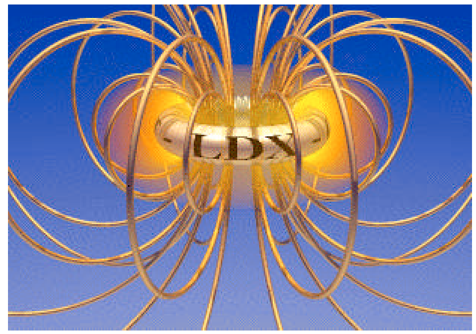
Glow Discharge Cleaning for LDX



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Abstract

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The Levitated Dipole Experiment (LDX) has completed design of its glow discharge cleaning (GDC) system. GDC will be used before first plasmas in LDX, as well as between experimental operations, to eliminate impurities from the vacuum vessel. The glow is created by a movable anode probe inserted through a flange on the underside of the vessel. The anode is biased with up t o 800V with respect to the vessel wall with 12kW DC po wer available for plasma formation.

Away from the anode, a biased tungsten filament will be installed to aid in discharge breakdown and reduce the likelihood of arcing[1]. The filament may also be used for preionization during experimental operations. GDC will be implemented with deuterium gas followed by a shorter period of helium gas. A reduced conductance pumping path will be incorporated into the vacuum system in order to better control pressure during GDC operation. The completed design and plans for initial tests of the GDC system will be presented.

[1] H.W Kugel, W. Blanchard, G. D'Amico, R. Gernhardt, and T. Provost, "*NSTX Filament Preionization And Glow Discharge Cleaning Systems*", PPPL Report (2000).

