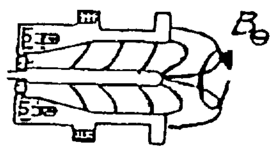
N93-13643

# SCALING AND APPLIED FIELD STUDIES OF MPD THRUSTERS WITH LASER DIAGNOSTICS

Thomas M. York
The Ohio State University
Columbus, Ohio

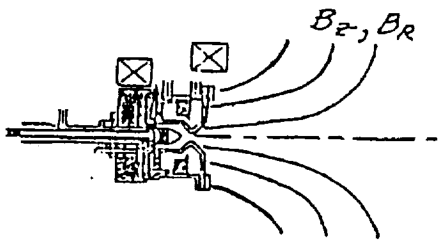
## Scaling of Plasma Thrusters-
## Match High Efficiency Thrusters To Available Power

### Self-Field MPD




Erosion Limited
Power Limited
Efficiency Limited
Physical Mechanisms for Limits not Understood
Self-Field Magnetic Expansion Effects Interdependent with Gas Heating

### 1/4-Scale Applied-Field MPD




Fields Influence Erosion
Fields allow Better Expansion at Low Power
Fields Enhance Expansion and Efficiency
Physical Mechanisms not yet Understood
Applied-Field Magnetic Nozzle Independently Controllable from Gas Heating Source

## Scaling Of Arcs And MPD-Arcs

### Properties And Functions:

**Size:** L

**Mass Flow:** $\dot{m}/Acs$

**Em Velocity:** $Uem = \left(\frac{I^2}{\dot{m}}\right)\frac{\mu o}{4\pi}\ln\left(\frac{Ra}{Rc}\right)_{EFF} \quad \alpha \; \frac{I^2}{\dot{m}} = \frac{j^2r^2z^2}{\dot{m}} \quad \alpha \; \frac{\vec{j} \times \vec{B}}{\dot{m}/Acs}\,z$

**Force Density:** $j \times B \quad \alpha \; \frac{I^2}{r^2 z} = j^2 z$

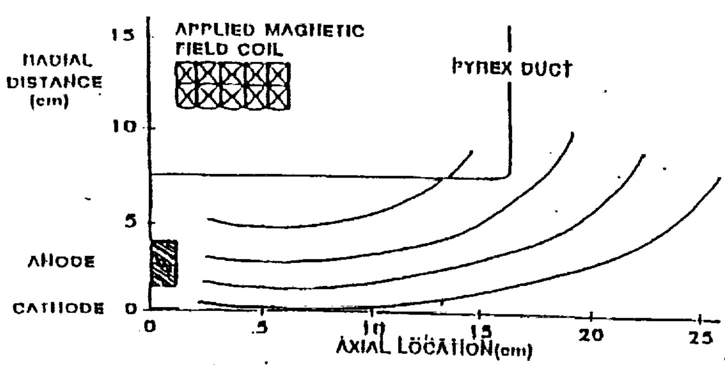
**Power:** $IV = I^2R$

**Eth Velocity:** $Ueth = \left(\frac{2I^2R}{\dot{m}}\right)^{1/2} \quad \alpha \left(\frac{I^2}{\dot{m}} R\right)^{1/2} \quad \alpha \left(\frac{j^2\,z^2}{\dot{m}/Acs} R\right)^{1/2}$

### 1/4-Scale Thruster:
**($\vec{j}$ x B and $\dot{m}$/Acs constant)**

| | | | |
|---|---|---|---|
| 1F | $L = L_{fs}/4$ | $I_{1/4} = I_{fs}/8$ | |
| 1F | $L = L_{fs}/4$ | $j_{1/4} = j_{fs} \times 2$ | |
| 1F | $L = L_{fs}/4$, $R$ = const. | $U_{eth} = U_{eth}$ (fs)/2 | (Electrode drop dominant) |
| 1F | $L = L_{fs}/4$, $\sigma$ = const. | $U_{eth} = U_{eth}$ (fs) | (Plasma drop dominant) |

## Magnetic Nozzle Studies




1/4 SCALE THRUSTER, FIELD COIL AND APPLIED MAGNETIC FIELD LINES

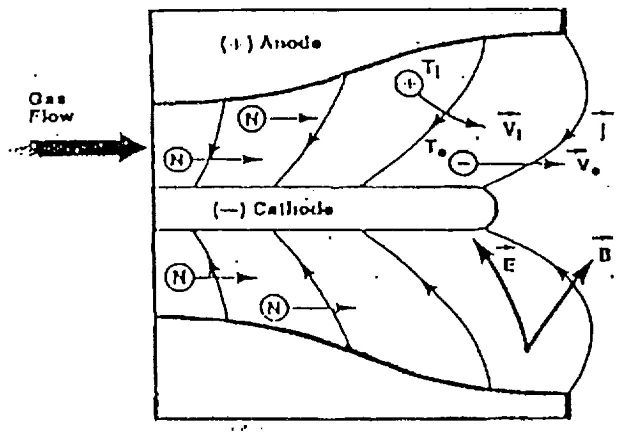
**Reported:**

- Self-Field plasma expands to low pressure in 5 cm (plasma $\dot{m}$ lost). Applied-field plasma expansion is controlled and has large ∫pdA thrust.
- Applied fields can be optimized for Uex max or high thrust with low Uex. This will allow optimization of Uex for mission requirements.

**Being Completed:**

- New switches and battery supply allow: .1-2sec nozzle field generation to study effects of field penetration into thrust chamber
- New coil design will change nozzle shape to study effects of extended length, gradual expansion, detachment, etc.

