Initial Plasmas in ET*

Prepared for ICC2000

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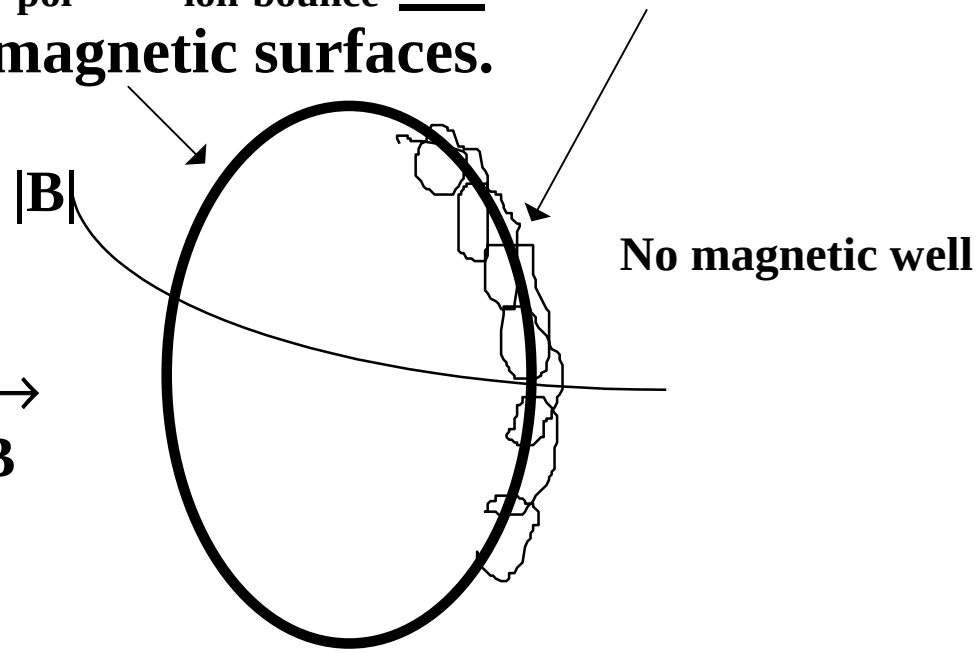
*** Electric Tokamak**

The ET Geometry

$R = 5$ m, $B = 0.25$ T, $A = 5$, $k = 1.5$ $a = 1$ m, $n < 2e13 cm^{-3}$,
$T_e < 2$ kV, $T_i < 3$ kV, $P_{oh} < 200$ kW, $P_{rf} < 2$ MW CW,
<10 MW pulsed, $P_{nb} < 200$ kW (for fueling, pulsed)

Orbits can be locked to magnetic surfaces in a torus

1) When $\omega_{pol} > \omega_{ion\text{-}bounce}$ *ion* drift orbits are locked to magnetic surfaces.



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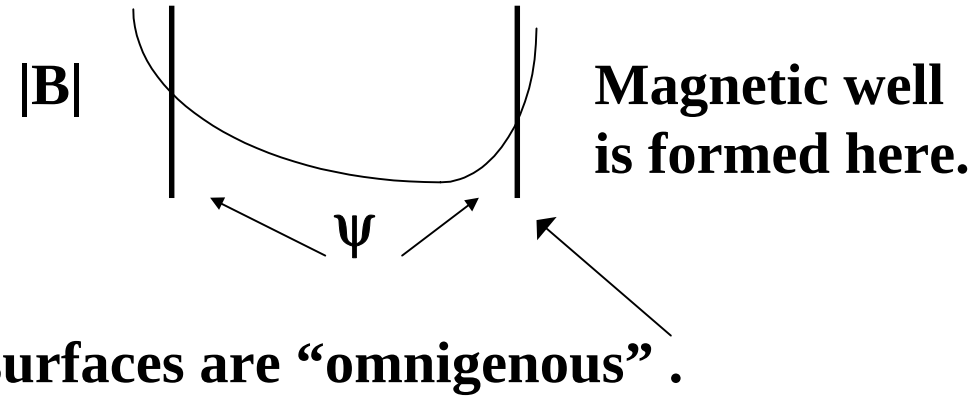
2) At high beta ($\beta >> \varepsilon$), *all particle* drift orbits are locked to the magnetic surfaces.



