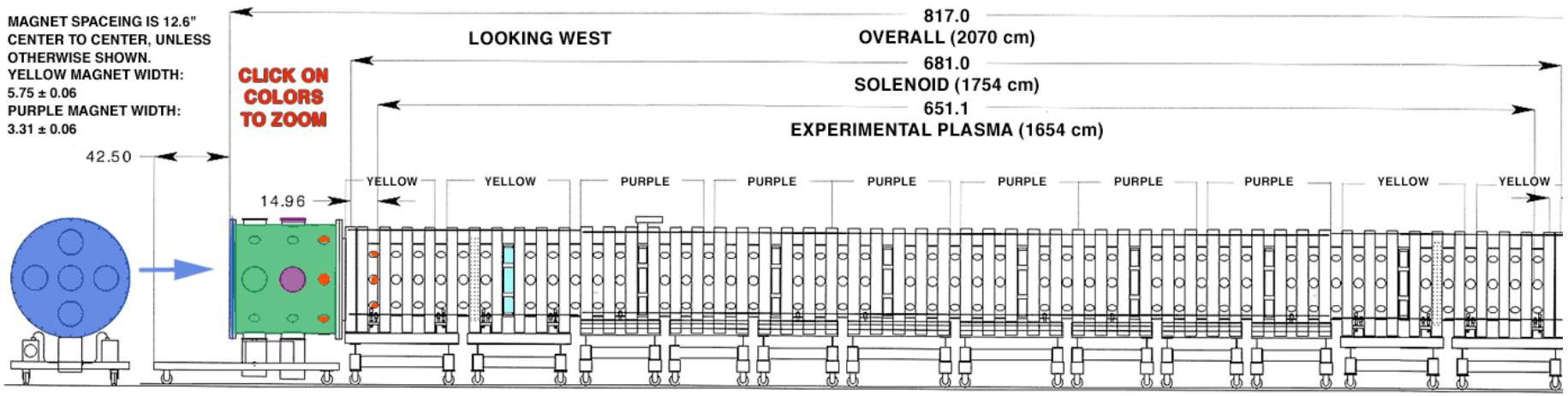
UCLA Experimental role in the Muri effort

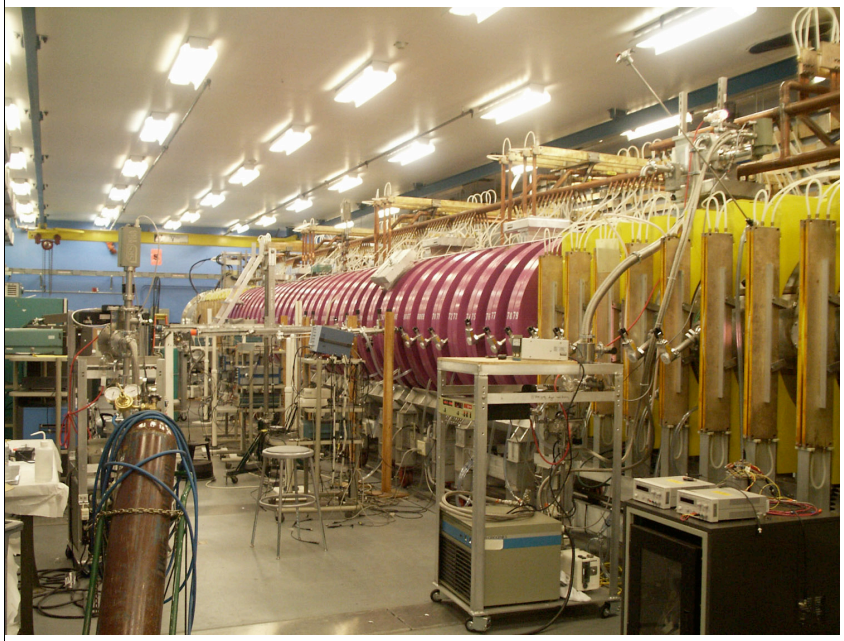
1) Description of the laboratory /diagnostics
2) Review of an experiment relevant to this effort
3) Results on Rotating Magnetic Fields
4) Planned Experiments

Walter Gekelman
George Morales
Jim Maggs

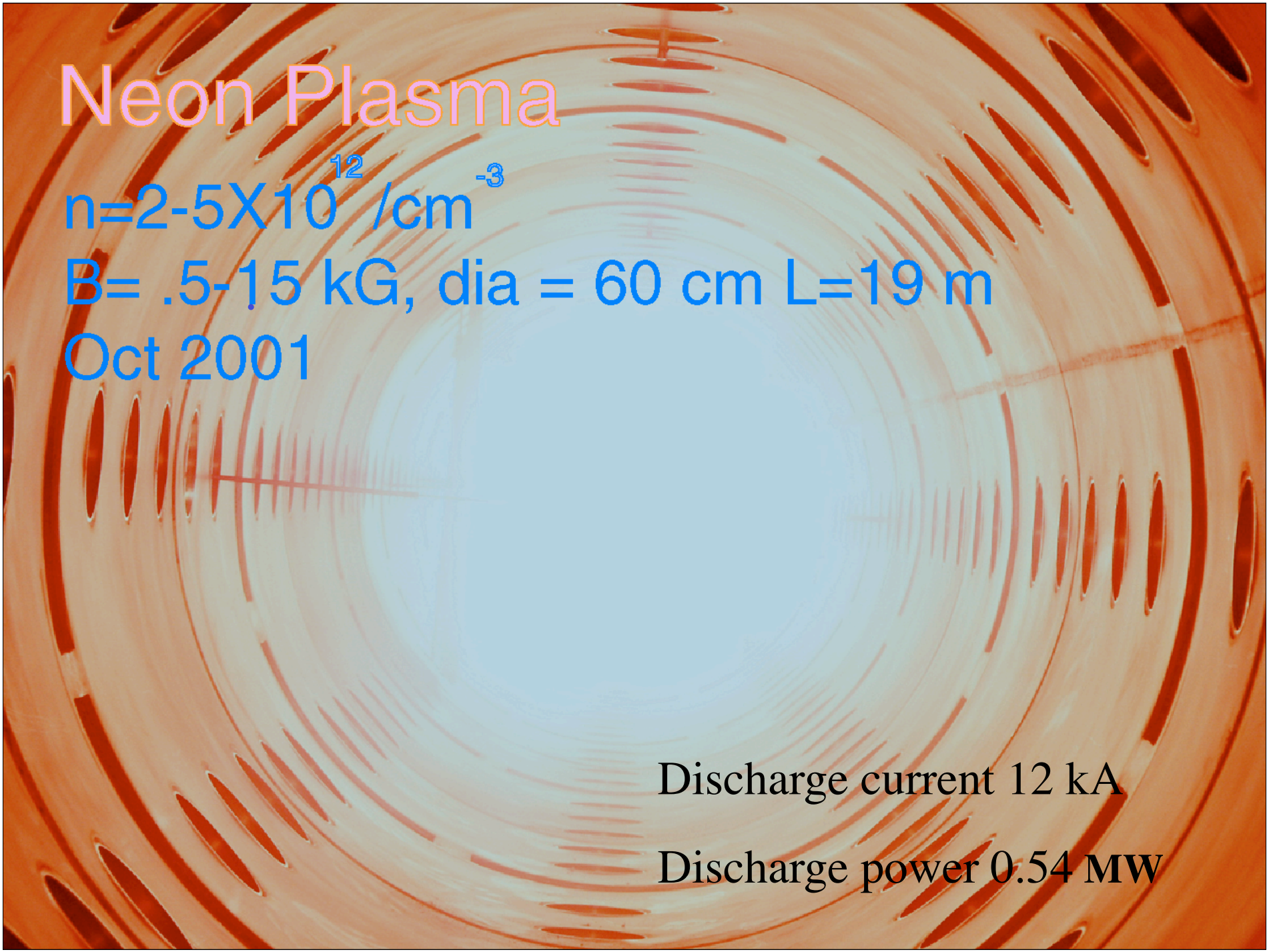
Alex Gigliotti (graduate student)
Pat Pribyl, Steve Vincena (staff scientists)

Large Plasma Device (LAPD)





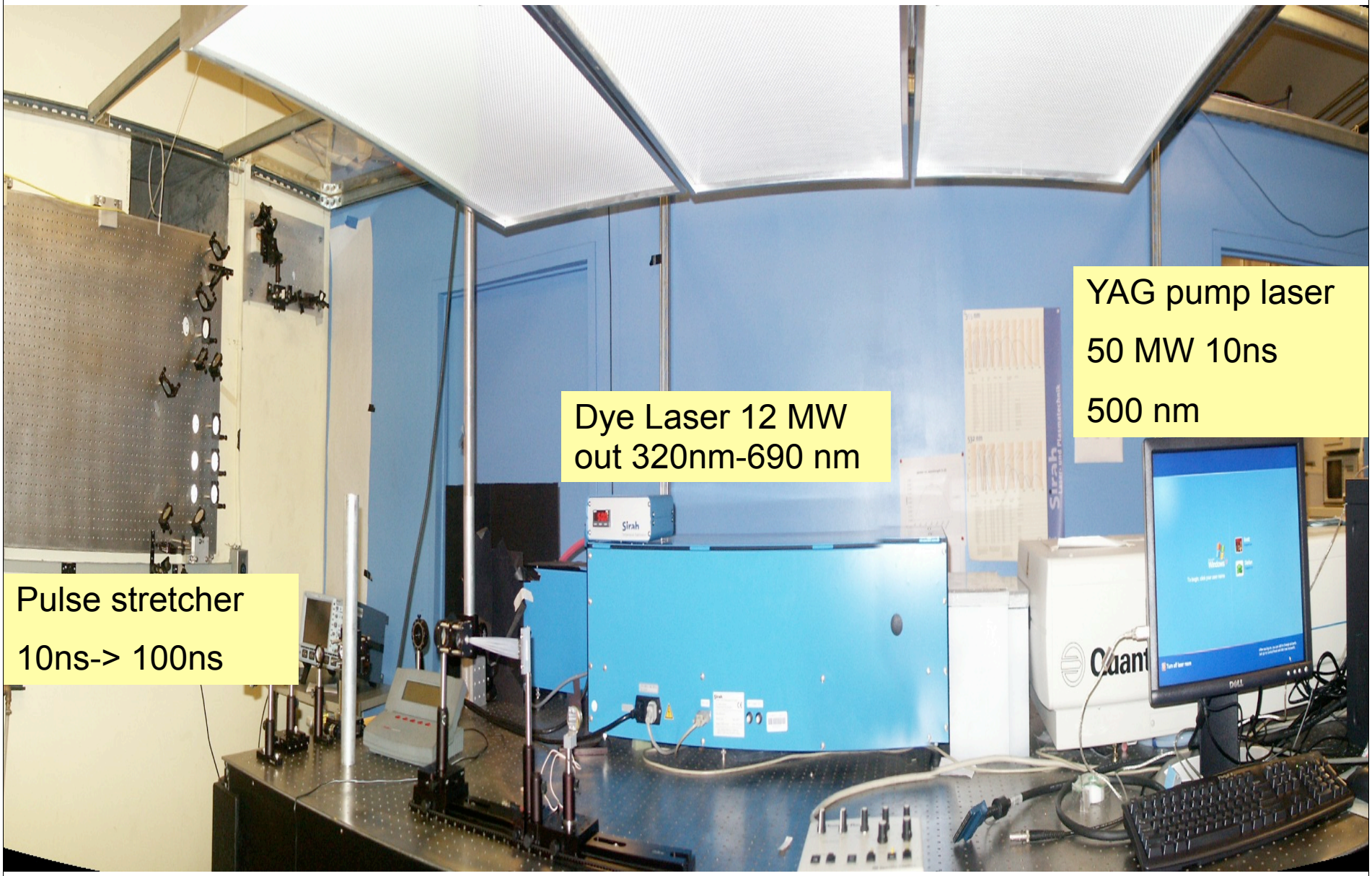
Over 450 Access ports
Computer Controlled Data Acquisition
Microwave Interferometers
Laser Induced Fluorescence
DC Magnetic Field: 0.05-4 kG , variable on axis
Highly Ionized plasmas $n \approx 5 \times 10^{12}$ cm^3
Plasma column up to 2000R_{ci} across diameter
Large variety of probes
Can create local(single/multiple) magnetic mirrors
Reproducible 1Hz operation
Now a user facility


Neon Plasma
n=2-5X10^12 /cm^-3
B= .5-15 kG, dia = 60 cm L=19 m
Oct 2001
Discharge current 12 kA
Discharge power 0.54 MW