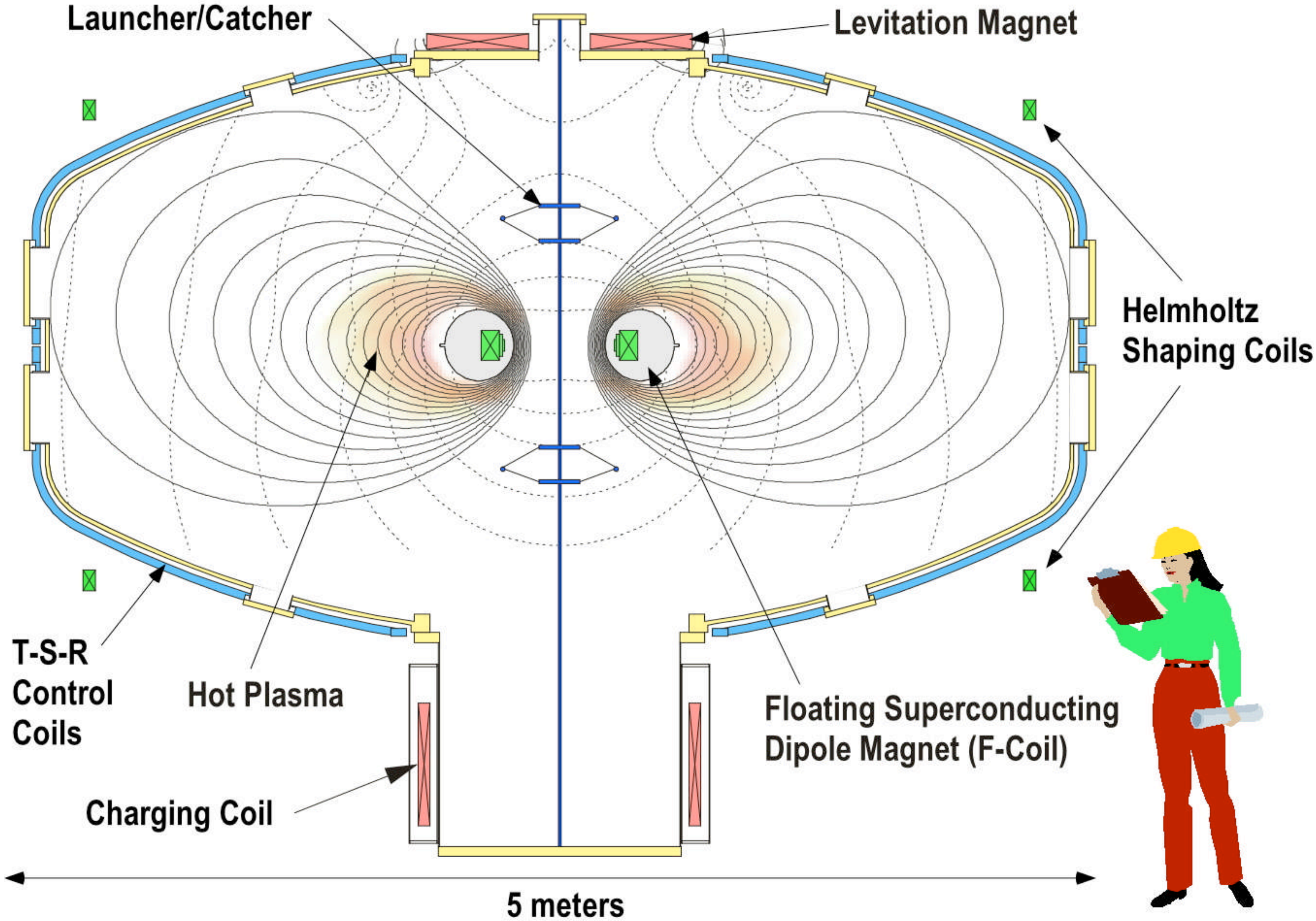
LDX Vacuum Vessel

Specifications:

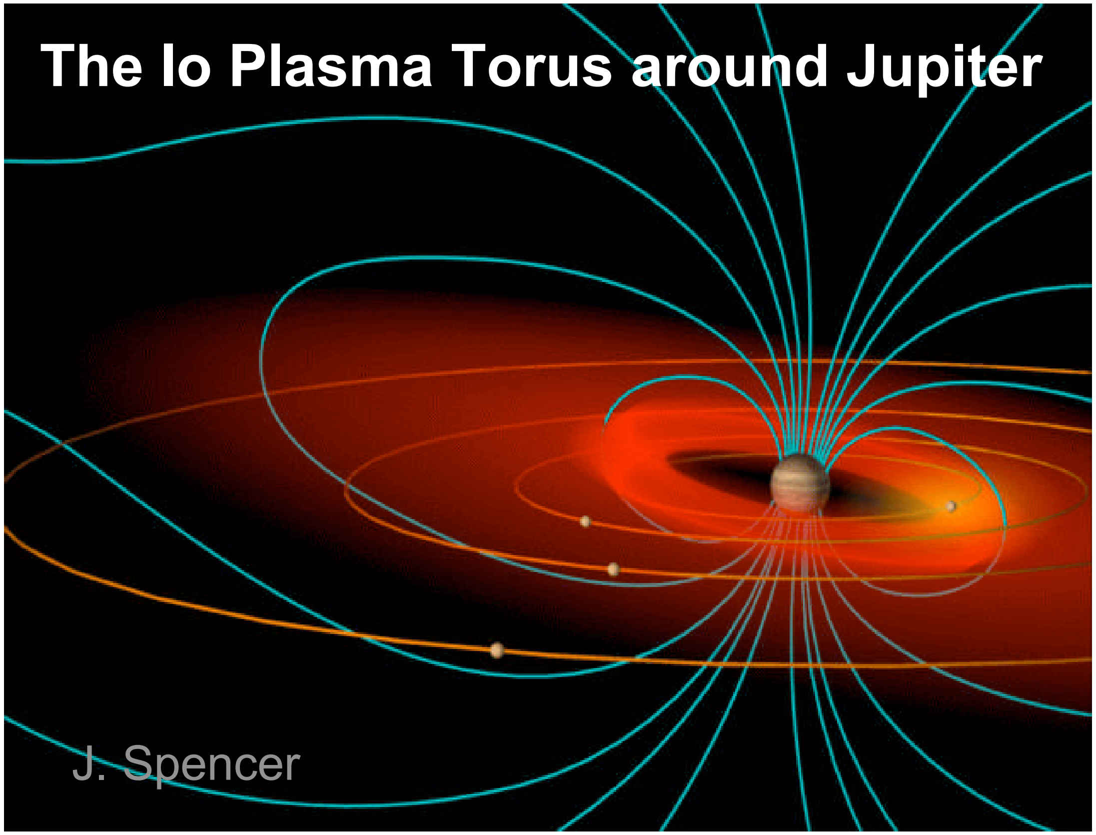
- 5 meter (198”) diameter, 3 m high, elevated off chamber floor
- 11.5 Ton weight
- 7.5 x 10^{-8} Torr base pressure
  - **Manufactured by Vacuum Technology Associates / DynaVac**
    - **Completed Sept. 1999**

Interior of Vessel- Initial Cleaning

LDX Experiment Cross-Section



Why dipole confinement?



