INTRODUCTION TO THE HYBRID PLASMA EQUIPMENT MODEL

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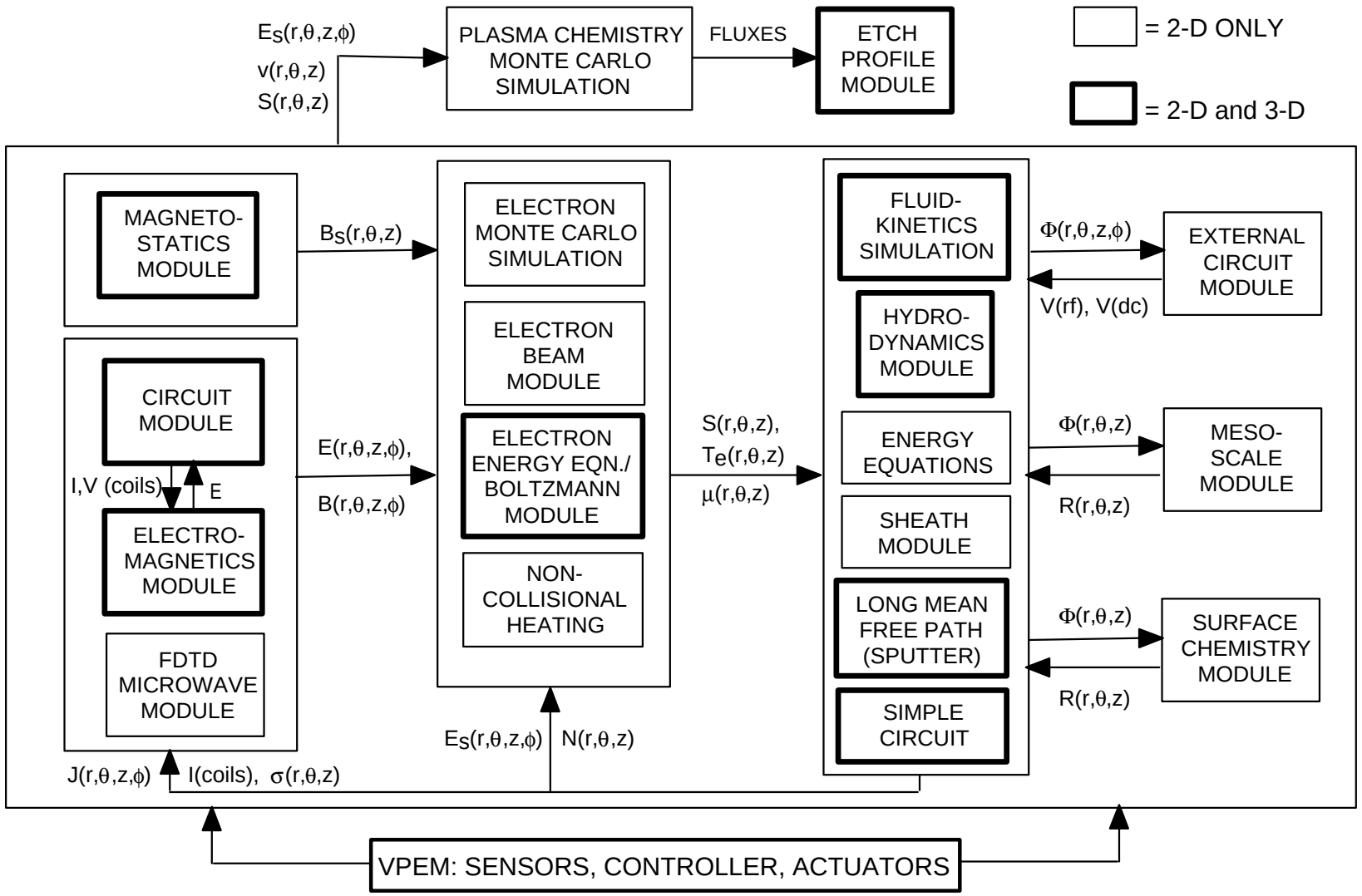
COMPUTATIONAL OPTICAL AND DISCHARGE PHYSICS GROUP
University of Illinois at Urbana/Champaign

