NAVSEA
WARFARE CENTERS
DAHLGREN

GUN & ELECTRIC WEAPON SYSTEMS DEPARTMENT (E)

Active Denial Technology

Presented by

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Acknowledgments

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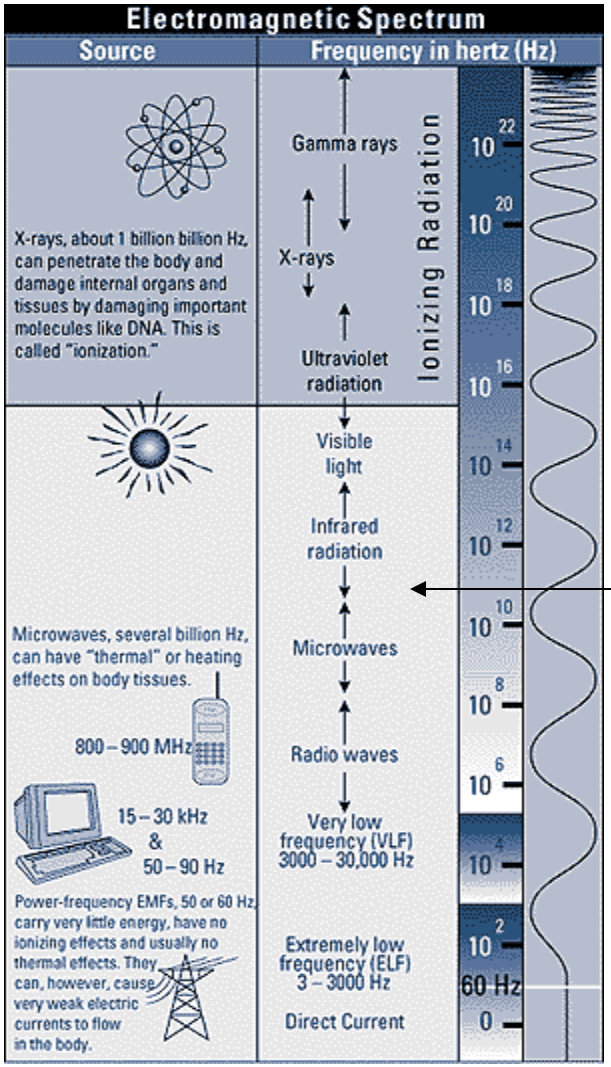
Outline

- Relation to Radiation Spectrum
- How Active Denial Technology Works
- Legal/Safety
- Evolution of Active Denial Systems
- Gyrotron Theory
- Current Technology Development Efforts
- Questions