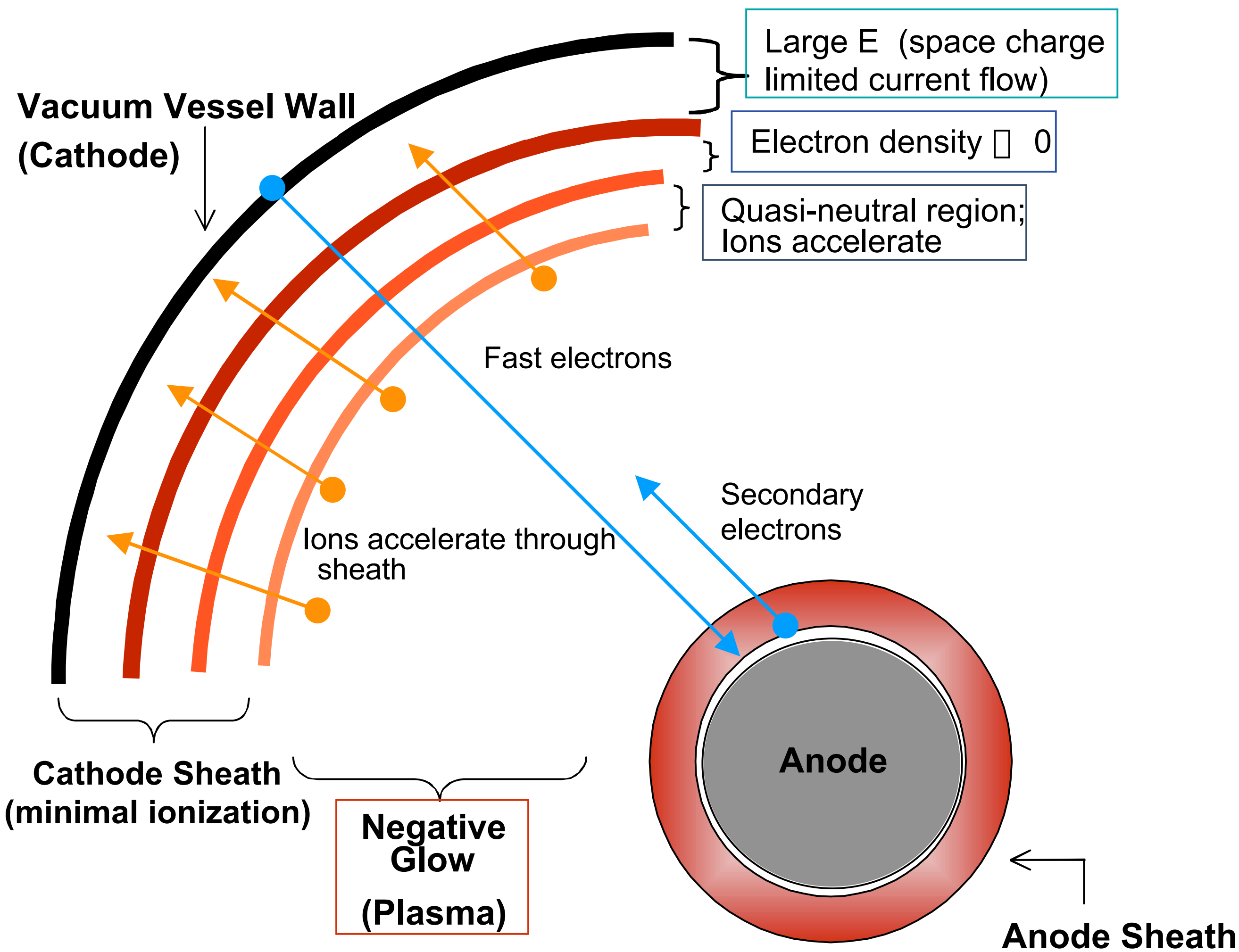
- Simplest confinement field
- Steady state
- High-β confinement occurs naturally in magnetospheres (β ~ 3 in Jupiter)
- Possibility of fusion power source with near-classical energy confinement
- Opportunity to study new physics relevant to fusion and space science

Dipole Confinement and LDX:

•Concept is based on observations of the plasma properties around Jupiter, created by a dipole confinement

• β ~ plasma pressure/ magnetic pressure

Glow Discharge Process



Anode Sheath

- Uniform ion density
- Collisionless region
- No ionization
- Accelerates secondary electrons back into glow

Cathode Sheath

- Minimal ionization
- Fast electrons take collisionless path through glow and hit anode
- Ions accelerated knock impurities off vessel wall

