{B}$) probe and a langmuir probe show a "quiet" period coincident with reversal of the toroidal field at the wall.



50 μsec/div

time of reversal of B_ϕ at the wall.

- Ion saturation current from a langmuir probe placed near the wall.



50 μsec/div

time of reversal of B_ϕ at the wall.

$\dot{B}$ from a magnetic probe placed near the wall.

SUMMARY OF EXPERIMENTAL WORK

We have operated Tokapole II with a forced-reversed toroidal field and have obtained unsustained RFP plasma states lasting up to 100 μsec. Coincident with reversal of the toroidal field at the wall we see a "quiet" period in plasma fluctuations. The force-free field parameter λ obtained from magnetic field profile measurements has spatial structure resembling that of the Modified Bessel Function Model (MBFM).

OUTLINE OF THEORETICAL WORK:

J.S. SARFF and L. TURNER

I. Description of a 2-D model for a force-free plasma in Tokapole II.

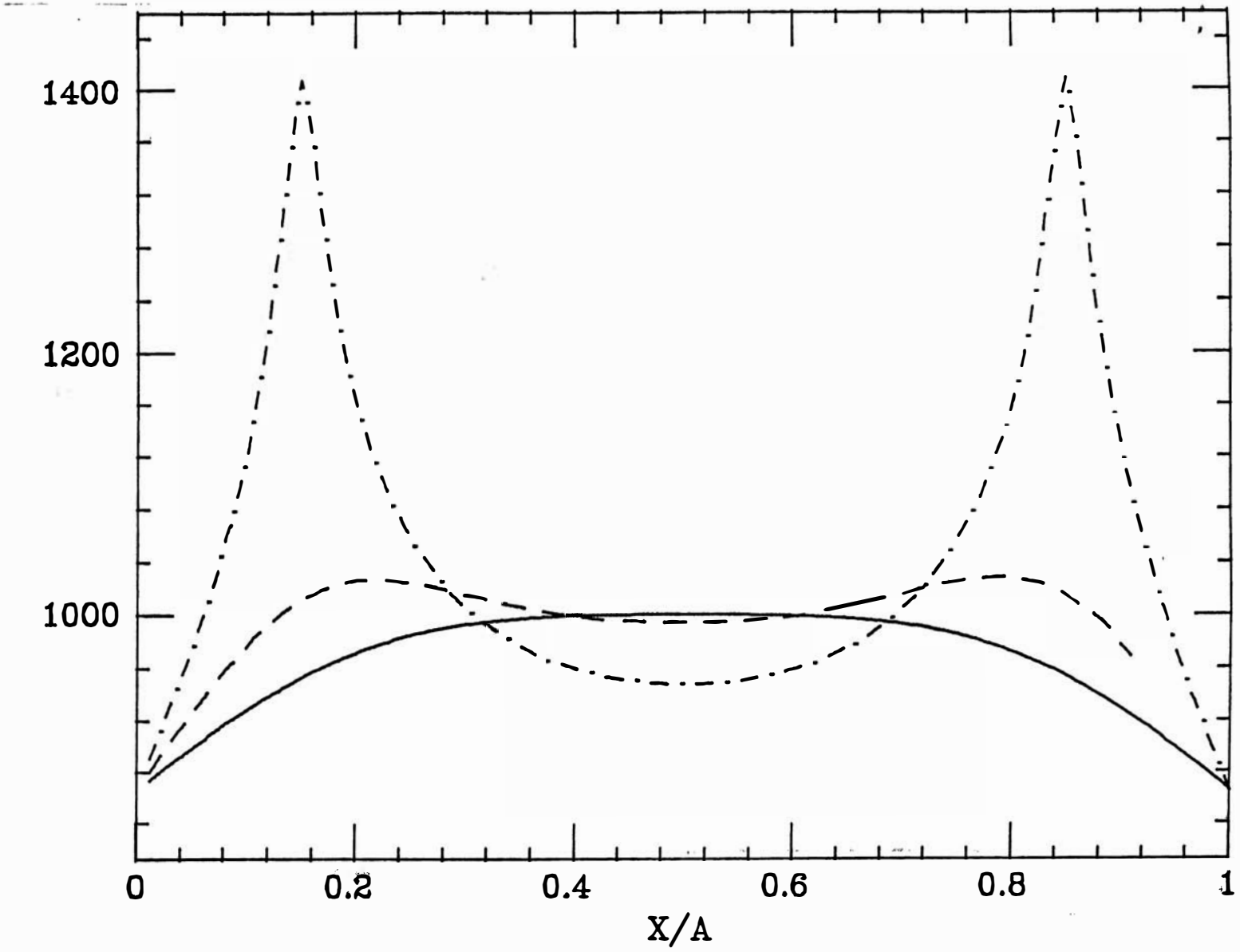
II. Flux contours and field profiles predicted by the model.