95 GHz Radio Frequency Radiation



Ionizing Radiations

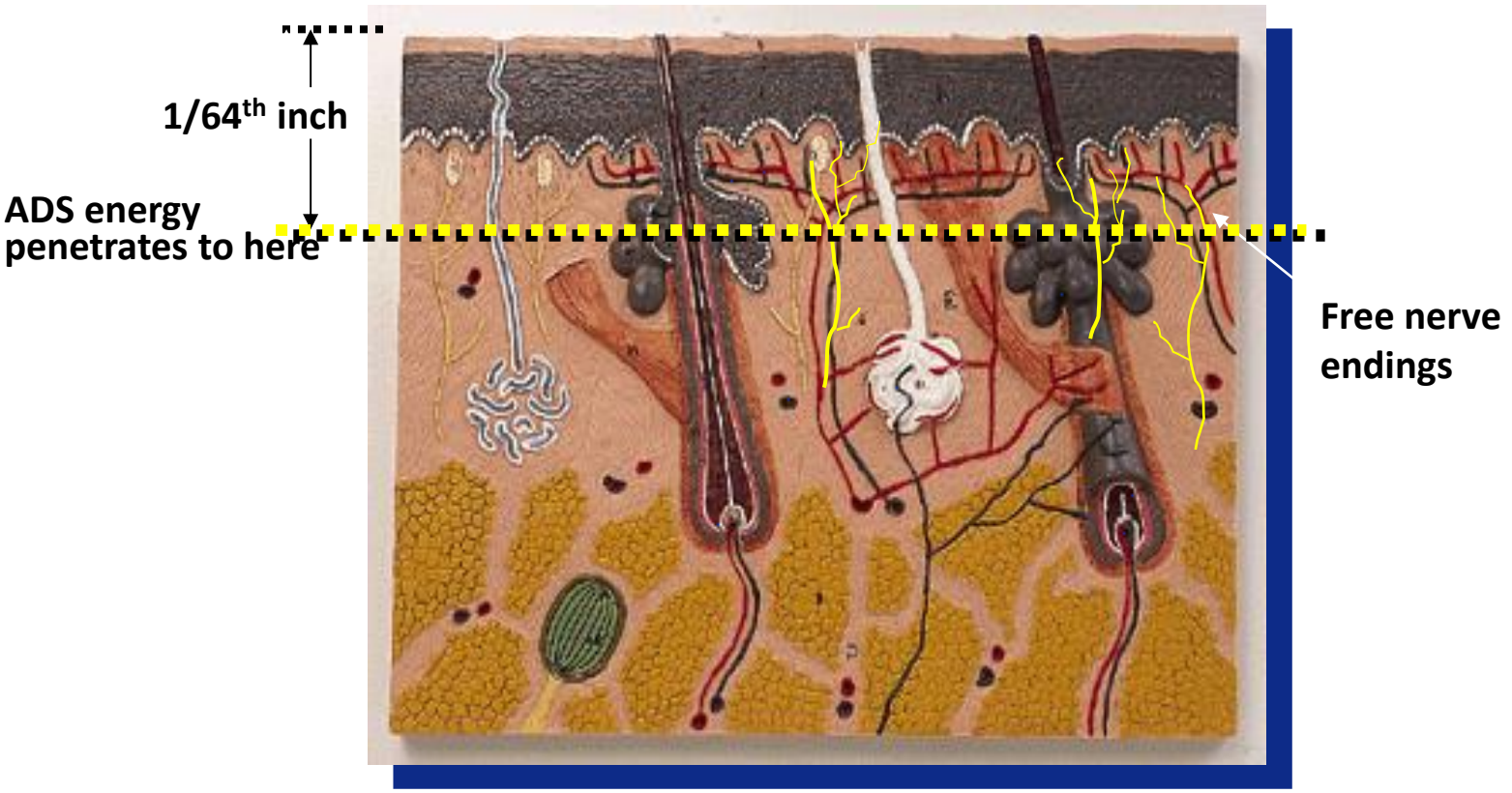
- Photon energy greater than ionization potential
- Stochastic effects: increasing risk with cumulative dose

ADS Operates Here (~9.5 X 10^{10} Hz) (mm waves)

Non-ionizing Radiations

- Effects vary strongly with wavelength/frequency
- Penetration depth inversely proportional to frequency
- No stochastic effects

How ADS Works



- Energy beam heats surface of skin
- Most of the energy is deposited in the first 1/64th inch
- This is where the nerve endings are located
- Causes thermal discomfort