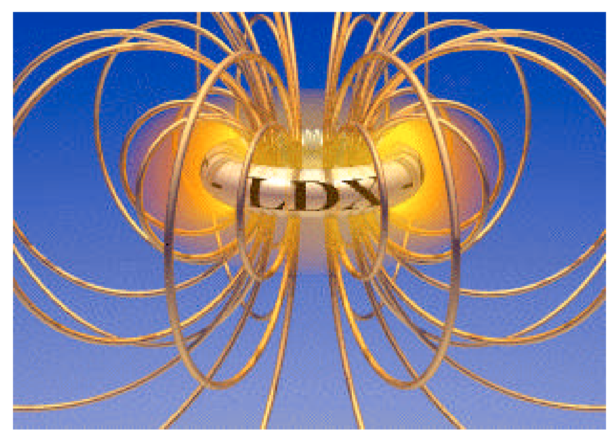
Potential Drop across Glow

The GDC Process

- Gas and Vacuum pumping systems:
    - Vessel pumped down to ~10^{-3} Torr
    - Gas pumping system introduces H or He gas into vessel
    - Glow initiated impurities liberated from vessel walls
    - Continual pumping removes liberated impurities from vessel

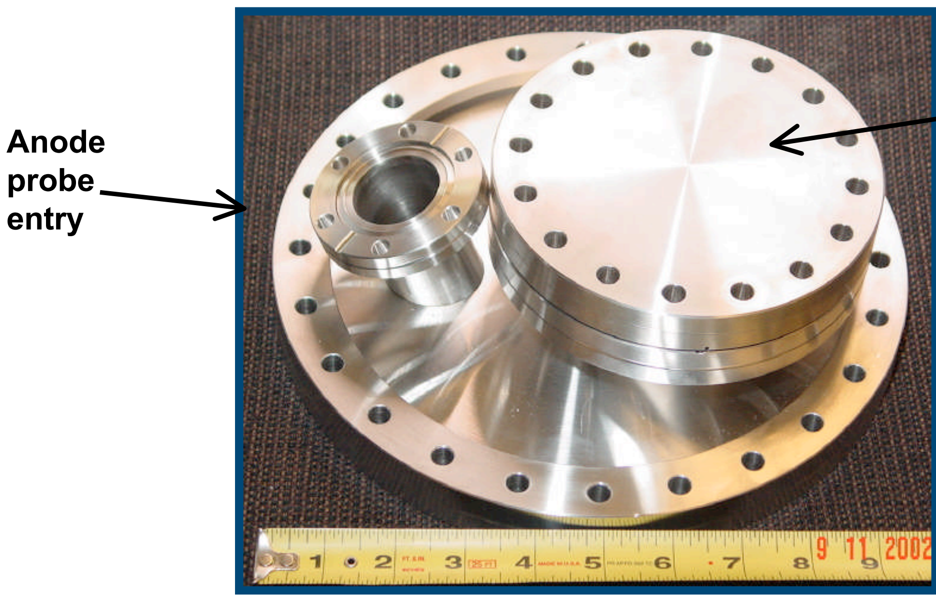
Importance of GDC for LDX

- LDX requires pure hydrogenic plasma□ experimental objective is to examine limits of stability in high pressure (high □) plasmas
- Large volume of plasma and limited power availability
- Impurities on the interior of LDX vessel wall (such as oxygen, nitrogen, etc.) ejected into confined plasma by plasma and neutral bombardment
- Ejected atoms radiate power, causing the plasma to cool
- Impurities can dissipate power enough to severely lower confined plasma pressure
- Thus, LDX vessel must be free of impurities to obtain experimental objective!