- **The Computational Optical and Discharge Physics Group (CODPG) at the University of Illinois develops computer simulations and computer aided design tools for low temperature plasma processes and equipment.**
  - **Plasma materials processing for microelectronics fabrication**
  - **Plasma remediation of toxic gases**
  - **Pulsed Power**
  - **Lighting sources and plasma display panels**
  - **Lasers and laser-materials interactions**
- **These physics based, design capable models are jointly developed and validated with industrial collaborators. The models may be delivered and licensed to our collaborators.**

HYBRID PLASMA EQUIPMENT MODEL (HPEM)

- **The Hybrid Plasma Equipment Model (HPEM) is a comprehensive modeling platform developed by the CODPG for low pressure (< 10's Torr) plasma processing reactors. The HPEM is capable of addressing:**
  - **Inductively Coupled Plasma (ICP) tools.**
  - **Reactive Ion Etchers (RIE)**
  - **Electron Cyclotron Resononance (ECR) sources**
  - **Magnetron sputter and Ionized Metal Physical Vapor Deposition (IMPVD)**
  - **Remote Plasma Activated Chemical Vapor Deposition (RPACVD)**
  - **Dust particle transport in plasma tools**
- **There are 2-d and 3-d versions of the HPEM.**
- **The HPEM is linked to profile simulators developed in the CODPG which predict the evolution of submicron features.**
- **The HPEM is now in use at 10 major semiconductor chip and plasma equipment manufactures.**

SCHEMATIC OF THE HYBRID PLASMA EQUIPMENT MODEL



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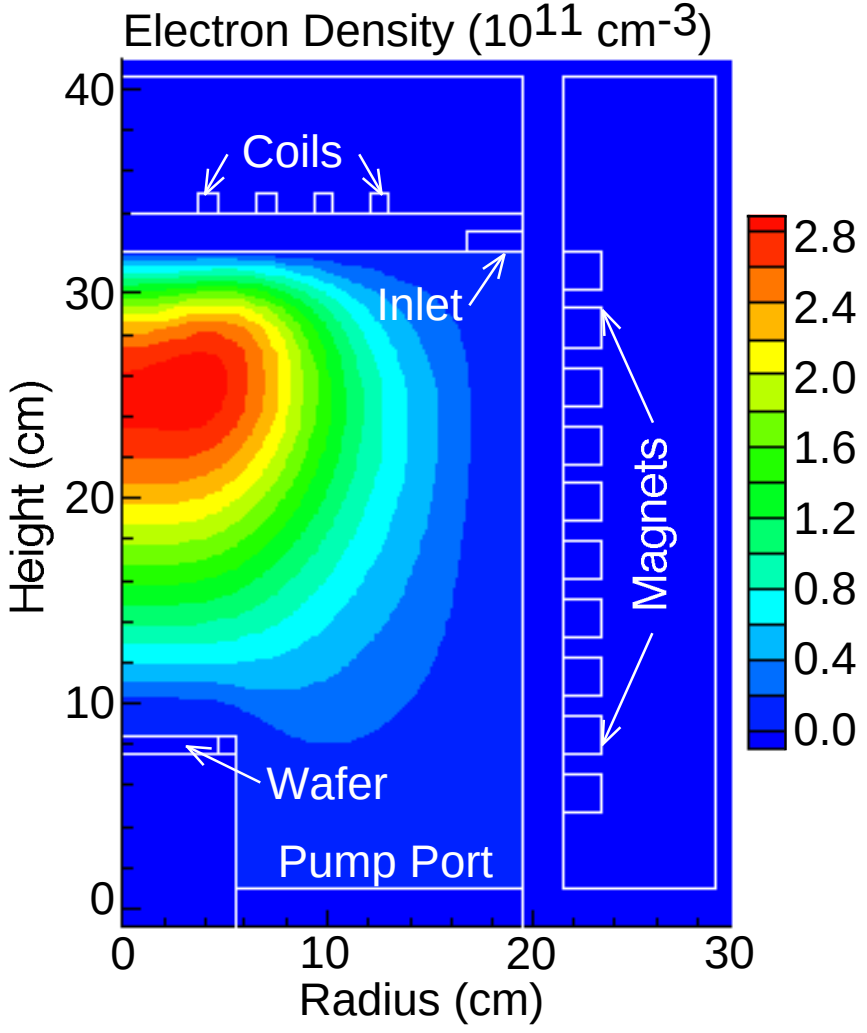
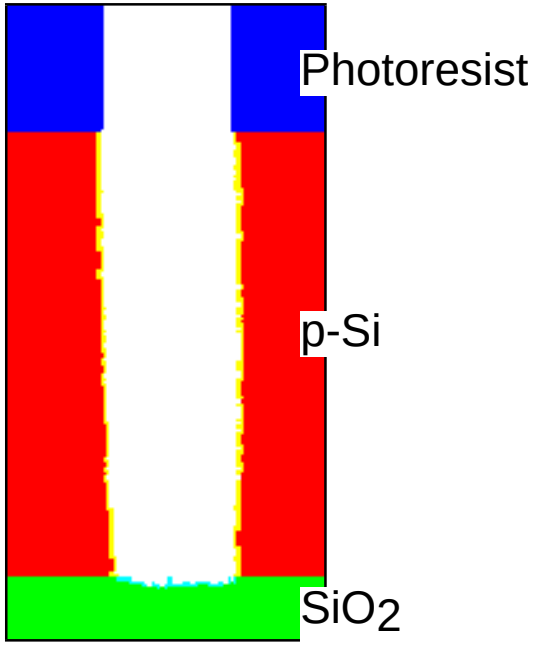
Example: HPEM SIMULATION OF p-Si ETCHING

