LAPTAG

LOS ANGELES PHYSICS TEACHERS ALLIANCE GROUP

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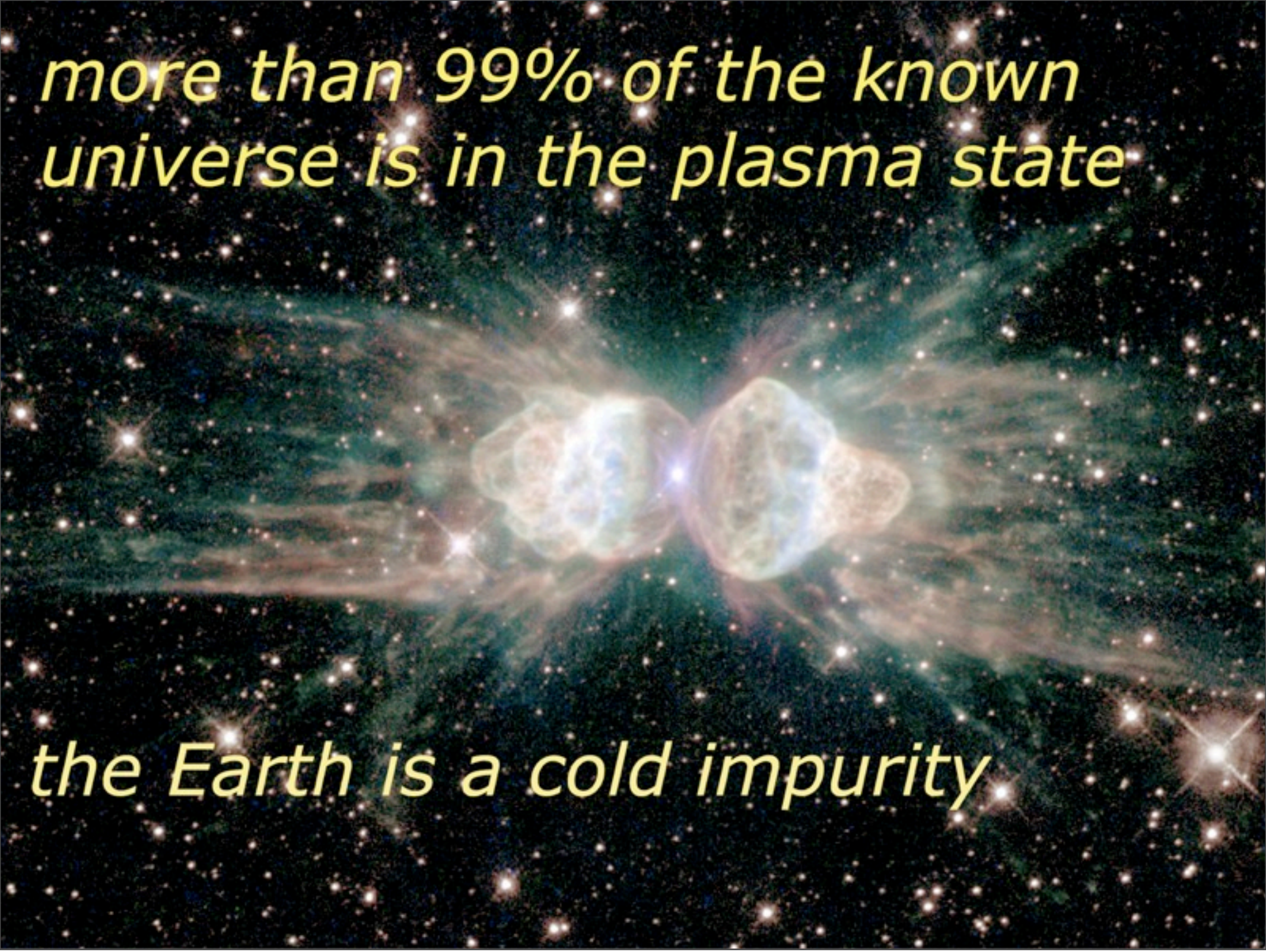
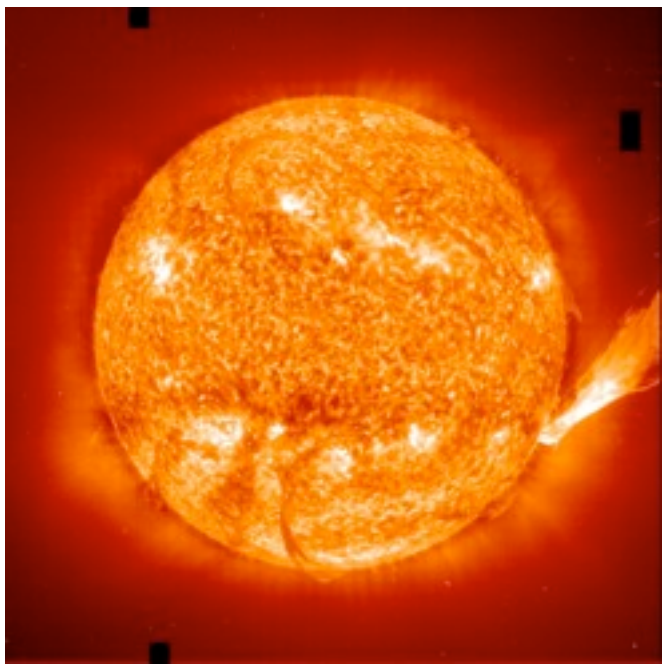

more than 99% of the known universe is in the plasma state
the Earth is a cold impurity