Critical E_r for Ion Drift Lock

<u>Classical ion confinement</u> is theoretically possible, if ion drift orbits are "LOCKED" to magnetic surfaces. This can be done if

$$\boxed{E_r > \varepsilon v_i B}$$

Or

$$\omega_{pol} > \omega_{ion\text{-}bounce}$$

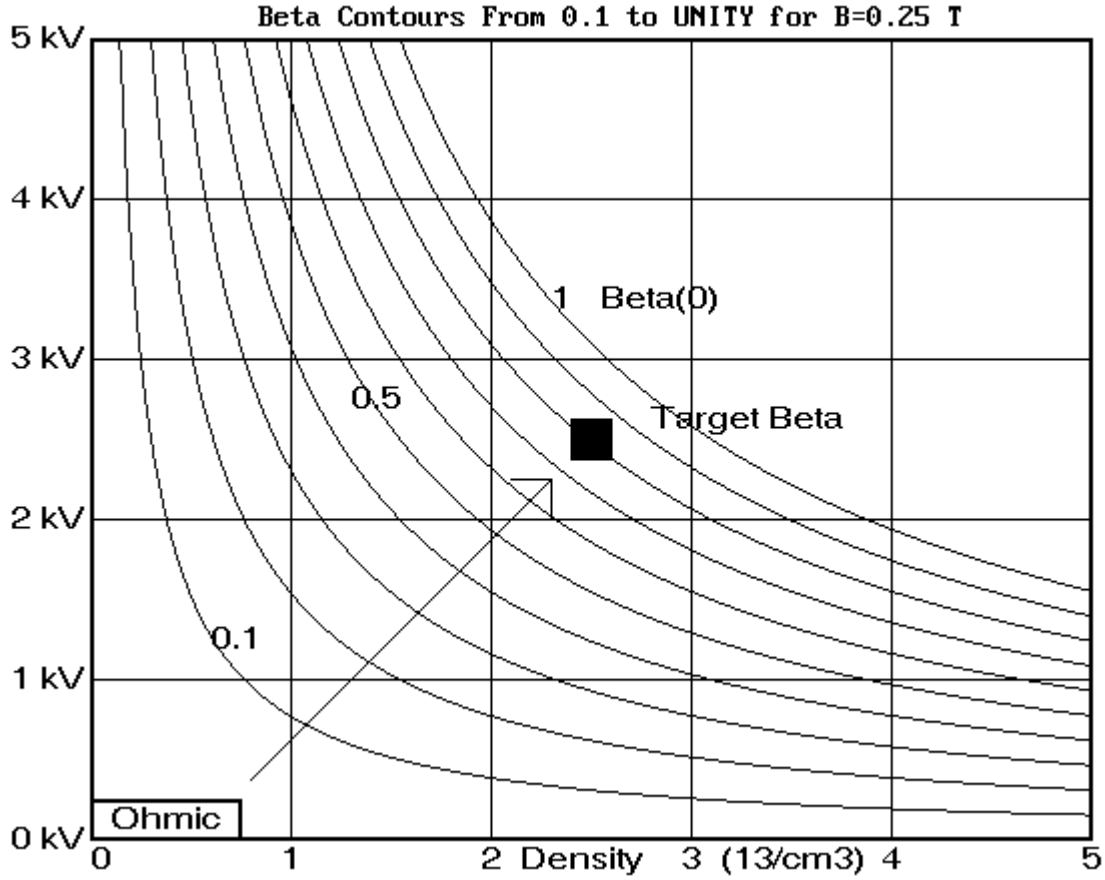
"Electric Tokamak" here implies highly rotating plasma with <u>electrified</u> <u>kinetic ions</u> and <u>MHD electrons</u>.

Note: due to the large E_r, <u>electric shear</u> is a subordinate process.

