

High Power RF Sources for Accelerators

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Source Development at CCR

- 91 GHz 10 MW Gyroklystron
- 30 GHz 25 MW Gyroklystron
- 50 MW X-Band Multiple Beam Klystron
- L-Band 1.5 GHz Klystron for JLAB
- L-Band Annular Beam Klystron

W-Band Gyrokystron

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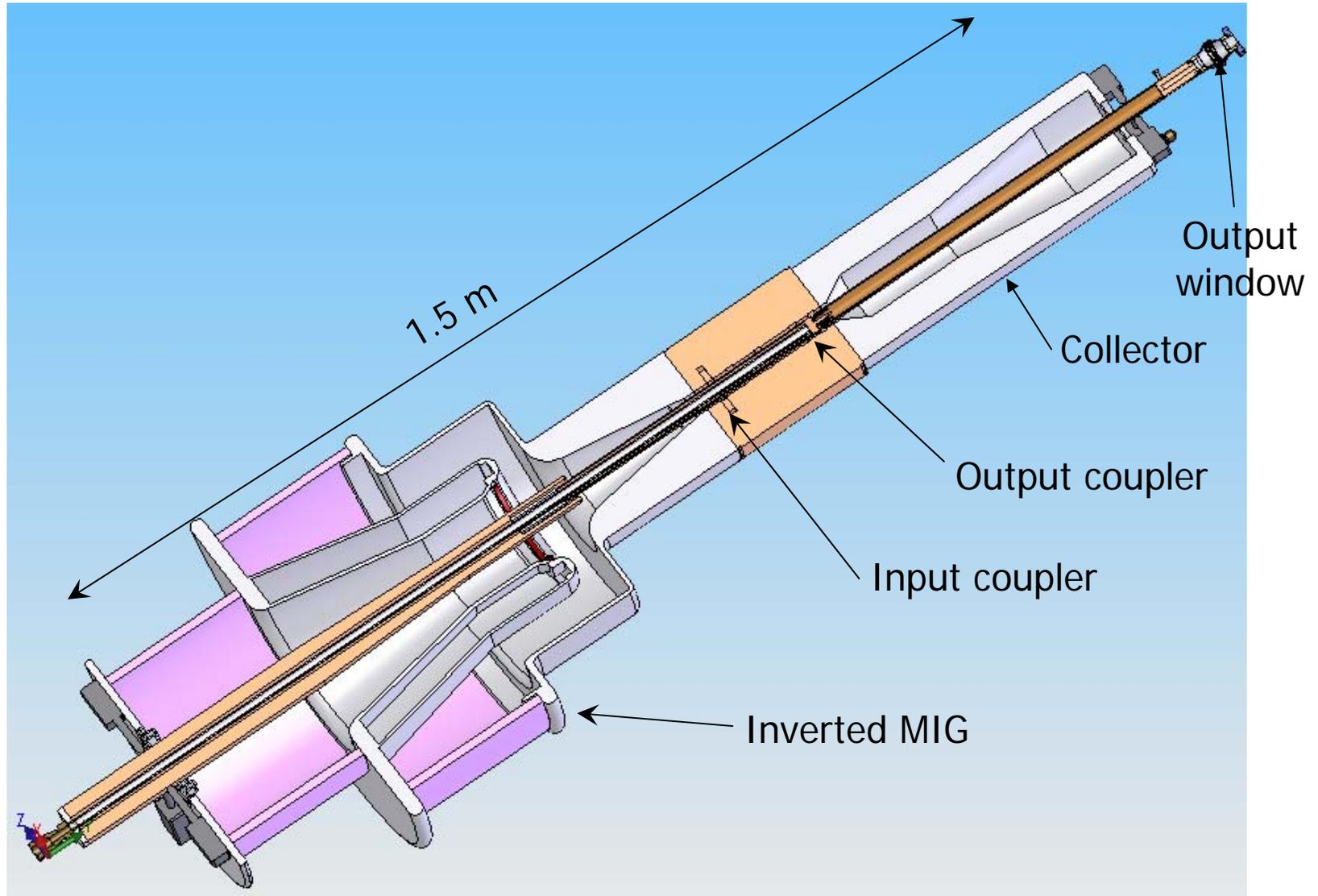
Specifications

Parameter	Goal
Frequency	91.386 GHz
Design Output Power	10 MW
Efficiency	37%
Gain	56 dB
Pulse length	~ 1 microsec
Duty cycle	~ 0.001
Operating mode	TE01 or TE02
Output mode	TE01/02 Composite
Operating Voltage	500 kV
Operating Current	50 A

Availability

- The gyrokylystron is fully assembled, baked, and ready for operation
- Superconducting magnet with power supplies are in inventory
- Two RF driver TWTs are in stock