Diagnostics and Capabilities

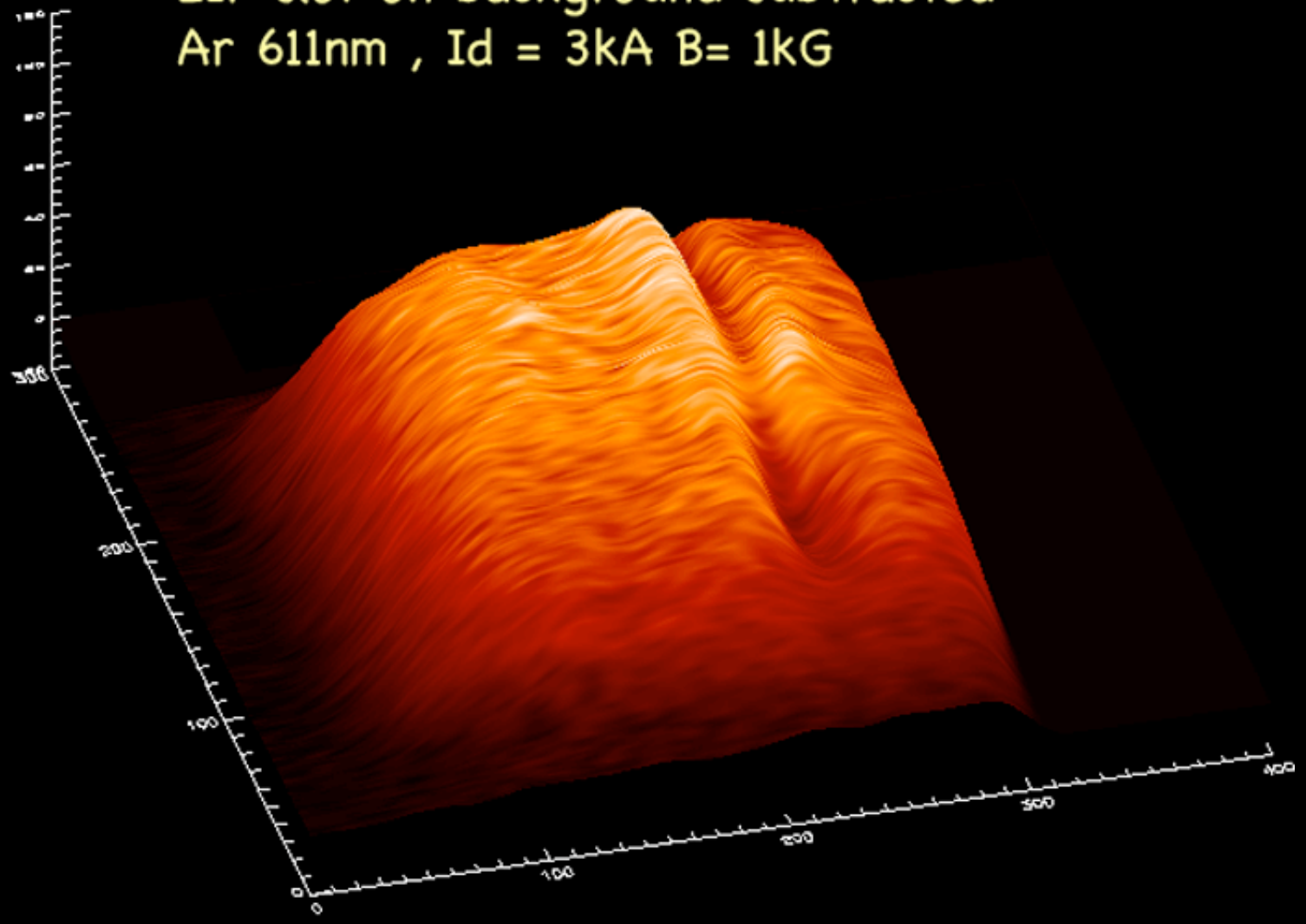
(new developments)

LIF system

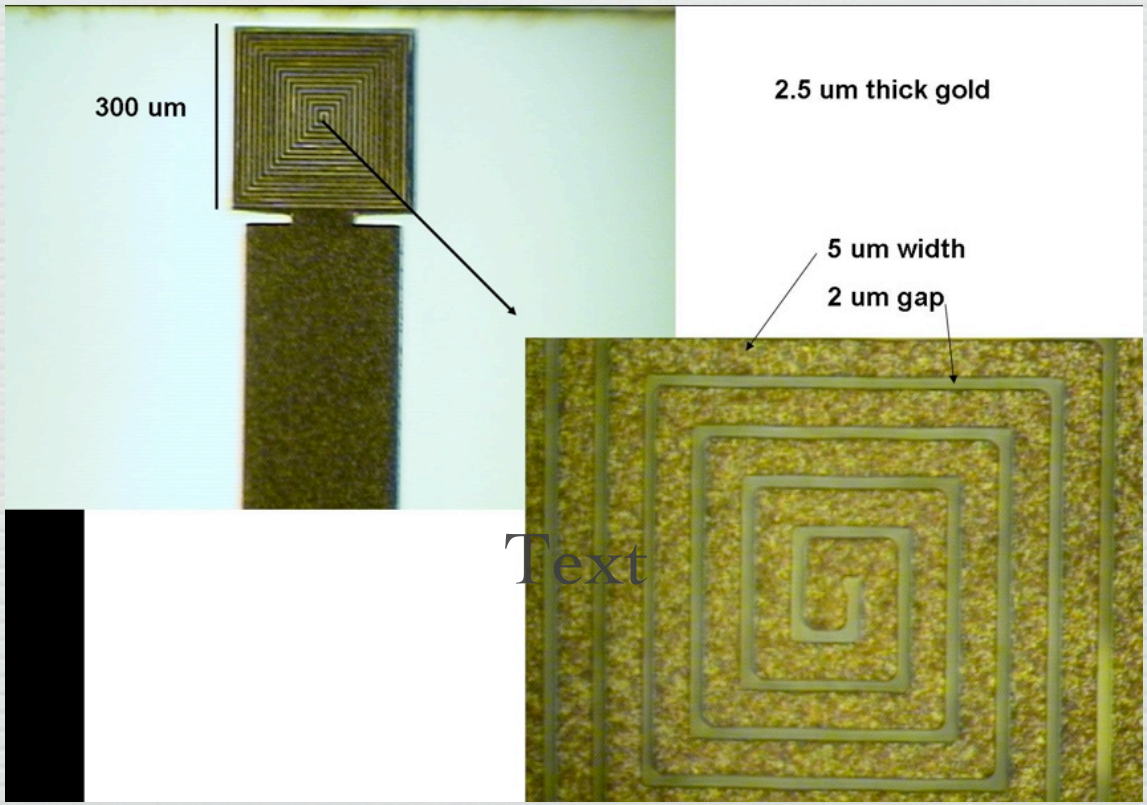

Pulse stretcher
10ns-> 100ns
Dye Laser 12 MW
out 320nm-690 nm
YAG pump laser
50 MW 10ns
500 nm

Density Perturbation as seen with Laser Induced Fluorescence

LIF slot on background subtracted
Ar 611nm , Id = 3kA B= 1kG

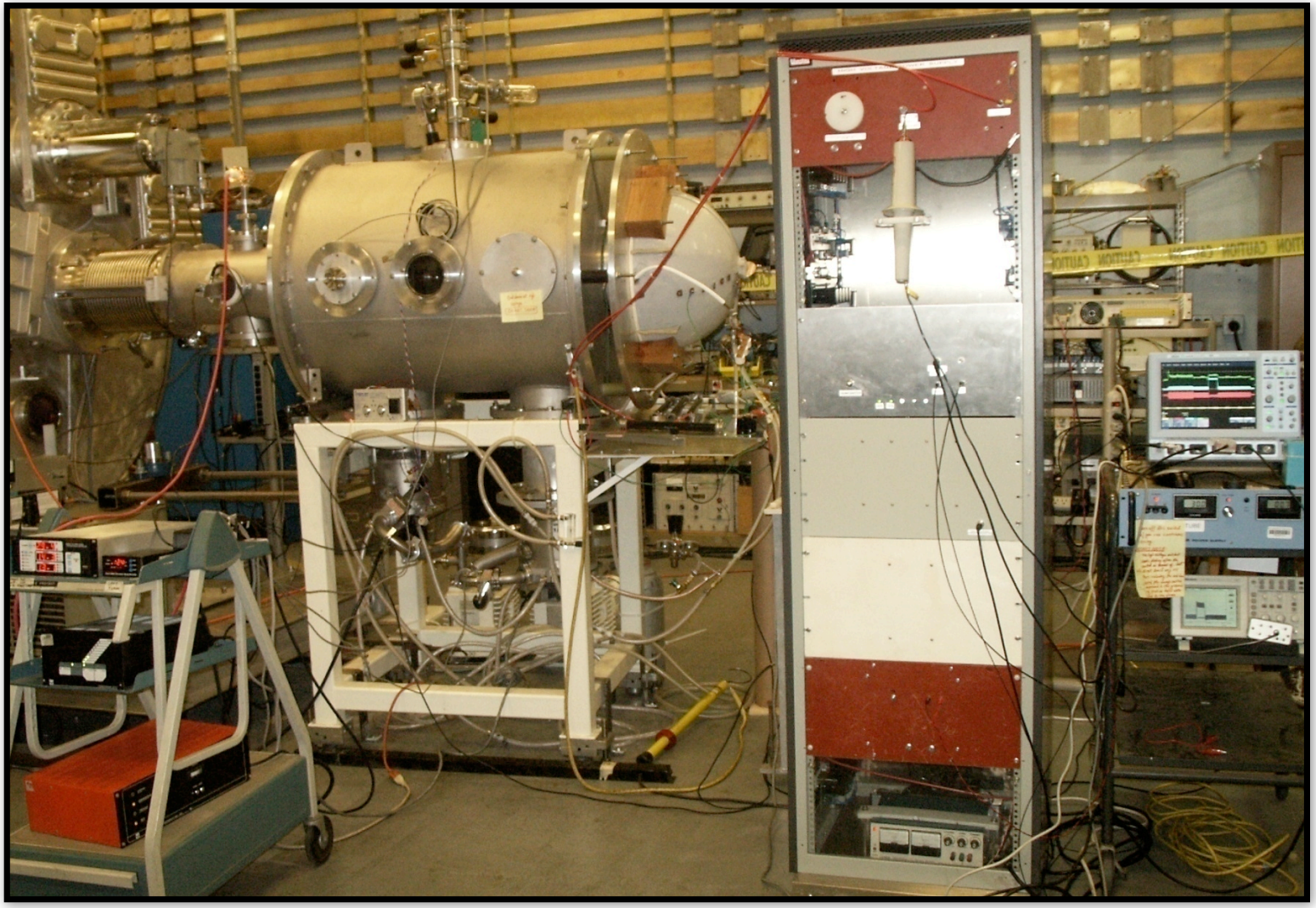


Magnetic Fields (Mems grown probes)



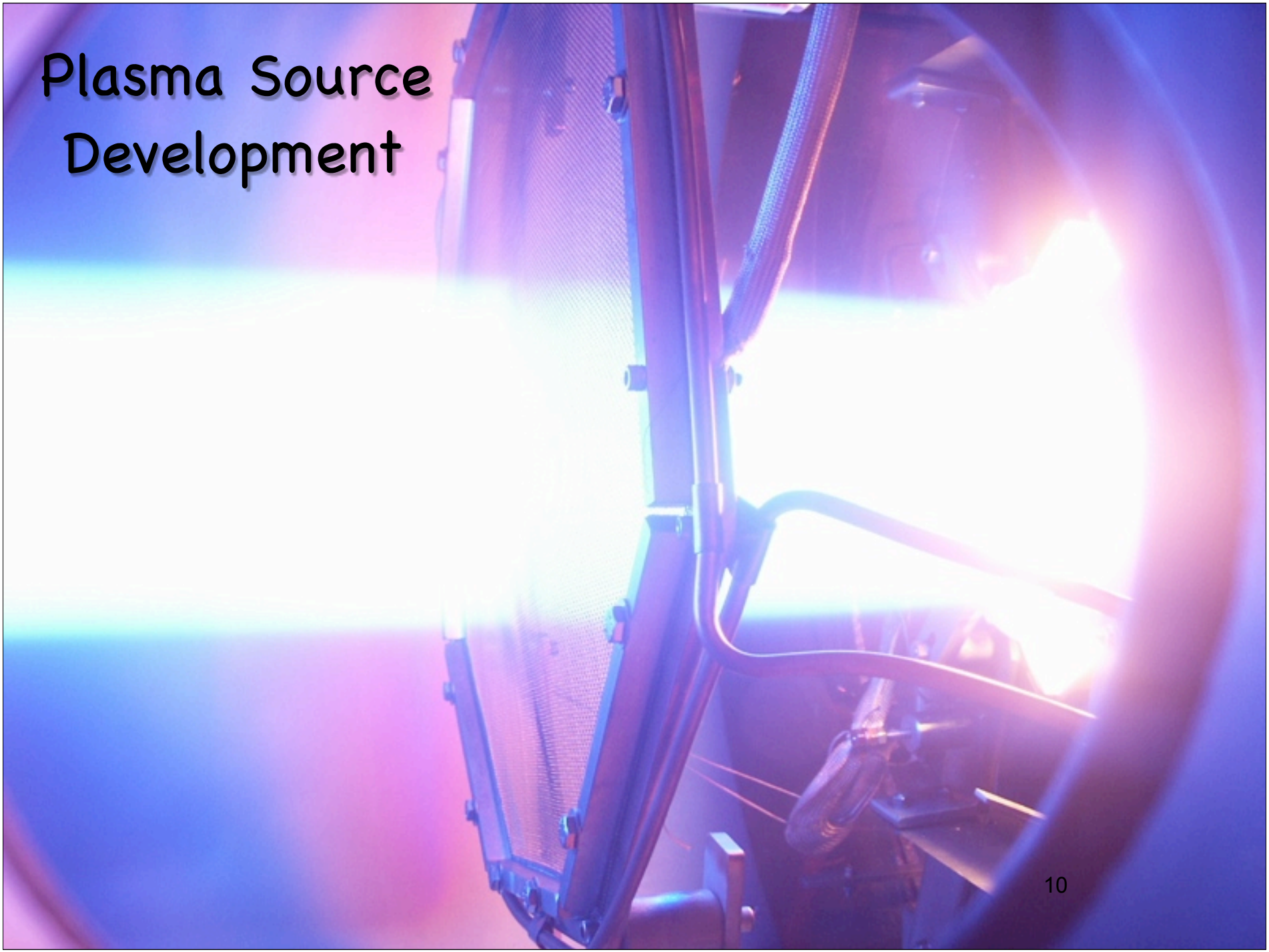
These will be used in combination with 3D probe drives (20x20x20 cm) 1 micron resolution

