ORNL/CEA Collaboration for ICRF on Tore Supra

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Areas of Collaboration

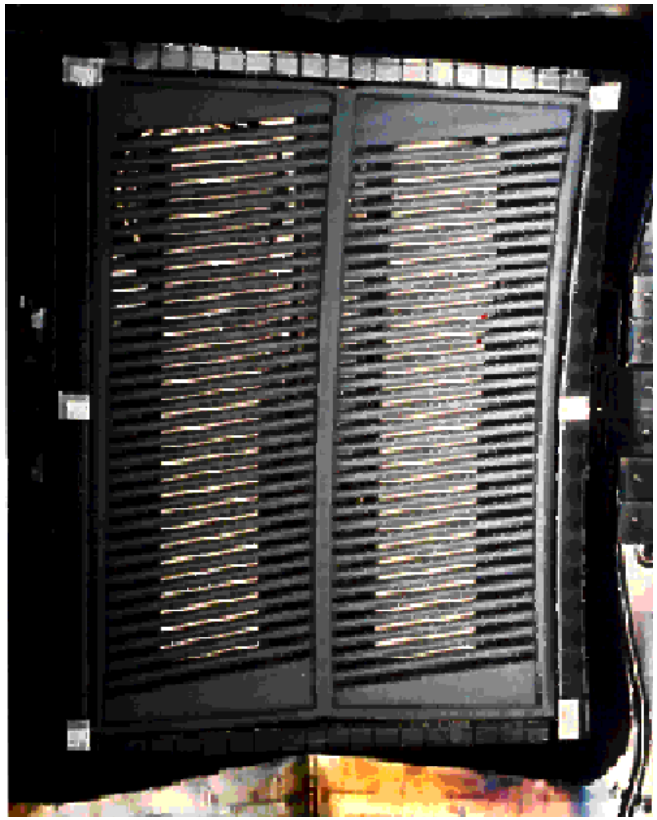
- **RF / edge plasma interactions - Tore Supra particularly well suited to investigate:**
  - **ICRF launchers have long pulse capability (30 s)**
  - **ORNL and CEA launchers have similar design but different protection limiters and Faraday shields which allow comparisons to be made**
  - **IR cameras can look at 2 launchers simultaneously**
  - **Advanced system in place for acquisition, storage and analysis of IR images**
- **Tests of internal matching component structures**
  - **Tore Supra developing components to replace present Comet capacitors**
  - **ORNL has a high voltage breakdown test stand which can investigate voltage handling of component structures**

Antenna surface heating due to RF/edge plasma interaction important factor in ICRF operational power limits

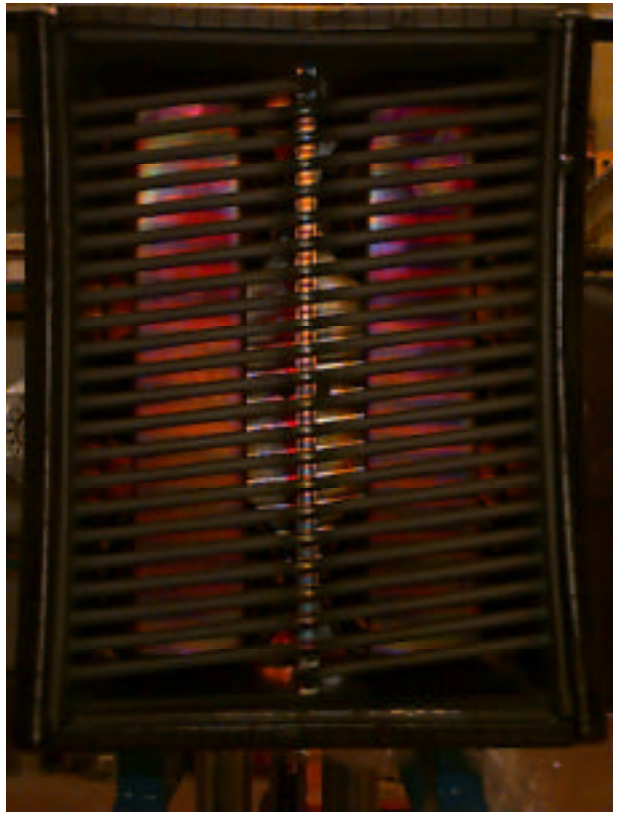
- The Tore Supra RDL antennas can inject power fluxes ≥ 12 MW/m^2
  - power limit for non-dipole operation is due to surface heating of antenna plasma facing structures
  - with 4 cm plasma gap and 90° phasing, limit can be as low as 1 MW per launcher (6 MW/m^2)
- Caused by RF/plasma interactions which act to produce a concentrated power flux over small areas of the structures
- Power flux can be estimated from IR measurements
- Possible mechanisms include electron acceleration through RF inductive fields and rectification of voltages present on antenna box due to finite inductance of structure