- The HPEM has been applied to analysis of a large variety of plasma etching systems. Here we show the electron density in an Inductively Coupled Plasma p-Si etching tool and the resulting etch profile.

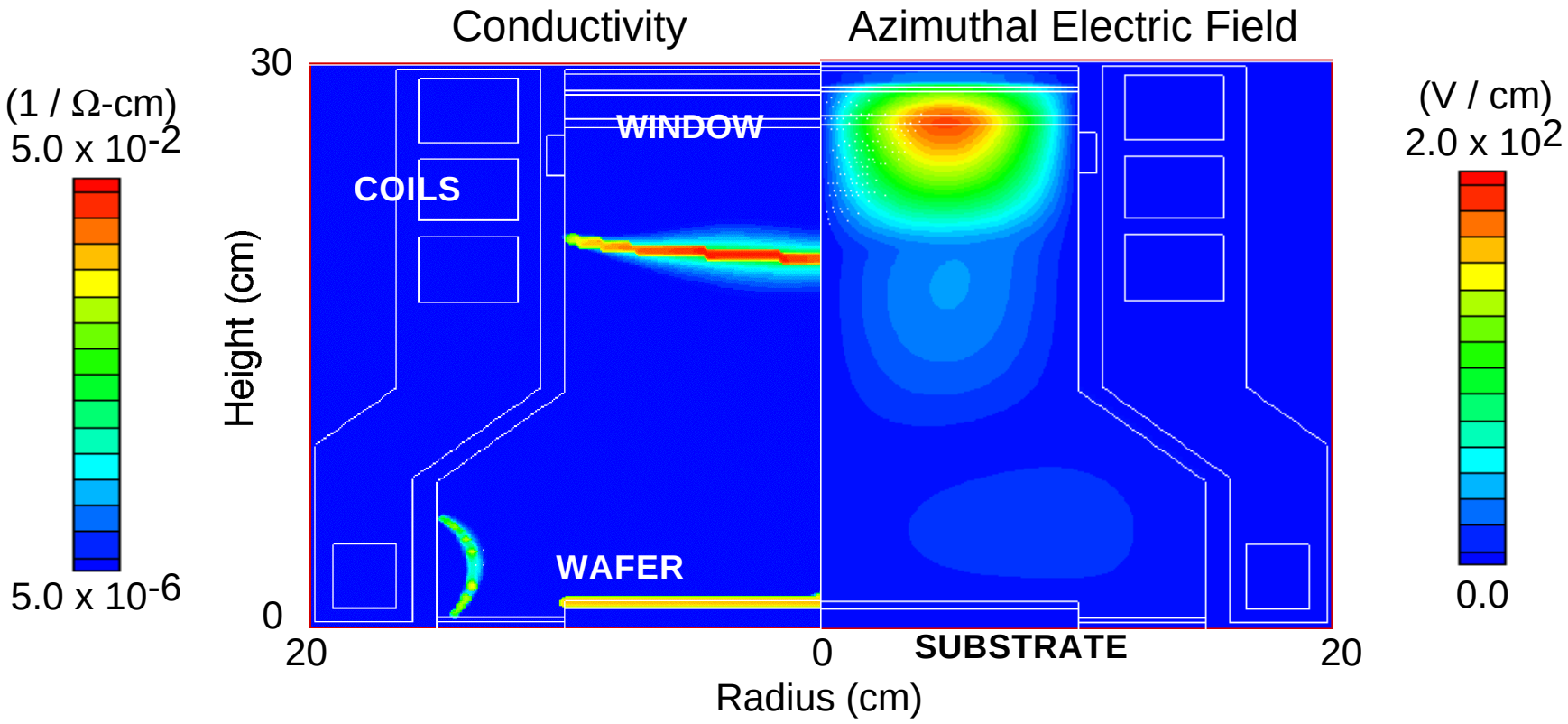




Gas Mixture:	Cl_2/Ar = 96/4
Pressure:	4 mTorr
Gas flow rate:	30 sccm
ICP power:	1000 W
Bias voltage:	100 V

Example: MICROWAVE ECR PLASMA SOURCE

- A Finite Difference Time Domain (FDTD) module has been developed for the HPEM to address microwave excitation of plasma sources.