He $V_{beam} > V_{Alfvén}$



The Ion Source set-up on LAPD

Plasma Source Development

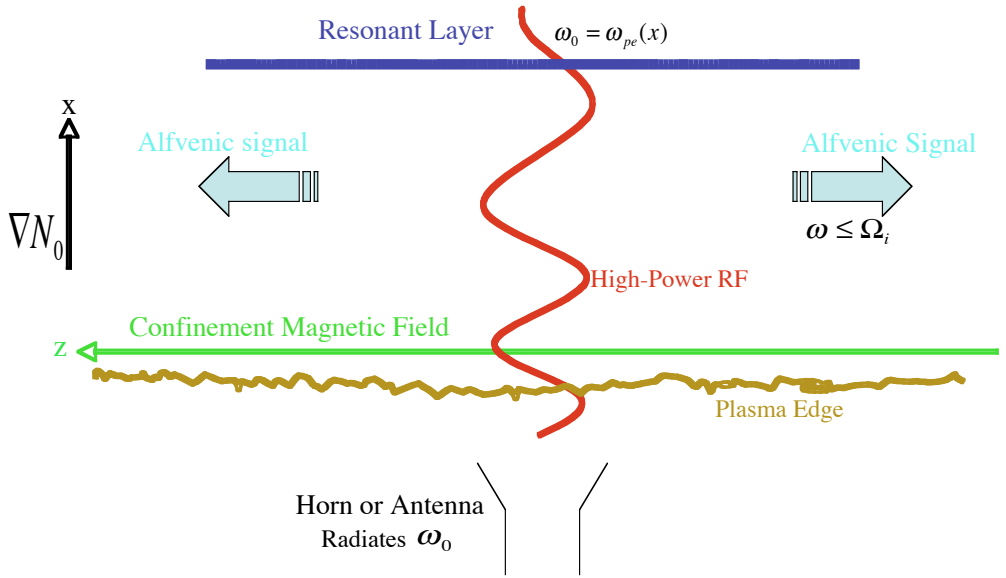


Example of Previous Work

- Microwave interaction at a plasma resonance (plasma frequency / upper hybrid)
- Generation of fast electrons
- Excitation of Shear Alfvén waves

Fast electron generation by microwaves

Schematic Cartoon of Problem



B. Van Compernolle Phd->Brussels
W. Gekelman
P. Pribyl
G. Morales

Related to Ionospheric Modification Experiments

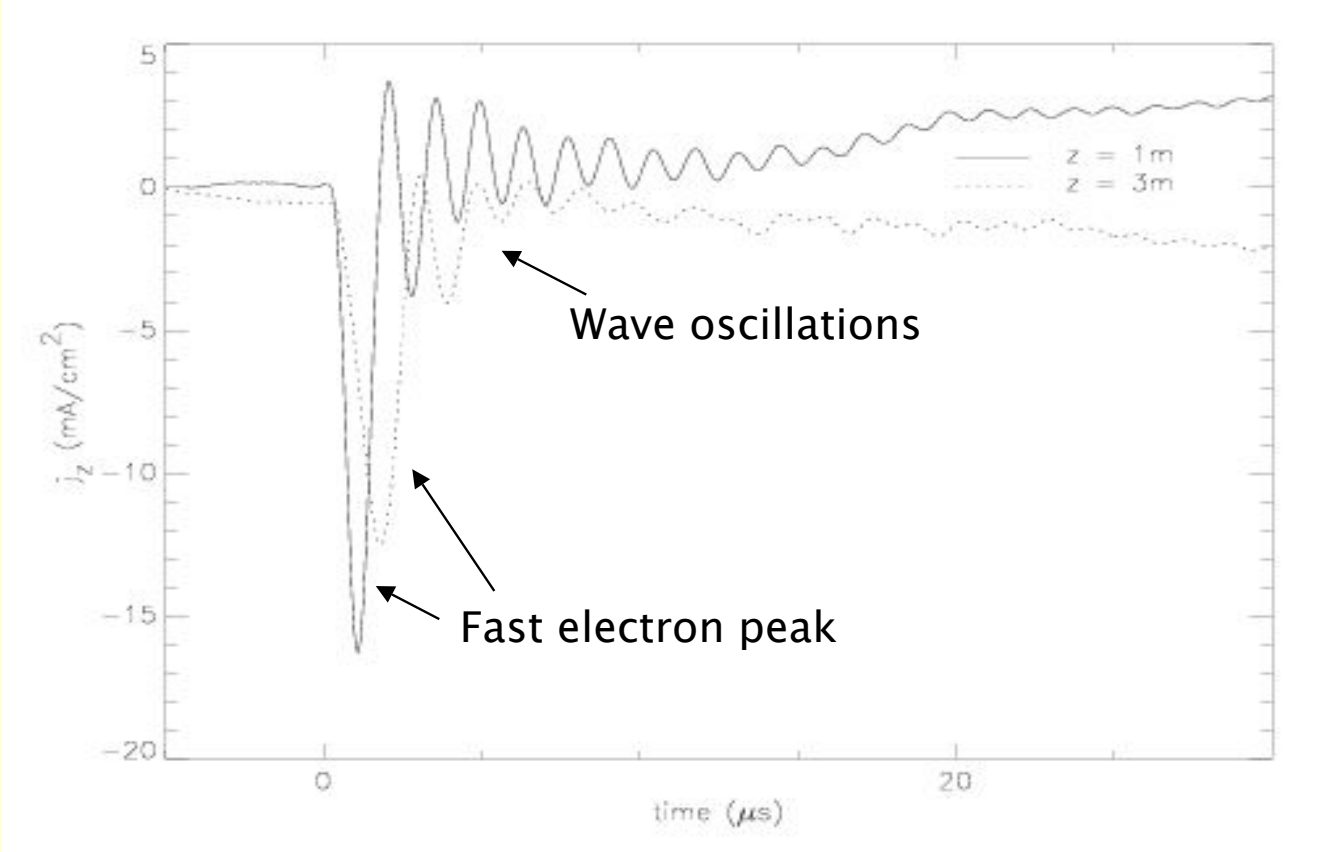
Fast Electrons

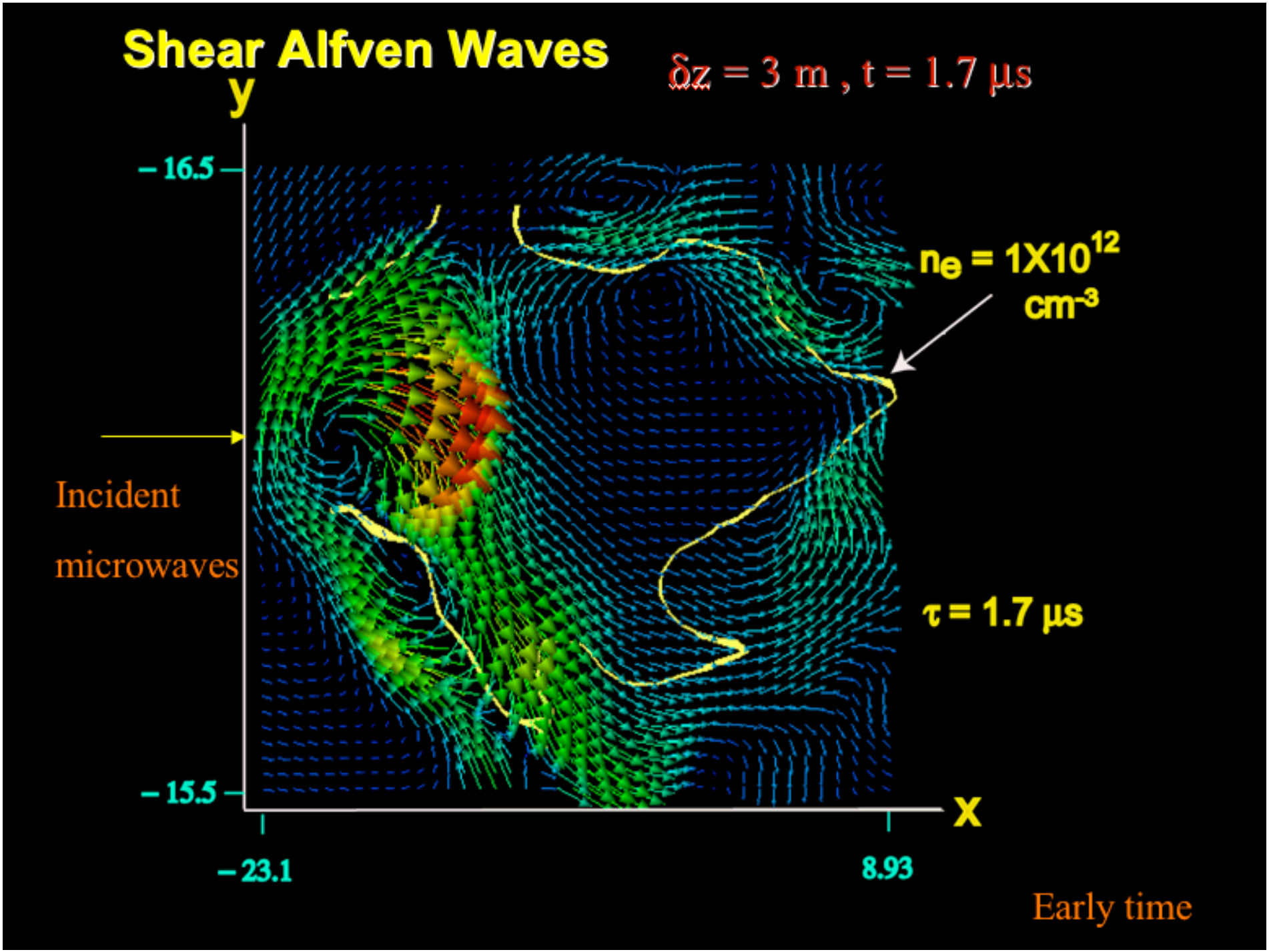
$$j_z = \nabla \times B_t$$

(x = –20 cm, y = 2 cm)

$v_{de} = 3 \times 10^8$ cm/s

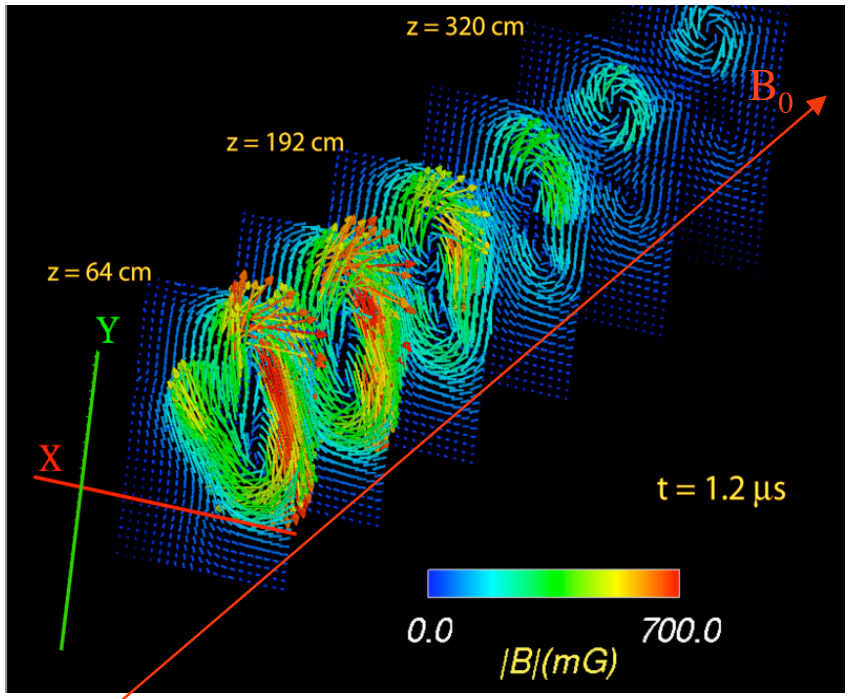
$dn_e/n_0 = 10^{-4}$




Shear Alfven Waves
δz = 3 m , t = 1.7 μs
y
– 16.5
– 15.5
– 23.1
8.93
x
$n_e = 1X10^{12}$ cm^{-3}
τ = 1.7 μs
Incident
microwaves
Early time