CEA and ORNL Antennas

CEA antenna
Ports Q1 & Q4



ORNL antenna
Port Q5



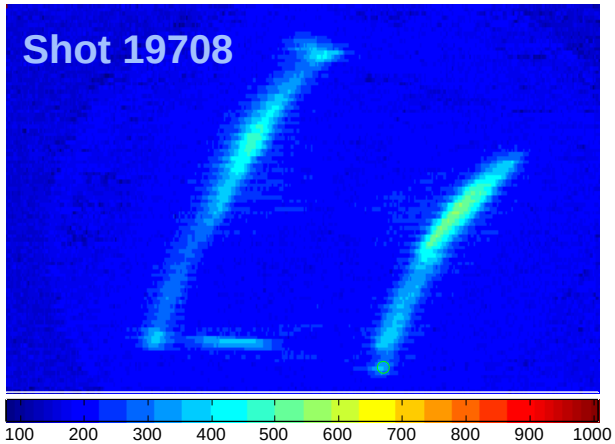
- **Differences:**
  - Recessed septum
  - Increased shield transparency
  - Shield open at top and bottom

Faraday shields have different heating characteristics

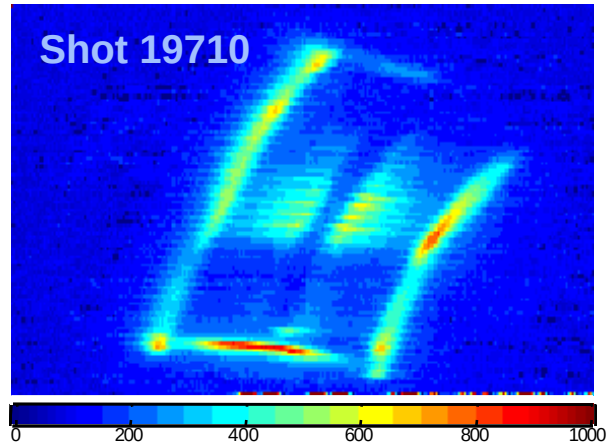
- **ORNL Faraday shield**
  - **Phase dependence: $\pi/2$ phasing much worse than π**
  - **Up down asymmetry, especially at toroidal center**
    - » **bottom of antenna much hotter than top**
  - **Bottom corner bumper tile temperatures sensitive to wave propagation direction**
    - » **$+\pi/2$ phasing different than $-\pi/2$ phasing**
    - » **hotter corner corresponds to wave toroidal propagation direction**
- **CEA Faraday shield**
  - **Most heating confined to side bumpers and center of antenna septum**
  - **Phase dependence evident, but not much up/down asymmetry**

Effects of phasing on ORNL antenna surface heating profiles is similar for different operating conditions