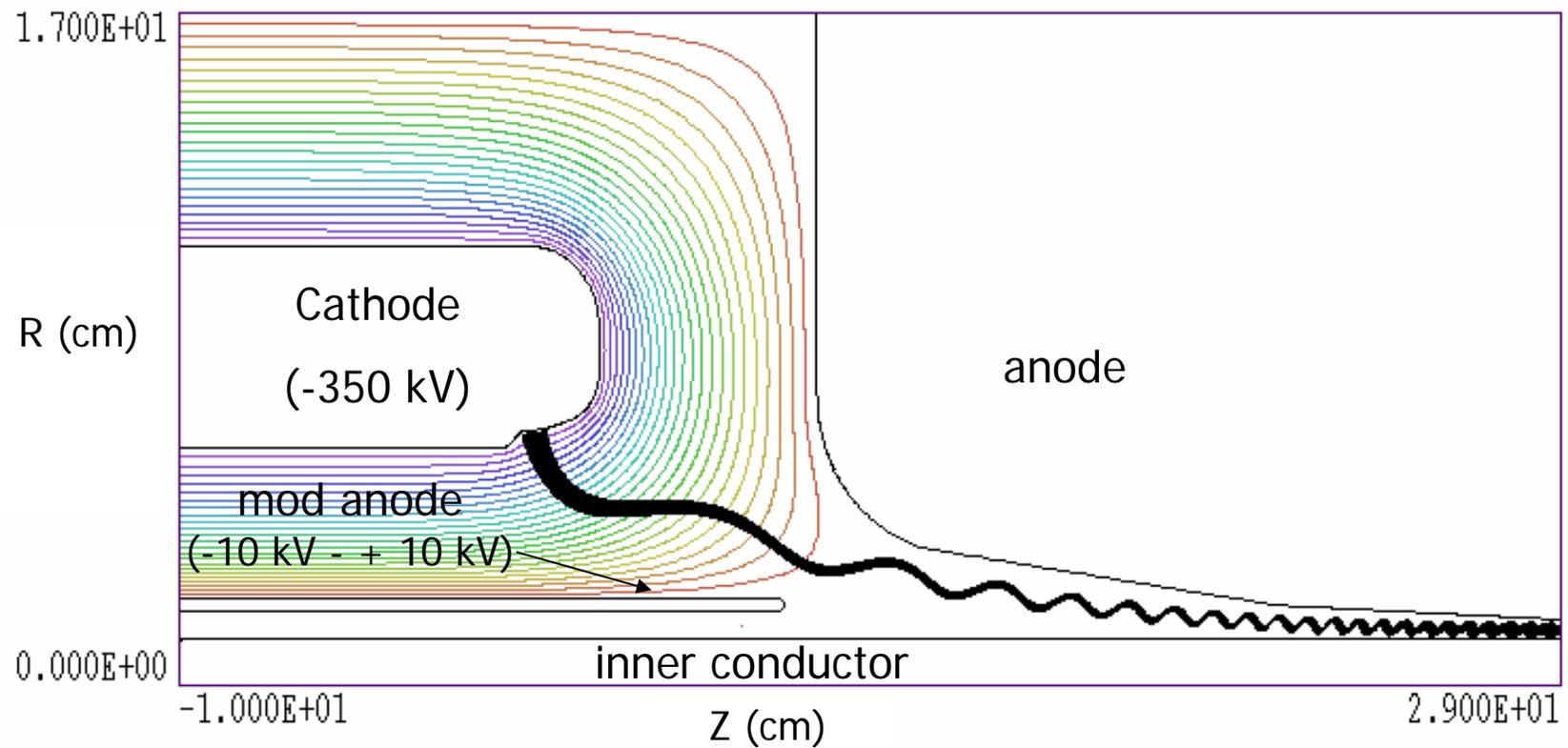




Gyroklystron Design Summary

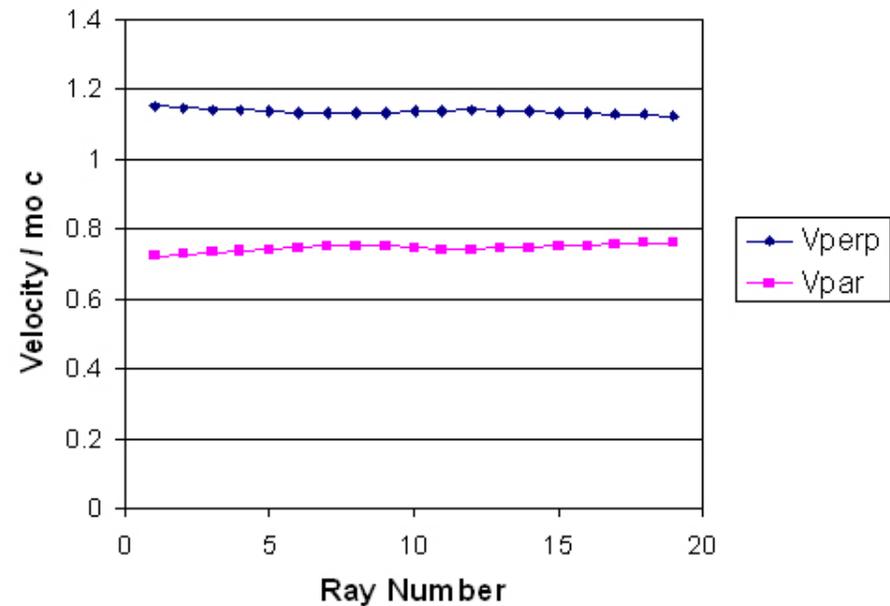
Parameter	Goal	Achieved Value
Frequency	30 GHz	30 GHz
Power	25 MW	33 MW
Efficiency	40%	54%
Gain	50 dB	55dB - 65 dB
Pulse length	~ 1 microsec	2 microsec
Duty cycle	~ 0.001	0.0024
Operating mode	TE01 or TE02	TE01
Output mode	TE01	TE01

Inverted MIG Electron Gun

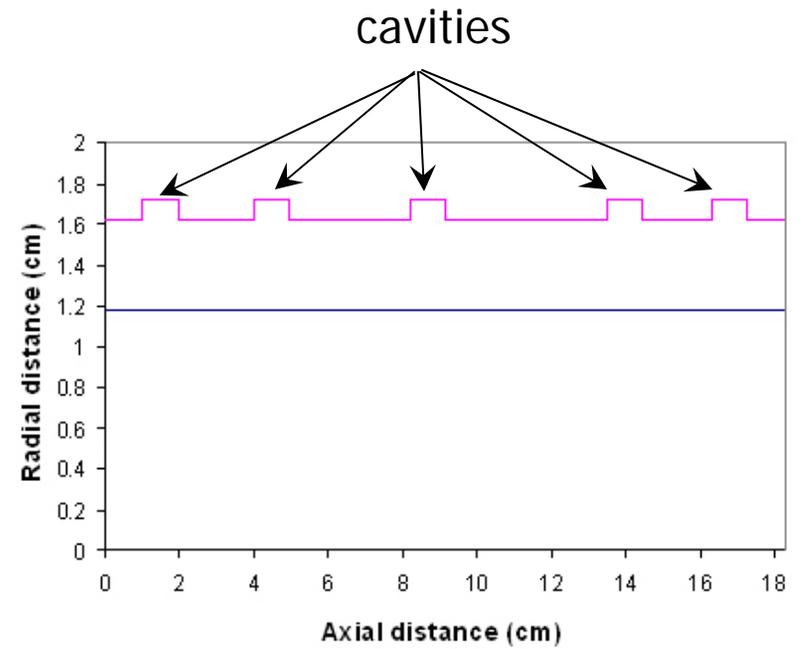
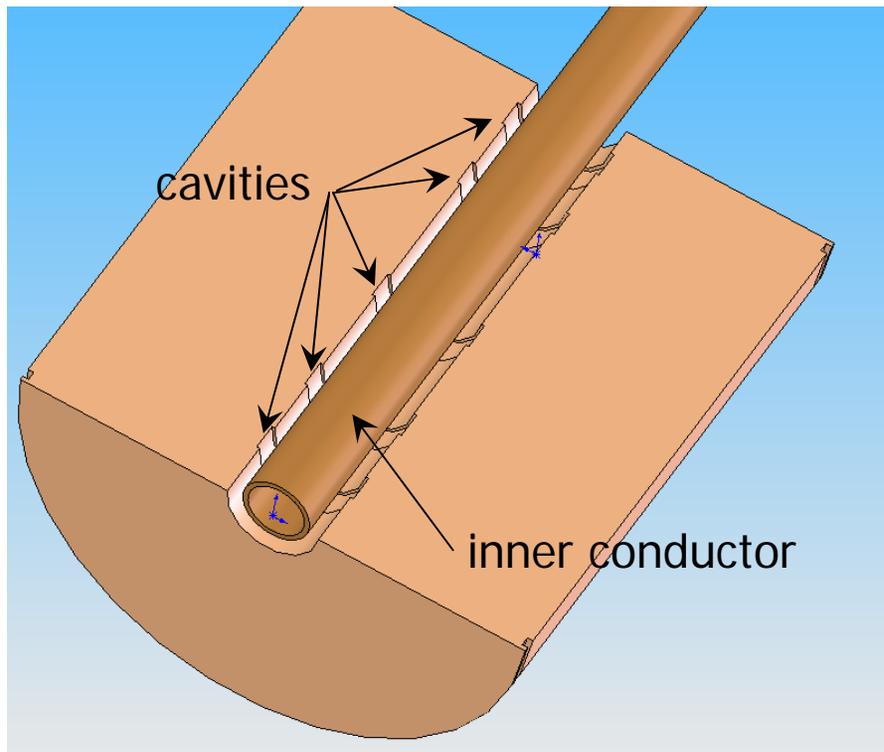