Alfven Wavepacket Excited in Experiment by O-Mode Pulse

Measured snapshot of wave magnetic field → at several axial positions away from O-mode beam injection



O-mode injection here

Muri Experimental Program

1) **Polarized , Intense shear Alfvén waves (rotating magnetic fields)**

2) Waves above the ion cyclotron frequency (Papadopoulos)

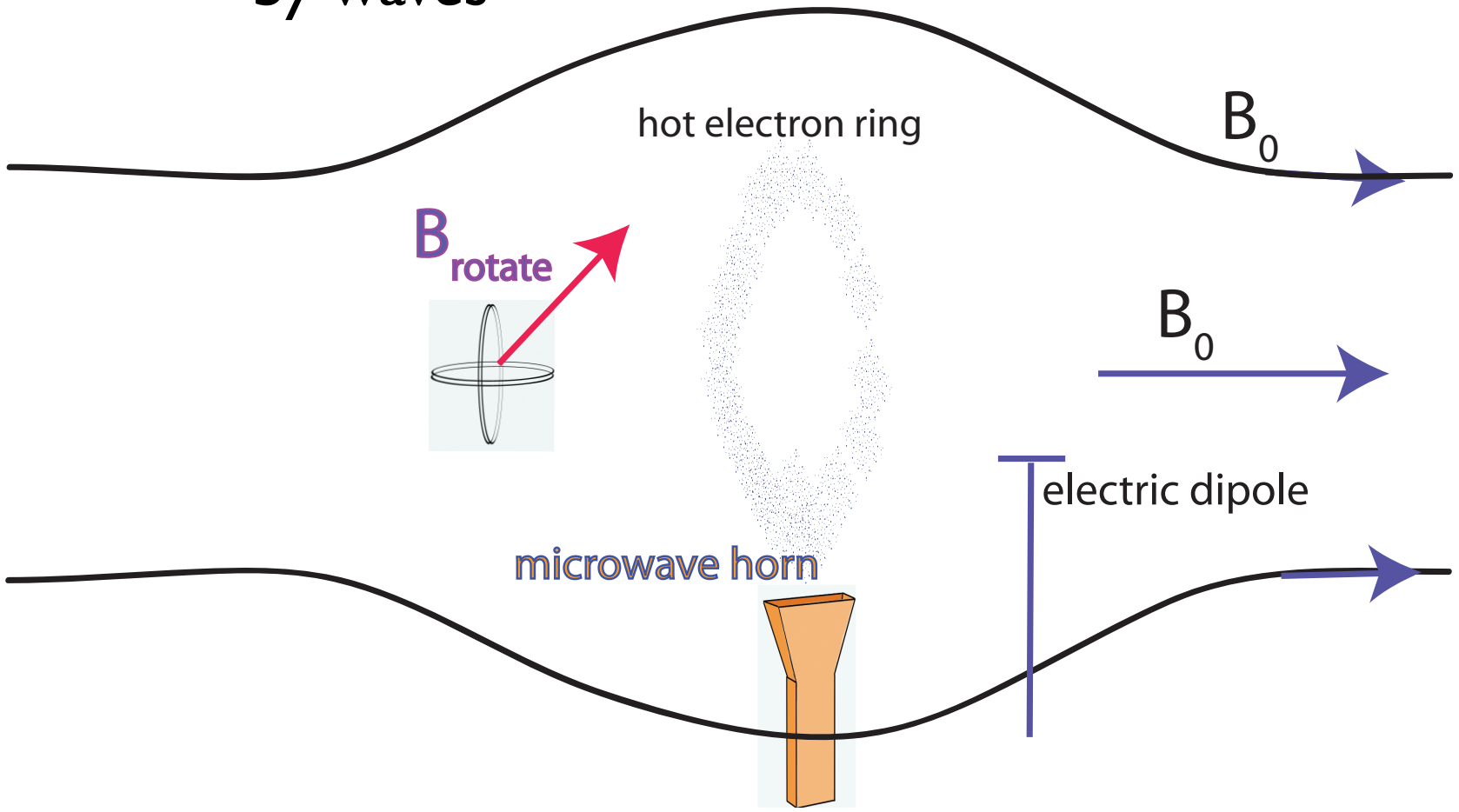
3) Whistler Wave Antenna studies (Chevalier)

4) Interaction of waves with a hot electron ring

Progress since July 2007

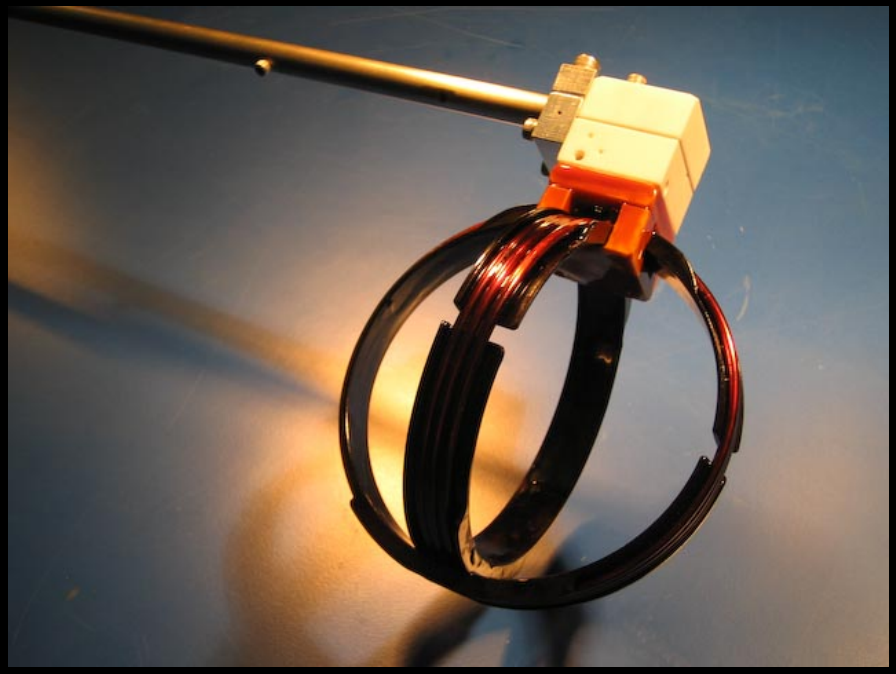
1) Designed and constructed rotating field antenna.
2) Constructed high power RF driver for antenna
3 Design of hot electron ring (RF) source
4) Explored several whistler wave antenna configurations
5) Campaigns:
    a) Rotating Alfvén waves (presently running on LAPD)
    b) Waves above the ion cyclotron frequency (data given to Maryland group)
    c) Whistler Campaign (1 week preliminary run)

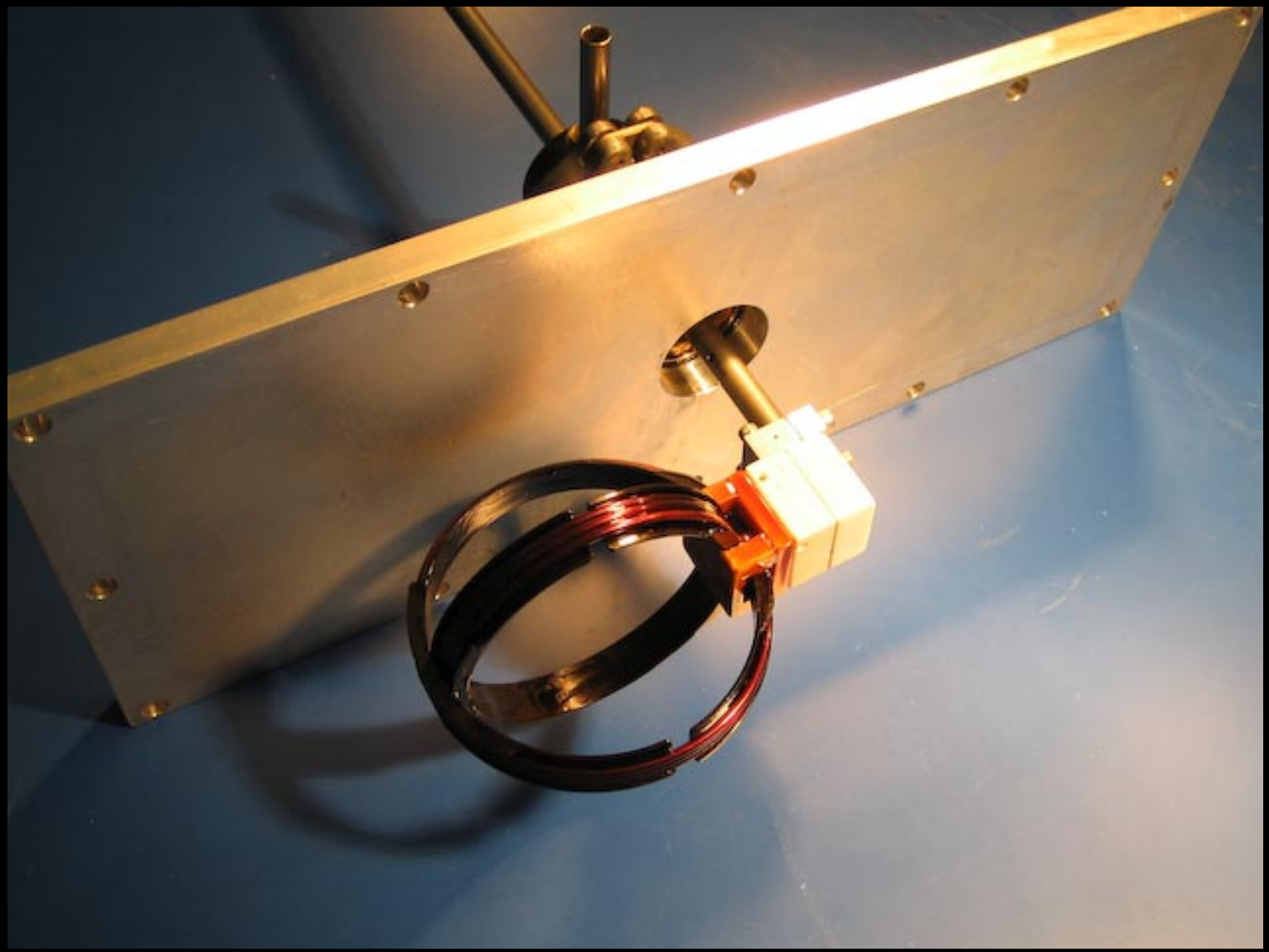
Destruction of hot electron rings by waves