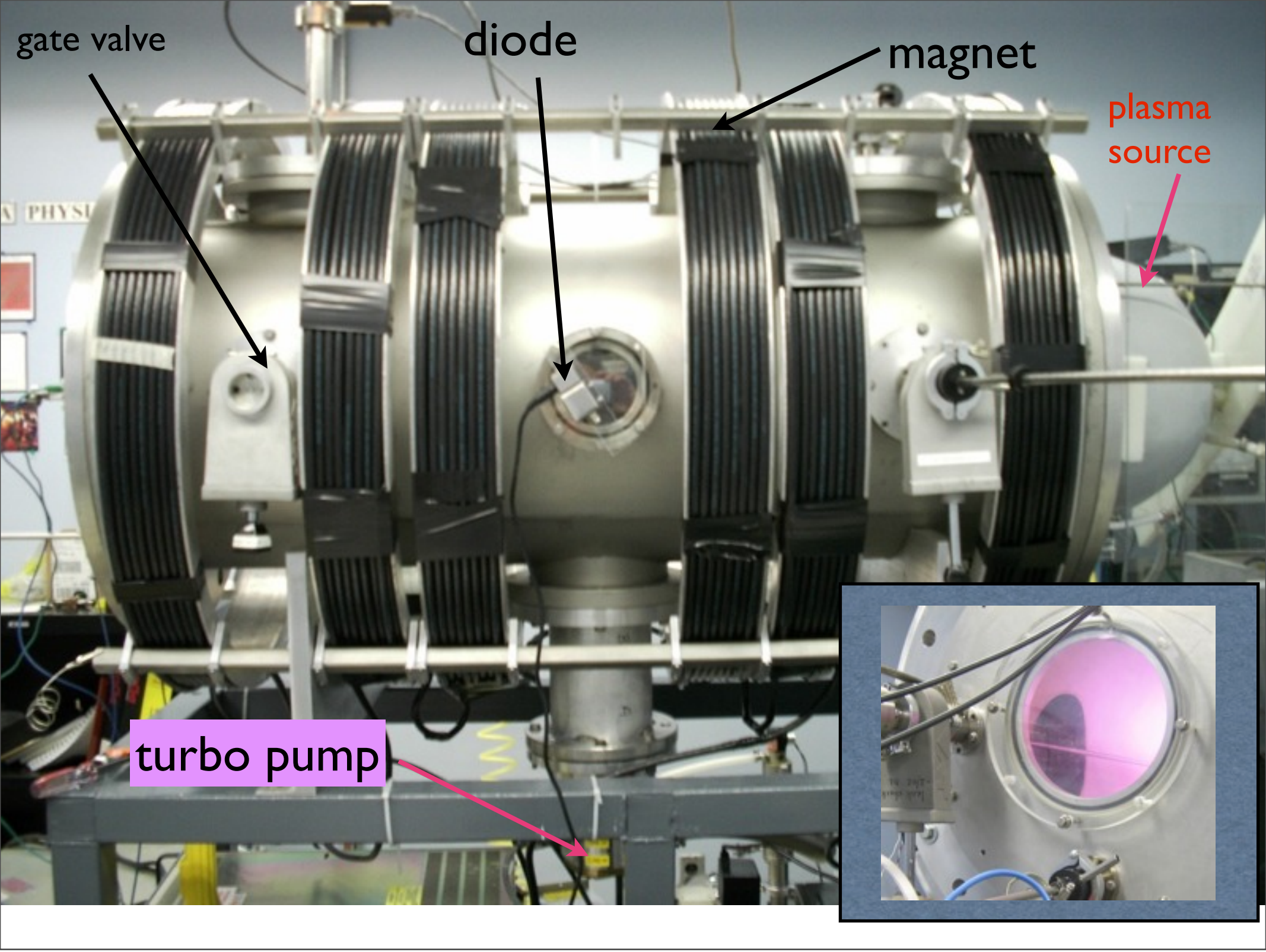
Examples of Plasmas

Aurora

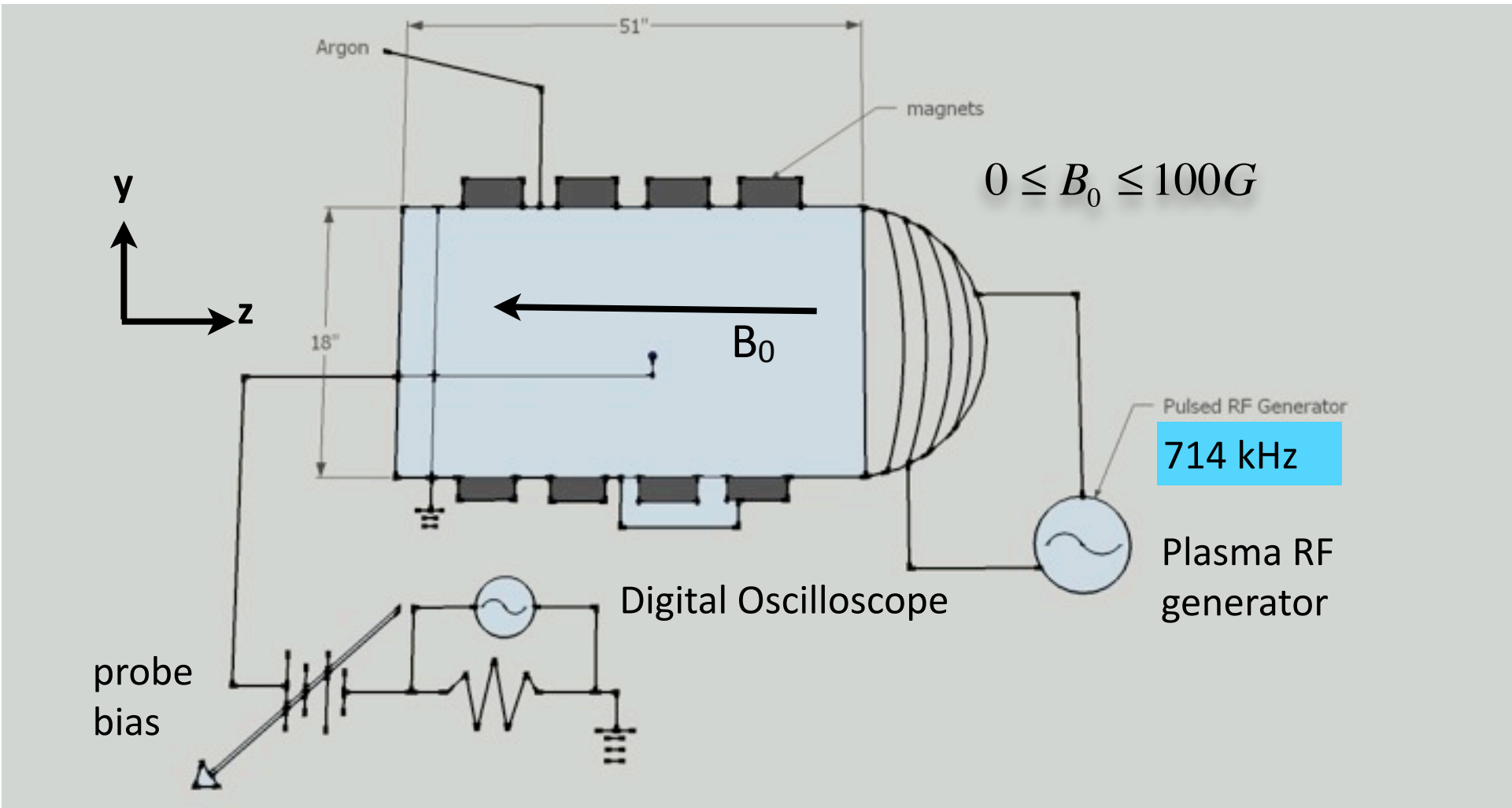
Sun



semiconductor manufacturing

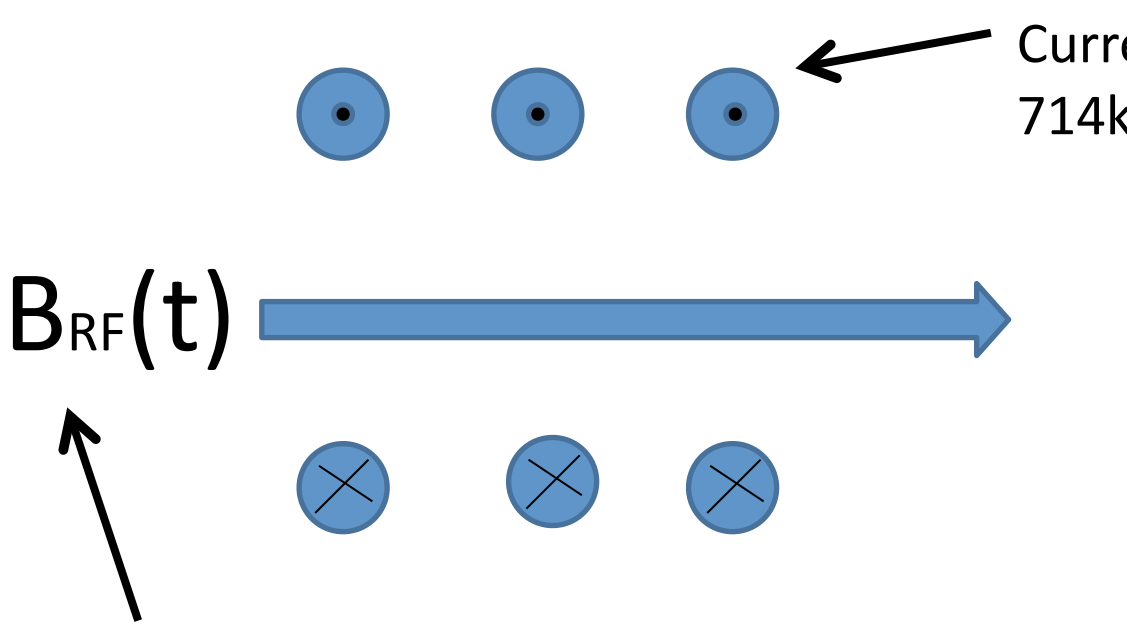

gate valve
diode
magnet
plasma source
turbo pump

Plasma Machine Schematic

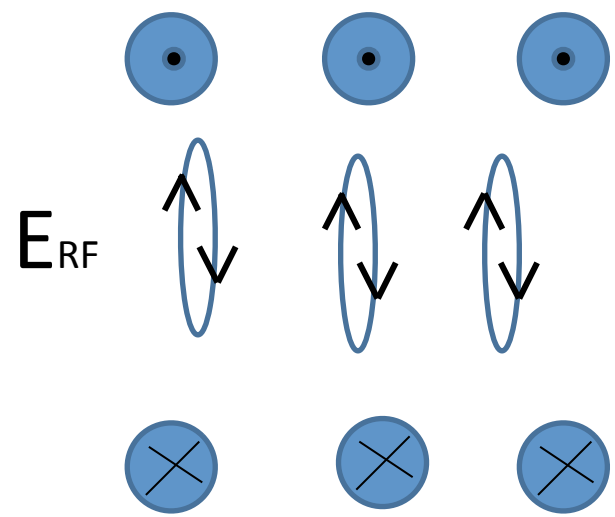


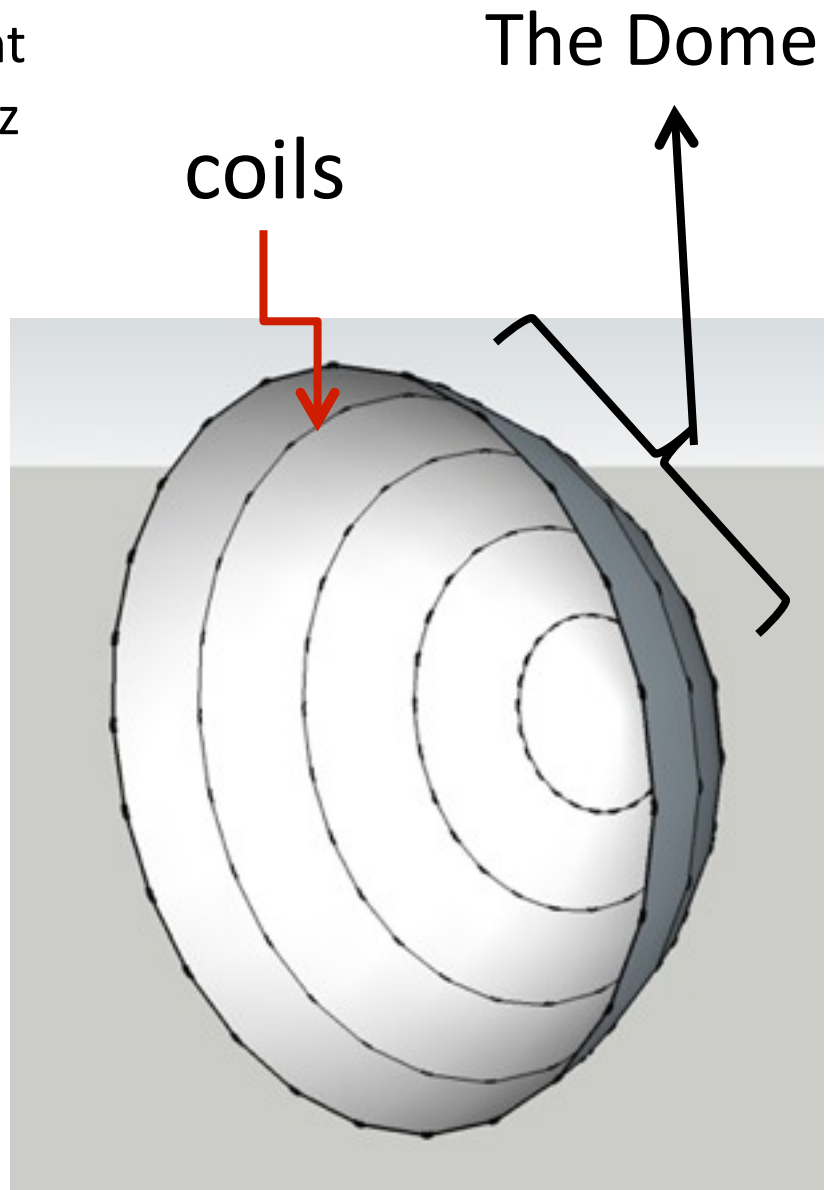
Laptag RF pulsed Plasma

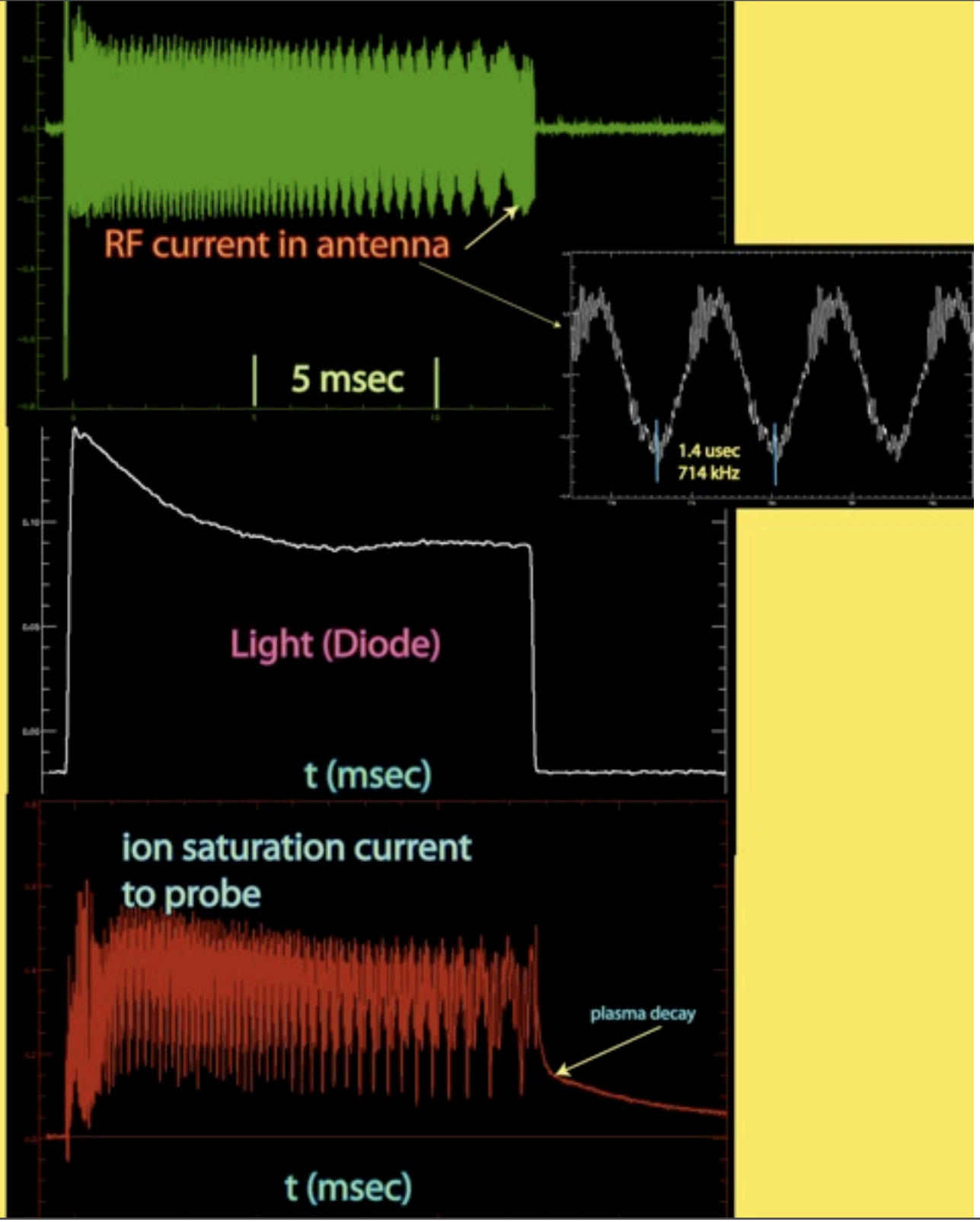
Plasma production