- Here we show the plasma conductiviity and microwave field intensity (2.45 GHz) in an Electron Cyclotron Resonance (ECR) reactor. The injected mode is TE_{01}.

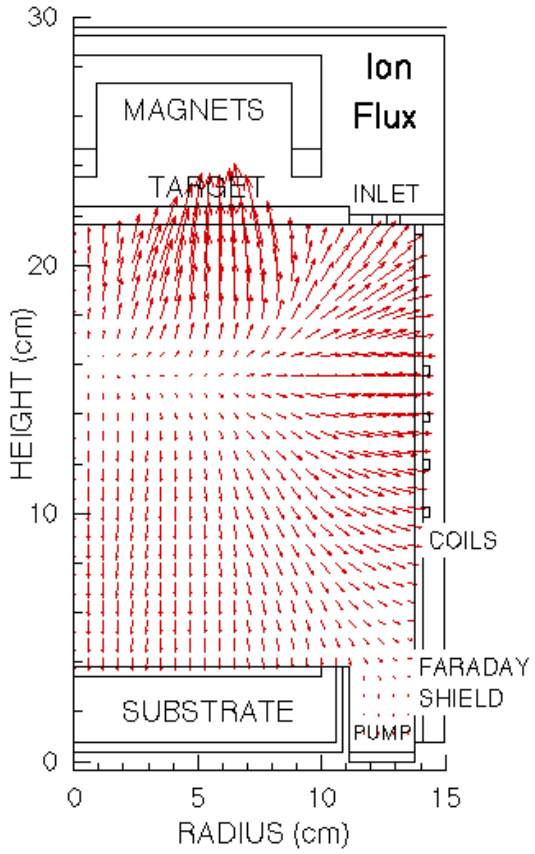


- N_2, 750 Watts, 1 mTorr, 10 sccm

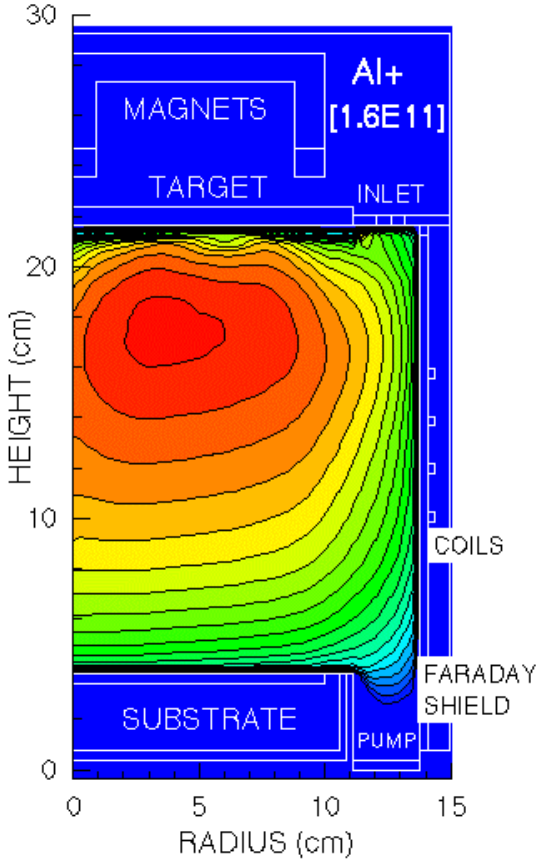
Example: IMPVD OF Al

- **Ionized Metal Physical Vapor Deposition (IMPVD) combines magnetron sputtering with an ICP plasma to produce ionized metal fluxes to the wafer.**