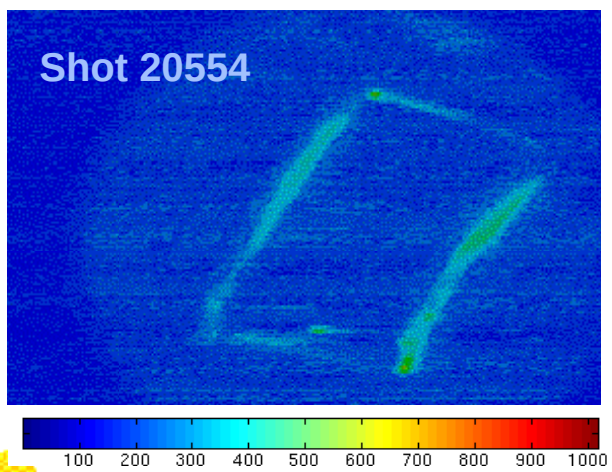
Φ=180°

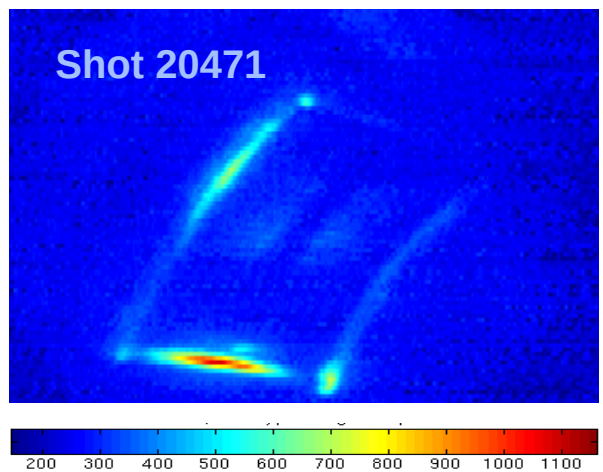


Φ = 90°



B_t = 2.15 T
Ip = 0.63 MA
$\langle n_e \rangle = 3\times10^{19}$ m^{-3}
f = 48 MHz





B_t = 3.7 T
Ip = 1.3 MA
$\langle n_e \rangle = 3\times10^{19}$ m^{-3}
f = 57 MHz

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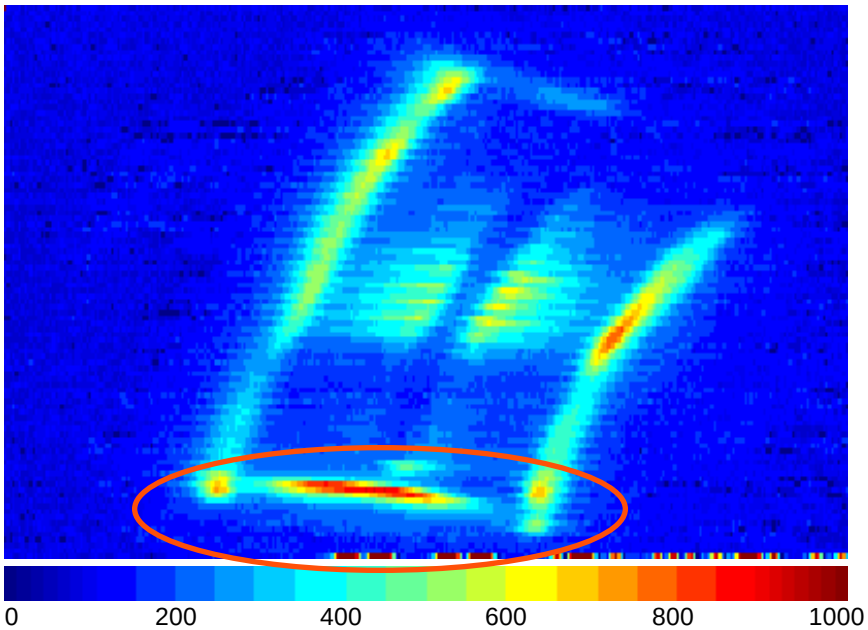
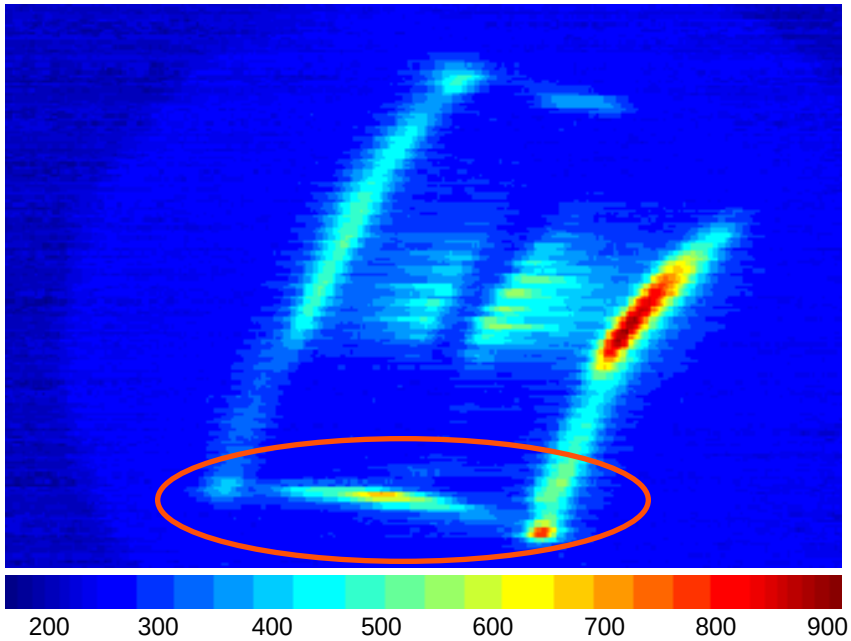
Heating on bottom corner bumpers tiles affected by wave propagation direction