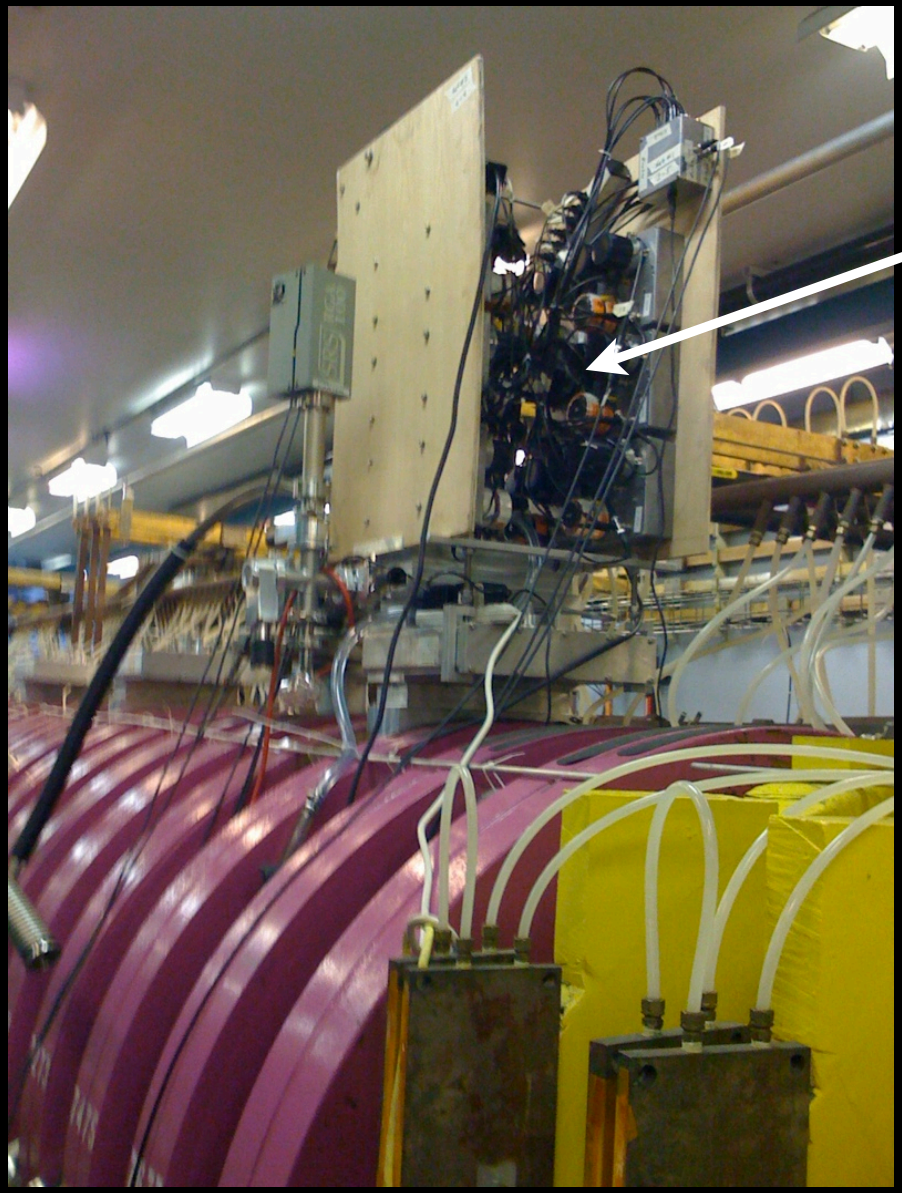


Intense shear Alfvén waves /rotating Magnetic fields

Antenna





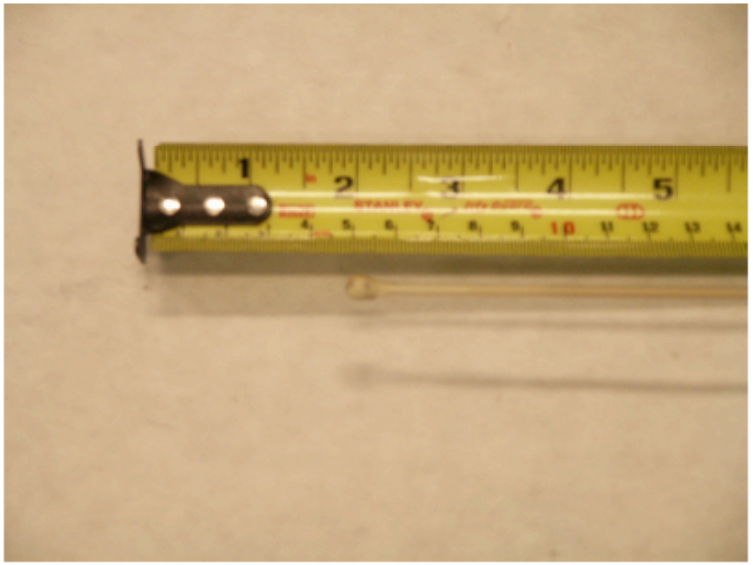


Designed and constructed (in house) high current (500 A p-p), high Voltage (3 kV) driver for ring antennas

Probes

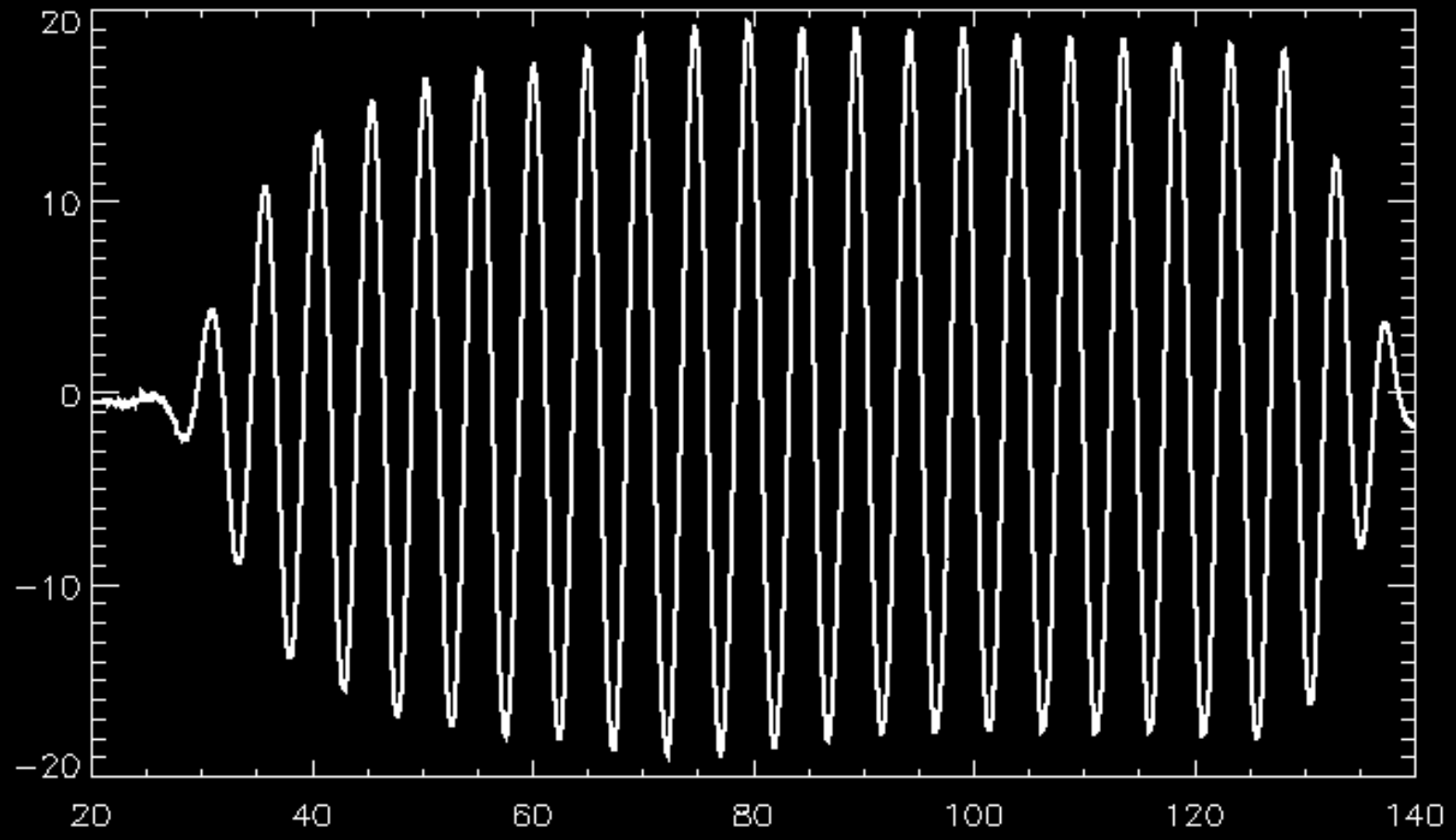
Three 3-axis differentially-wound B-dot probes measure magnetic field.

$$\varepsilon = -\frac{\partial}{\partial t}\int \vec{B}\bullet\hat{n}dA$$



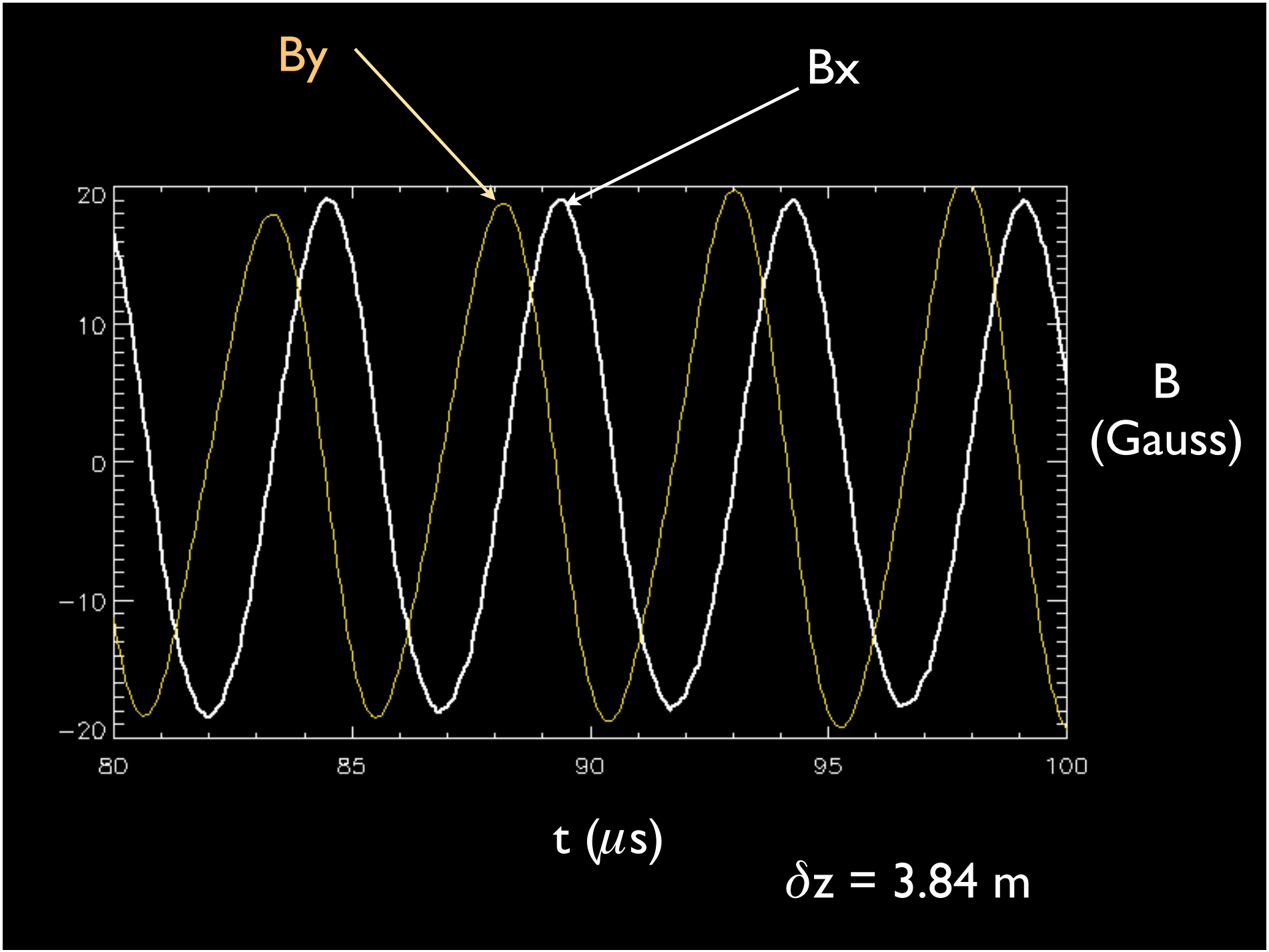
- Calibrated up to 50MHz
- 5mm in size
- Attached to computer-controlled data-acquisition system
- At 1Hz rep rate, probe gradually sweeps out a 12cm x 11.5cm plane with position resolution of 5mm

Measured wave magnetic field Bx(t)