Gun Parameters

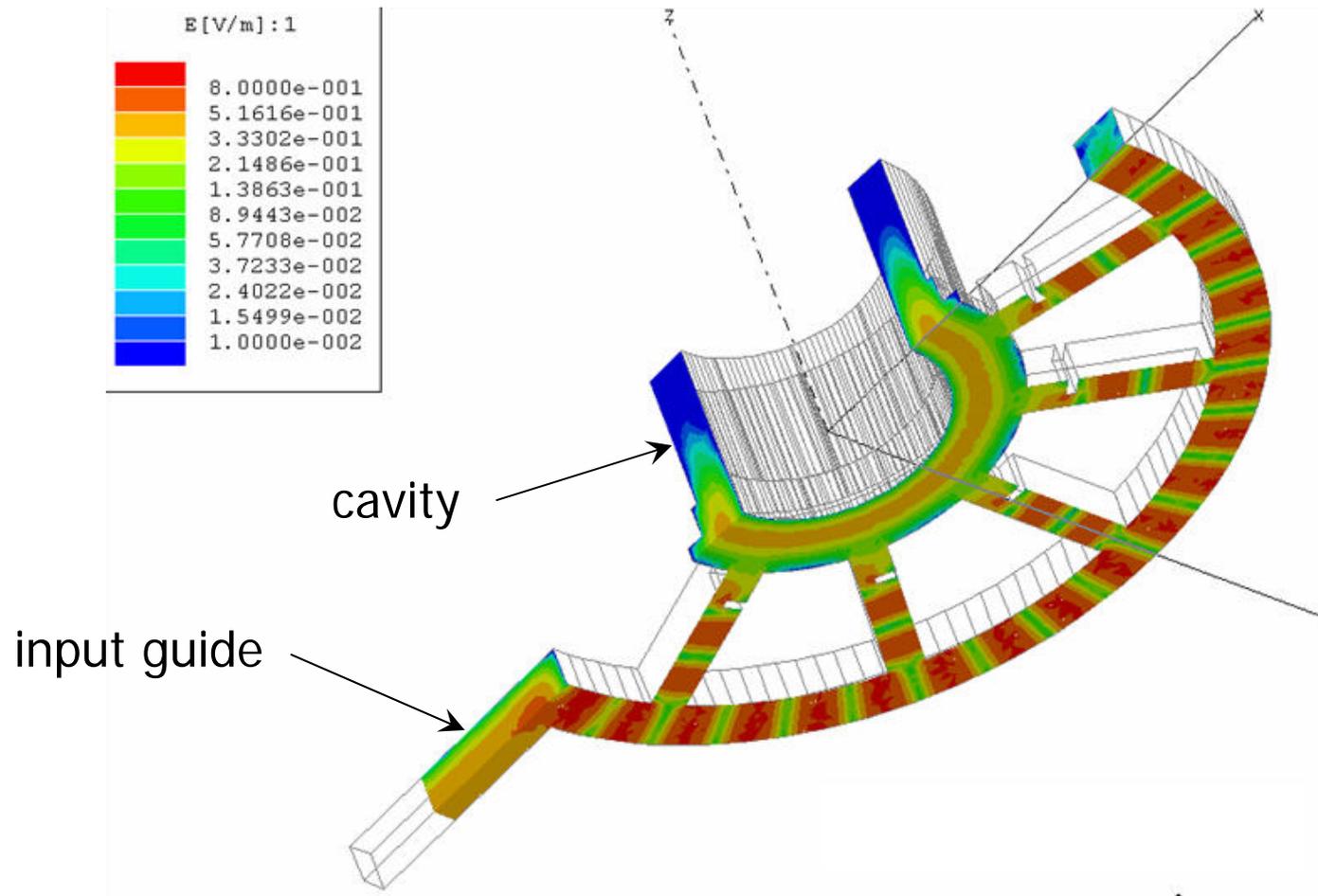
Voltage	350 kV
Current	179 A
Cathode current density	6.4 A/cm ²
Max electric field	
Focus electrode	120 kV/cm
Inner conductor	156 kV/cm
Beam (fully compressed)	
Area compression	20:1
Alpha ($v_{\text{perp}}/v_{\text{par}}$)	1.5
Parallel velocity spread from optics	1.2%
with temp, rough	3 %