- **ORNL Antenna**

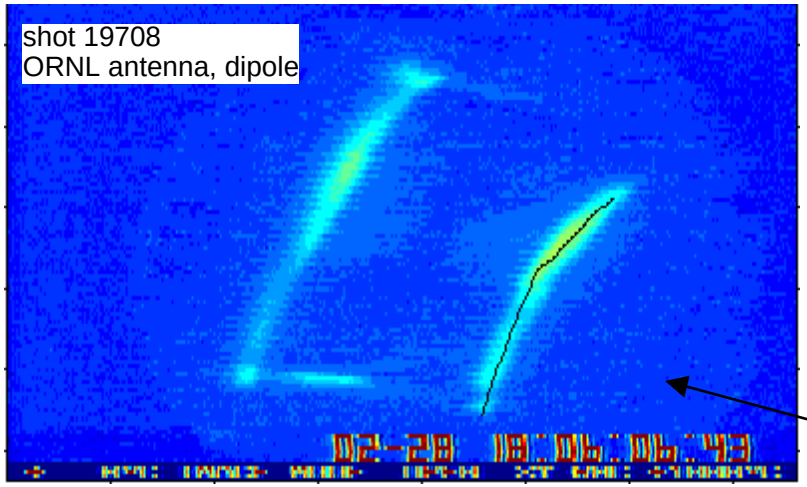
Phase of RF current = $+\pi/2$

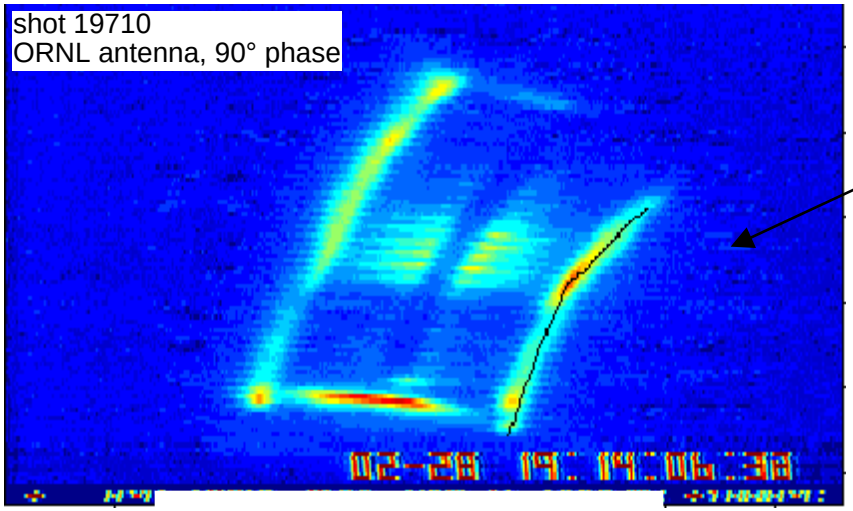


Phase of RF current = $-\pi/2$



Fast temperature rise high transient fluxes (max . 15-20 MW/m^2) for FWCD (90º) phasing