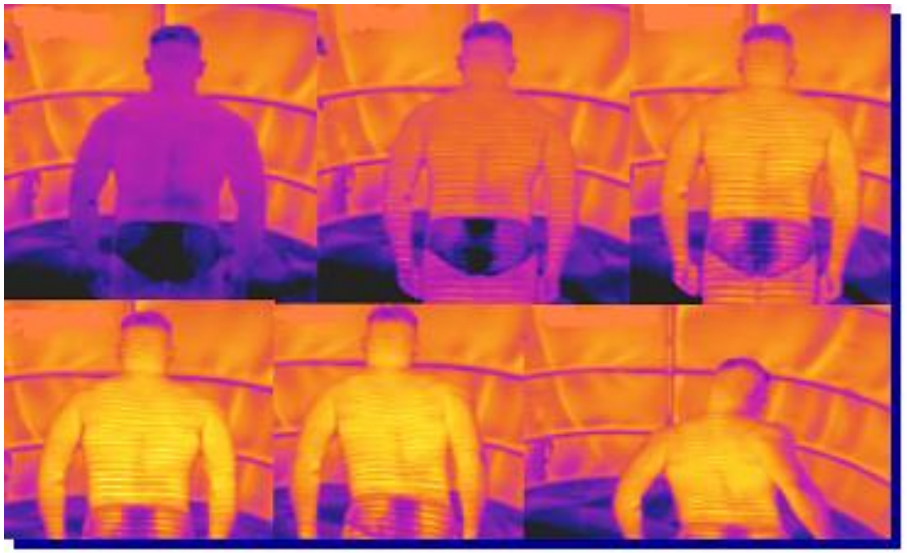
How ADS Works

Activate ADS

Skin Gets Hot

Thermal Discomfort

People Flee



ADS/ADT Legal, Treaty and Policy Compliance

- ✓ Multiple Legal Reviews Completed
  - The development, acquisition, use and possession of the Active Denial System is allowed under U.S. Domestic Law
  - Law of Armed Conflict
    - * ADS does not cause unnecessary suffering that is disproportionate to the military advantage of using the weapon
    - * ADS is discriminate and capable of being controlled and directed against a lawful target
    - * There is no specific rule of law prohibiting the use of ADS
- ✓ ADS Arms Control Compliance Reviews Completed
  - ADS is compliant with relevant arms control treaty obligations

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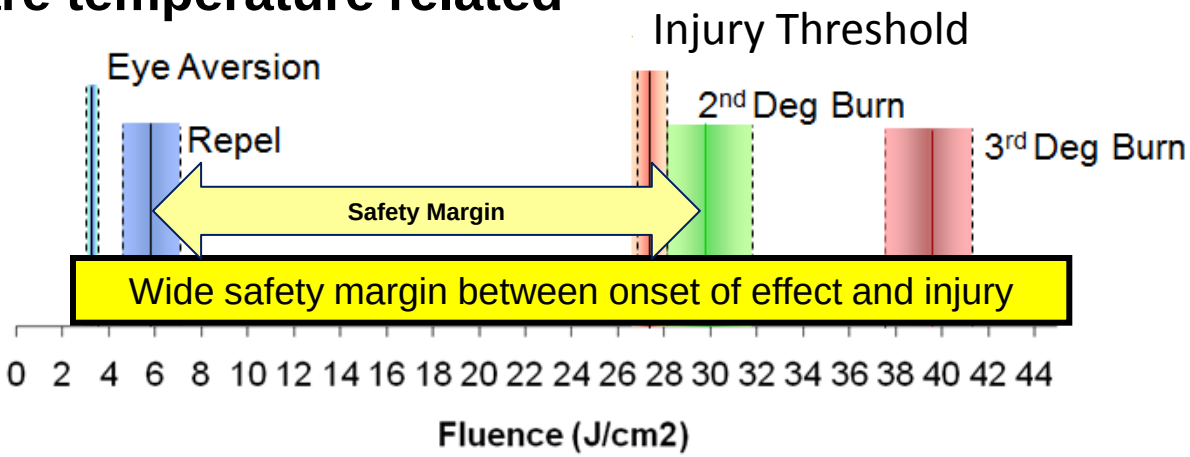
Safety

- **Energy required to produce repel—Varies**
- **Energy level that results in injury—Stable**
- **Both are temperature related**



ADS effect is thoroughly tested

- Human Effects Risk Characterization complete
  - Over 700 volunteers and 11,000+ exposures (laboratory and field)
- Data extending back 15+ years
- Peer-reviewed research results
- Numerous independent reviews

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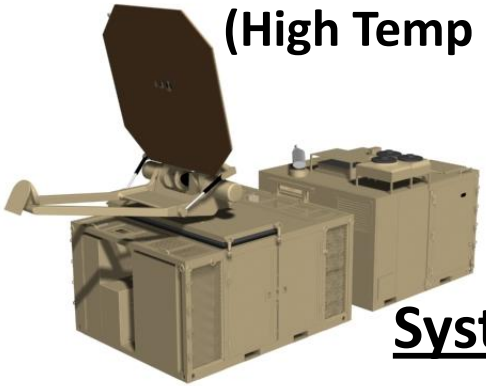
Evolution of Active Denial Systems
as of Jan 2015