Changing magnetic field makes E_{RF} (Faraday's Law)





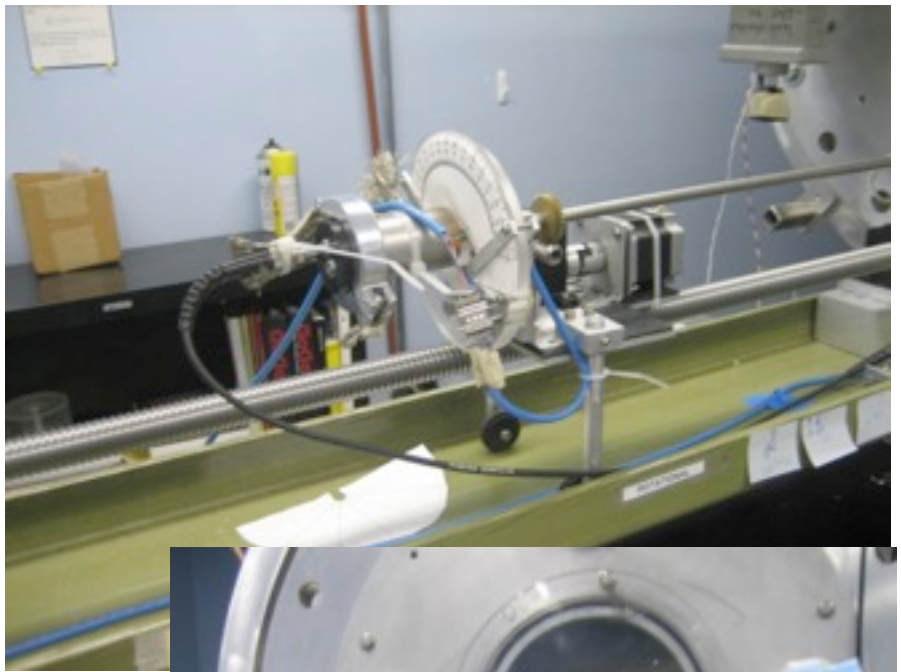


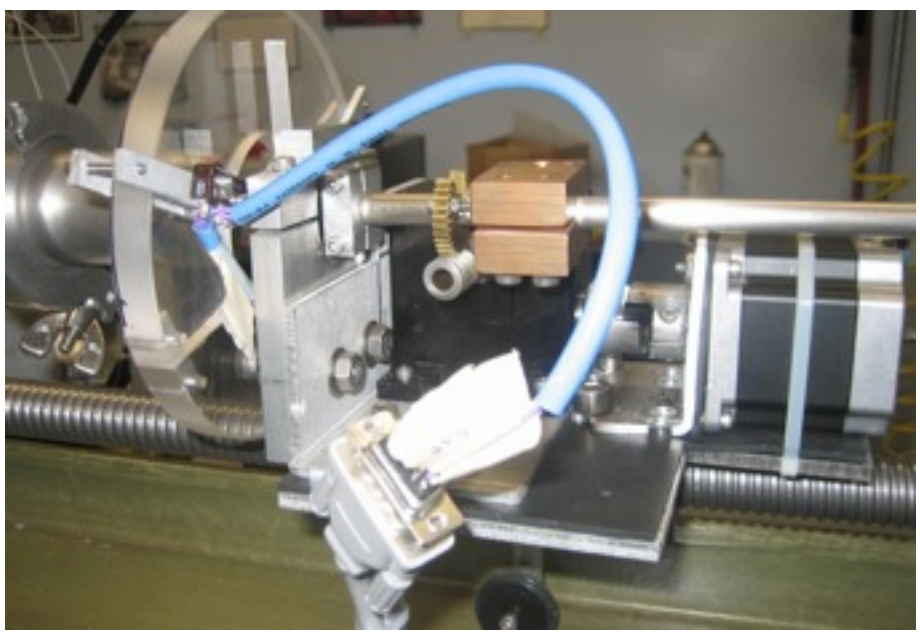
The plasma is pulsed

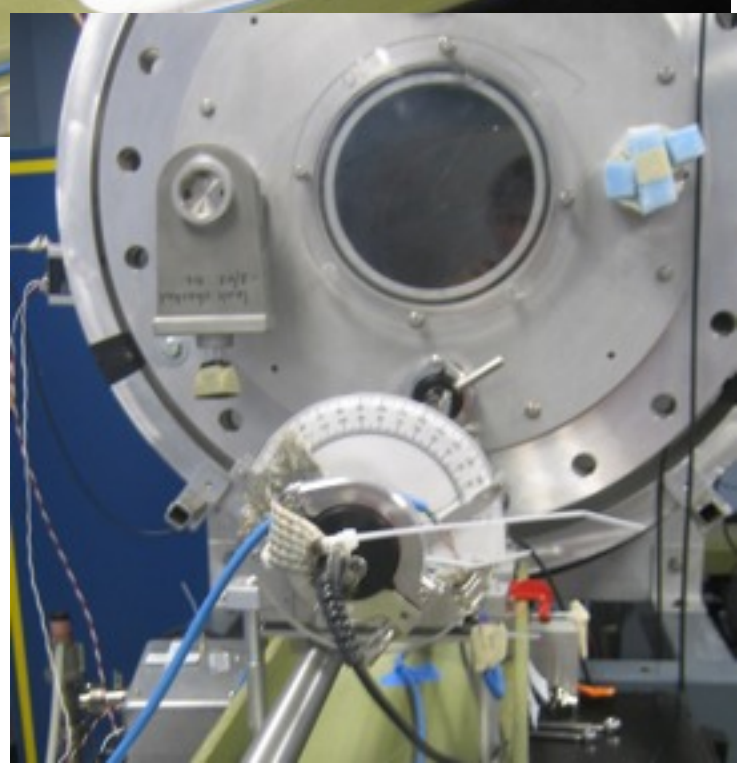
Antenna - 1 kW
(714 kHz)

Probe Drive

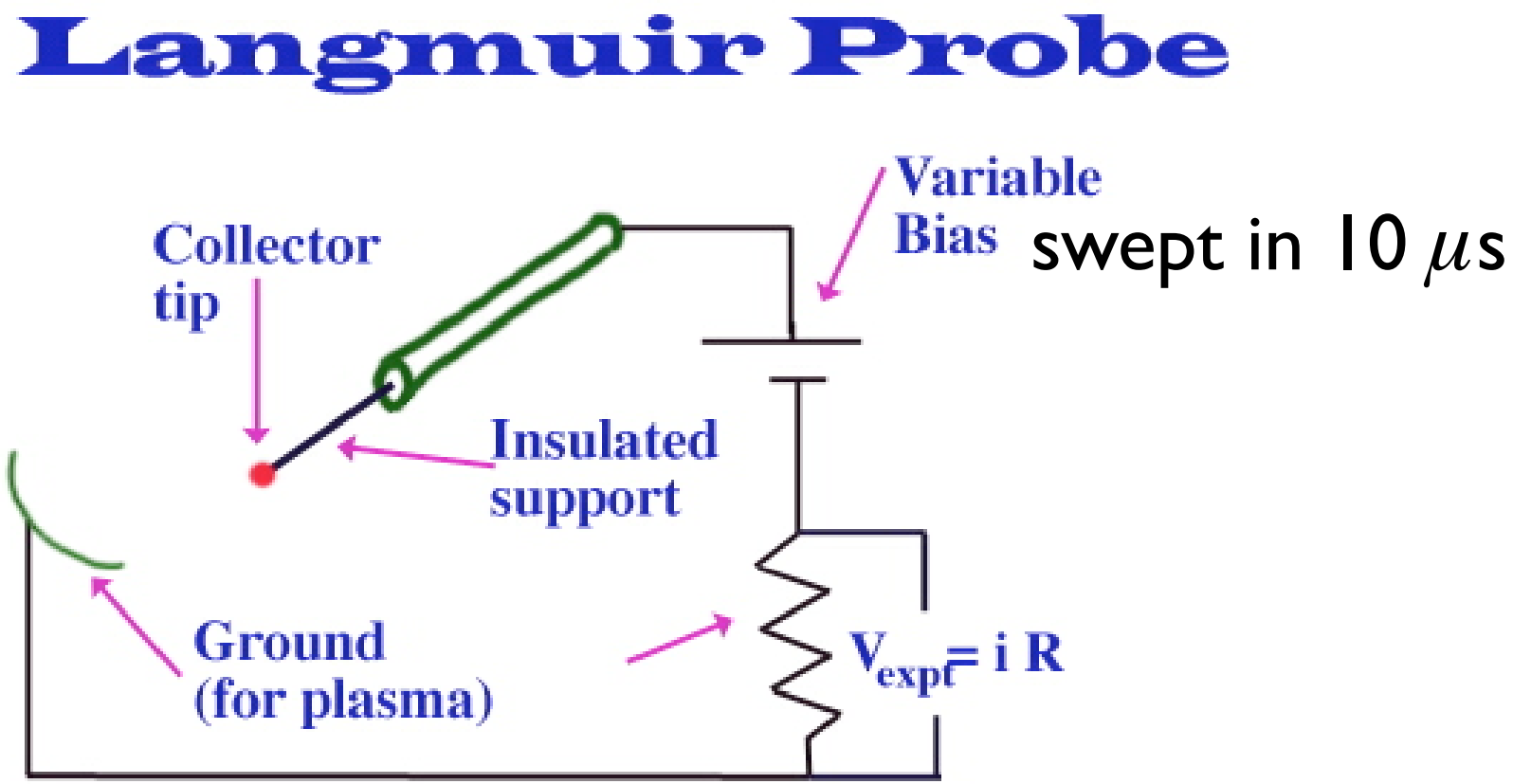
- The probe is 0.08 cm^2 Ta disk on a 26.4 cm arm attached to the end of the probe shaft. The probe drive allows rotational and axial motion of the probe through the plasma.