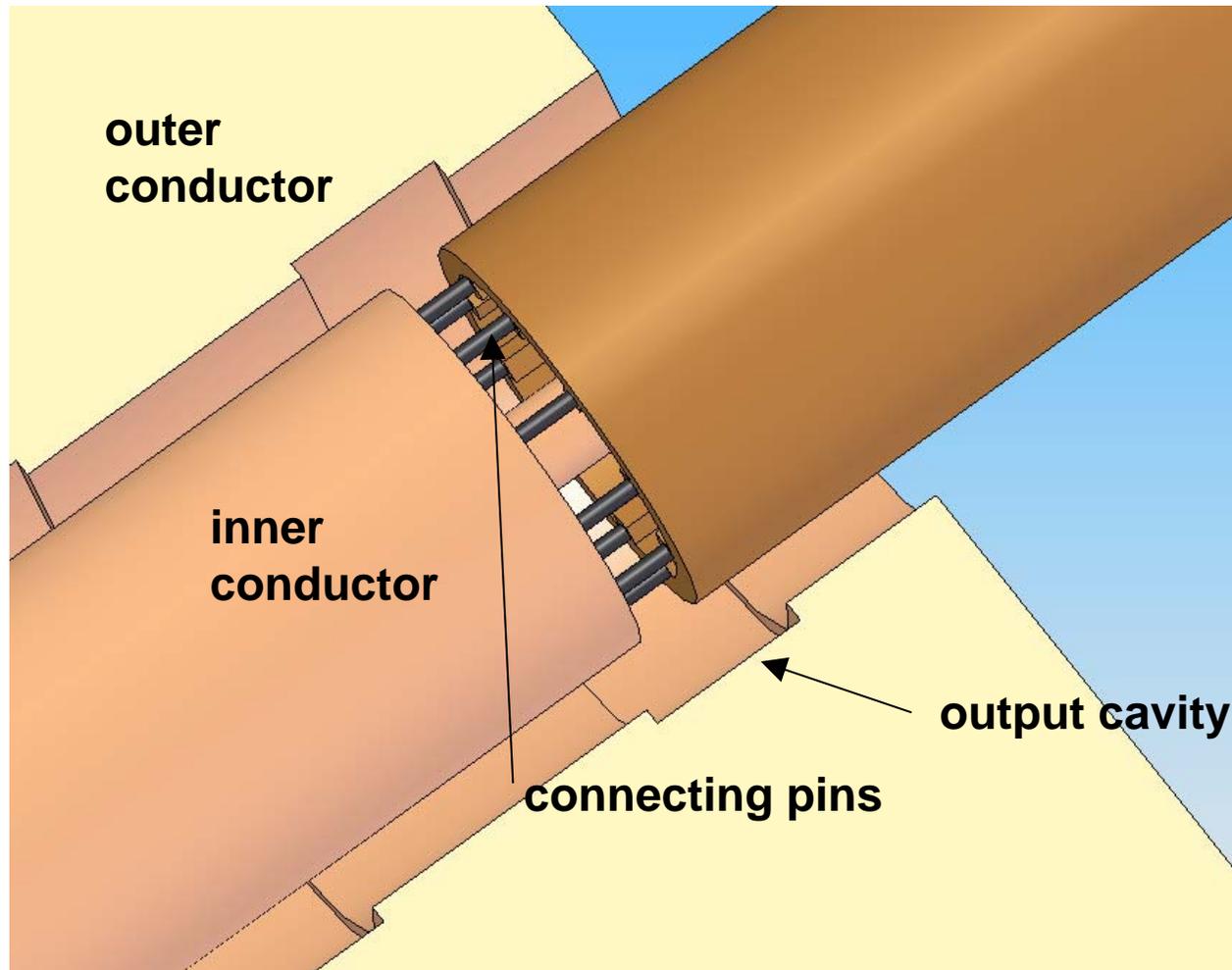
RF Structure

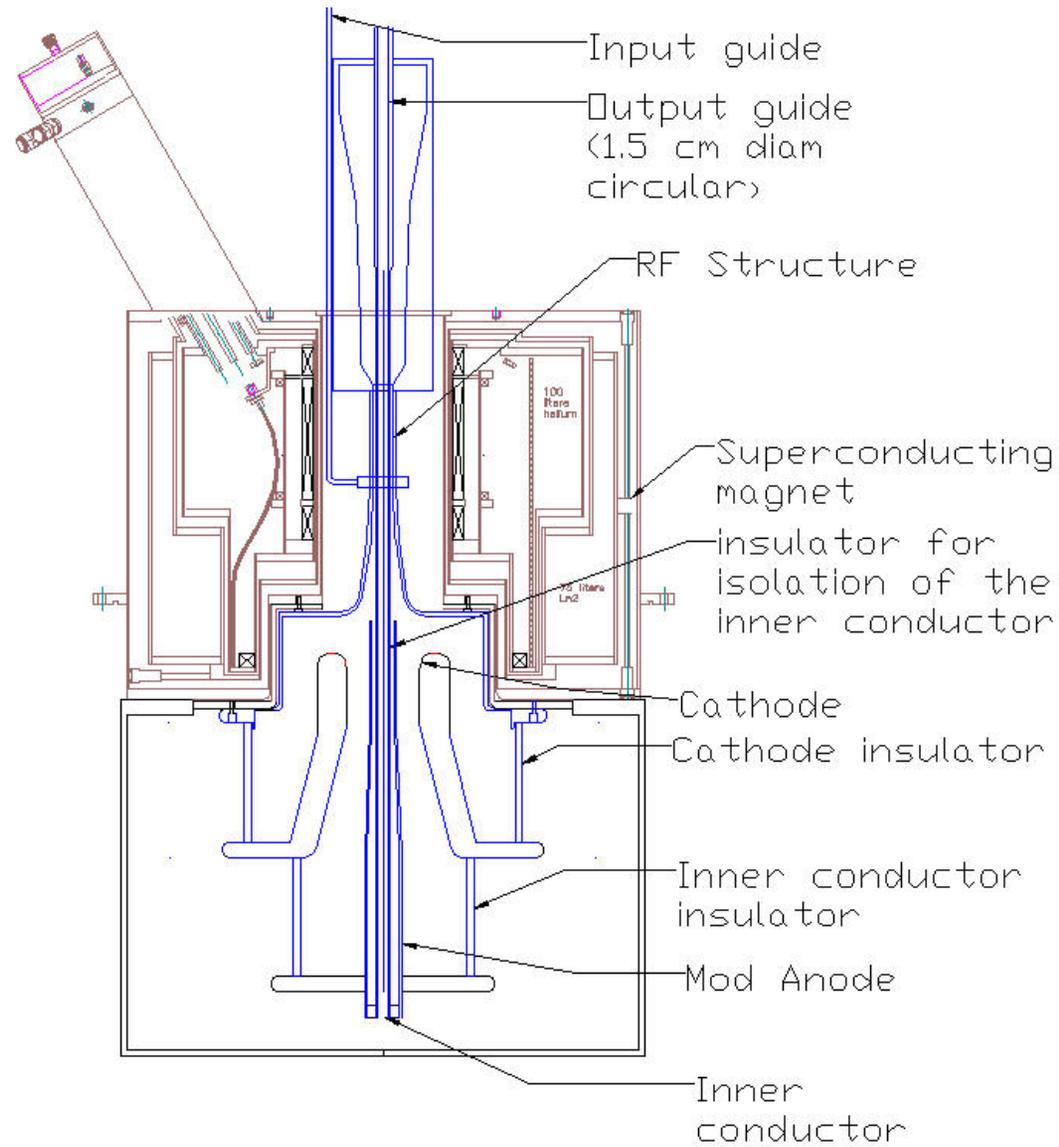


Input Coupler



Output coupler



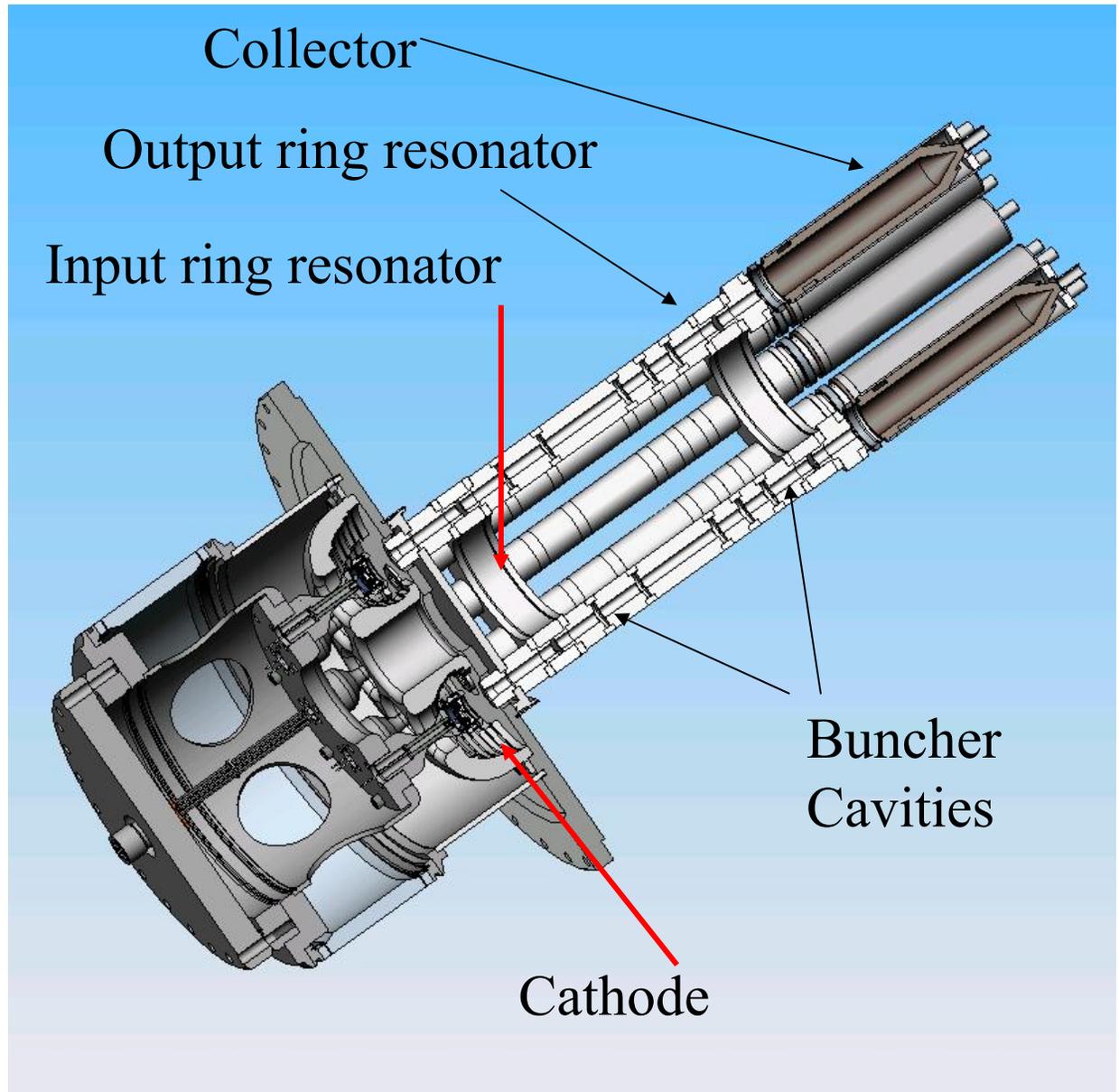


Superconducting Magnet

Magnet is
procured and
available