System 0

AC Wall Power Stationary

System 1 - ACTD

Mobile DC Gen Set (High Temp Sensitive)

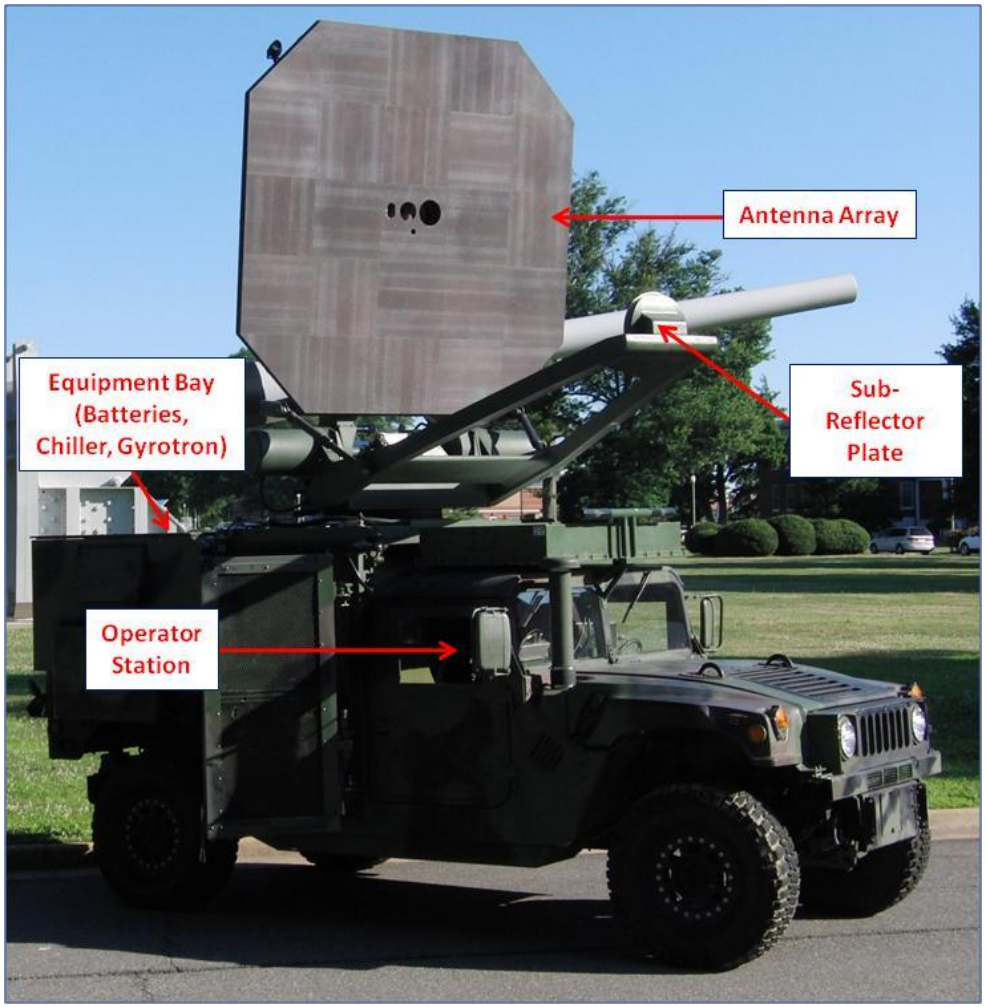


System 2

Mobile Truck Mountable: Transmitter, Prime Power, Operator Station

Solid State-ADT Skid Plate

Active Denial System Test NSWCDD



Testing of Active Denial System Demonstrator at NSWC in 2010.

Field strength and spot size measurements at representative ranges were collected.