Research Goal

Explore the Science and Technology of unity beta fusion plasmas in a large torus

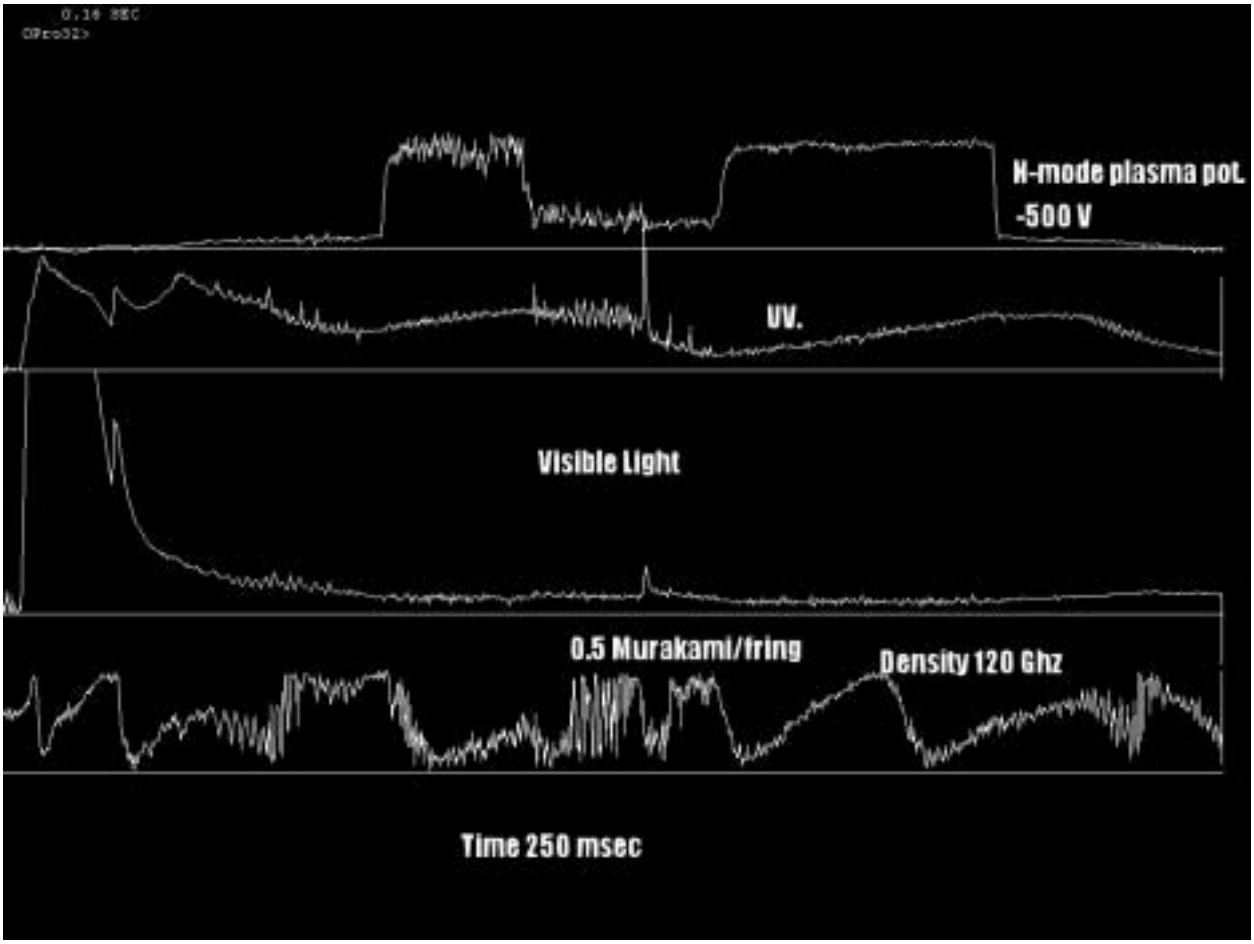
T(0), n(0) and β(0)



The required density is $5xn_{OH}$
The required temperature is 10 xT_{OH}

We at the "O" in the box as of Feb. 2000.