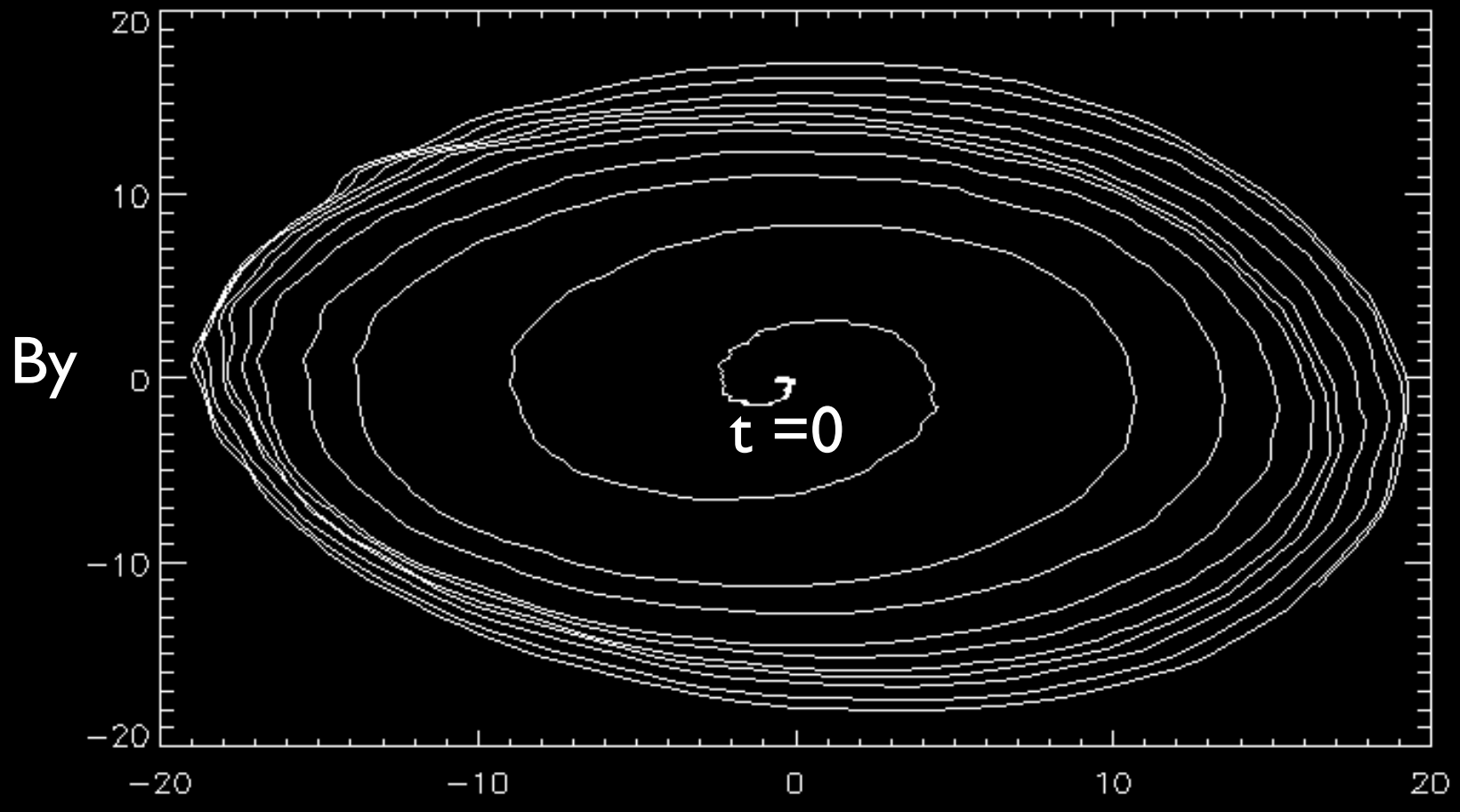


$\delta B_w/B_0 = 4\%$

x = y = 0.
$\delta z = 3.84$ m

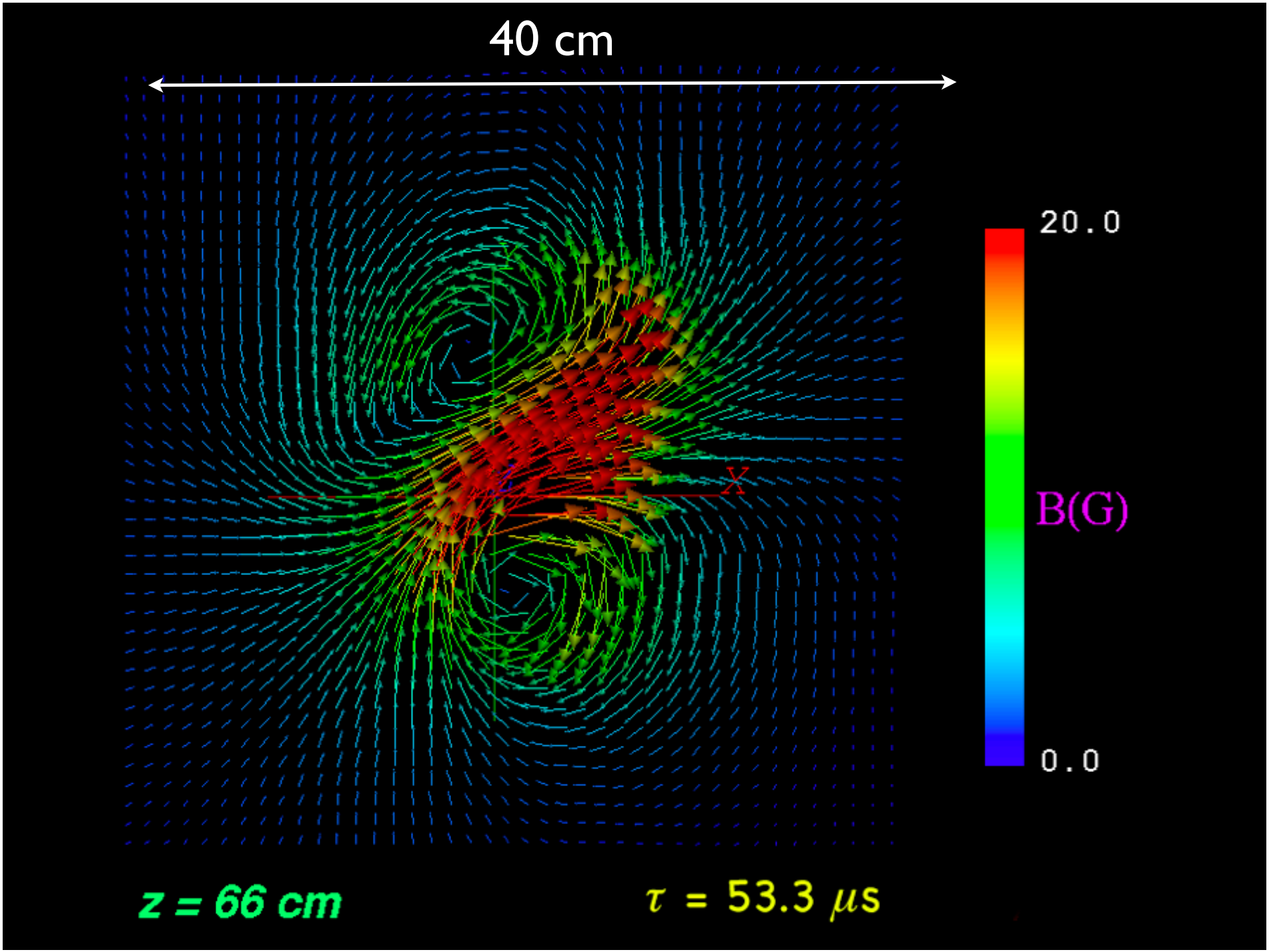

By
Bx
20
10
0
−10
−20
80
85
90
95
100
B
(Gauss)
t (μs)
δz = 3.84 m