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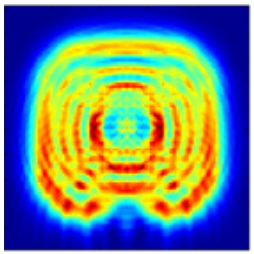
ADS System Test Instrumentation

Sensors used for Power Measurements

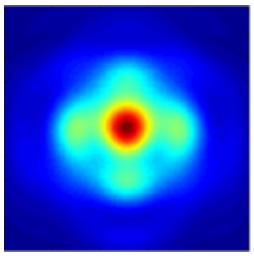
NWSCDD
Sensor Array

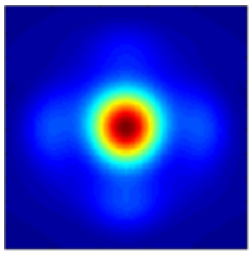
AFRL
Sensor and Resistive Fabric
(Visual of spot via IR camera)

Beam Formation

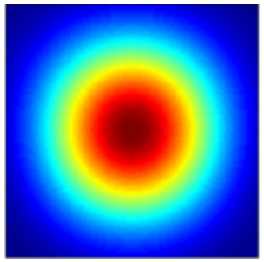


RF Energy Pattern as it leaves the antenna



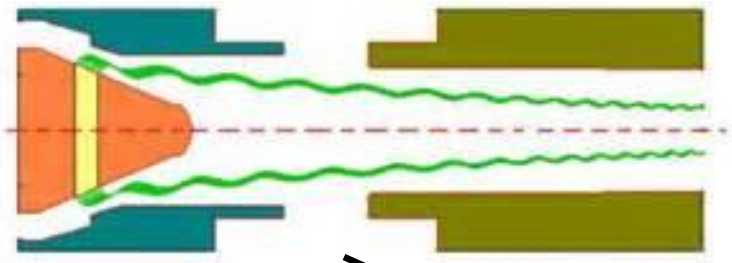


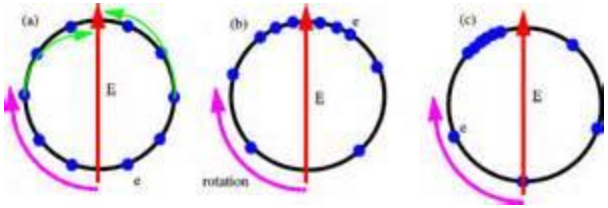
RF Energy Pattern forms into a coherent beam at the "Near-Field/Far-Field Boundary"



RF Energy Pattern on target area. Depending on antenna directivity and distance to target, spot size can be from a few inches across to several meters across.

Gyrotron Theory



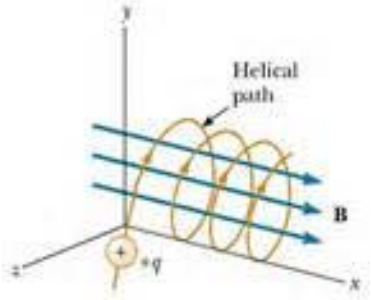


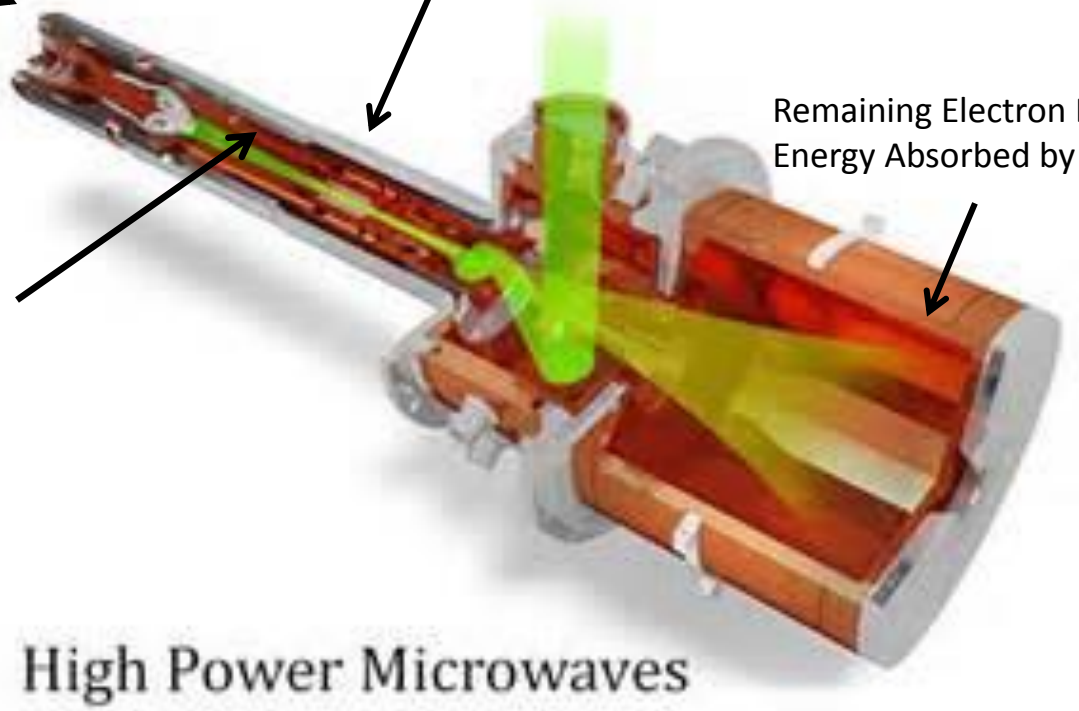
Electrons interact with magnetic field resulting in generation of electric field (RF)