III. Summary.

DESCRIPTION OF OUR 2-D MODEL

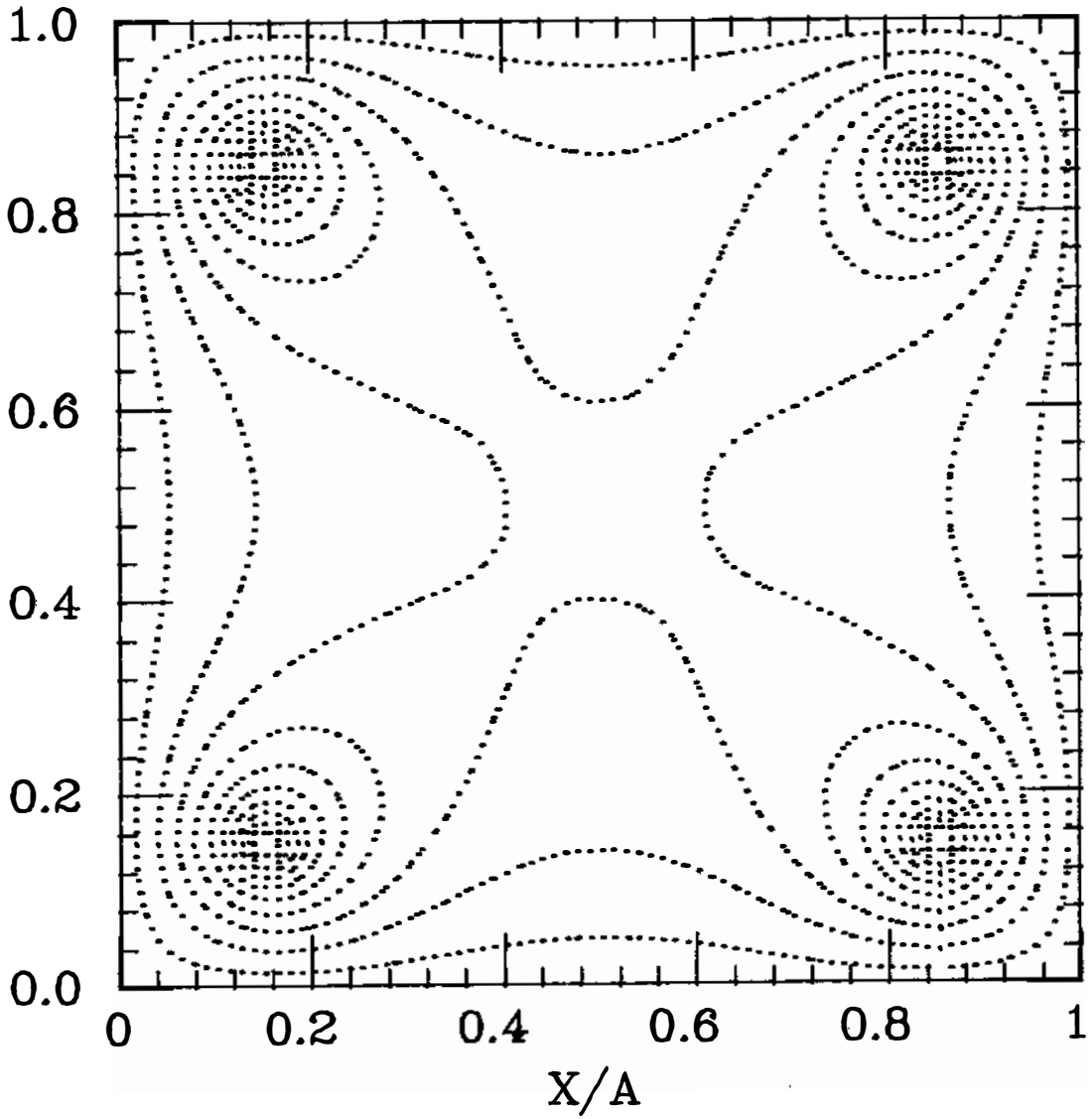
We have obtained a 2-D, analytic solution for the force-free magnetic field within a rectangular domain surrounded by a conducting boundary. Within this domain, the magnetic field satisfying $\nabla \times \underline{B} = \lambda \underline{B}$ with constant λ is evaluated in the presence of filamentary current sources (an idealization of the copper hoops). From this solution we obtain the predicted magnetic field profiles and flux contours which we can compare with the experimentally determined profiles.