• Ion Flux

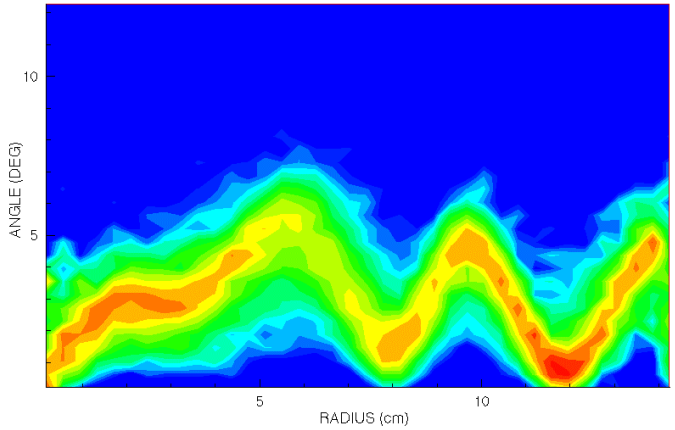


• Al^+ Density



- **The HPEM addresses both plasma transport and "sputtering physics".**
- **Ion and radical energies and angles to all surfaces are produced.**

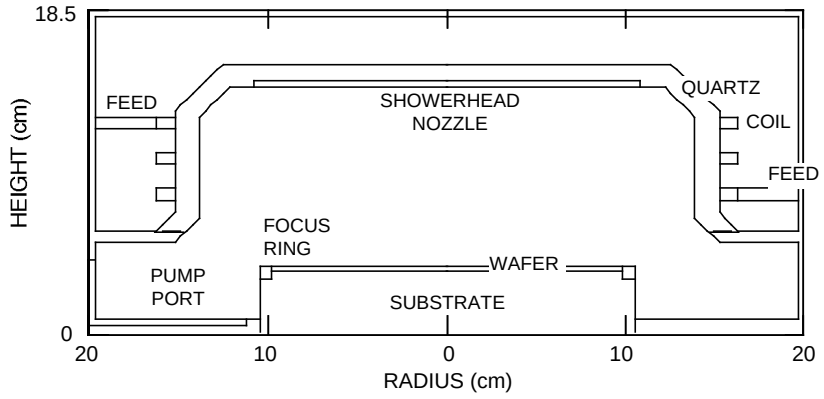
• Angle of Al^+ to Target



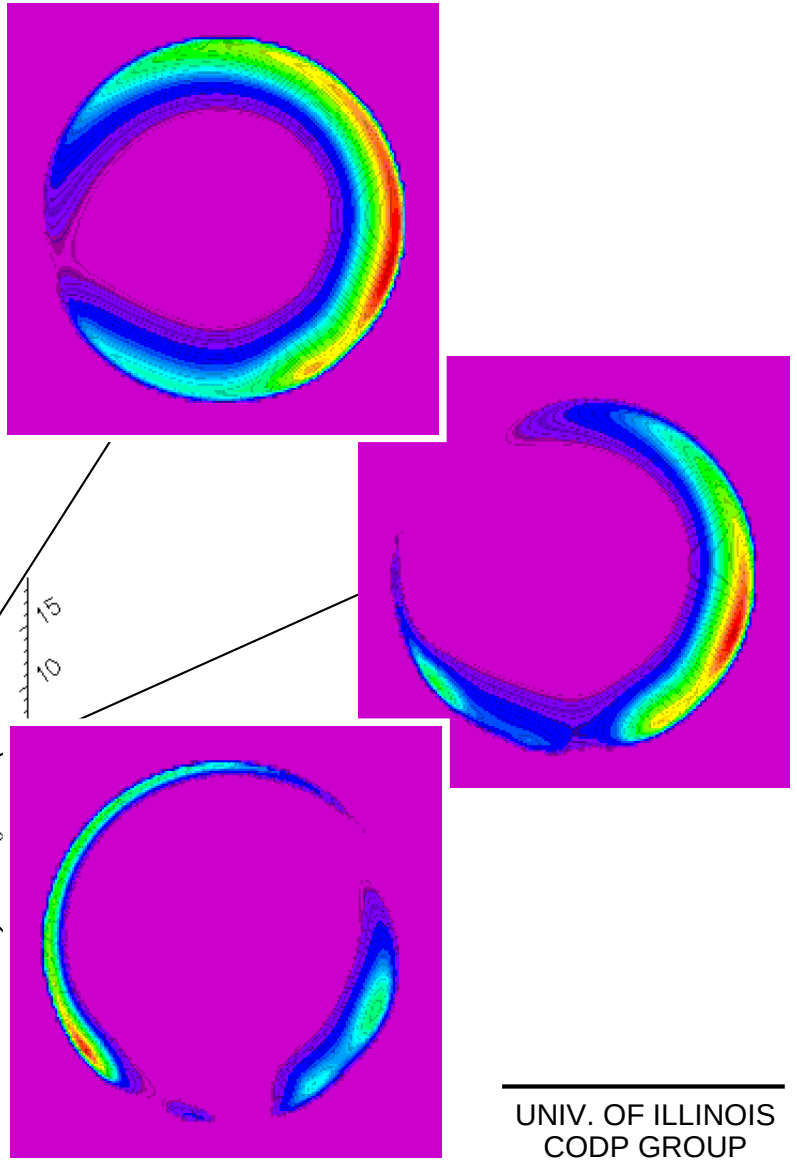
- **Ar 20 mTorr, -200 V dc, 2 MHz ICP 1.25 kW, 40 V 10 MHz bias**