Electrons leave filament , interaction with magnetic field results in electrons spinning around the magnetic lines of force. The frequency of rotation is determined by the strength of the magnetic field.

RF Energy Exits

Remaining Electron Beam Energy Absorbed by Collector





100 KW Gyrotron

VGB-8095 Gyrotron Oscillator

CPI Communications & Power Industri microwave power products divis

CPI gyrotrons were the first commercially available high-power, long-pulse/CW, high-frequency devices for plasma fusion experiments and other scientific and industrial applications. CPI-MPP provides an extensive line of gyrotrons that cover frequencies from 28-140 GHz with power levels ranging from 10 kW to 1.3 MW.

The VGB-8095 gyrotron provides up to 100 kW of continuous output power at 95 GHz, and employs a compact cryogen-free refrigerator-cooled superconducting magnet system.

Features

- High Efficiency, Long-Pulse Operation
- Gaussian Output Beam
- CVD Diamond Output Window
- Diode Electron Gun
- Cryogen-Free Superconducting Magnet

Typical Operating Parameters

Power Output	100 kW
Pulse Length	CW
Cathode Voltage	-43 kV
Body Voltage	+7 kV
Beam Current	5 A
Frequency	95±0.2 GHz
Efficiency	50%
Gyrotron Weight	375 lbs
Output Mode	TEM_{00}

