U.S. SMALL TOKAMAK PROGRAM
(Presented at the 1983 Tokamak Seminar at Princeton Plasma Physics Laboratory on February 1, 1983)

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U.S. SMALL TOKAMAK PROGRAM
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PRESENTED AT THE 1983 TOKAMAK SEMINAR AT
PRINCETON PLASMA PHYSICS LABORATORY ON
FEBRUARY 1, 1983.
MATERIAL LARGELY TAKEN FROM THE 1982
SMALL TOKAMAK USERS MEETING AT
NEW ORLEANS, LA ON NOVEMBER 1, 1982.

SUMMARY AVAILABLE AS UNIVERSITY OF WISCONSIN
PLASMA PHYSICS REPORT #DOE/ET/53051-47.
<table>
<thead>
<tr>
<th>DEVICE</th>
<th>R(cm)</th>
<th>2A(cm)</th>
<th>B_I(KG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Columbia Torus II</td>
<td>22.5</td>
<td>13x25</td>
<td>5</td>
</tr>
<tr>
<td>2. UCLA Microtor</td>
<td>30</td>
<td>20x25</td>
<td>30</td>
</tr>
<tr>
<td>3. Cal Tech Encore</td>
<td>38</td>
<td>24</td>
<td>1.5</td>
</tr>
<tr>
<td>4. MIT Versator II</td>
<td>40</td>
<td>30x30</td>
<td>15</td>
</tr>
<tr>
<td>5. RPI Rentor</td>
<td>45</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>6. Texas Tech</td>
<td>46</td>
<td>26</td>
<td>7</td>
</tr>
<tr>
<td>7. Cal Tech</td>
<td>46</td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>8. Colorado</td>
<td>50</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>9. Wisconsin Tokapole II</td>
<td>50</td>
<td>44x44</td>
<td>10</td>
</tr>
<tr>
<td>10. Texas Pretext</td>
<td>53</td>
<td>35</td>
<td>11</td>
</tr>
<tr>
<td>11. UC Irvine</td>
<td>60</td>
<td>34</td>
<td>6</td>
</tr>
<tr>
<td>12. UCLA Macrotor</td>
<td>90</td>
<td>90x150</td>
<td>6</td>
</tr>
</tbody>
</table>
\[ \tau_E = 6 \times 10^{-21} \overline{n} a^2 \]

"ALCATOR SCALING"
MAJOR CURRENT AREAS OF STUDY

RF WAVE PROPAGATION AND HEATING

RF CURRENT DRIVE

TRANSPORT STUDIES

IMPURITY CONTROL

HIGH BETA

LOW Q

DIAGNOSTIC DEVELOPMENT
RF WAVE PROPAGATION AND HEATING

ECRH
VERSATOR II \((150 \text{ kw} - \Delta V_{\text{EO}}/V_T \leq 70\% )\)

TOKAPOLE II \((10\text{ kw} - \Delta V_{\text{EO}}/V_T \sim 50\% )\)

LOWER HYBRID
VERSATOR II \((120 \text{ kw} - \Delta T_I = 50 \text{ eV})\)
ENCORE (RAY TRACING)

ICRF
MACROROR
TOKAPOLE II \((\text{PUMP OUT OBSERVED})\)
TEXAS TECH (WAVE PROPAGATION)

ALFVEN WAVES
PRETEXT \((\text{RESONANCE IDENTIFICATION AND})\)
TOKAPOLE II \((\text{HIGH POWER HEATING})\)
24cd layer at r = -17.7 cm

**Graph 1:**
- **Y-axis:** E PLUS ARB UNITS
- **X-axis:** RADIUS CM
- The graph shows a peak at around r = -9 cm with a gradual decrease towards r = -1 cm and -14 cm.

**Graph 2:**
- **Y-axis:** E MINUS ARB UNITS
- **X-axis:** RADIUS CM
- The graph shows a peak at around r = -9 cm with a gradual decrease towards r = -1 cm and -14 cm.
CURRENT DRIVE

LOWER HYBRID
VERSATOR II (120 kW - ΔI ~ 10 kA)
ENCORE (50 kW - SMALL CURRENT OBSERVED)

ICRF
MICROTOR (PLANNED)

FAST ALFVÉN WAVE
TEXAS TECH (PLANNED)

NEUTRAL BEAMS
COLORADO (3 keV - PLANNED)

BOOTSTRAP CURRENT
WISCONSIN OCTUPOLE (I ~ 1 kA)
VERSATOR II LHCD/ECH EXPERIMENTS

- STABILIZATION OF THE "TAIL-MODE" WITH ECH.

![Graphs showing data for O.H., LHCD, and LHCD/ECH experiments.](image-url)
TRANSPORT STUDIES

MACROROT (DC POTENTIALS)
\( \phi > 0 \) RECycles IONS AT EDGE
\( \phi < 0 \) CAUSES IMPURITY ACCUMULATION

CALTECH (FLUCTUATING POTENTIALS)
\[ \frac{\delta n}{n} \approx 0.2 - 0.5 \text{ FOR } 0.75 < r/a < 1 \]
\[ \langle \delta n \delta E \rangle \text{ GIVES } D = D_{BOHM} \text{ AT OUTER EDGE} \]

RENTOR (ION BEAM PROBE)
ELECTRON INJECTION

electron injection current

NO ELECTRON INJECTION

UCLA MACROTOR
IMPURITY CONTROL

MACROTOR-PUMPED LIMITER

CALTECH-BIASED LIMITER WITH BUNDLE DIVER TOR

MICROTOR-HOT WALL (700°C) OPERATION

TOKAPOLE II

-ECRH STARTUP
-MARSHALL GUN REFUELING
Local toroidal divertor can control plasma-limiter interaction.

\[ B_{\text{coil}} = -B_T \]

Flux to limiter decreased by \times 4

\[ B_{\text{coil}} = +B_T \]

Flux to limiter increased by 60%

May be useful in pumped-limiters.
HIGH BETA

TORUS II

$\langle \beta \rangle \approx 12\%, \quad \beta_0 \approx 42\%$ obtained

Diamagnetism and outward current shift seen growing $\delta N$ on outside seen

Variable plasma pressure profile

MACROTOR

$\beta_0 = 8\%$ obtained by ramping down $B_T$
LOW q
WISCONSIN TOKAPOLE II

Q REMAINS FIXED AT 0.4 DURING SAWTEETH SEPARATRIX MAY LIMIT ISLAND GROWTH
POOR ENERGY CONFINEMENT (<100 \mu SEC),
DIAGNOSTIC DEVELOPMENT

RPI-ION BEAM PROBE \((\delta_\phi, \delta_N)\)

MICROTOR

1-SHOT IR LASER SCATTERING \((\omega(k))\)

FARADAY ROTATION \((b_p)\)

PRETEXT

ALFVÉN WAVES + CO2 LASER INTERFEROMETER \((q(r))\)

CALTECH

2-D VISIBLE IMAGING OF \(H_\alpha\)
EDGE TURBULENCE can be seen by visible IMAGING of Hα.

- Light fluctuations are locally correlated with probe $\tilde{n}$. 

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CALTECH TOKAMAK

![Diagram of a fast photodiode array, lens, and probe focused into a curved surface with a time graph showing fluctuations. Time is labeled as (50μsec/div).]
USES FOR SMALL TOKAMAKS

DETAILED BASIC PLASMA PHYSICS STUDIES
- STABILITY
- CURRENT DRIVE
- IMPURITY CONTROL

TESTING NEW IDEAS QUICKLY AND CHEAPLY

DIAGNOSTIC DEVELOPMENT

STUDENT TRAINING