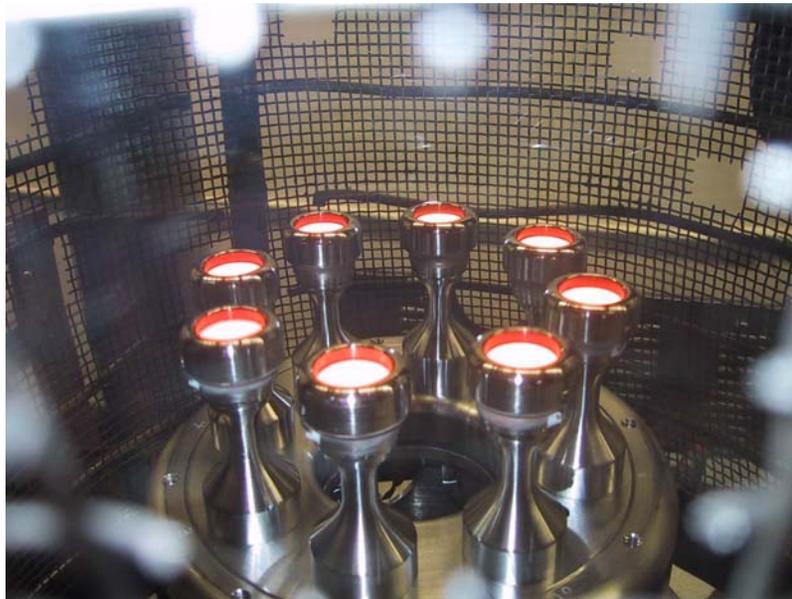


**50MW X-Band
MBK Mechanical
Assembly**



Eight Beam Electron Gun Design

- Confined Flow Focusing
- Beam Area Convergence Equals 20:1
- Beam Power Equals 100MW
- Simulated by TOPAZ Verified by OMNI TRAK
- Beam Analyzer Test