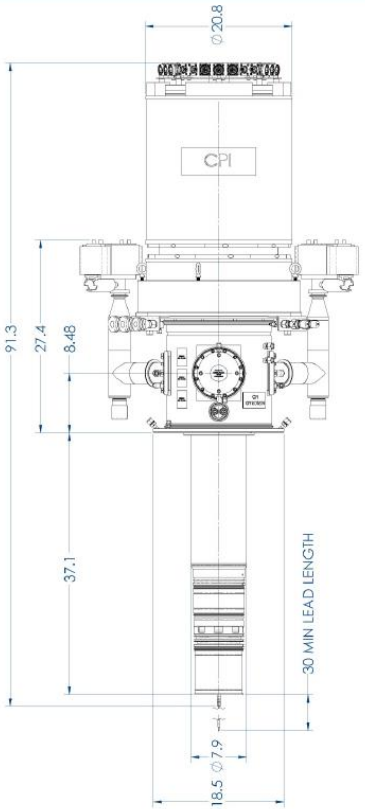
Megawatt Class Gyrotron

VGT-8115 Gyrotron Oscillator

Communications & Power Industries
microwave power products division

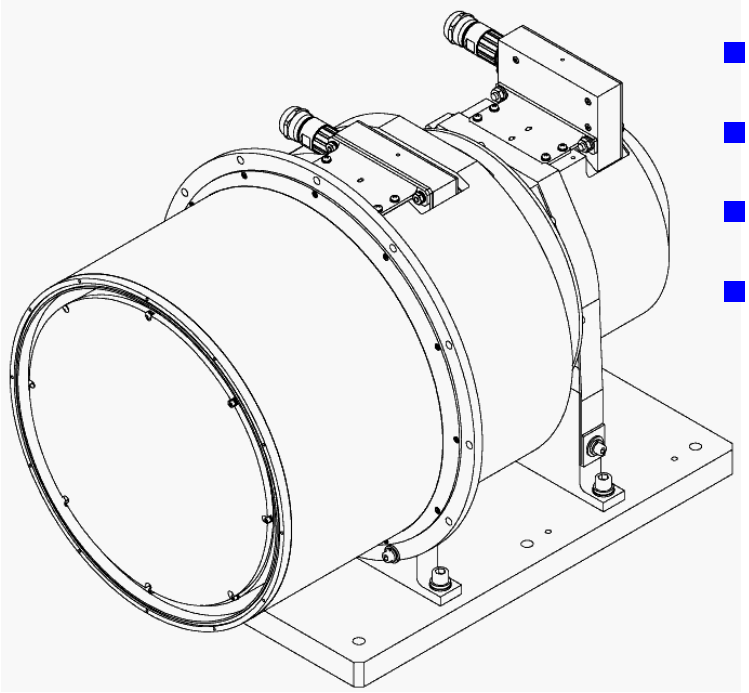
CPI gyrotrons were the first commercially available high-power, long-pulse/CW, high-frequency devices for plasma fusion experiments and other scientific and industrial applications. CPI-MPP provides an extensive line of gyrotrons that cover frequencies from 28-263 GHz with power levels ranging from 25 W to 1.4 MW.

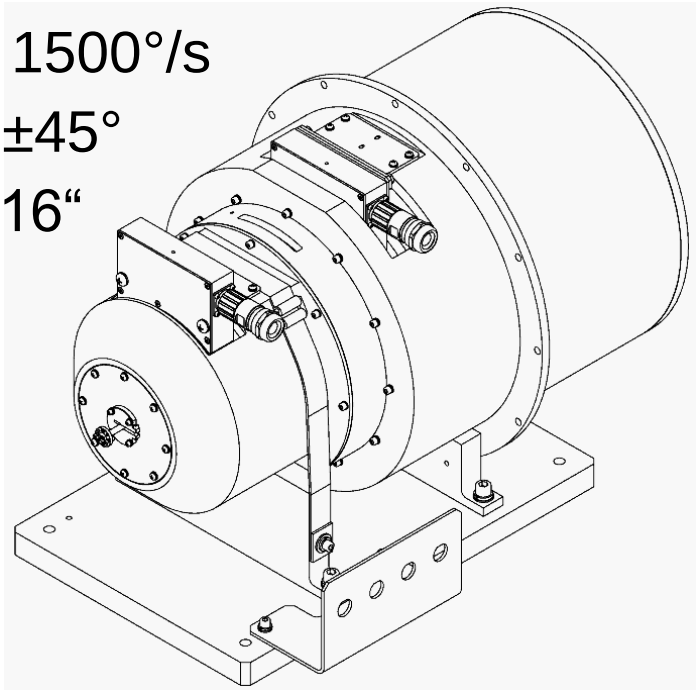
The VGT-8115 gyrotron delivers up to 1.2 MW of output power at a frequency of 110 GHz for electron cyclotron heating and current drive in fusion plasmas.



CPII 10” Planar Scanning Antenna

- High speed scanning planar antenna
- Scanning speed: 1500°/s
- Scanning range: ±45°
- Size: 24“ x 16“ x 16“
- Weight: 120 lbs





- Power supply: weight = 50 lbs, volume = 1.4 ft^3
- Antenna Control Unit (ACU): weight = 10 lbs, volume = 1.0 ft^3