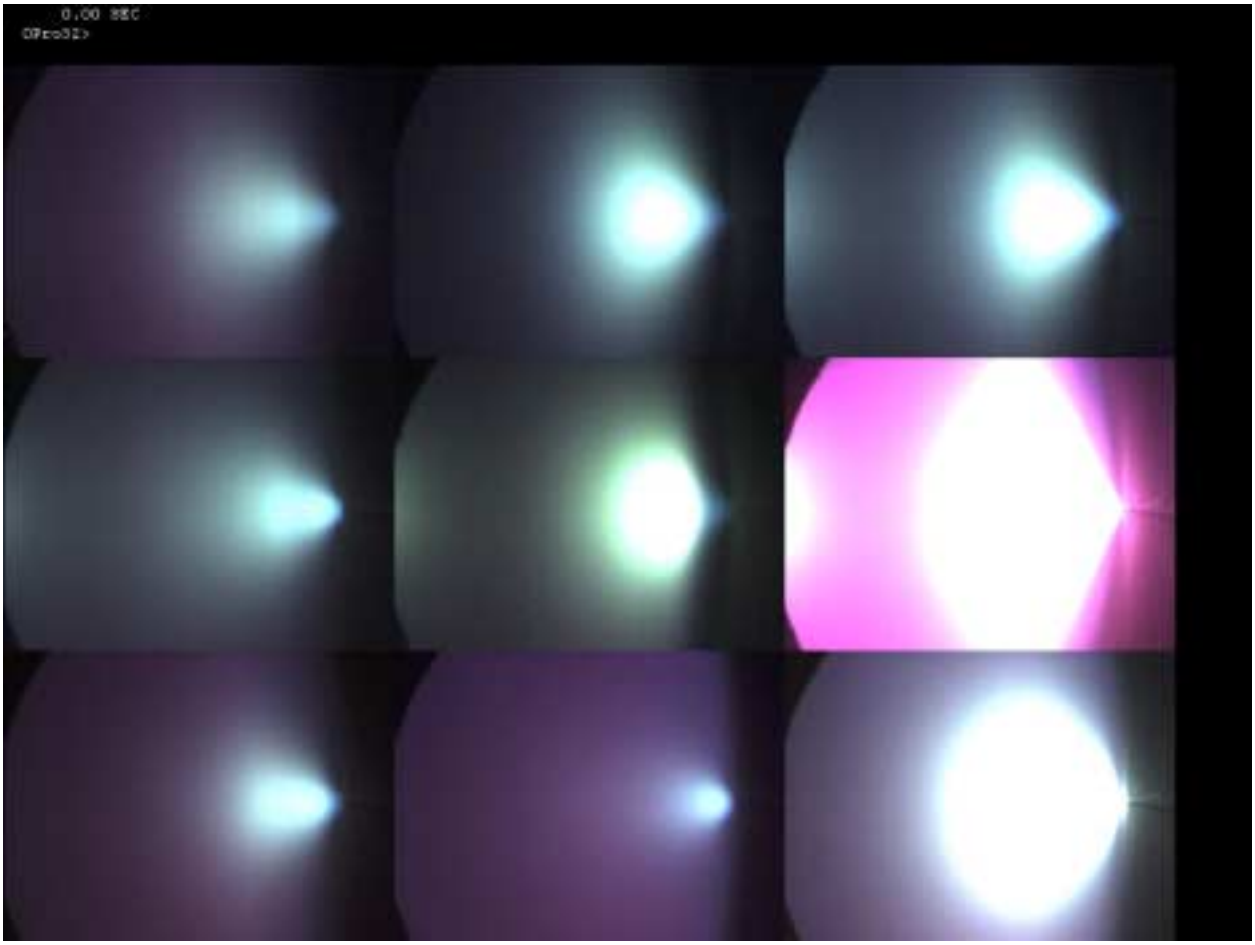
H-mode Shot



This picture show the density build-up in H-mode. Inferred particle confinement time is longer than H-mode or the shot.