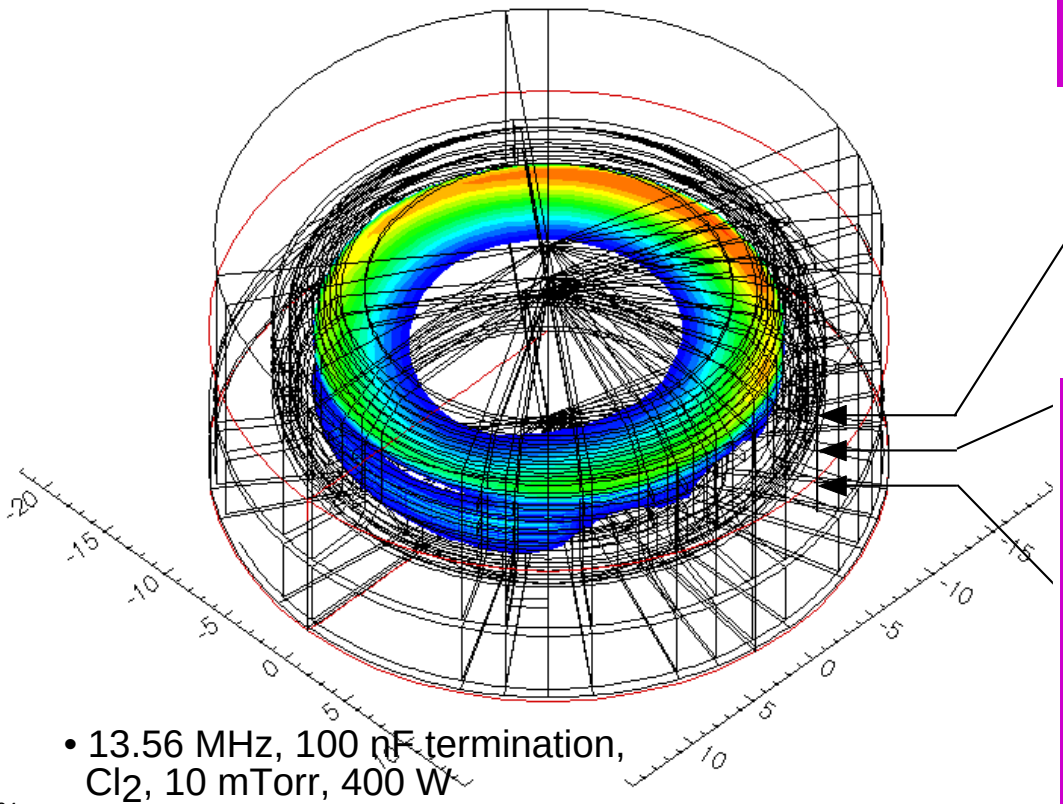
Example of HPEM-3D: AZIMUTHALLY ASYMMETRIC POWER DEPOSITION

- HPEM-3D has been applied to analysis of transmission-line effects in ICP reactors which produce azimuthally asymmetric power deposition.