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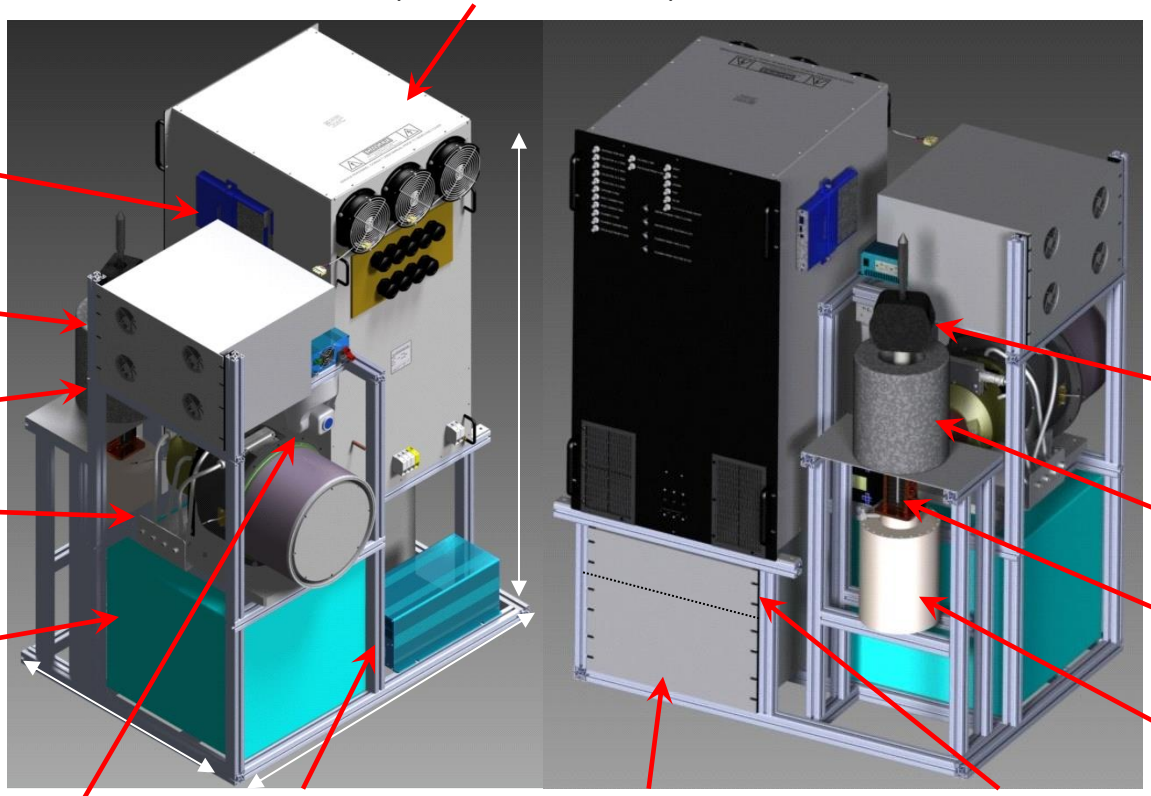
CPII 30” Planar Scanning Antenna

Joint Non-Lethal Lens Scanner Antenna		
KEY PERFORMANCE VALUES WITH STANDARD HARDWARE COMPLEMENT		
RF/Electrical Parameters		
Frequency range		95 GHZ (nominal)
Beam width		0.30°
Gain		54.5 dBi (50% efficiency)
Side lobes		25dB (typical)
RF Interface		Tall guide 0.10 x 0.267” (H, E plane) WR-10 available
Control interface		RS-422
Mechanical Parameters (Nominal @20°C)		
Size	Antenna	22L x 38W x 38H in
	Electronics cabinet	21W x 42L x 28H in
Weight	Antenna	275 lbs
	Electronics cabinet	60 lbs
Beam Scan rate		1500°/sec
Beam Travel		±45° conical region
Power consumption		10 A @ 208 VAC , 3ϕ
Motor Voltage (max)		270 VDC
Motor current	Peak (max acceleration)	40 A
	Steady state	3 A
Input Power		208 VAC, 3ϕ
Pointing accuracy		0.02°
Software Interface		
User Interface		GUI
Software controlled modes		Linear scan (constant scan); variable speed
		Point and Dwell on target
		Scan between multiple targets with user defined dwell on each target

Compact ADT Project

Collaborative project with UC Davis



- Skid plate size estimate: < 48” x 36” x 72”
- Skid plate weight estimate: < 1500 lbs

Questions