Profiles of B-toroidal in a square a×a with four enclosed filamentary currents for the force-free field paramter $a\lambda=0.5$. Three profiles are shown: y/a=0.5 (on the midplane), y/a=0.16 (near the currents), and y/a=0.3.

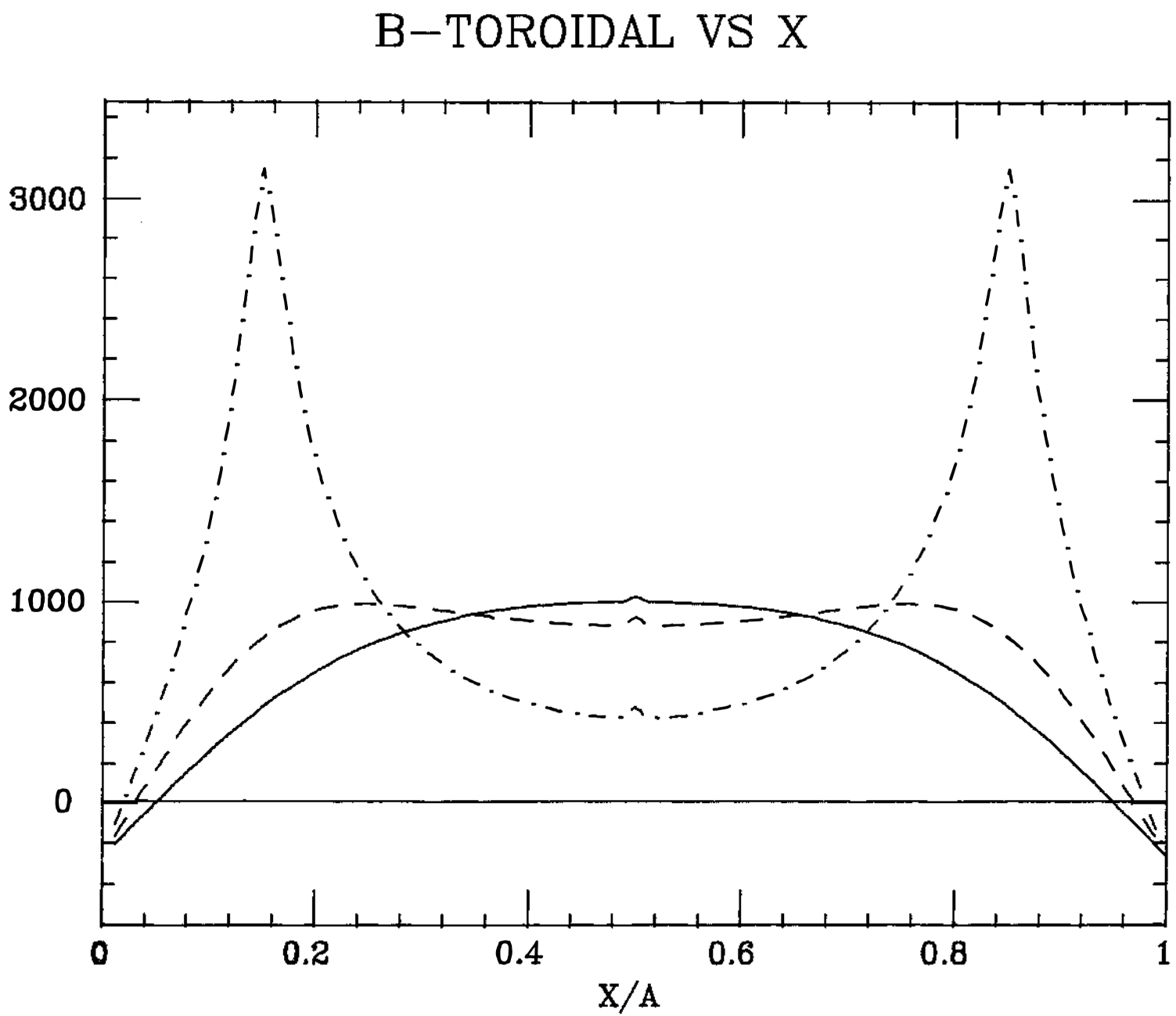


SOLID: Y/A=0.5 DASH: Y/A=0.3 DOTDASH: Y/A=0.16

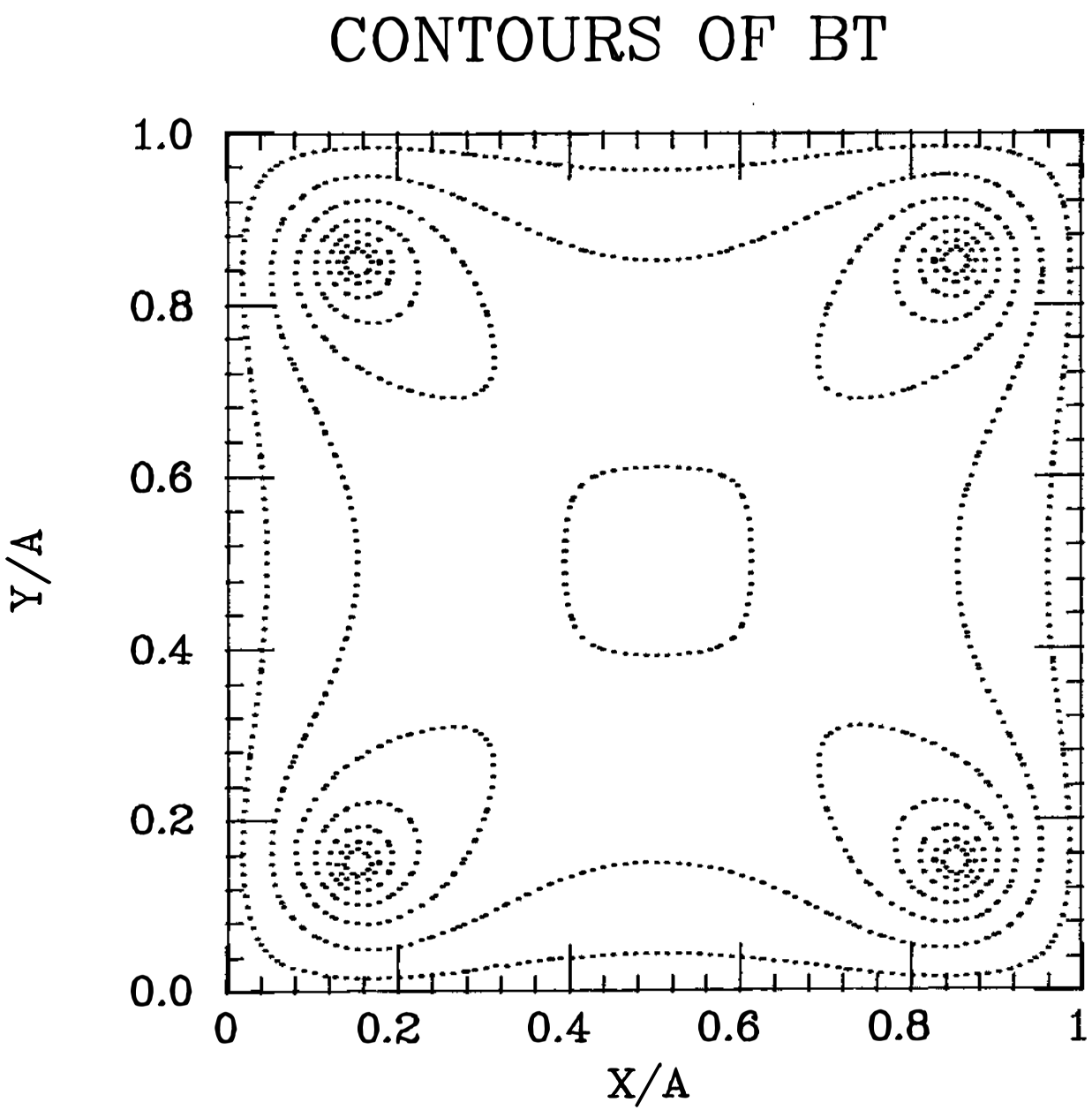
Flux contours of B-toroidal in a square a×a with four enclosed filamentary currents for the force-free field parameter aλ=0.5.