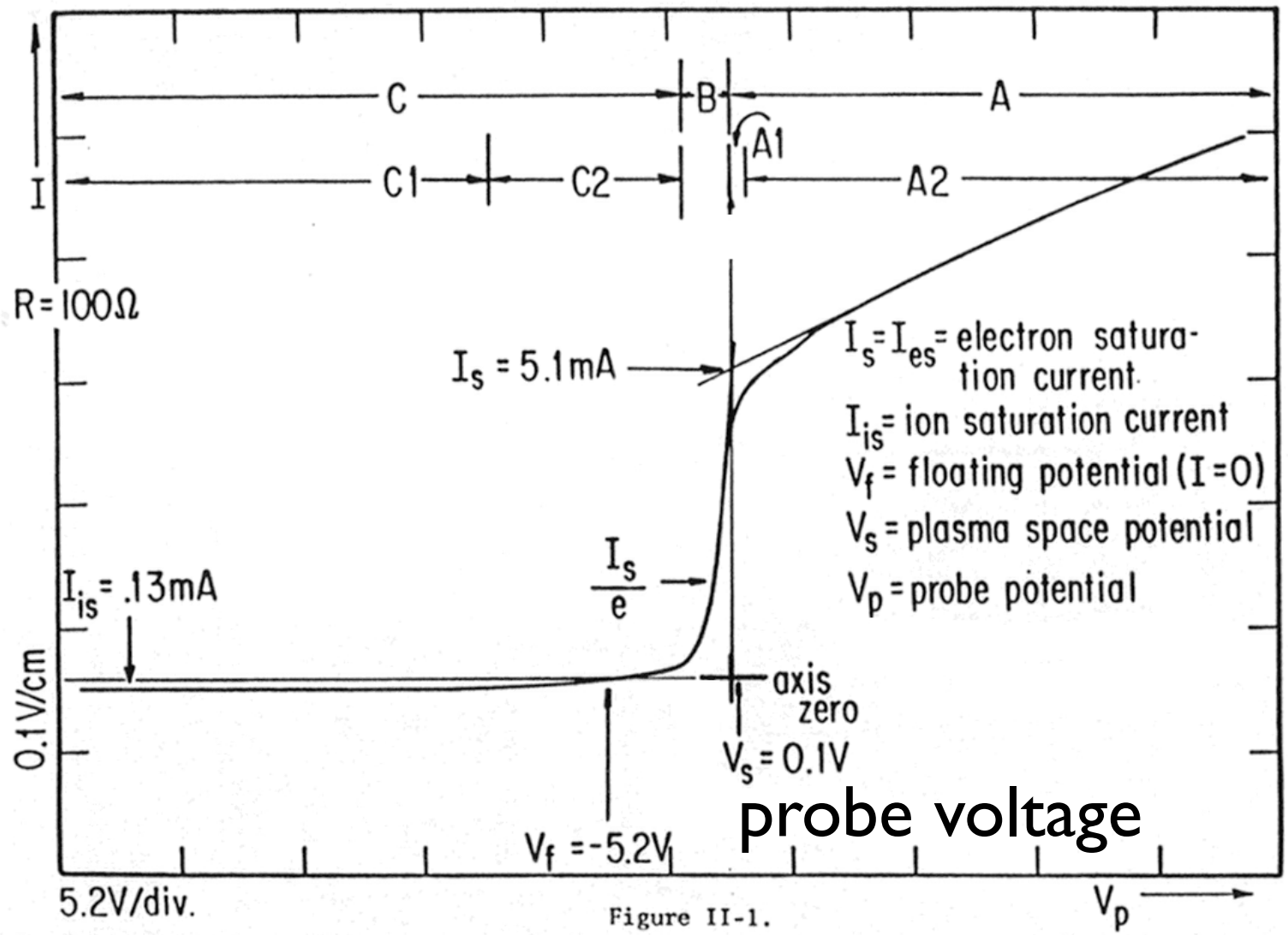




langmuir probe



swept in 10 μs



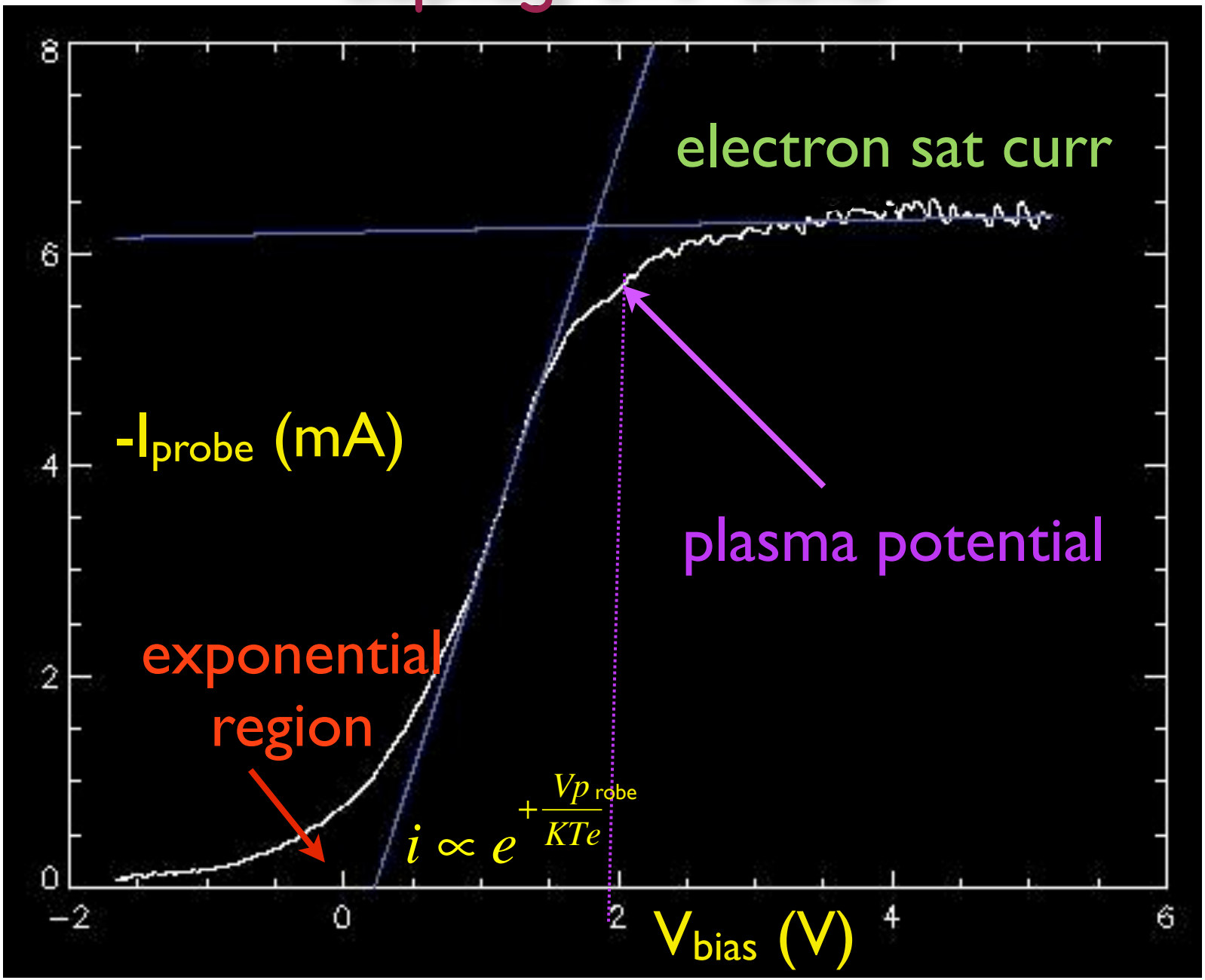
-i_{probe}

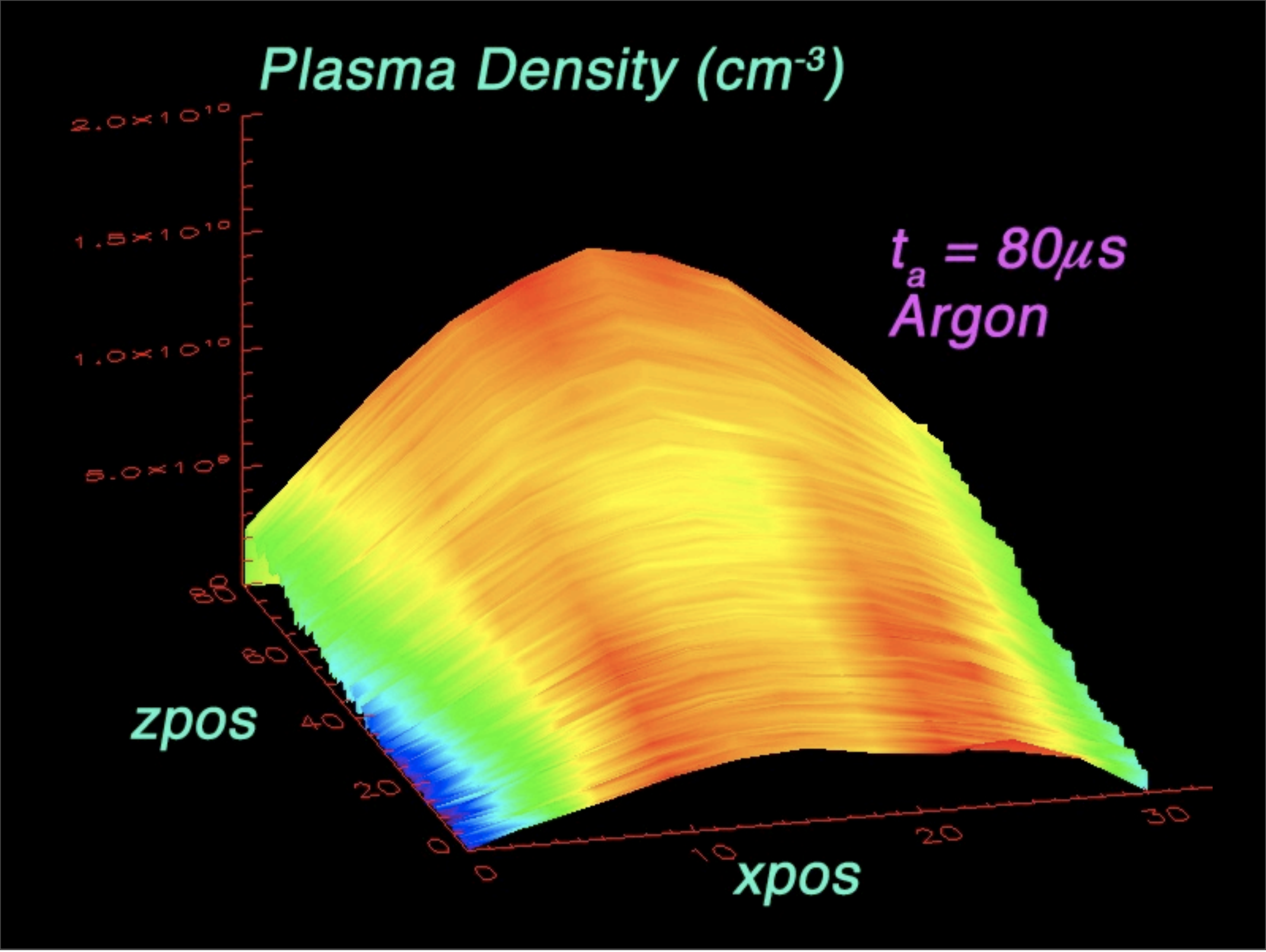
probe voltage

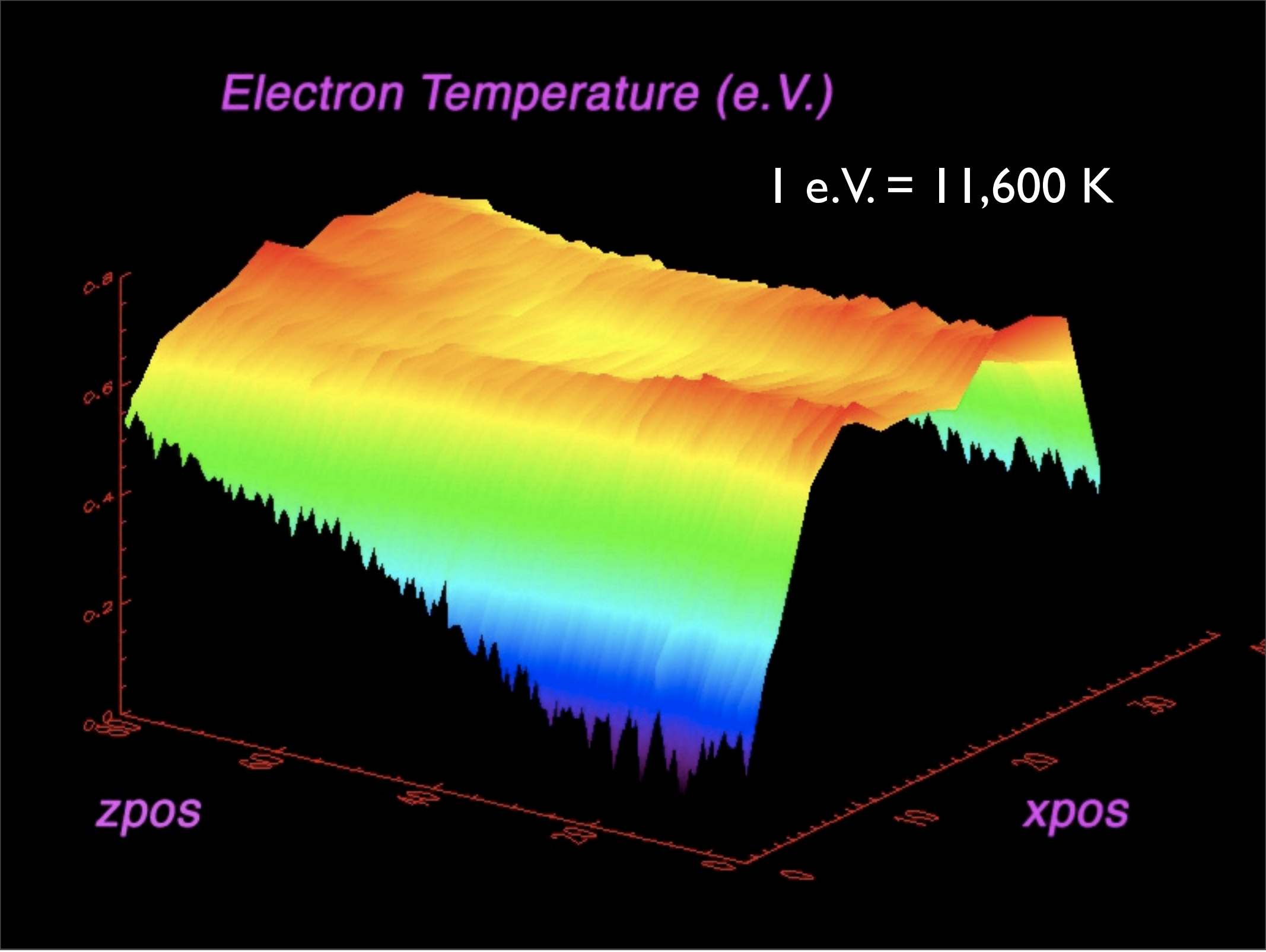
Figure II-1.

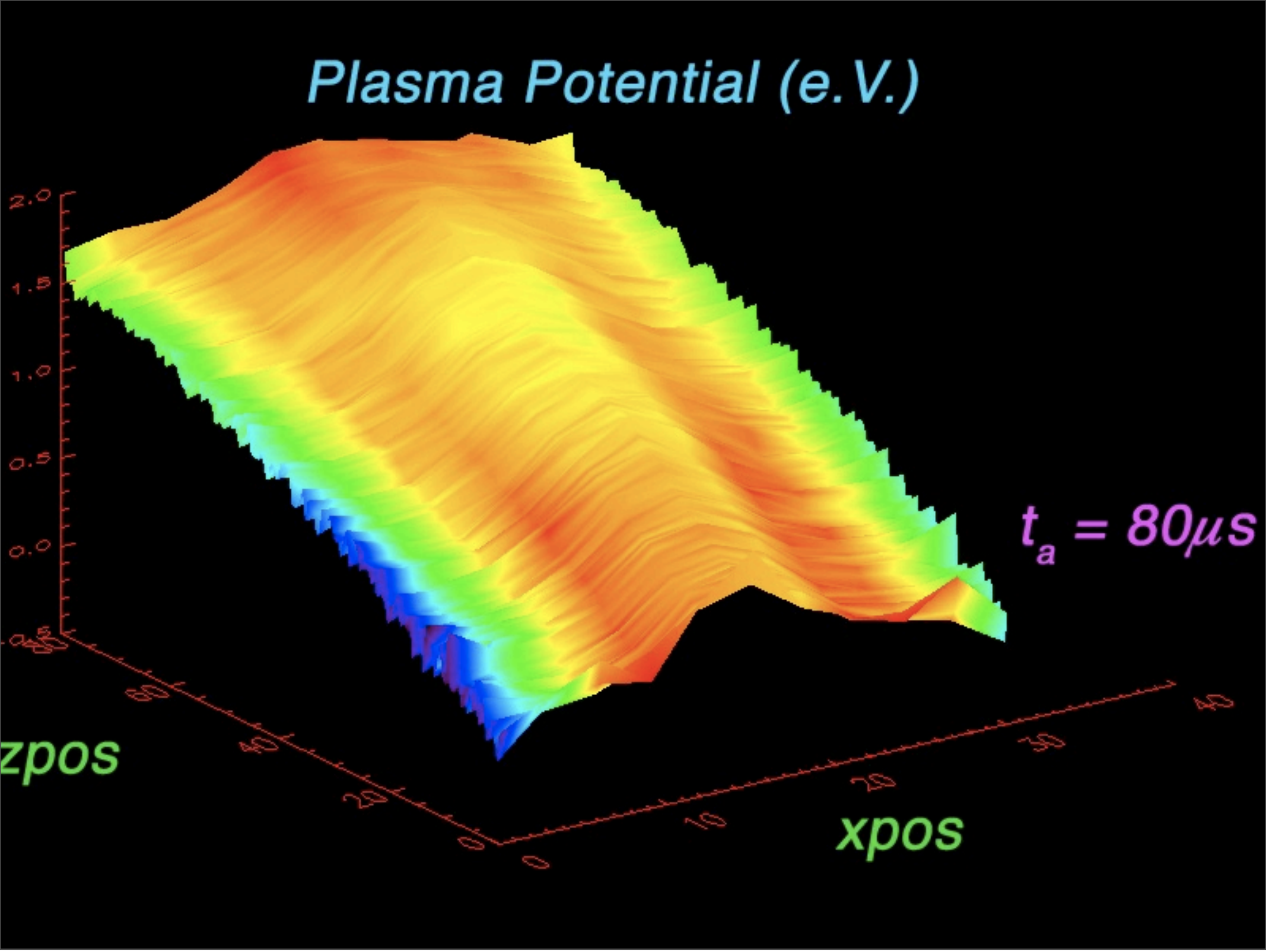
Sample Langmuir Probe Characteristic (Radial disc probe placed near center of single plasma): Region C1 - Ion saturation (electrons repelled); Region C2 - Ion saturation plus small primary electron current; Region B - Secondary electrons added to current of primaries and ions; X - Probe at space potential (zero electric probe field); Region A1 - Electron saturation with cooler ions being repelled; Region A2 - Electron saturation, no ion current. T_e (1.0 eV for this data).