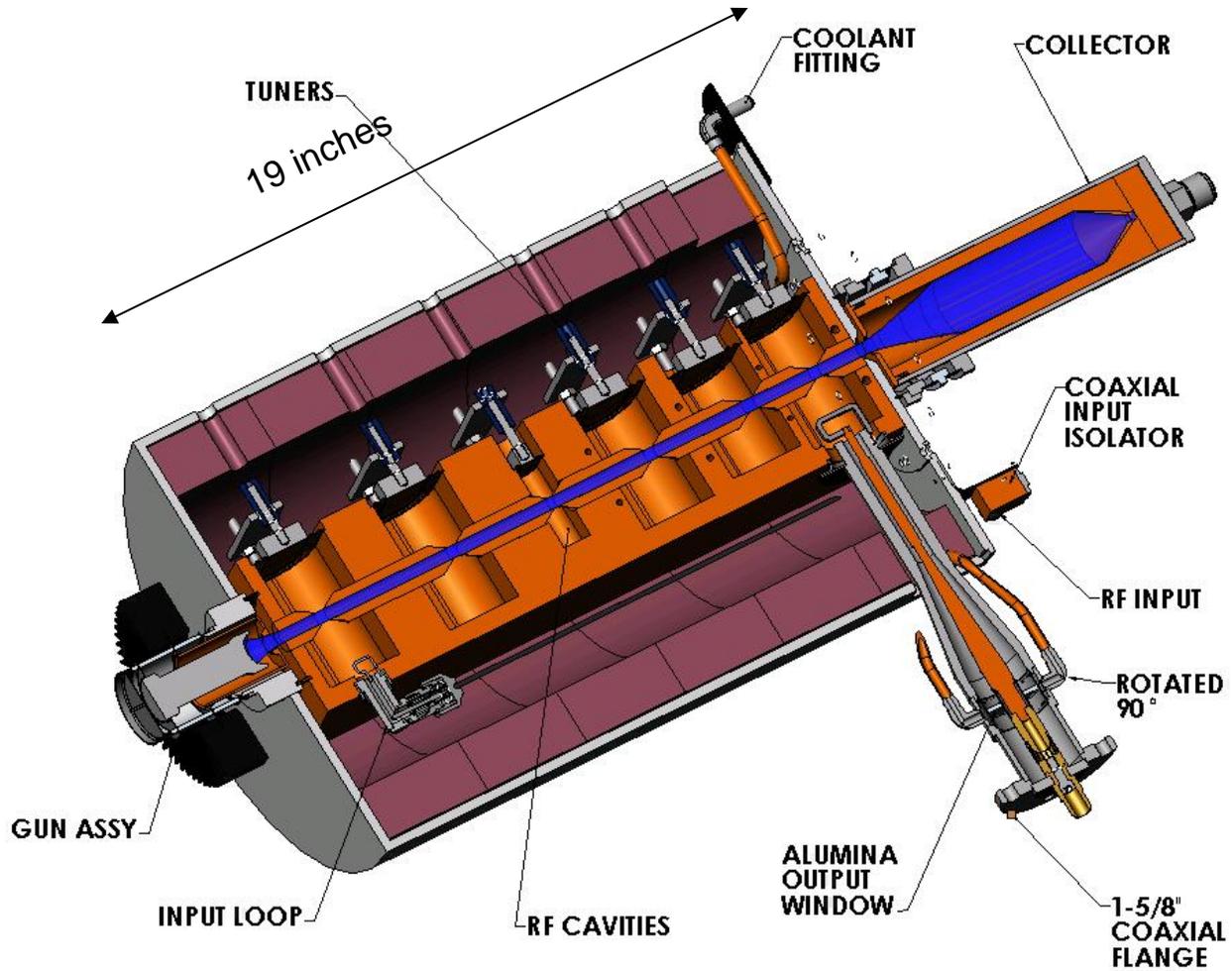
Currently in Final Assembly

- All parts and subassemblies complete
- Final cold test of output cavity last week
- Tests schedule for Fall 2006



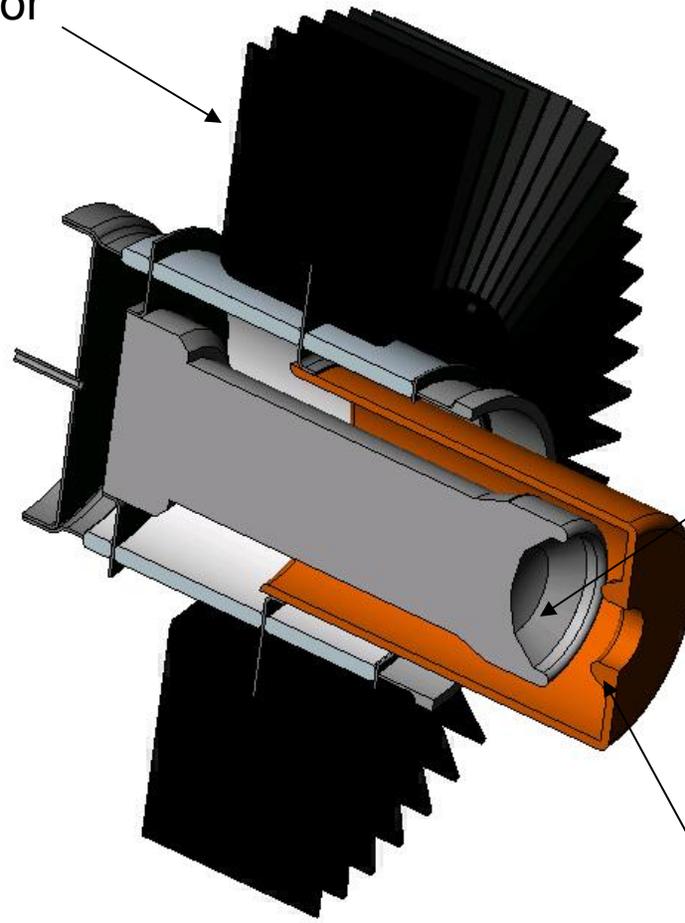
17 kW L-Band Klystron Parameters

Frequency	1497 MHz
Saturated Power	19 kW (16 kW)
Operating Power	15 kW (13 kW)
Power Range	50% - 100%
Voltage	18.8 kV
Current	1.76 A
Small Sig. Gain	56 dB (>50 dB)
3 dB Bandwidth	>6 MHz (>6 MHz)
Efficiency full power half power	59% (> 50%) 47%



Electron Gun

Heat sink/radiator



Cathode

Mod anode

Initial Test Results

- Power to 18 kW
- Efficiency 50%
- Operation limited to lower edge of band due to arcing in the output coax
- Coax has been modified
 - Inner diameter increased and smoothed
 - Coupling loop is now cooled

