Where is the plasma edge in tokamaks?[1]

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Conventional answer to the question in the title would be "at the separatrix". Another, less specific formulation "at the last closed flux surface" essentially means the same in the case of the separatrix limited plasma.

In fact, the question of the title has much more profound sense than it could sound on the first glance. Here I present the MHG stability theory of free boundary plasma in a tokamak environment where plasma is always in an electric contact with the in-vessel conducting structures. It is shown that surface currents due to plasma MHD perturbations, which play crucial role in stabilizing the free boundary modes, in a real situation can be shared between the plasma and the "wall", thus changing the stability conditions and making the otherwise stable plasma unstable.

During the vertical disruption events this surface current sharing effect leads to excitation of the kink mode $m/n = 1/1$ even when the surface safety factor $q > 1$ (on JET $q \simeq 1.5$). Lasting for a certain period as a locked mode the kink mode can create significant and worrisome for ITER sideway forces acting on the vacuum vessel.

In a quasi-stationary plasma, the current sharing effect was discovered experimentally by Hiro Takahashi and Eric Fredrickson on DIII-D who measured halo currents ("Hiro" currents) associated with plasma perturbations. The physics of the Hiro currents explicitly introduces the edge plasma density into MHD stability conditions and determine (a) stable LiWF regime at very low densityies (b) QHM with edge harmonic oscillations at a slightly higher density, (c) ELMs at even higher density, (d) L-mode with blobs at higher density, and (e) high density disruptions.

Only the plasma in the LiWF regime obeys the conventional ideal MHD. In all others regimes the plasma edge is unstable with respect to the Takahashi Kink Modes (TKM) due to plasma electric contact with the in-vessel structures. Correspondingly, TKMs disturb the plasma configuration inside the separatrix and break the "idealistic" theoretical views on it as a plasma boundary.

Now, having in addition the results of the Resonance Magnetic Perturbation (RMP) experiments on DIII-D it is possible to give a consistent with the reality answer to the question in the title: the plasma edge is located at the tip of the temperature pedestal. Behind it, in the so-called "transport barrier", there is no plasma confinement.

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