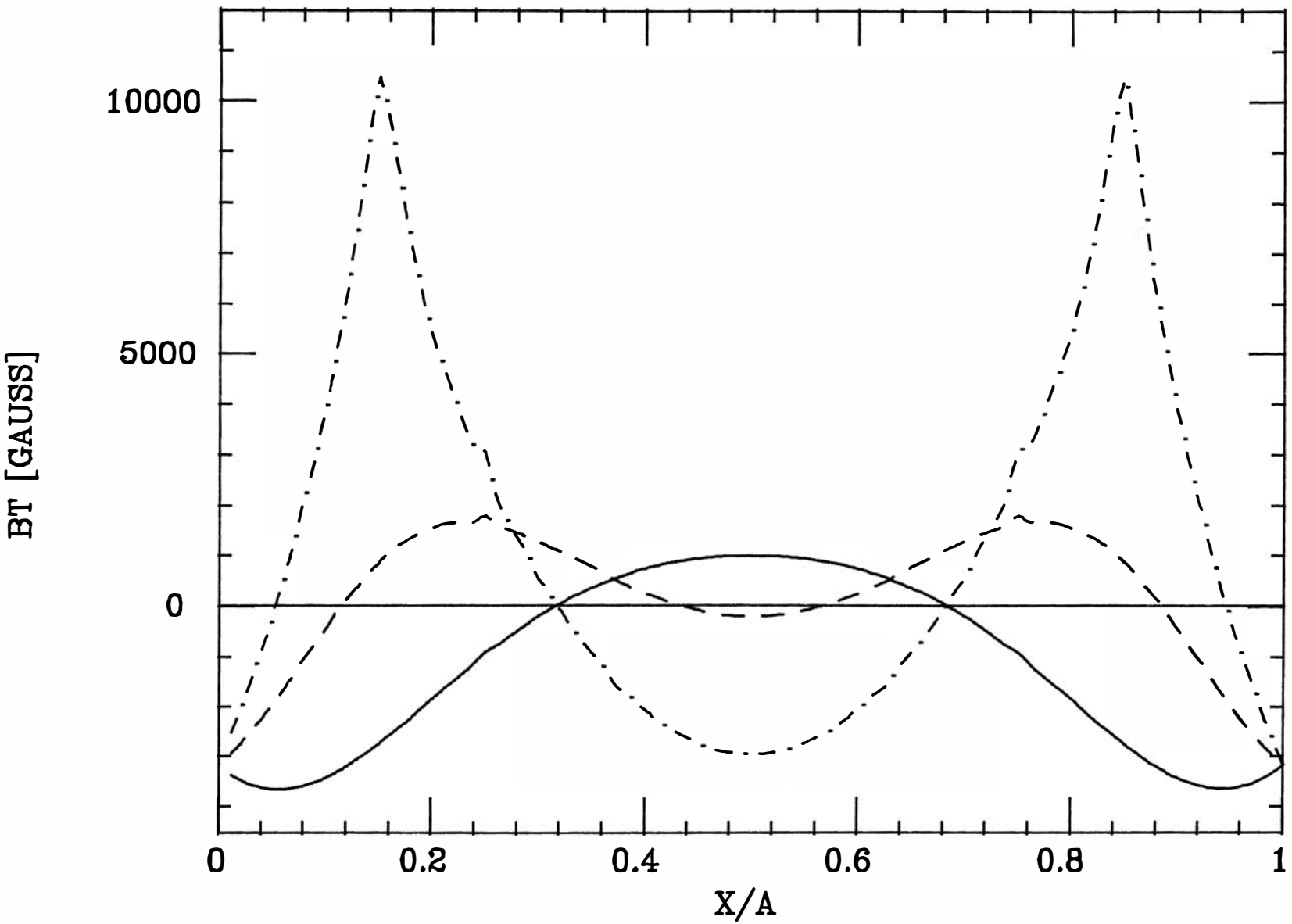
Profiles of B-toroidal for $a\lambda = 3.0$.