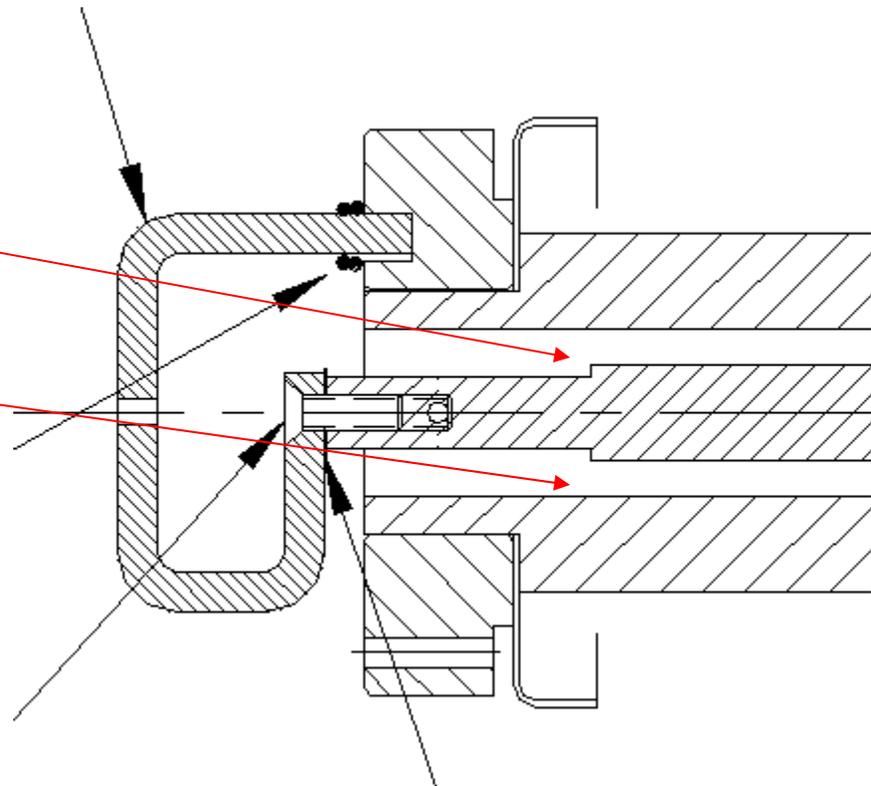
Output Coupler Inspection

- Excessive heating of loop causing sagging



Interior Damage to Coupler

- Excessive arcing at inner conductor step
- Melted copper between conductors



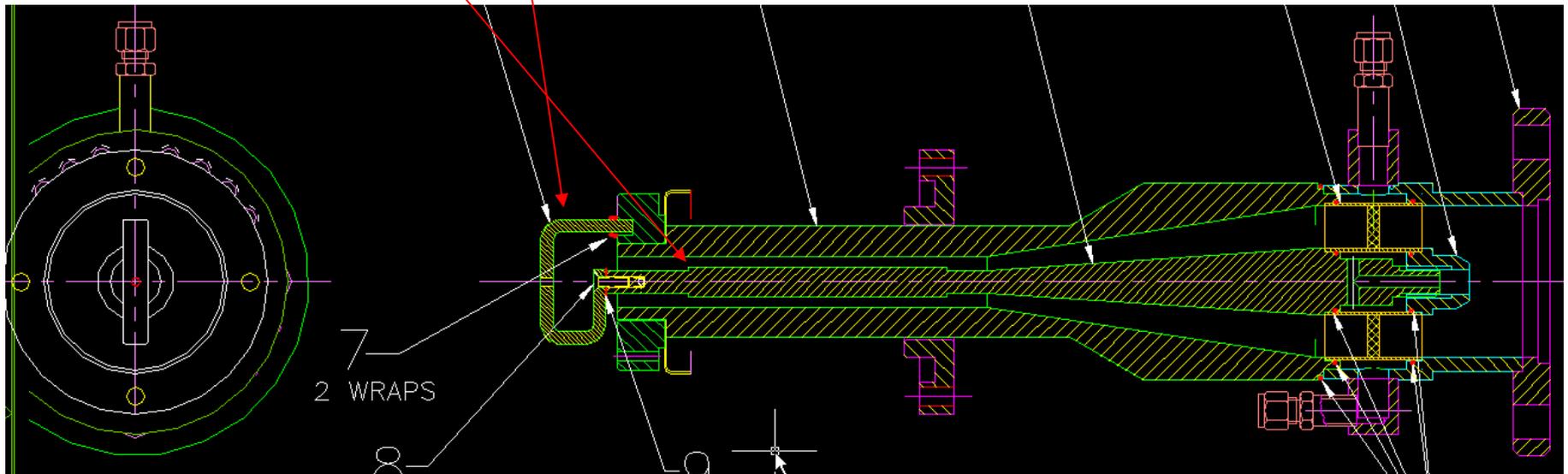
Output Coupler Modifications

- Removed inner conductor step
- Increased coax dimensions to reduce electric fields
- Redesigned cooling to loop and inner conductor

Initial Output Coupler

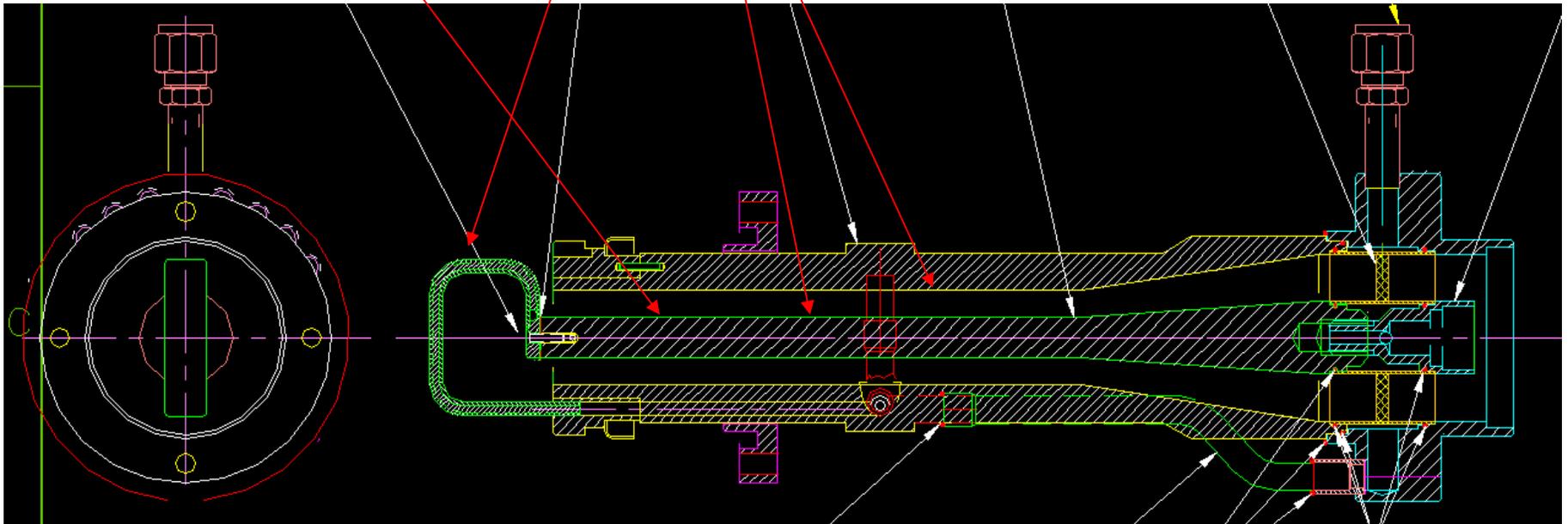
Problems with initial coupler

- Arcing at inner conductor step
- Overheating of inner conductor and loop

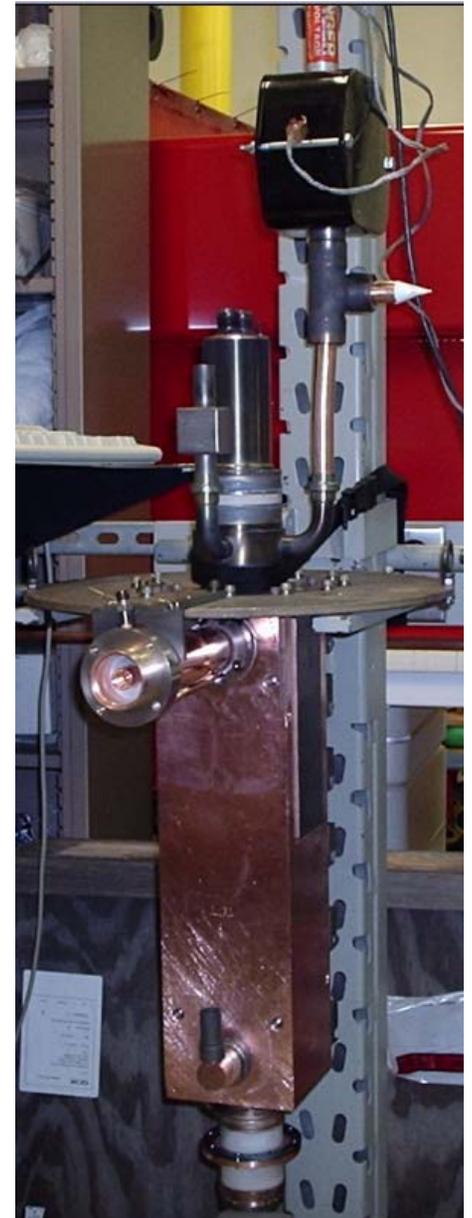


Modified Output Coupler

- Added water cooling to loop
- Eliminated inner conductor step
- Increased diameter of outer conductor