# Advanced Diagnostic Techniques Needed For Obtaining Particle Velocity, Density, Temperature And Current Distributions In Plasma Thrusters




Need to Measure:

- Electron, Ion and Neutral Densities
- Electron and Ion Temperatures
- Current Densities
- Species
- Potential and Magnetic Field
- Velocity Profiles

## Non-Intrusive Laser Diagnostics For Arcs And MPD-Arcs

THOMSON SCATTER FOR Ne , Te
- 2J Ruby system used to measure Ne , Te on 1/4 scale
- Confirmed Ne , Te indications of Langmuir in B
- Established point reference for multi-beam interferometer

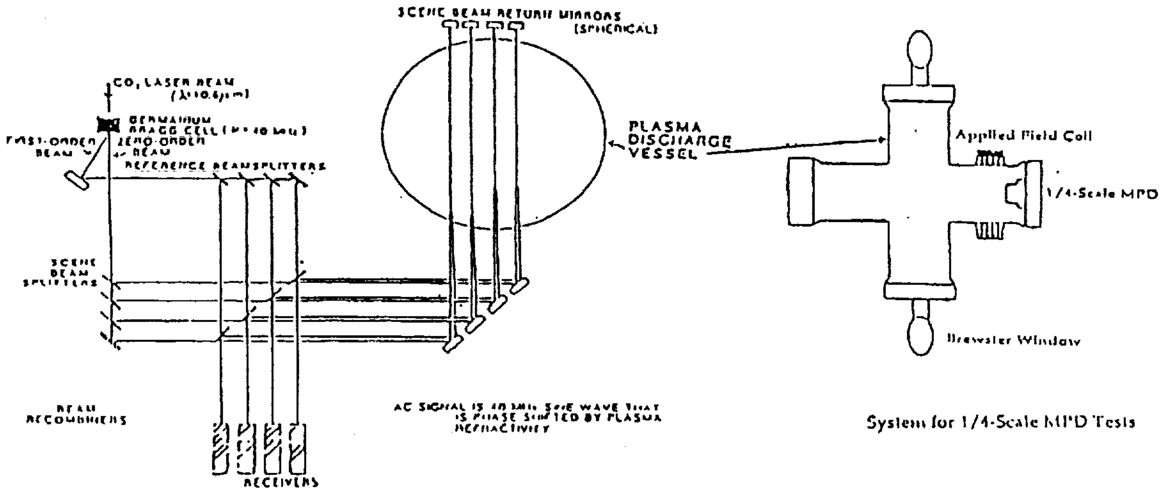
THOMSON SCATTER FOR ( ELECTRON ) FLOW VELOCITY
- 2J Ruby system used to get $V \gtrsim$ Sonic on experiment
- Electron velocity confirmed equal to ion velocity
- Could be applied to ARC and MPD-ARC

MULTIBEAM INTERFEROMETER FOR Ne(r) = f(z) PROFILES
- 50W CO2 CW system being used with 4 beams on chords
- Abel inversion allows Ne(r)
- Allows comprehensive view of applied field effects

DIAGNOSIS OF Ne FLUCTUATIONS FOR TRANSPORT STUDIES
- 50W CO2 CW System can be used for ARC and MPD-ARC studies
- FIR wavelengths and new detectors possible
- Fluctuations between .01 and 1. cm with 1 kHz - 10GHz in plasma with $10^{18}$ - $10^{17}$ $cm^{-3}$ possible

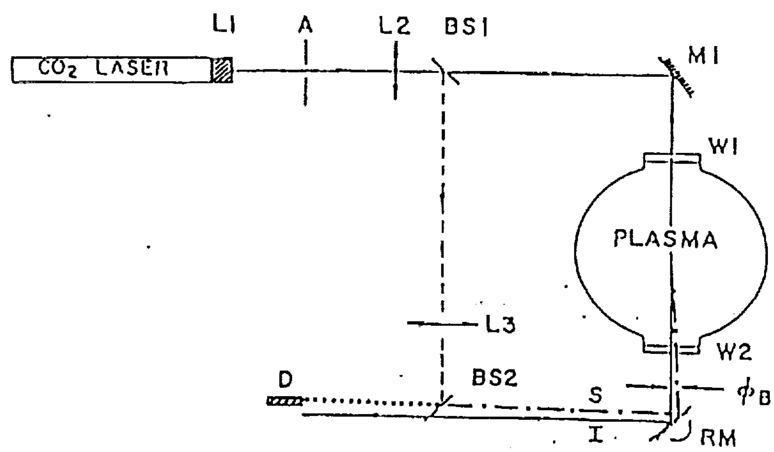
MAGNETIC FIELD AND CURRENT DENSITY WITH FARADAY ROTATION
- Laser beam rotated ∝ B, as $\theta < \lambda_0^2$ Ne B dZ
- Long $\lambda_0$ generates high sensitivity ( 118.8 m possible )
- Need interferom. determination of Ne dZ to unravel

## Schematic of Multi-Beam Interferometer For Electron Density Profile Determination




System for 1/4-Scale MPD Tests

## Schematic of Diagnostic System to Determine Density Fluctuations Magnitude and Orientation To Define Anomalous Transport




A schematic diagram for small angle $CO_2$ laser scattering from a plasma. A rotating mirror RM scans the scattered radiation S at angle $\phi_B$ to be coincident with the LO beam at BS2 and detector. The fluctuation of wavelength $\lambda$ is determined from $\phi_B = 2\mathrm{Sin}^{-1}(\lambda_o / 2\lambda)$