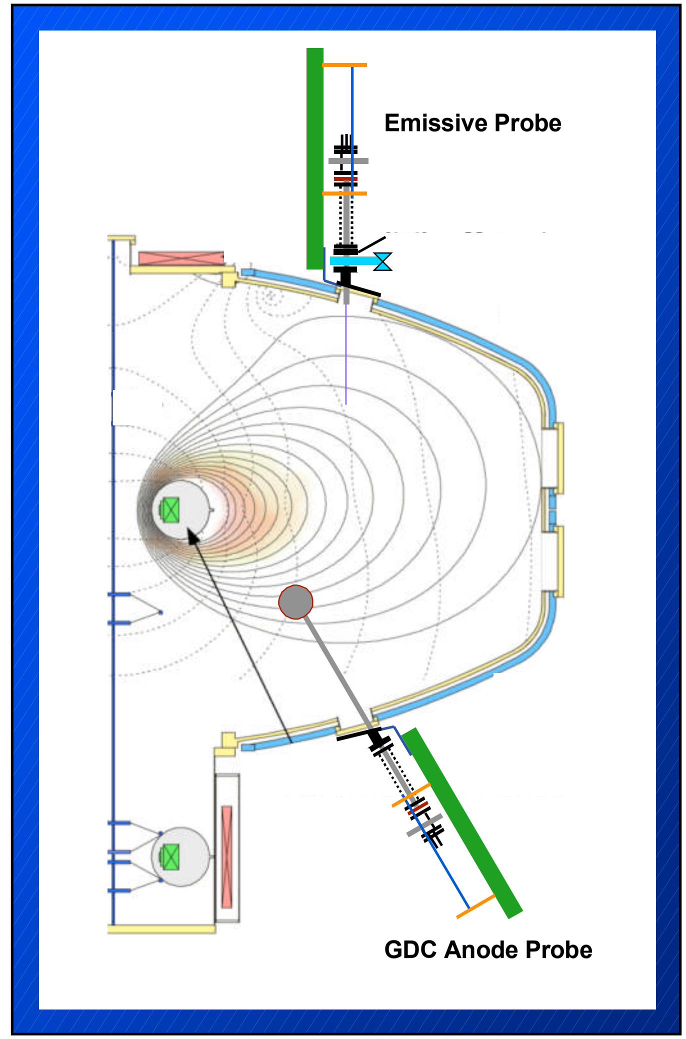


GDC Anode Probe

- GDC anode probe enters and retracts from main vessel via mounting system connected to pre-existing flange on vessel
- Probe attached to rigid, insulated stainless steel rod
- End of rod outside vessel connects to full nipple flange
- Vacuum-operated bellows encloses rod between exterior of vessel and full nipple flange



GDC Flange

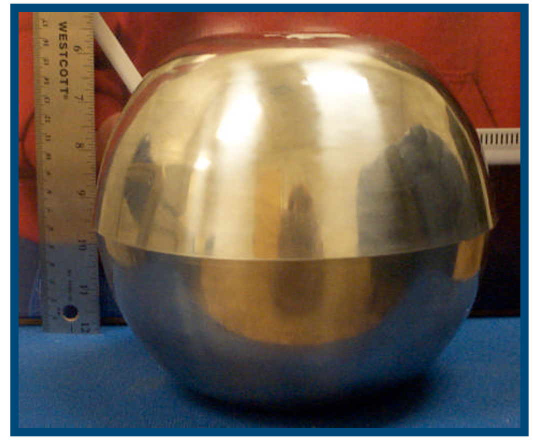


* Drawing by Eugenio Ortiz, November 10, 2002

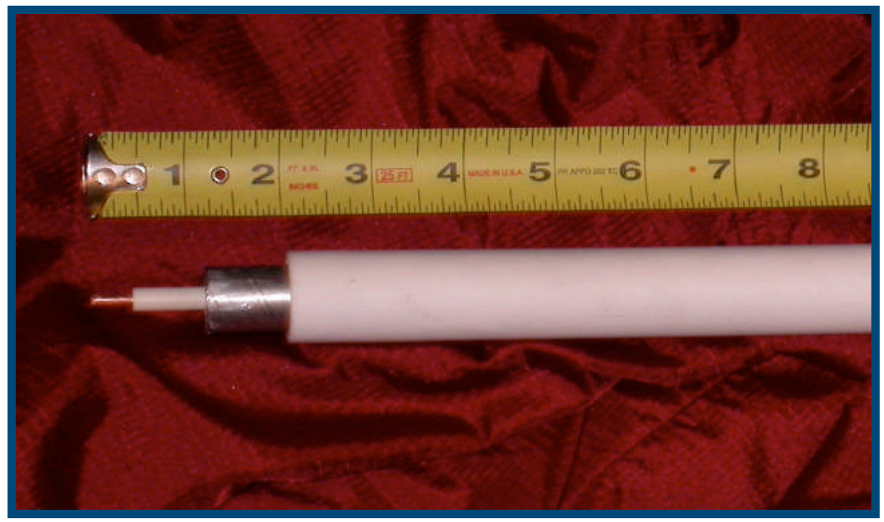
GDC Anode Probe

Anode Support Shaft

- Biggest concern in design: arcing!
- Shaft design takes into careful account possibility of arcing
- 1/8” copper conductor shielded with 1/4” OD alumina tube
- 3/4” OD stainless steel main support rod shielded with 1”OD, 40” long alumina tube
- Steel rod is welded to a blank flange at lower end
- Shaft housed in bellows mechanism for insertion and retraction of GDC probe