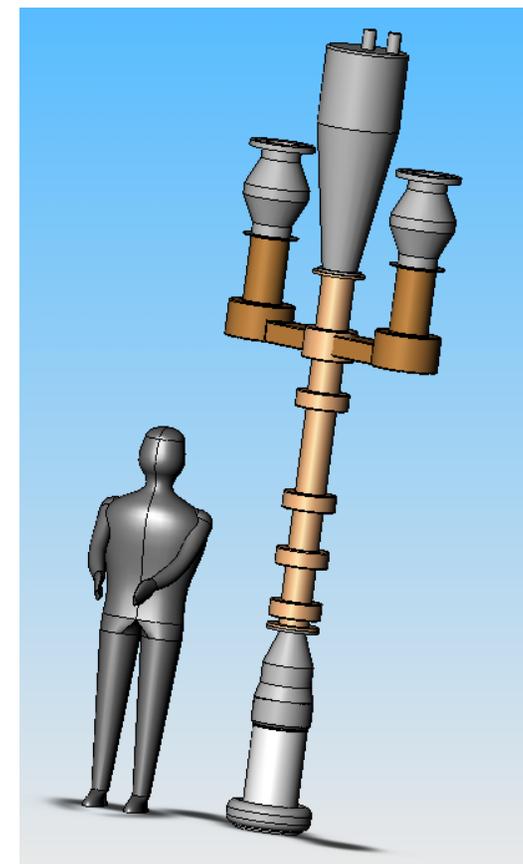


Klystron



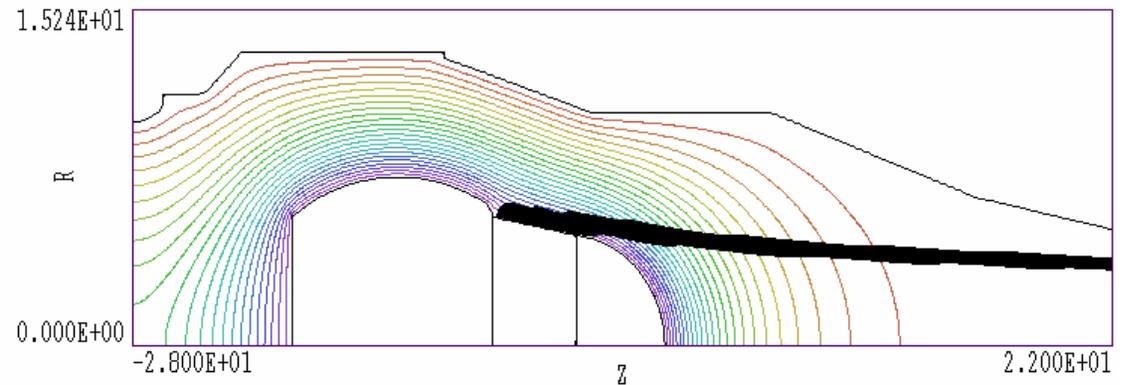
1.3 GHz 200 MW Annular Beam Klystron

Frequency	1.3 GHz
Power	200 MW
Efficiency	46%
Beam Voltage	475 kV
Beam Current	1100 A
Pulse Width	1 microsecond
Pulse Repetition Frequency	120 Hz



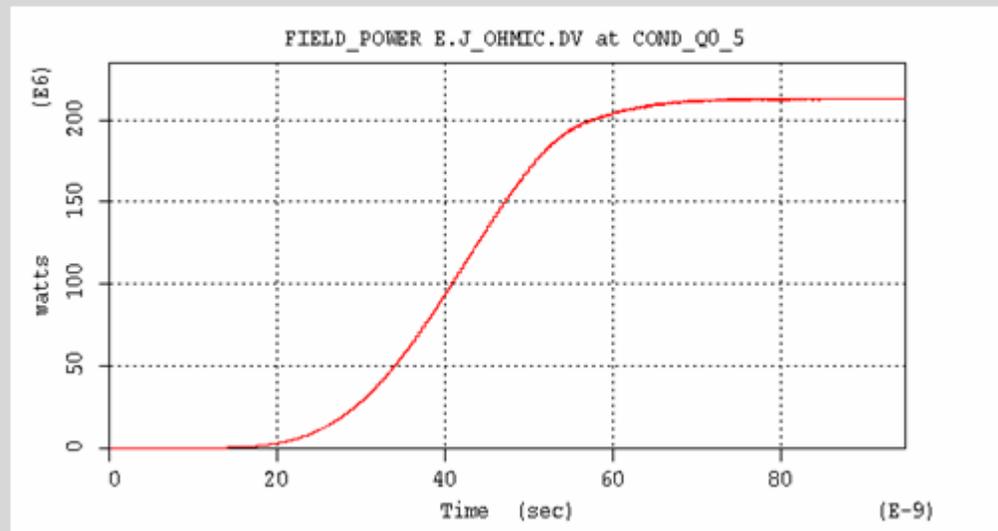
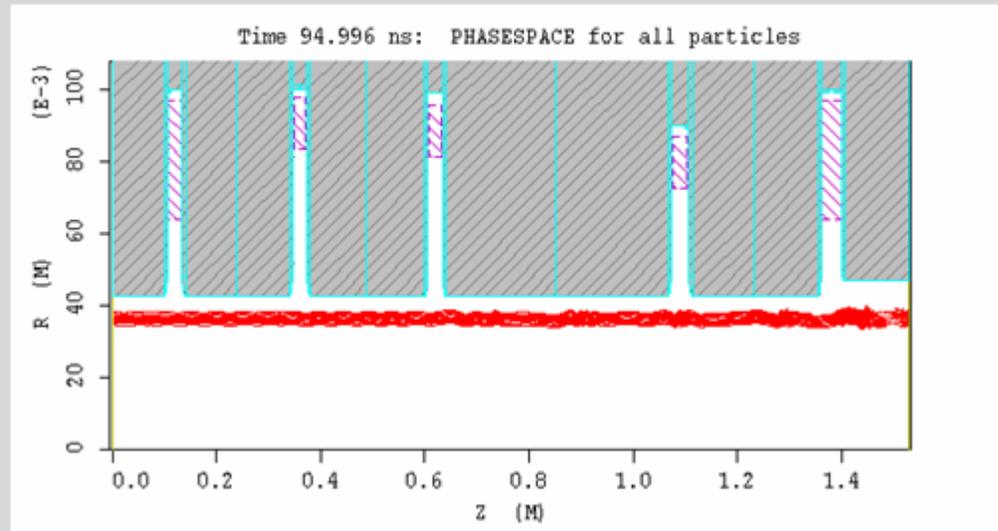
Electron Gun

Voltage	500 kV
Current	1100 A
Cathode loading	7.8 A/cm ²
Cathode radius (average)	5.43 cm
Beam radius Inner	3.40 cm
Outer	3.84 cm



Circuit Design

MAGIC Simulation



ABK Design Parameters

Parameter	Annular Beam
Beam voltage	475 kV
Beam current	1100 A
Beam Perveance	3.36 micropervs
Drift Tube Radius	4.249 cm
Beam Filling Factor	0.8/0.9
Beam Radius	3.4 cm 3.82 cm
Beam Current Density	1148 A/cm ²
Maximum Efficiency	45.6%
RF Output Power	238 MW
RF Input Power	1.21 kW
Saturated Gain	45.4 dB
Output Cavity Gap Voltage	744 kV
Output Cavity Electric Field	180 kV/cm
Magnetic Field	3700 Gauss ($B_z = 2 \times B_r$)

Summary

- There are any options for RF sources, depending on the parameters