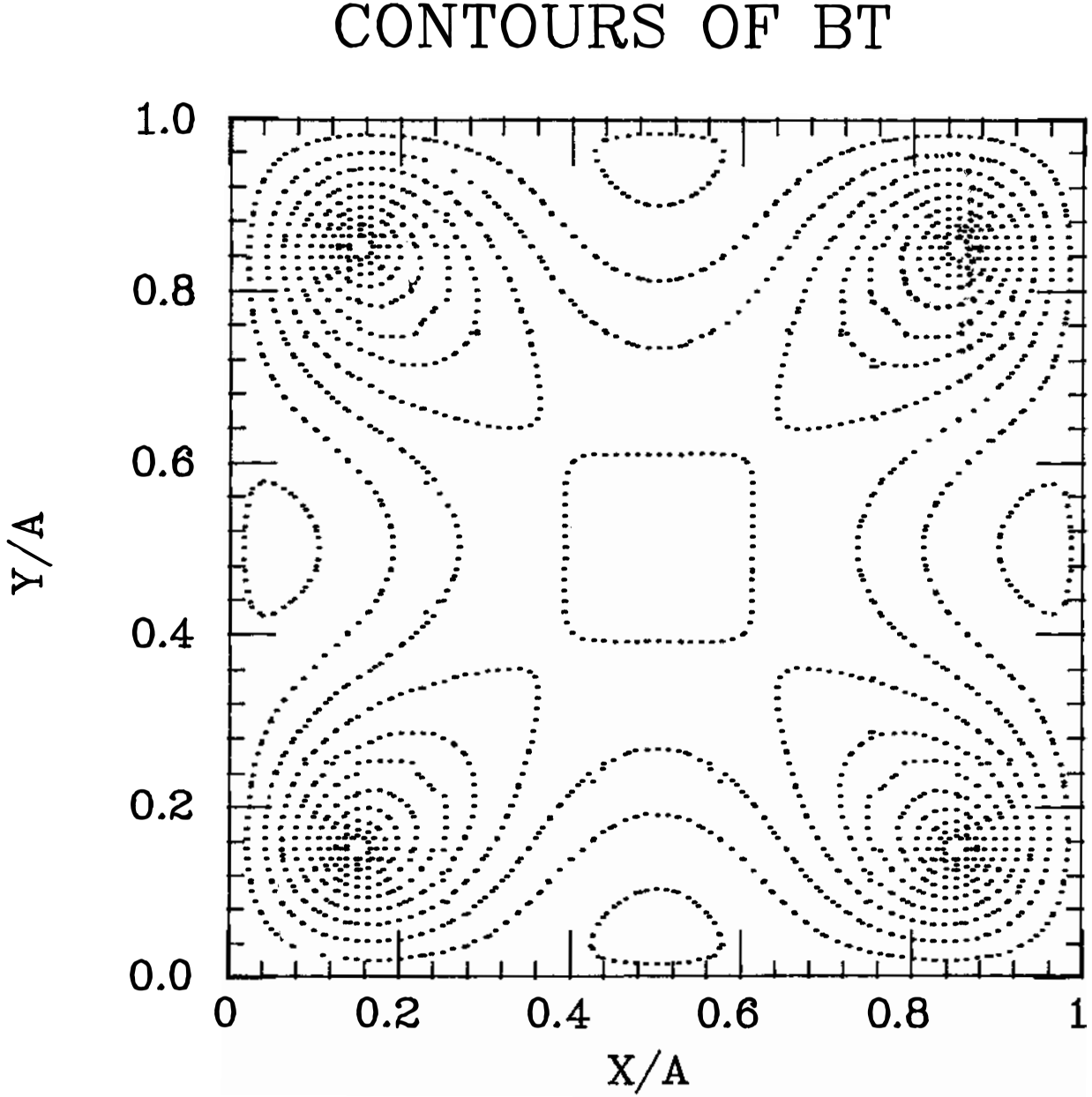
Flux contours of B-toroidal for $a\lambda = 3.0$.



Profiles of B-toroidal for aλ=10.0.



Flux contours of B-toroidal for aλ=10.0.



SUMMARY OF THEORETICAL WORK

From our 2-D analytic solution of $\nabla \times \underline{B} = \lambda \underline{B}$ in a rectangular domain with enclosed current sources we have obtained magnetic profiles and flux plots characterizing constant λ force-free magnetic states in a Tokapole-like geometry. The magnetic profiles measured experimentally in Tokapole II differ substantially from the predicted profiles which implies that, if the plasma is force-free, λ cannot be constant. In fact, the experimentally determined profile shows λ is not constant.