Laptag I-V data




Plasma Density (cm-3)
2.0x10^10
1.5x10^10
1.0x10^10
5.0x10^9
80
60
40
20
0
zpos
0
10
20
30
xpos
ta = 80μs
Argon


Electron Temperature (e.V.)
1 e.V. = 11,600 K
0.8
0.6
0.4
0.2
0
zpos
xpos


Plasma Potential (e.V.)
2.0
1.5
1.0
0.5
0.0
zpos
xpos
$t_a = 80\mu s$

Summary and Conclusions

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1) A magnetized plasma device was constructed

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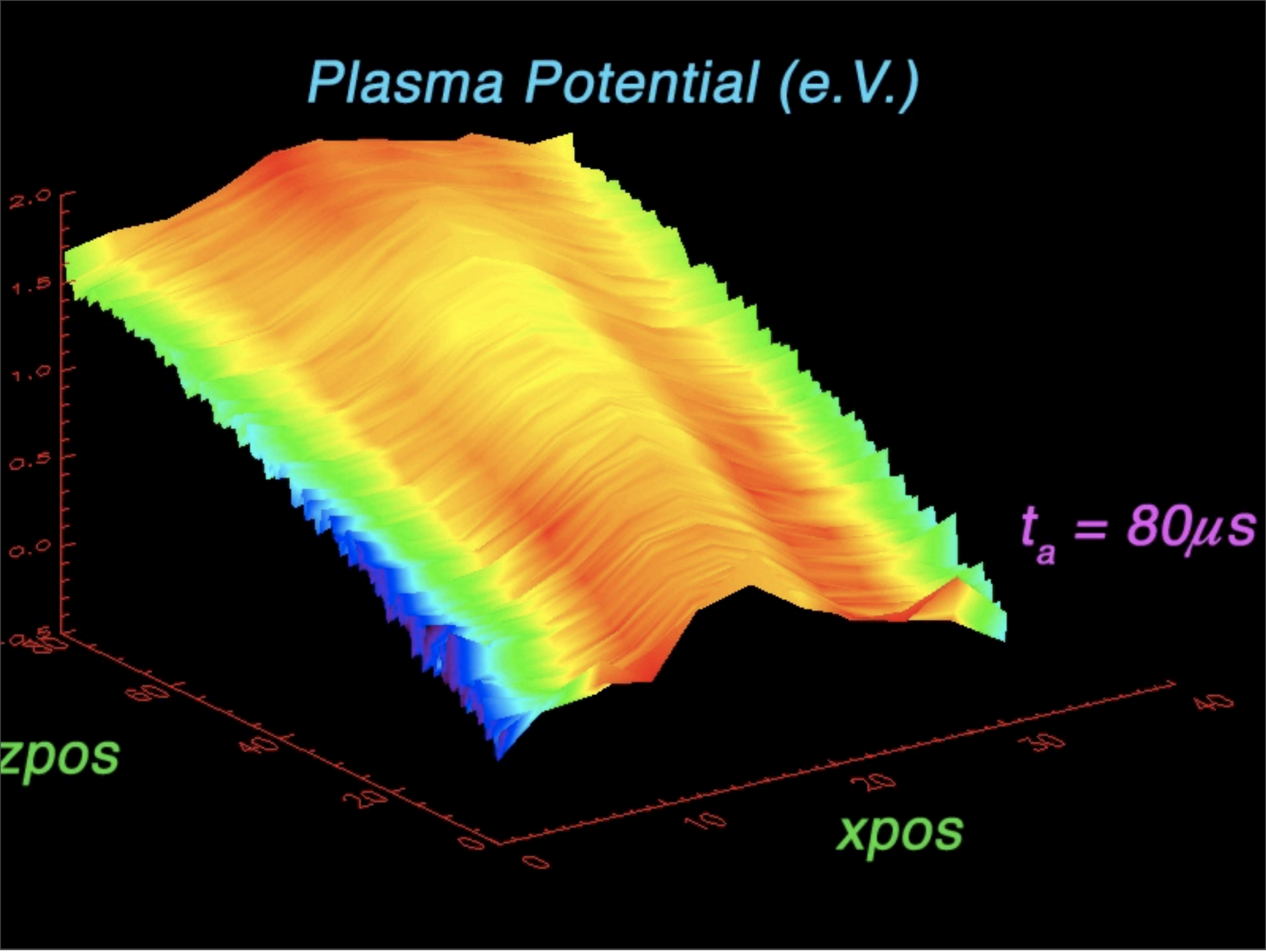
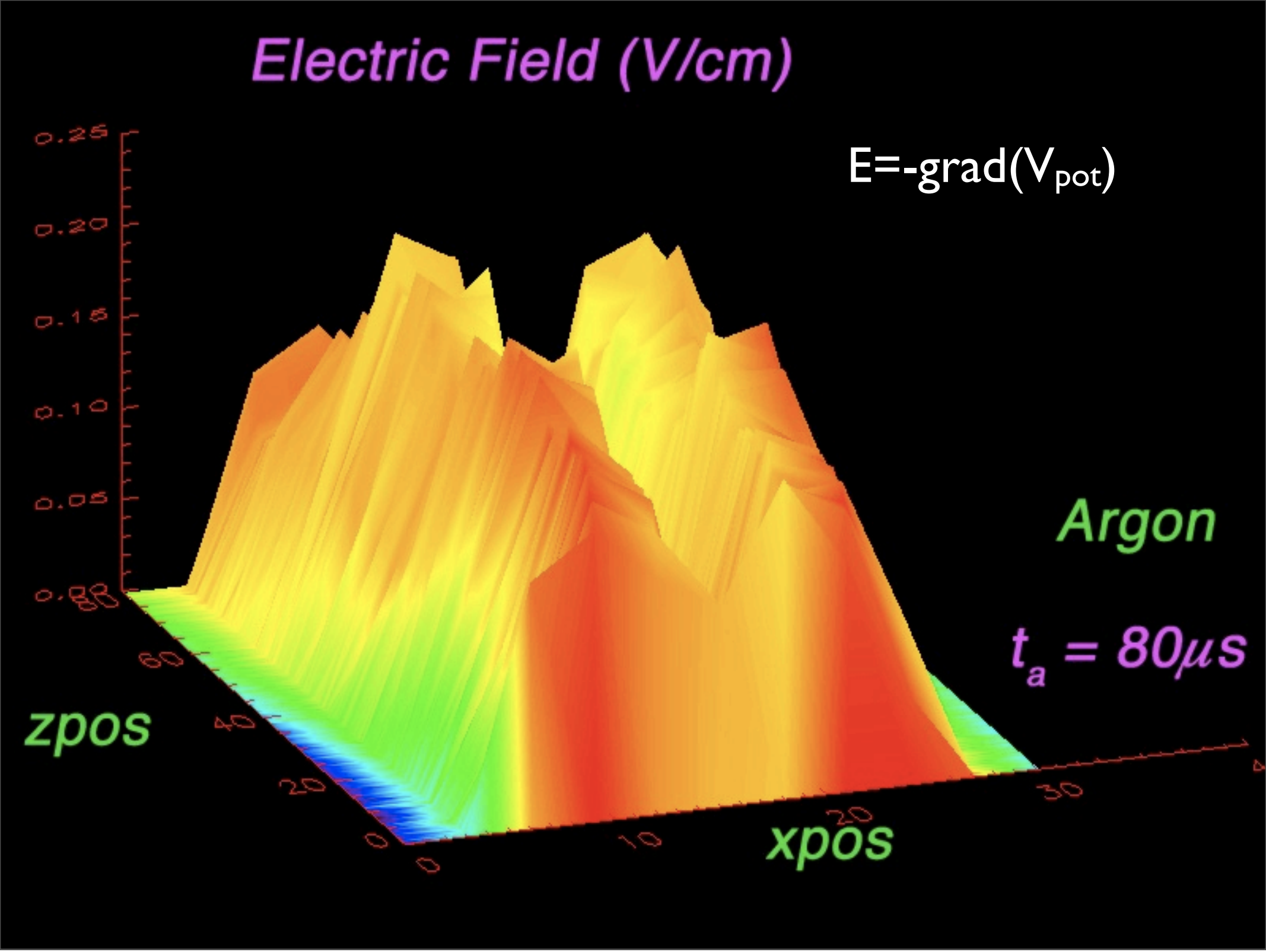
5) Computer analysis was used to determine (n, Te, Vp)

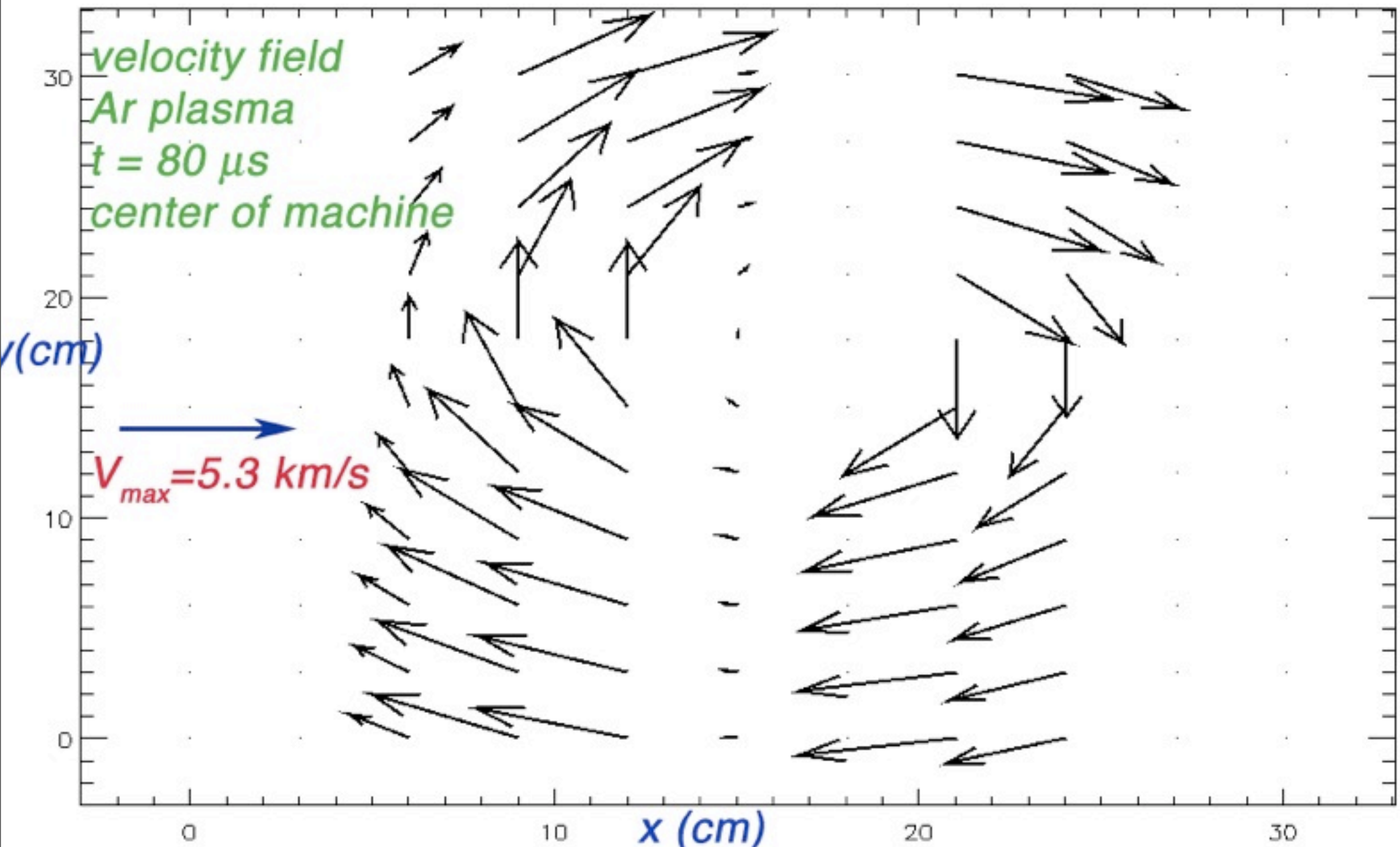

Probe Measurements to
Detect Plasma Rotation


Plasma Potential (e.V.)
2.0
1.5
1.0
0.5
0.0
zpos
xpos
$t_a = 80\mu s$


Electric Field (V/cm)
E=-grad(V_pot)
0.25
0.20
0.15
0.10
0.05
0.00
Argon
t_a = 80μs
zpos
0
20
40
60
0
10
20
30
xpos