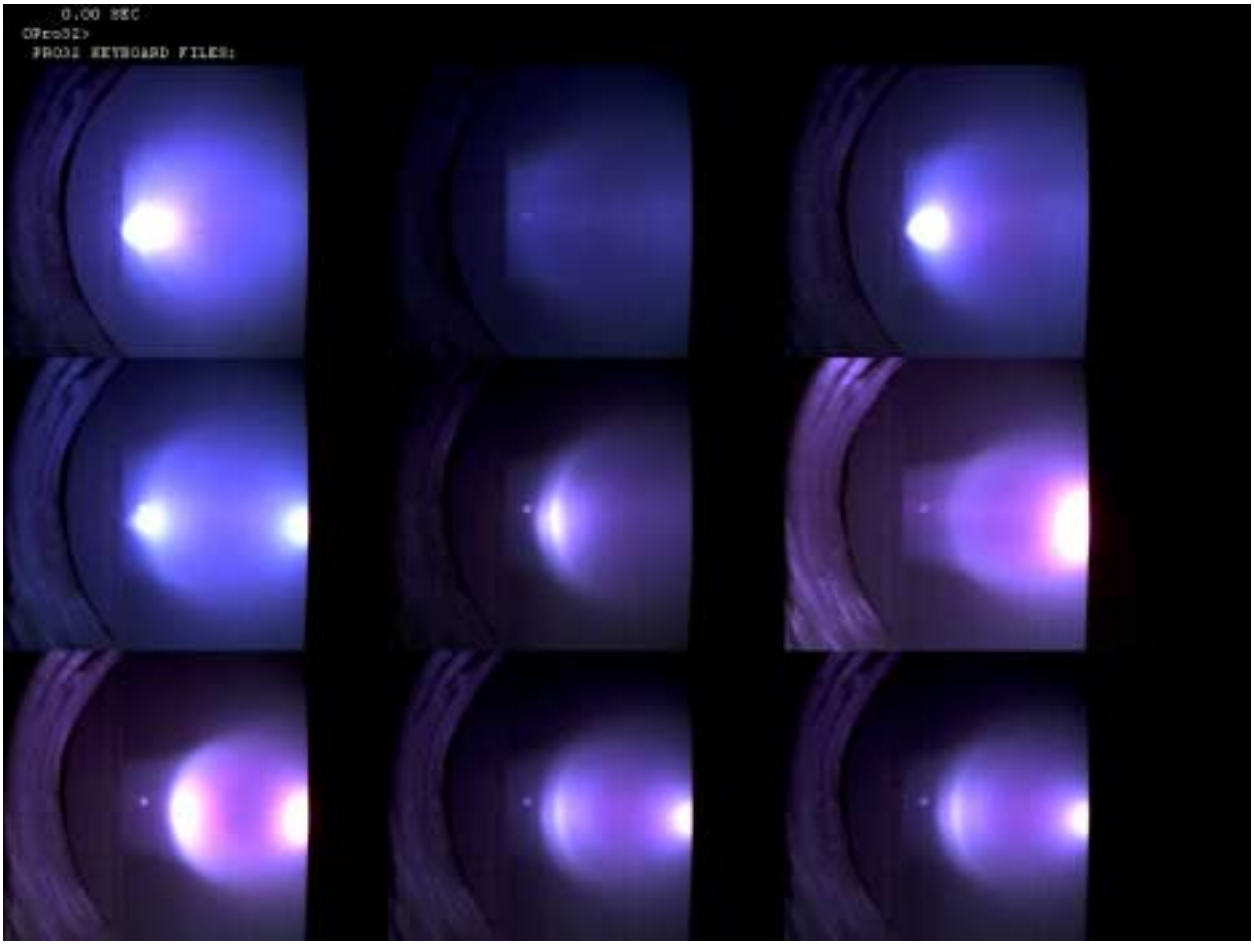
He/Hydrogen Puffing

(Top View)



This is a top view of the outer boundary. Picture six shows a hydrogen puff. The others show helium puff. Some variation with H-mode has been found --- less radial penetration.

Hydrogen Puffing (Tangential View)



These are tangential views of high field side and low field side gas puffing. On some photos inner structures can be seen suggestive of rational magnetic surfaces.

Achieved Plasma Parameters

R = 5 m, B = 0.08 T, A = 5, kappa = 1, a = 1 m,
n < 2e12cm^{-3}, T_e < 200 V, T_i < 100 V

- Low loop voltage (>400 mV)
- Twice Murakami density (need 5x)
- Z < 1.1 (ok)
- Peak beta 2.5% (need 100%)
- Electrode driven H-mode (need RF)
- V_{pol} < 50 km/sec (right on)
- Good confinement (tau(0) =150 msec)

RF physics:

Good high field side and low field side loading is realized just as we calculated for the design.

Design Validation

ET was designed using:

- $V_{loop} = 0.75/a^{1/2}$ (V, m)
- $q(0) = 1$, $Z_{eff} < 1.1$
- $n(0) < B/R$ ($1e20/m^3$, m, Tesla),
- IOC type boundary H-mode

The above has been validated at B=0.08 T.

Tau0=3/2en0(Te0+Ti0)/(j0E)

R = 5 m, B = 0.08 T, A = 5, a = 0.9 m, V=0.7 V,
n = $2e12 cm^{-3}$, T_e = 120 V, T_i = 60 V, j0=26 kA/m2

Tau0 = 150 msec validates the ohmic ET design.

Program Plan

- **Finish device fabrication (May,2000)**
  (OH, ICRF, old diagnostics)

- **Bust the Murakami limit 5x**
  (High field side power and fuel input)

- **Explore current profile control** (HH-ICRF)
  (Achieving reverse shear is project critical)

- **Explore unity beta stability**
  (Path: Plasma rotation and RS with $q_{min} > 1.3$)

Future direction:

- **POP proposal for 1 Tesla , 1 sec confinement (any time soon)**

Summary

ET got:

- Low loop voltage
- Twice Murakami density (ok for now)
- Low Zeff with Ti-dep.
- Low peak beta 2.5% (ok for now)
- Good H-mode
- Good high field side RF loading
- Rapid poloidal rotation < 50 km/sec
- Excellent confinement
- $tau_E(0)$ ~150 msec
- $tau_N(0)$ >150 msec in H-mode

Ready for collaboration after the first machine physics publication.
Circa. Summer 2000.