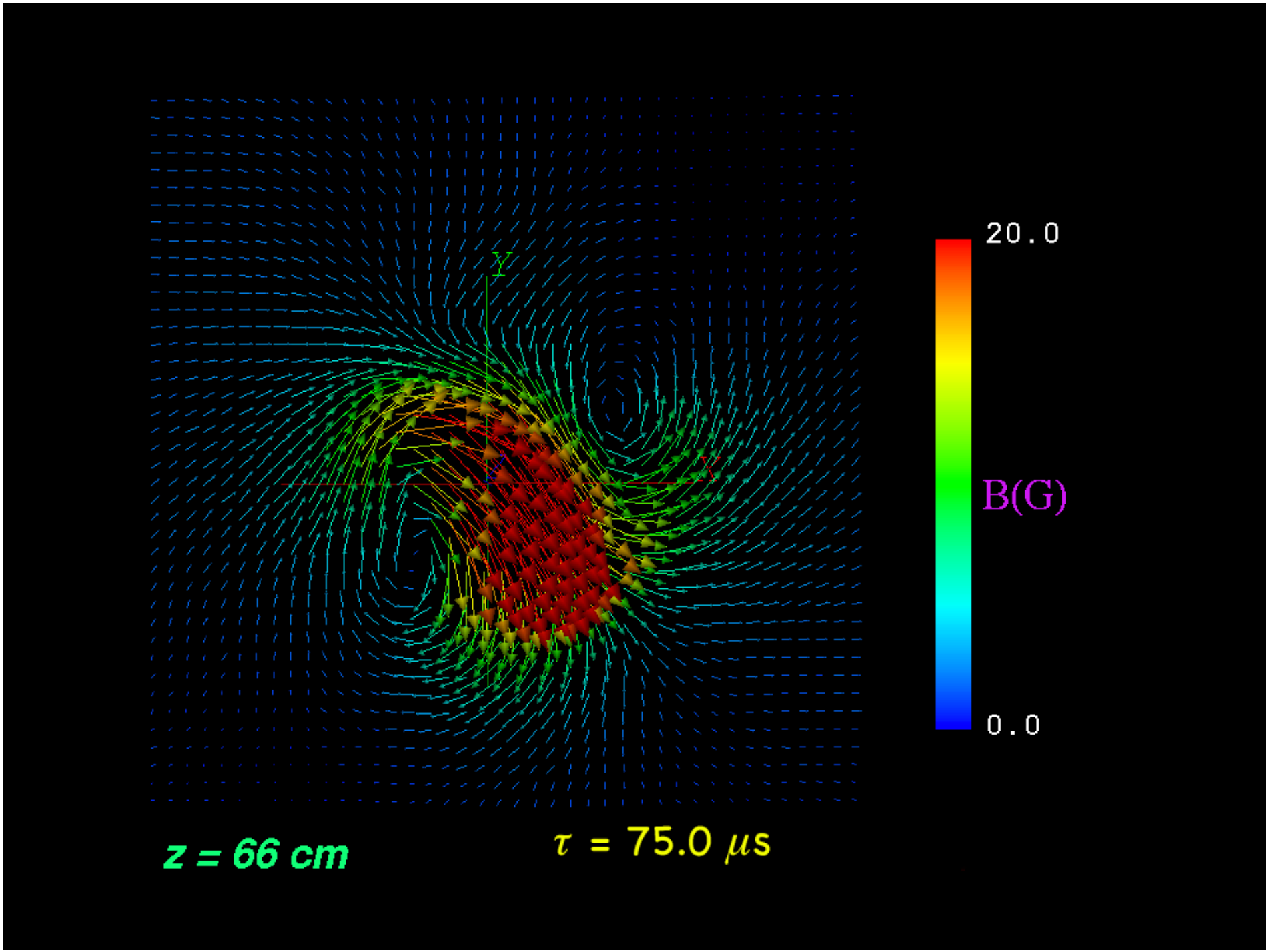
Hodogram Bx-By $\delta t = 120\ \mu s$

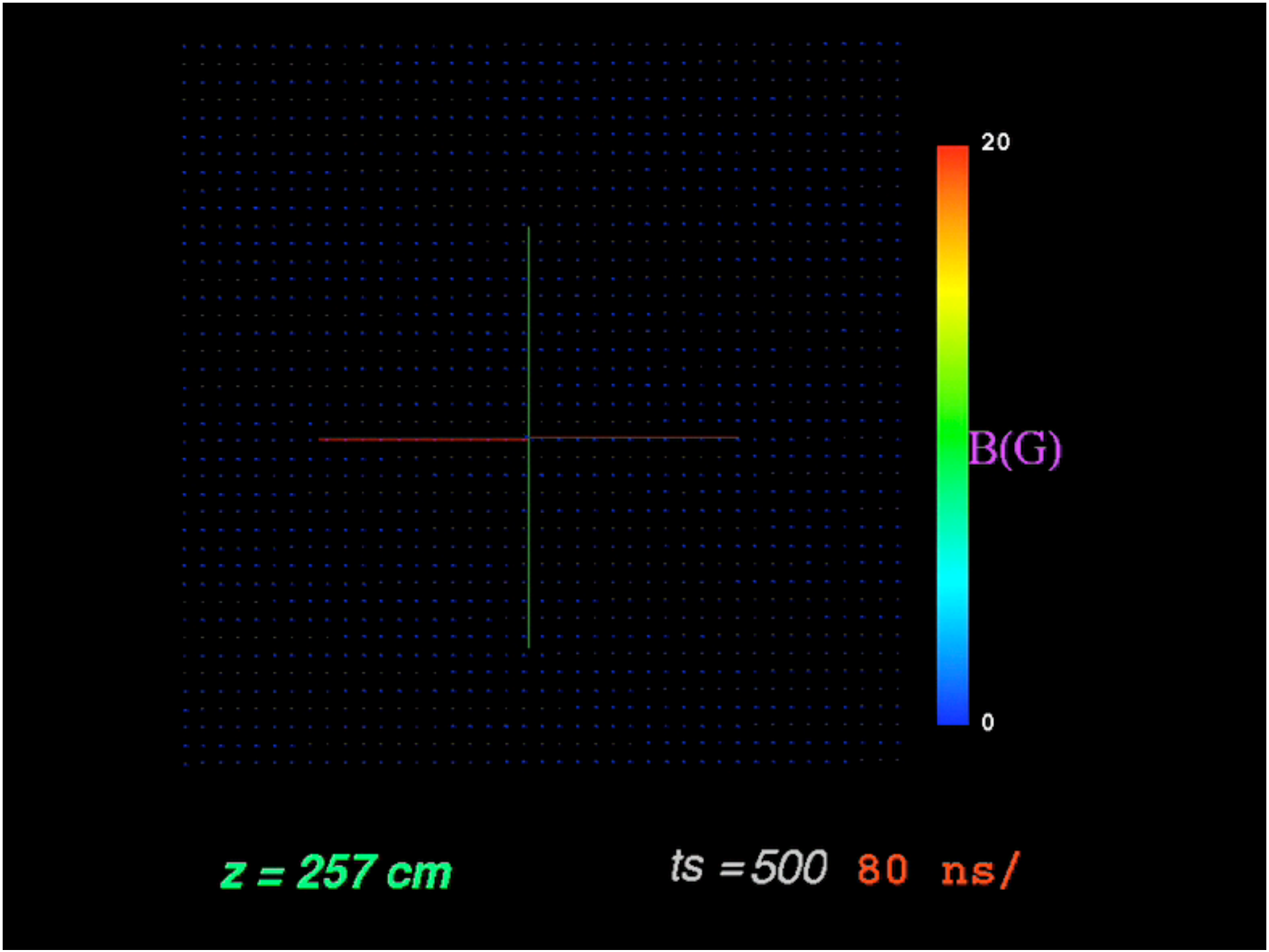


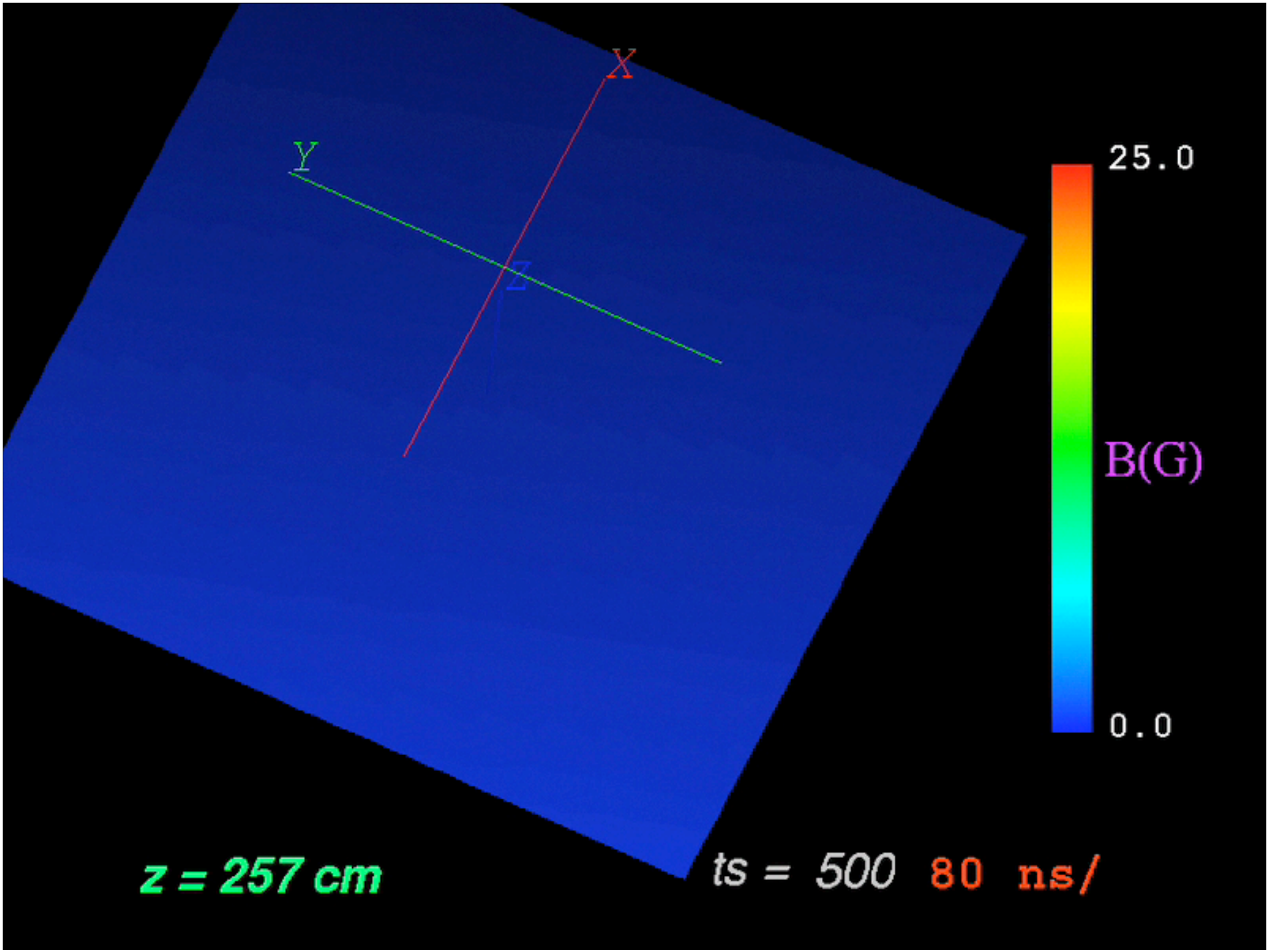
By

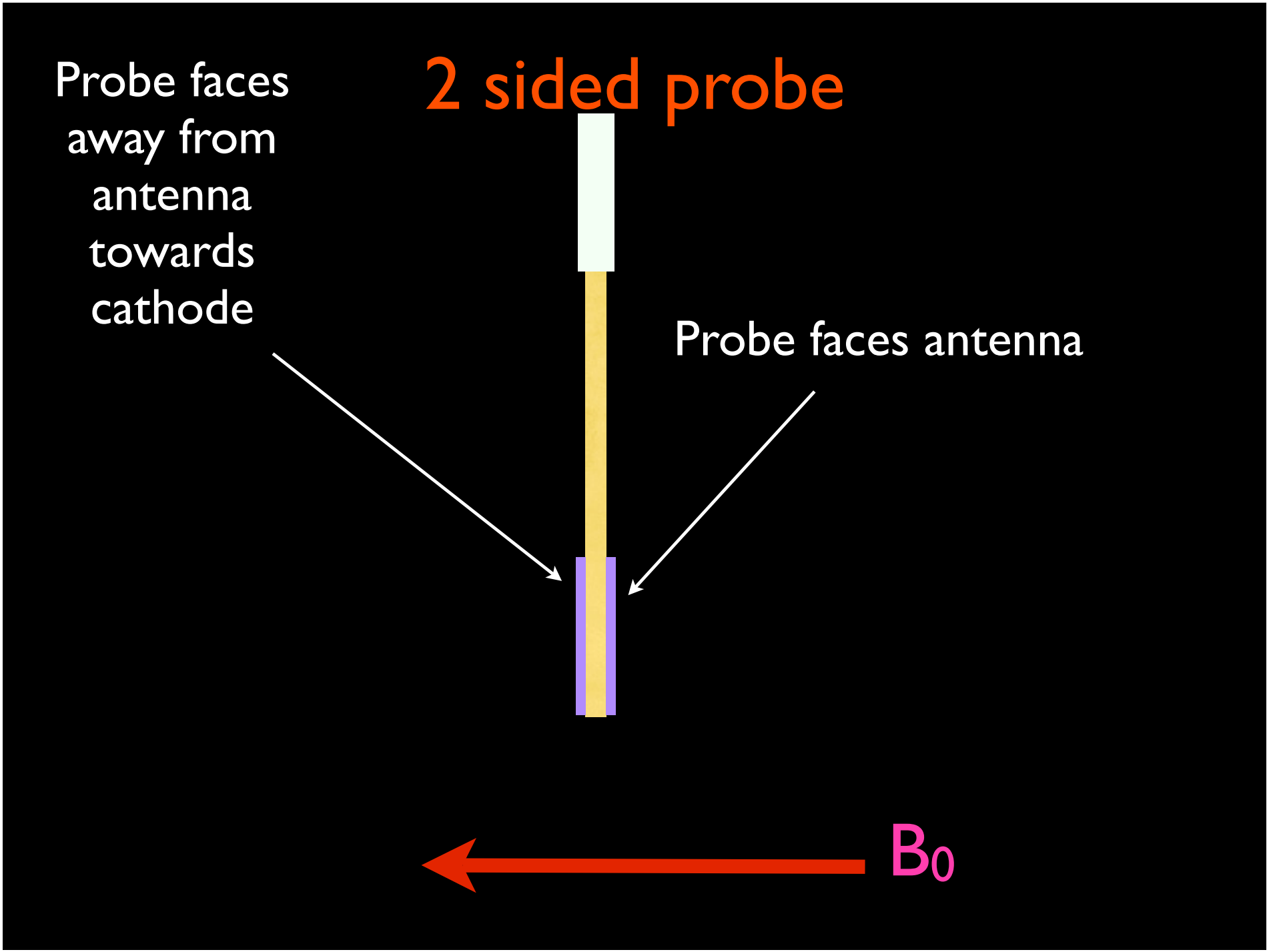
Bx (Gauss)