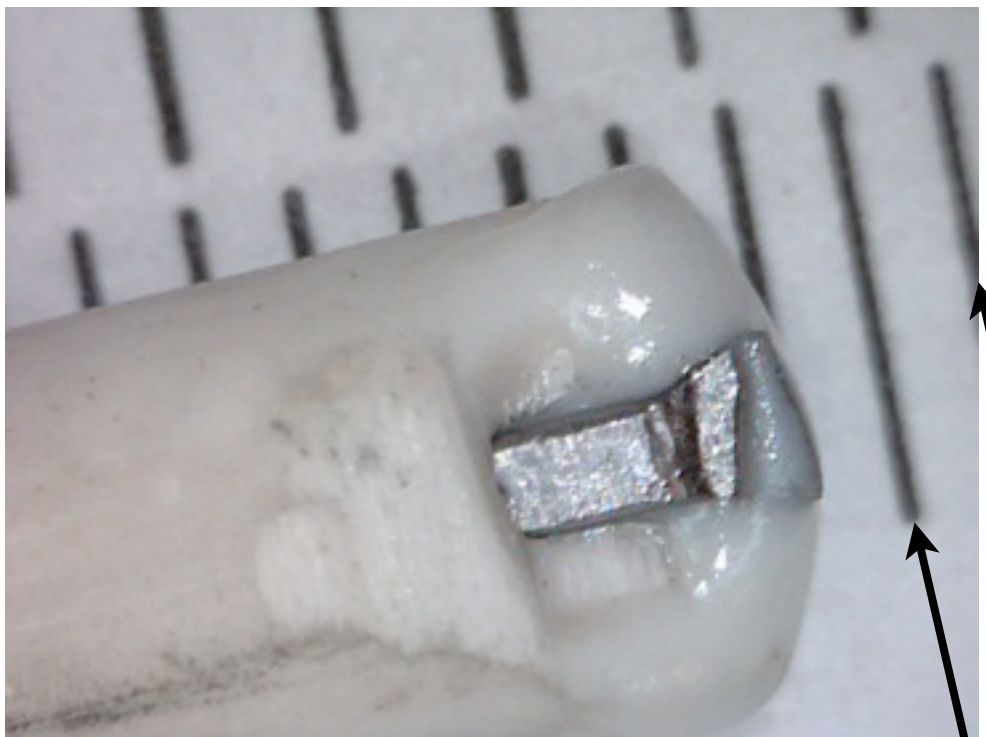
PLASMA Drift

$$\vec{v} = \frac{\vec{E} \times \vec{B}}{B^2} \qquad |v| = \frac{E}{B}$$


velocity field
Ar plasma
t = 80 μs
center of machine
V max=5.3 km/s
y (cm)
x (cm)
0
10
20
30

v_{eth} = 400 km/s

"Mach" probe (2 faces)



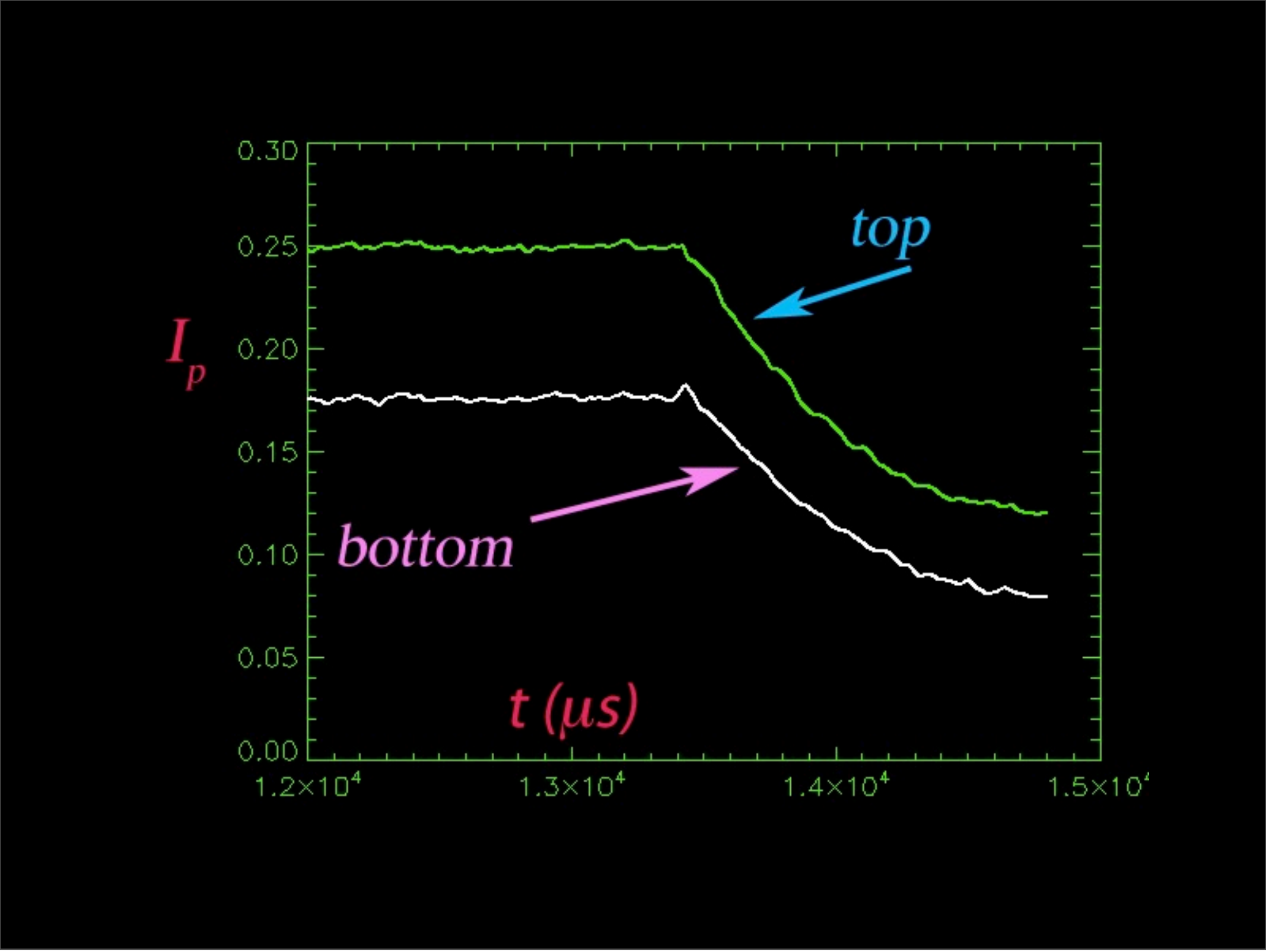
1 mm

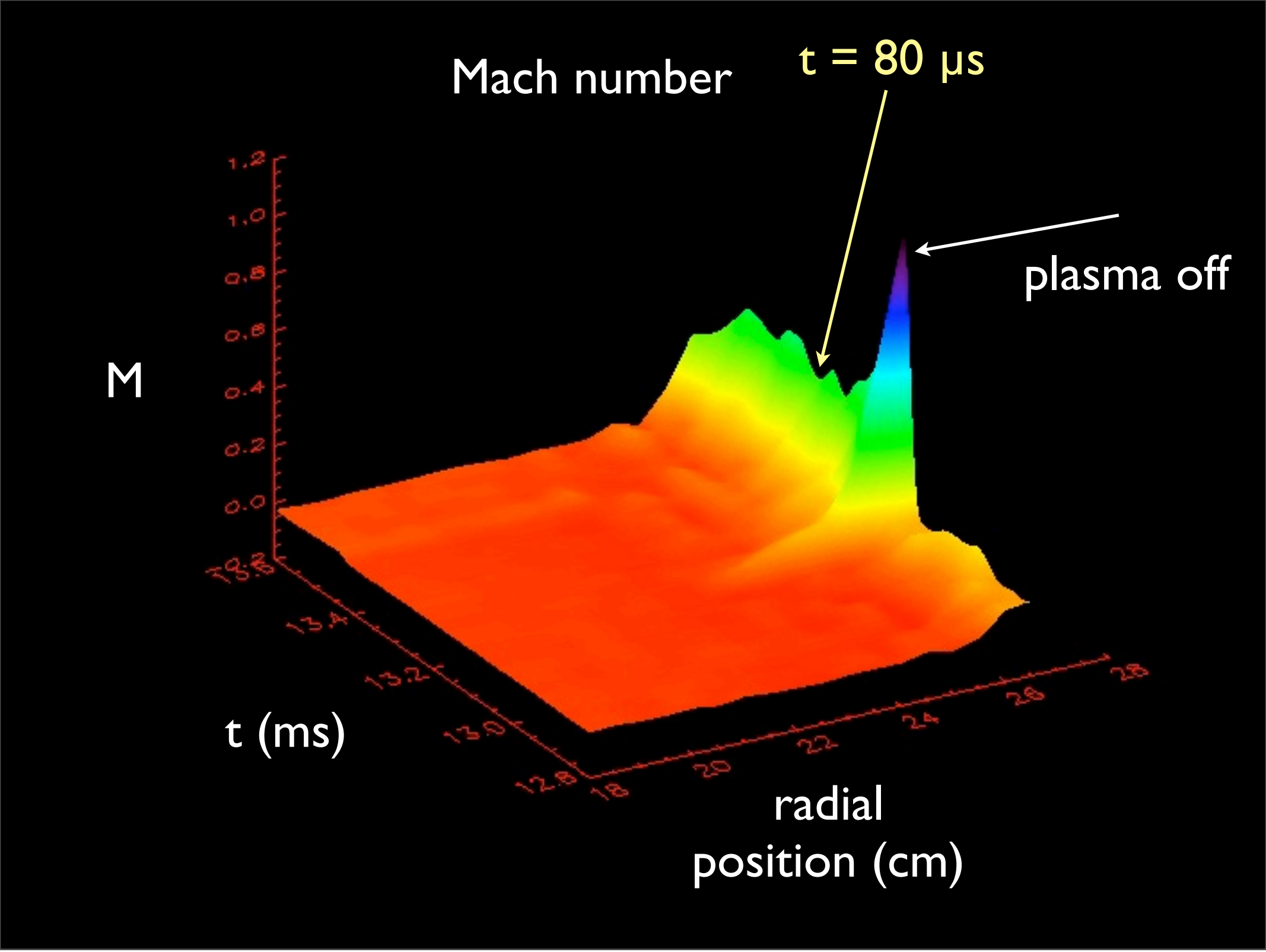
$$M = \frac{v}{c_s} = \frac{I_{bottom} - I_{top}}{\langle I_{bottom}, I_{top} \rangle}$$