- Power deposition:
  Max = 0.92 W-cm^{-3} (2 decades)





- 13.56 MHz, 100 nF termination, Cl_2, 10 mTorr, 400 W

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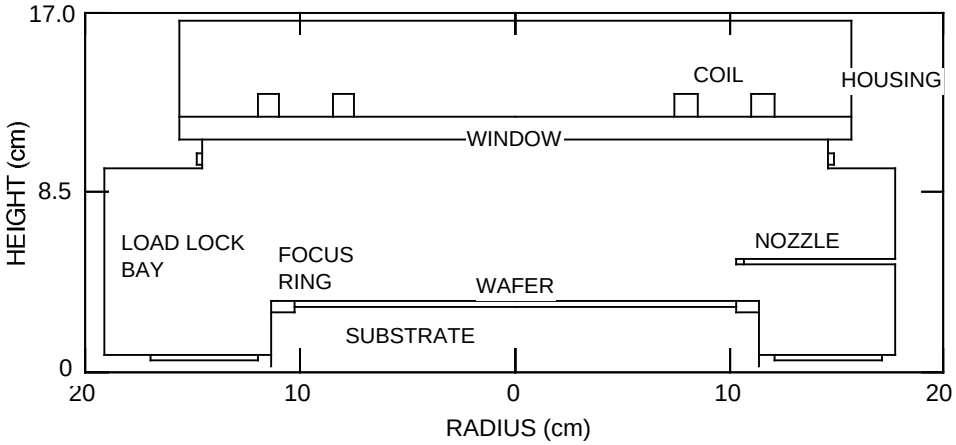
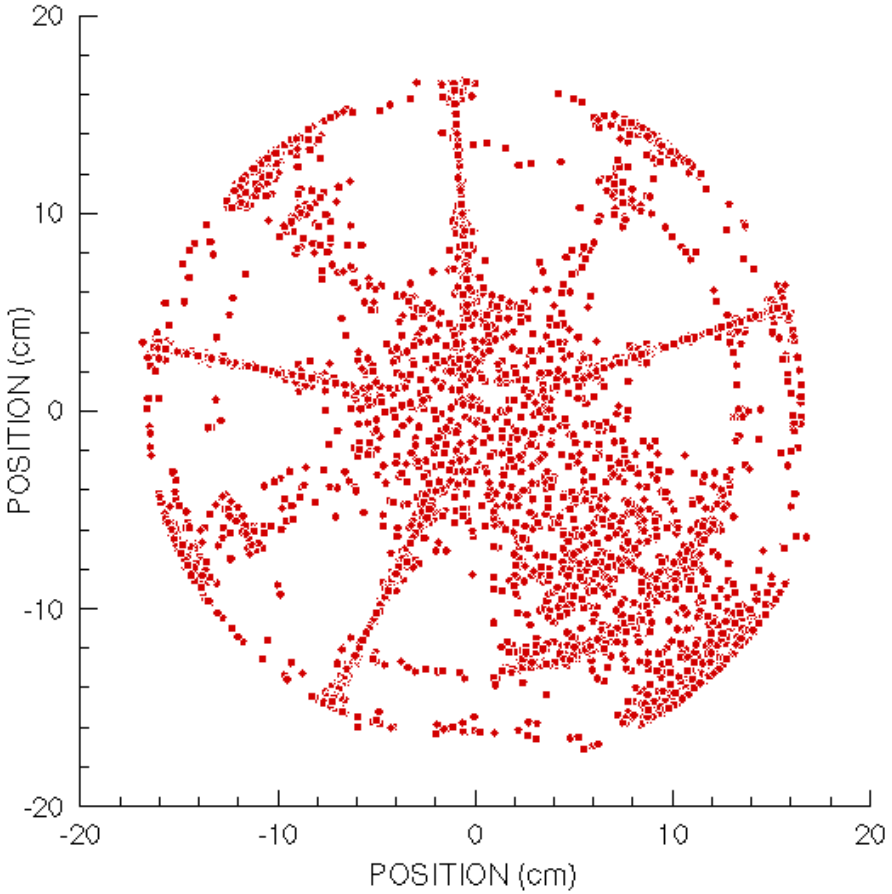
Example of DTS: NOZZLE GENERATED DUST PARTICLE TRAPS

- The Dust Transport Simulator (DTS) uses results from the HPEM to follow trajectories of dust particles in plasma tools.
- HPEM-3D was used to model an ICP reactor having 4 nozzles and a size load lock bay.
- The DTS predicts that dust particle traps are produced by these structures.



• Plasma Tool Geometry

• Top view of particle positions



• Ar, 10 mTorr, 100 W

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