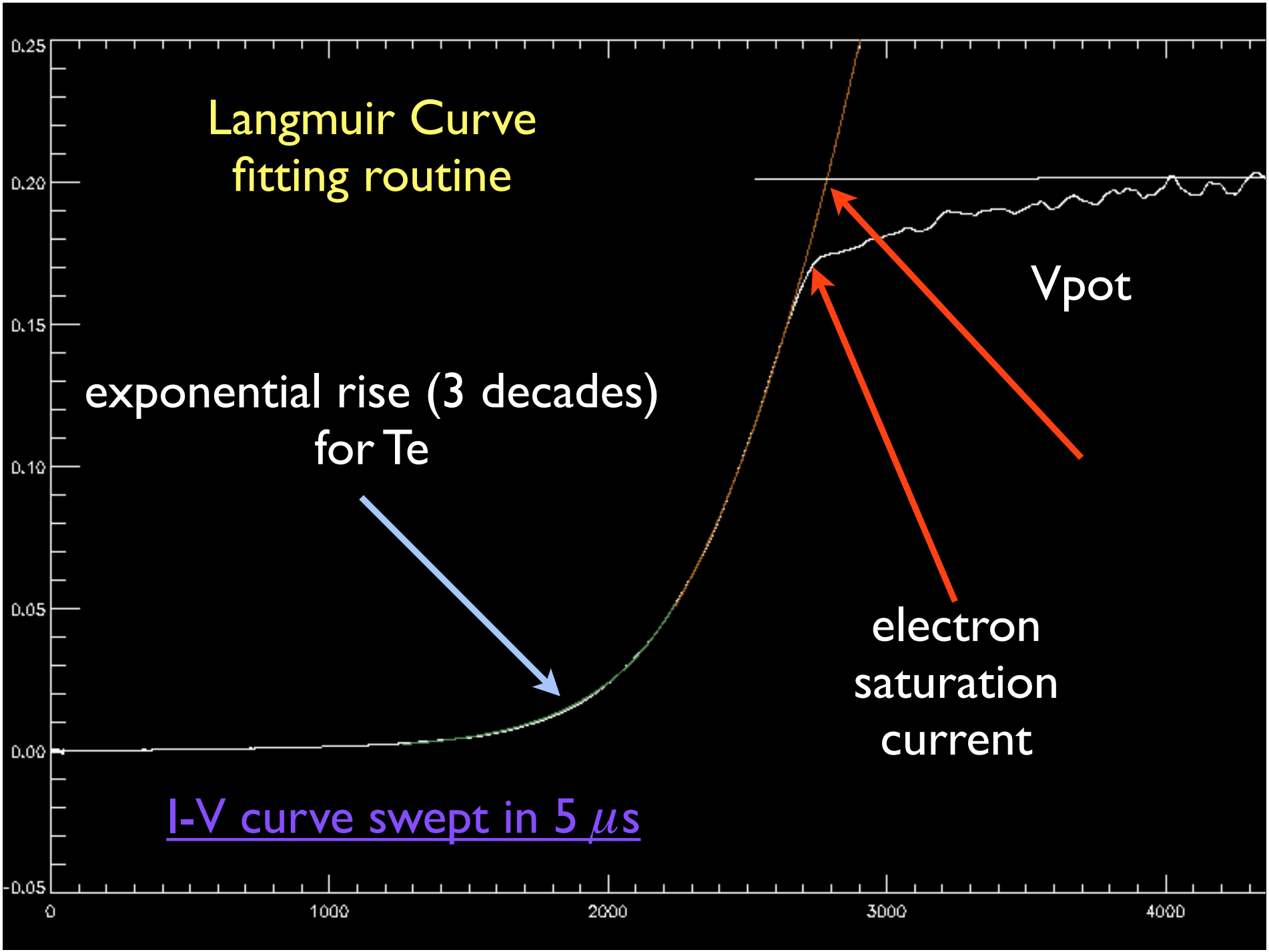

40 cm
20.0
B(G)
0.0
z = 66 cm
τ = 53.3 μs

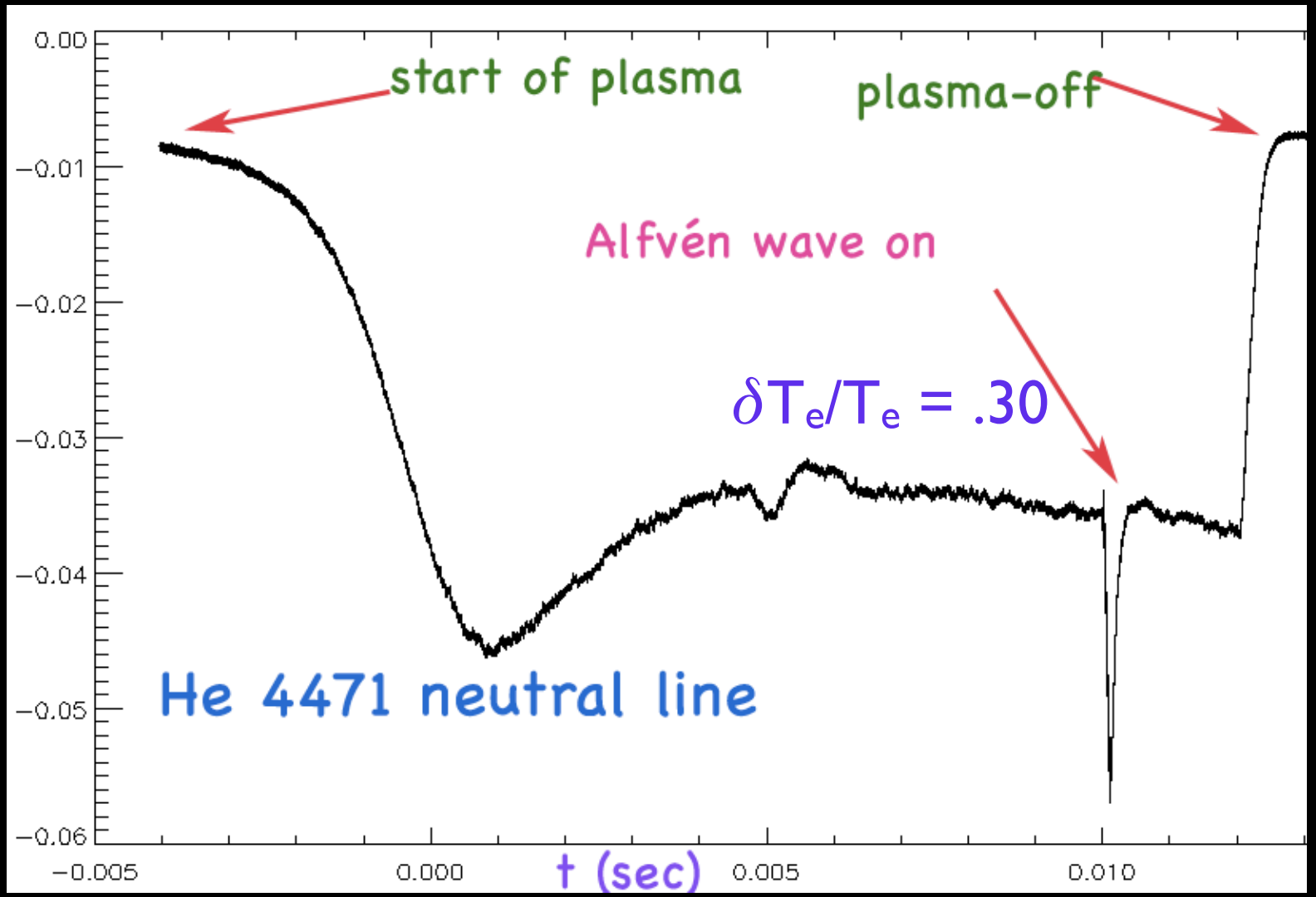

20.0
B(G)
0.0
z = 66 cm
τ = 75.0 μs

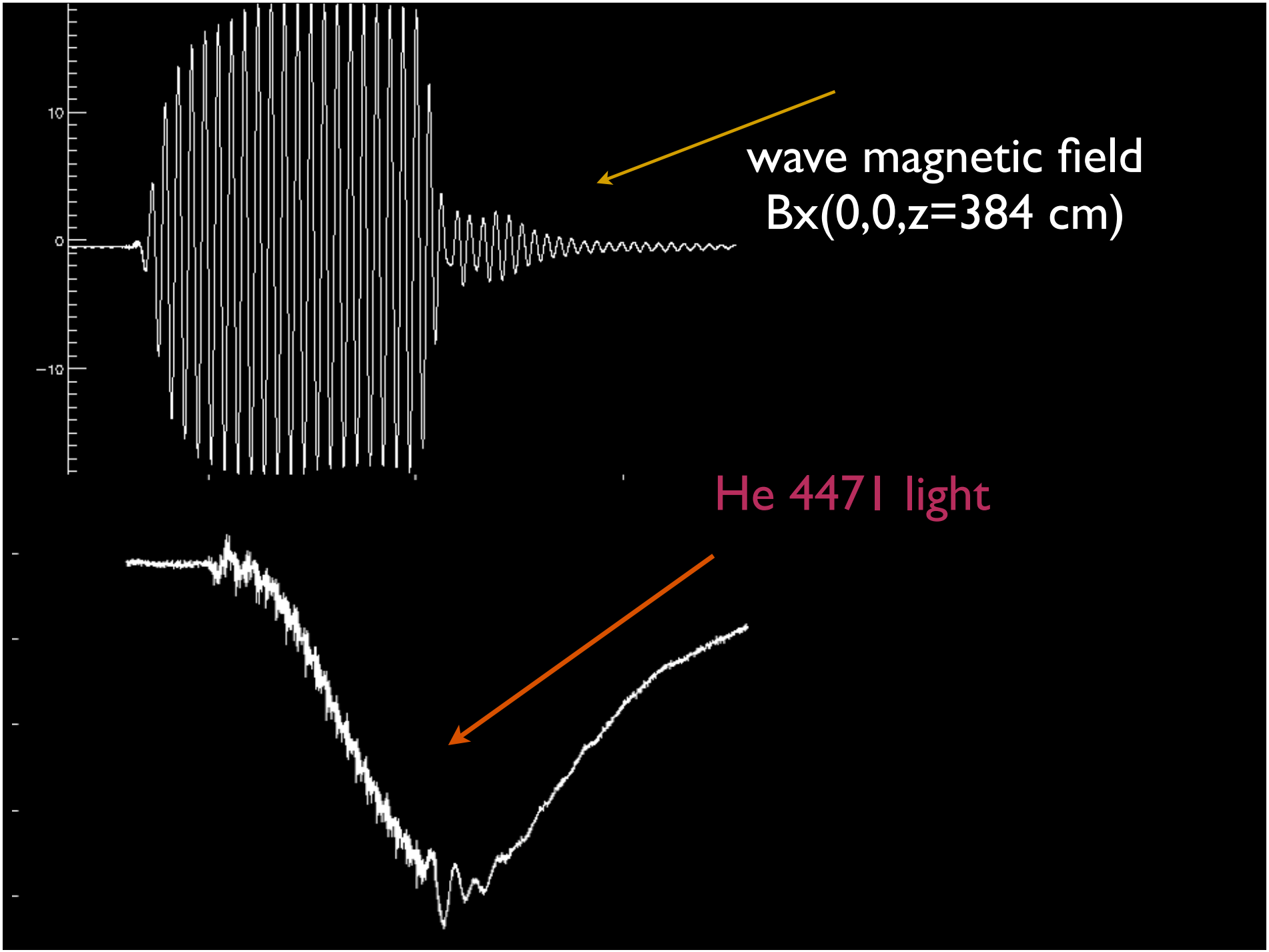

20
B(G)
0
z = 257 cm
ts = 500 80 ns/


X
Y
Z
25.0
B(G)
0.0
z = 257 cm
ts = 500 80 ns/

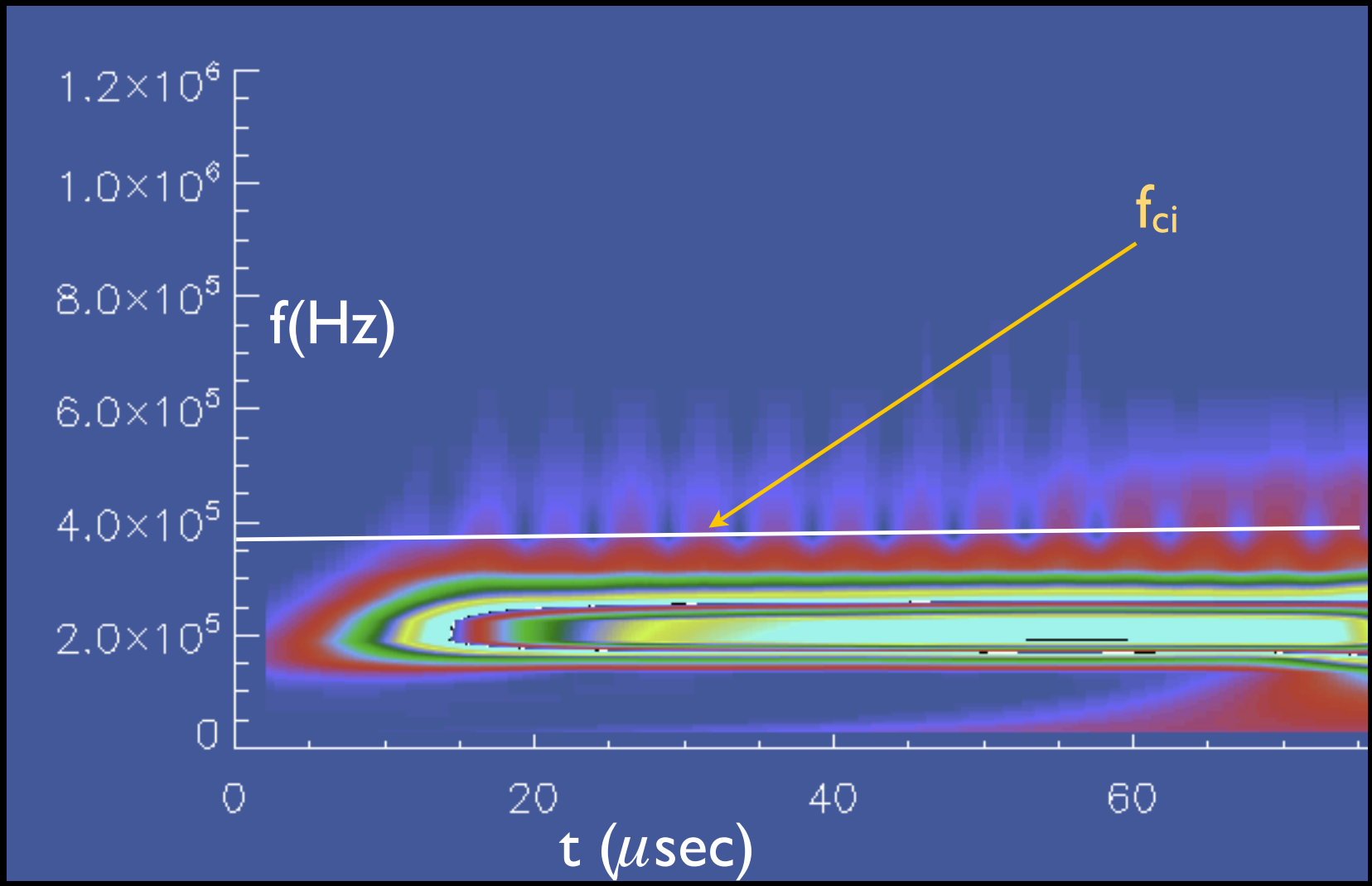

2 sided probe
Probe faces away from antenna towards cathode
Probe faces antenna
B0


Langmuir Curve
fitting routine
exponential rise (3 decades)
for Te
Vpot
electron
saturation
current
I-V curve swept in 5 μs
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
0
1000
2000
3000
4000


start of plasma
plasma-off
Alfvén wave on
$\delta T_e/T_e$ = .30
He 4471 neutral line
0.00
−0.01
−0.02
−0.03
−0.04
−0.05
−0.06
−0.005
0.000
t (sec)
0.005
0.010


10
0
−10
wave magnetic field
Bx(0,0,z=384 cm)
He 4471 light

Wavelet transformation Bx(x=0,y=0,z= 3.84m)



Planned Experiments

1) Creation of Mirror-Trapped Electron Populations
2) Interaction of Trapped Electrons with Rotating Magnetic Fields, Alfvén Waves, Whistler Waves, Lower Hybrid Waves
3) Measurement of Antenna Radiation Patterns
4) Wave particle Interactions in the Presence of Fast Ions

Breadth of UCLA local Program

1) resonant absorption of high power microwaves
2) effect of electric fields on plasma confinement
3) dynamics of magnetized plasma flows
4) interaction of laser generated plumes with magnetized plasmas
5) dynamics and formation of filamentary structures
6) electron heat transport in magnetized plasmas
7) novel microwave diagnostics of plasmas
8) development of microscopic probes
9) interaction of Alfvén waves with boundaries, flows and plasma resonances
10) interaction of current channels