Flow, v

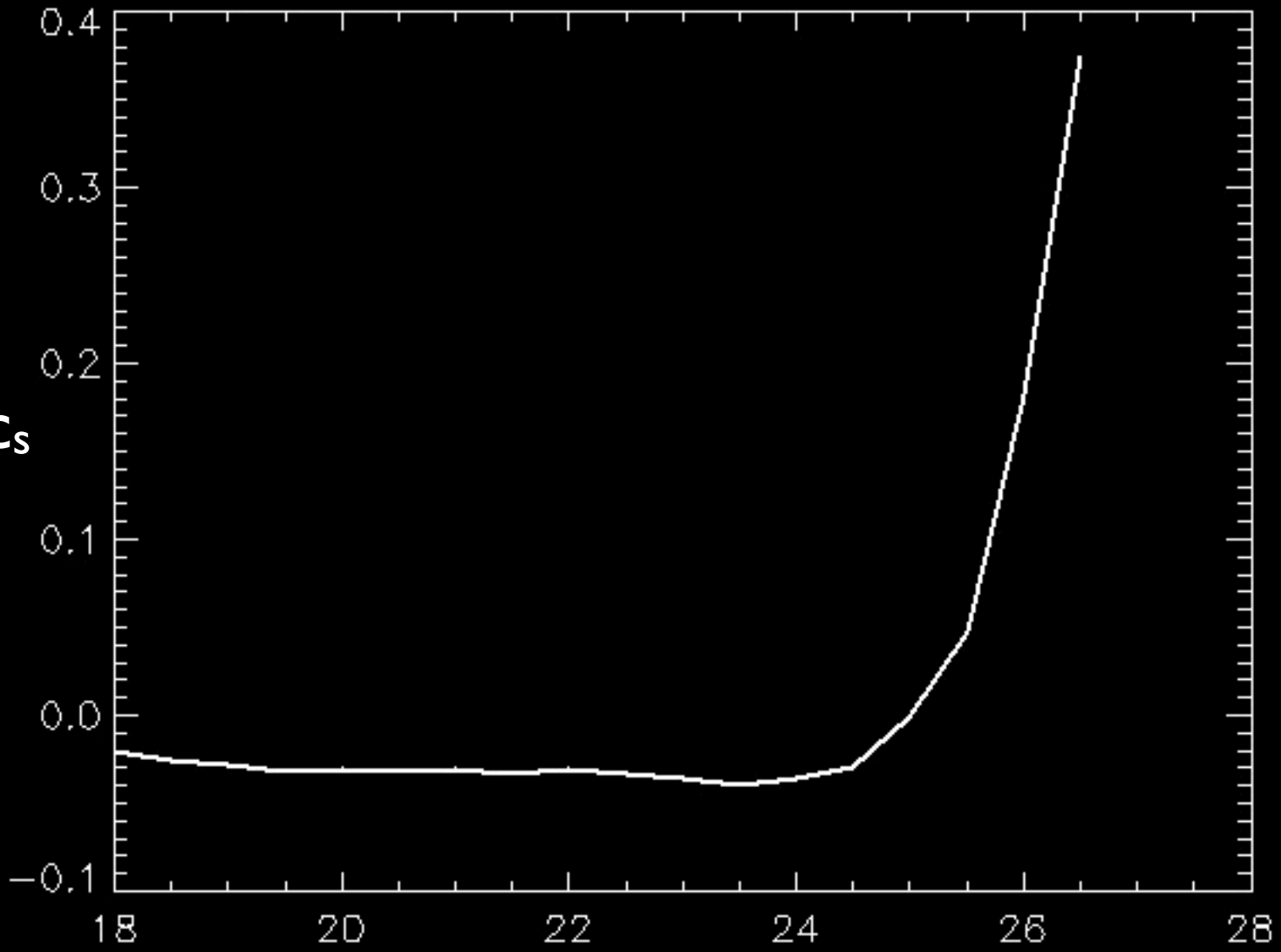
$$c_s = \sqrt{\frac{KT_e}{M_{ar}}} = 4.3 \times 10^5 \ \text{cm/s}$$

ion sound speed


0.30
0.25
0.20
0.15
0.10
0.05
0.00
I_p
top
bottom
t (μs)
1.2×10⁴
1.3×10⁴
1.4×10⁴
1.5×10⁴


Mach number
t = 80 μs
plasma off
M
1.2
1.0
0.8
0.6
0.4
0.2
0.0
13.6
13.4
13.2
13.0
12.8
t (ms)
18
20
22
24
26
28
radial
position (cm)

Mach number (t_a = 80 μs)



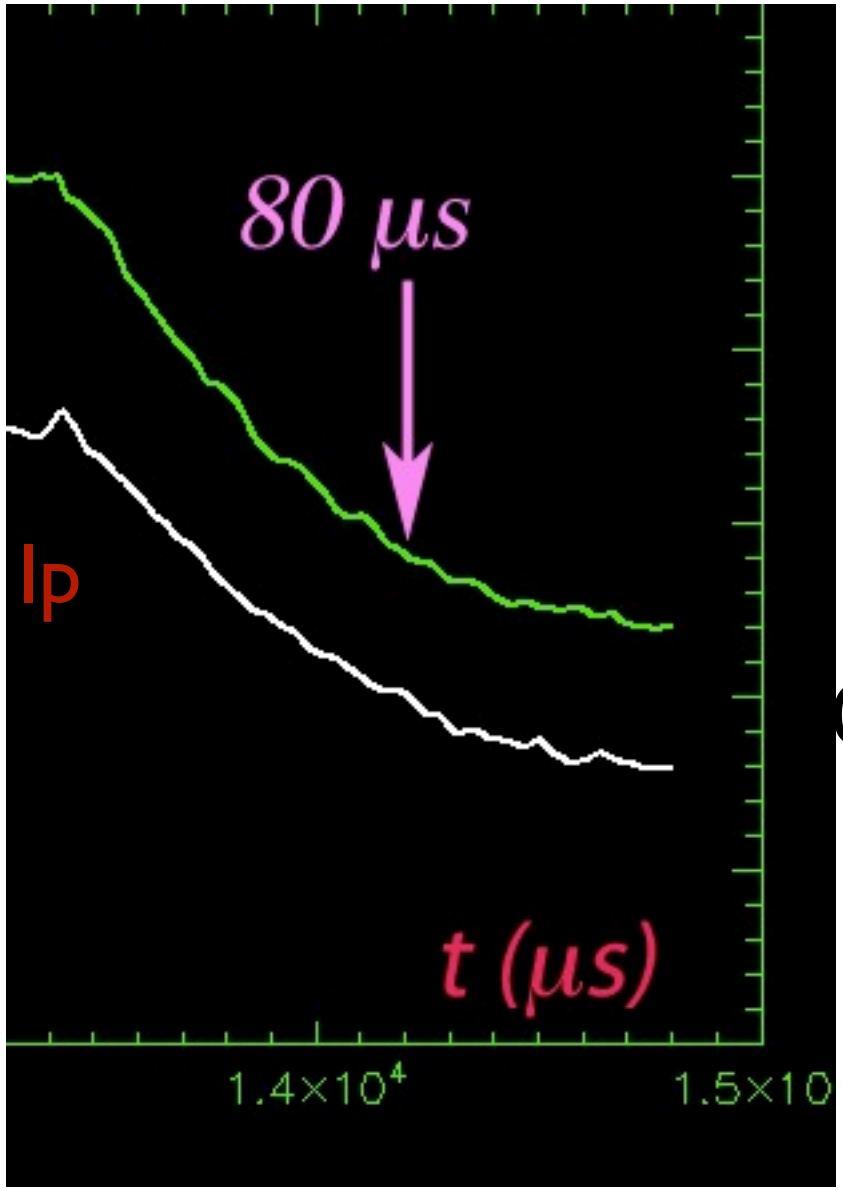
$M=v/c_s$

radial position (cm)

From Mach probes

$$v = Mc_s = \frac{.04}{.11} c_s = 0.38 c_s = 0.38 \bullet 4.3 \times 10^5$$

$$v = 1.63 \times 10^5 \text{ cm/s} = 1.63 \times 10^3 \text{ m/s}$$



0.1

From E/B measurement

v = 5.3 x10^3 m/s

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5) The measured drift agreed with the E/B velocity to within a factor of three

Everybody is invited to join LAPTAG

google LAPTAG

Plasma density		$n = 1.5X10^{10}$ cm^{-3}
Electron Temperaure (e.V.)	Note 1 e.V. = 11,600 K	T_e =0.8 e.V.
Magnetic Field (center)		B_{0z} =30 G
electron plasma frequency	$f_{pe} = \sqrt{\frac{4\pi e^2 n_e}{m_e}} = 8.98 \times 10^3 \sqrt{n_e}$	f_{pe} =1.1X10^9 Hz
electron cyclotron frequency	$f_{ce} = \frac{eB}{cm_e} = 2.8 \times 10^6 B(Gauss)$	f_{ce} =8.4 X10^7 Hz
Ion plasma frequency	$f_{pi} = \sqrt{\frac{4\pi e^2 n_i}{M_i}} = 210\sqrt{\frac{n_i}{\mu}}$; $\mu = \frac{M_i}{m_p}$	f_{pi}= 4.06X10^6 Hz
Ion cyclotron frequency	$f_{ci} = \frac{eB}{cM_i} = 1.52 \times 10^3 \sqrt{\frac{B}{\mu}}(Gauss)$	f_{ci} = 1.14x10^3 Hz
electron thermal speed	$v_{the} = \sqrt{\frac{KT_e}{m_e}} = 4.19 \times 10^7 \sqrt{T_e}$	v_{the} =3.8x10^7 cm/s
electron Gyroradius	$r_{ce} = \frac{m_e v_{\perp e}}{eB} = 2.38 \frac{\sqrt{T_e}}{B}$	r_{ce} = 7X10^{-2} cm (.7 mm)
Ion Gyroradius	$R_{cI} = \frac{m_I v_{\perp I}}{eB} = 102 \frac{\sqrt{T_I}}{\sqrt{\mu}B}$	R_{ci} = 15.2 cm

Argon Plasma 80μs after the RF producing the plasma is shut off