•Stainless steel anode inserted into vacuum vessel for GDC



•View of shaft upper end-- will go inside probe

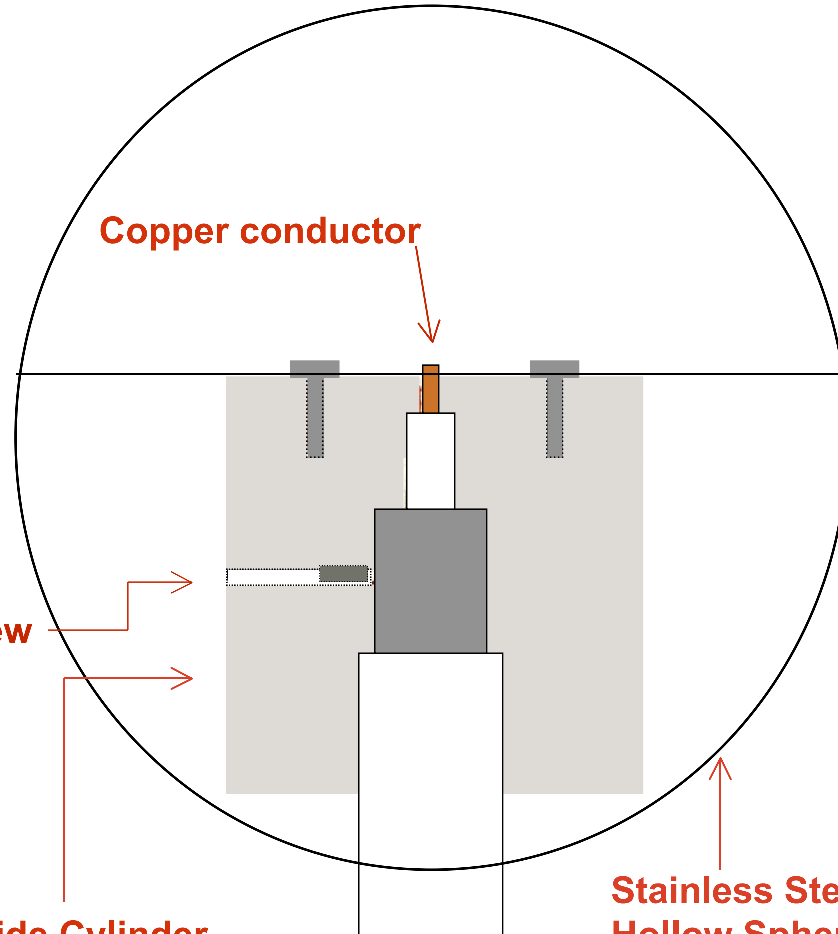
•Provides power to anode via copper wire- copper wire is attached to the inside of anode

Inside Anode Probe

- Key to inside of probe is boron nitride cylinder
- Cylinder provides insulated termination points for all shaft components
- 1/8” copper conductor exits top of cylinder and is attached to inside of steel probe
- BN cylinder is supported inside spherical anode via steel disk welded inside anode

Half of steel anode

Cross-section of anode probe



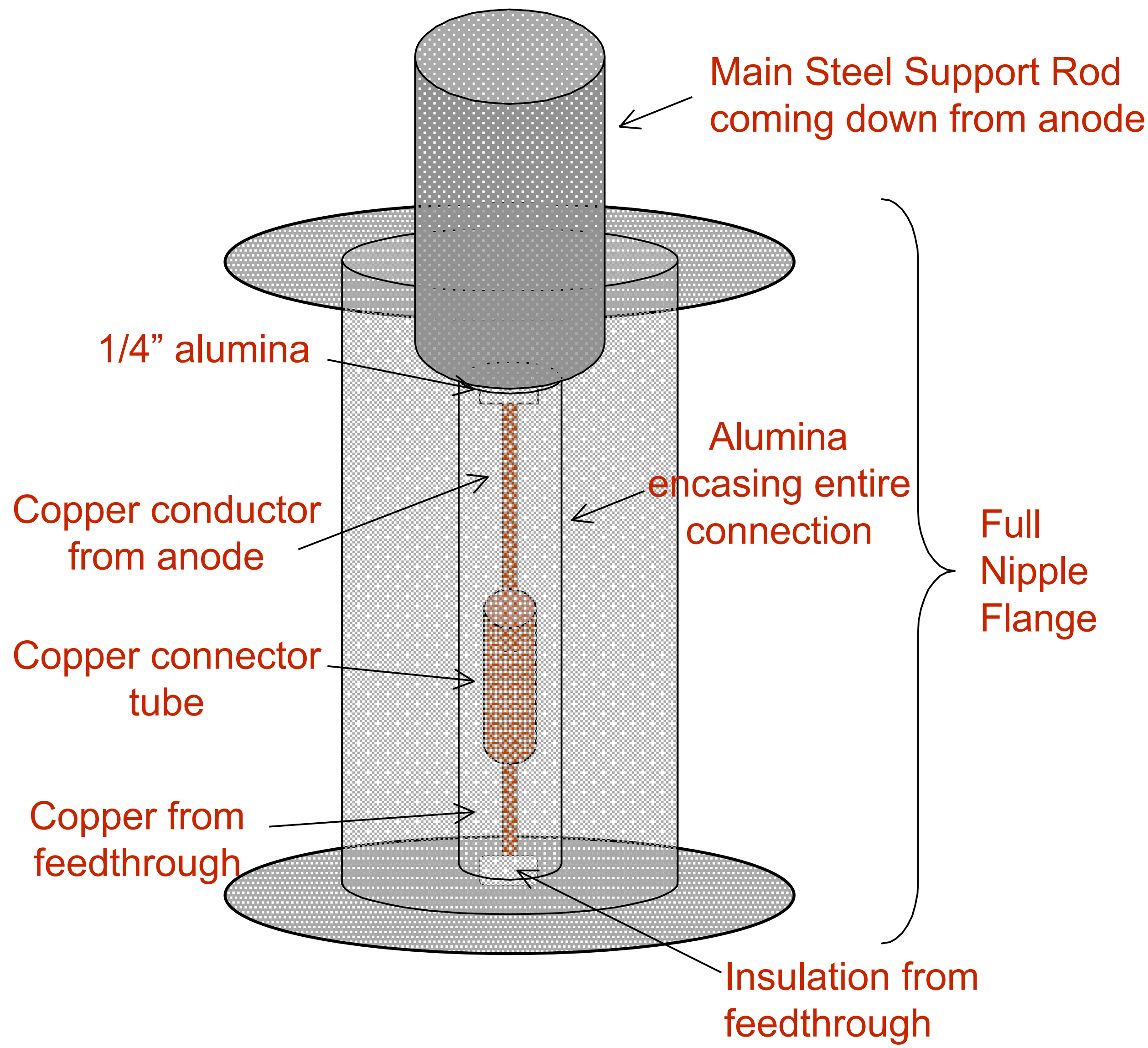
Anode Power Supply

12 kW Power Supply

•Manufactured by Spellman HV, Oct. 2002

- 10.5” H x 19” W x 19” D rack mount supply
- Output:
  - 800V DC
  - Up to 7.5 A
- Floating ground isolates power supply from chassis ground
- Selected for high current output, remote operation capability, and front console design

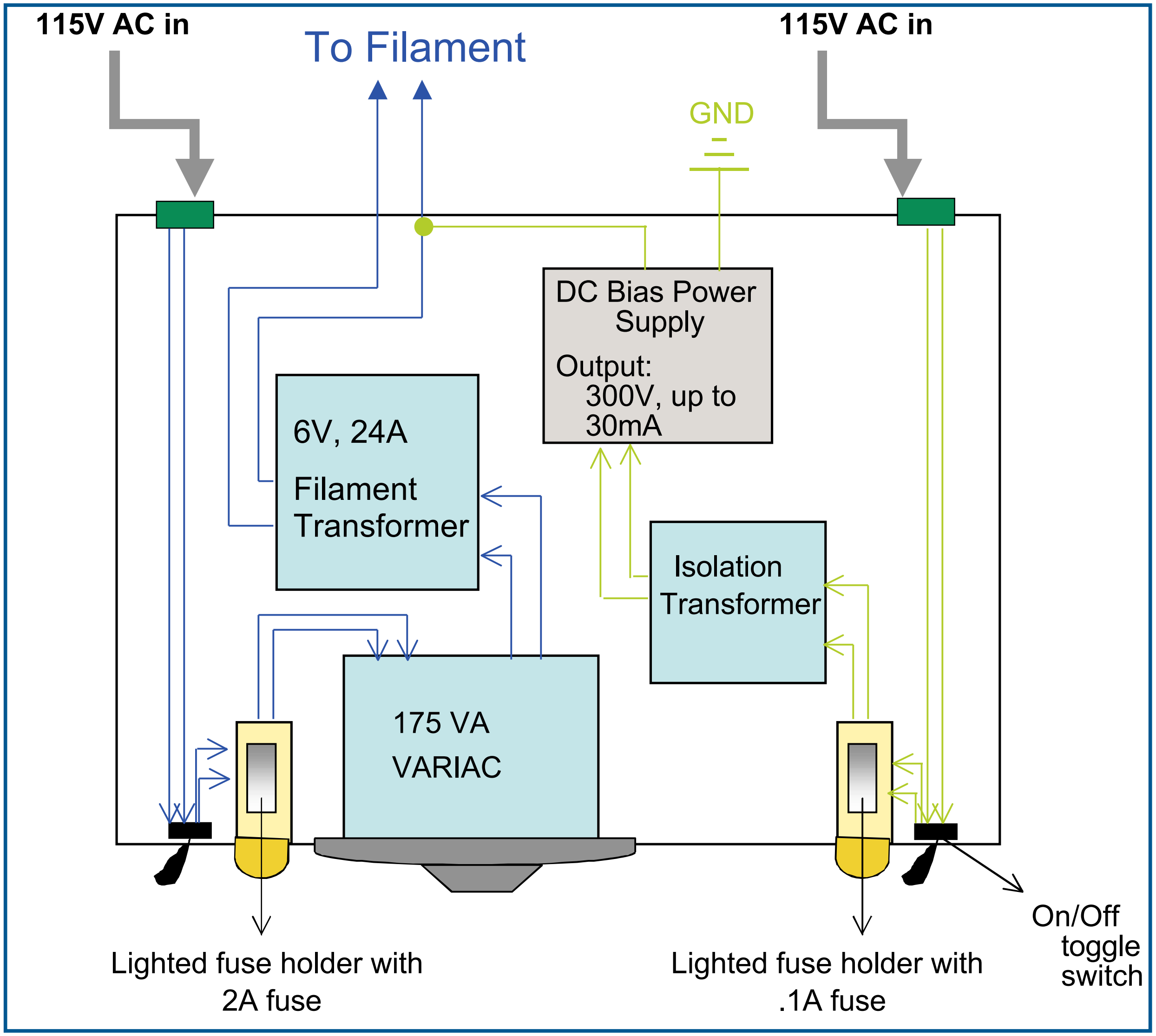
Power Transfer Connection



- 1/8” copper conductor attached internally to anode must make solid connection with power supply
- Very high risk of arcing inside full nipple flange many regions where ‘line of site’ between copper and other metals could cause arcing and effect discharge

Preinoization Filament

Power transfer system to Filament



- •Biased tungsten filament inserted near anode
- •Aids in glow discharge by providing added electron source
- •Also useful for illuminating inside of vacuum vessel

Bias Power Supply and Tungsten Filament

GDC Operation Plan

- Preionization filament may not be used in first GDC plasmas in order to test only anode and high-voltage power supply
- Very long period of glow discharge will run before first LDX plasmas to thoroughly clean vessel
- GDC will use hydrogen gas and then a shorter period of helium gas

- Currently do not have Z-detector to monitor what is removed from vessel during GDC
- Do have 2-pi bolometer (photodiode with green filter)
- This will be used to assess GDC

GDC Operation Plan

- Residual Gas Analyzer (RGA) will monitor vacuum conditions between plasma shots
- Option to run GDC between shots will be determined by vacuum conditions as indicated by RGA
- GDC will run for approximately 7 hours total in between run days

- GDC operates at pressure ~10^{-3} Torr
- Future Goal:
  - Would like to automate GDC system in the future- anode power supply is capable of remote operation
  - This would also require modifications to gas and pressure systems

Conclusions

- GDC uses unconfined plasma to remove impurities from inside of LDX vacuum vessel
- Removal of impurities essential for LDX experiment
- GDC design based on pre-existing flanges in LDX vessel
- Largest issue in design was to avoid arcing
- GDC first plasmas expected in December 2002!

For more information/updates on LDX GDC, contact Sarah Dagen: dagen@psfc.mit.edu

References

1. H.W Kugel, W. Blanchard, G. D'Amico, R. Gernhardt, and T. Provost, "***NSTX Filament Preionization And Glow Discharge Cleaning Systems***", PPPL Report (2000).
2. ITER report, 1999