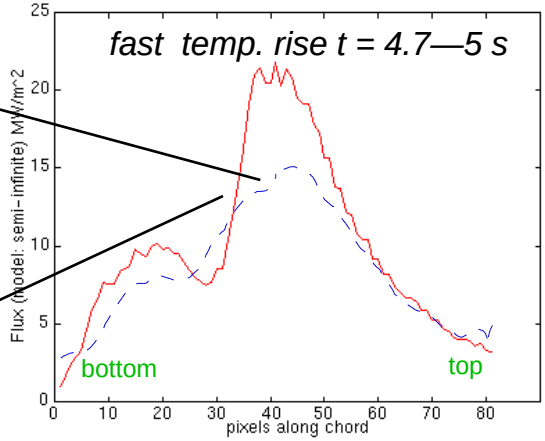




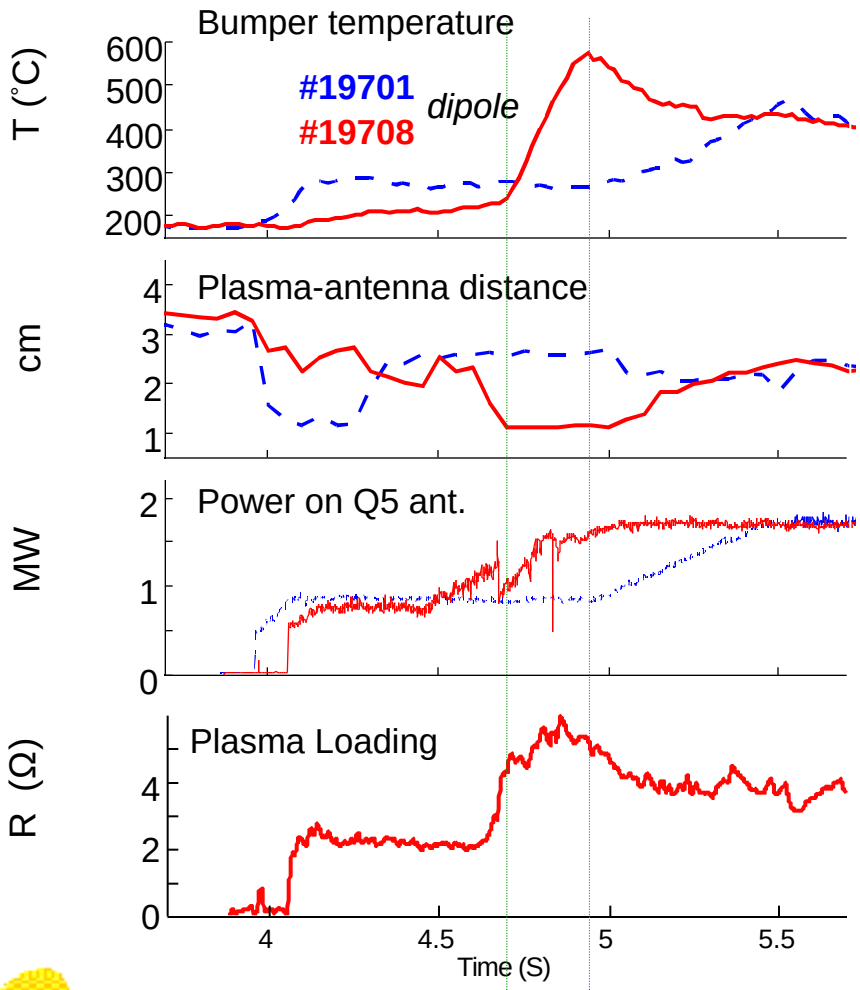
Temperature (°C)

- **Small gap and high power (2 MW)**

Heat flux along contour shown at initial temperature rise (inertial)



Peak temperature reached depends on power and plasma/antenna gap



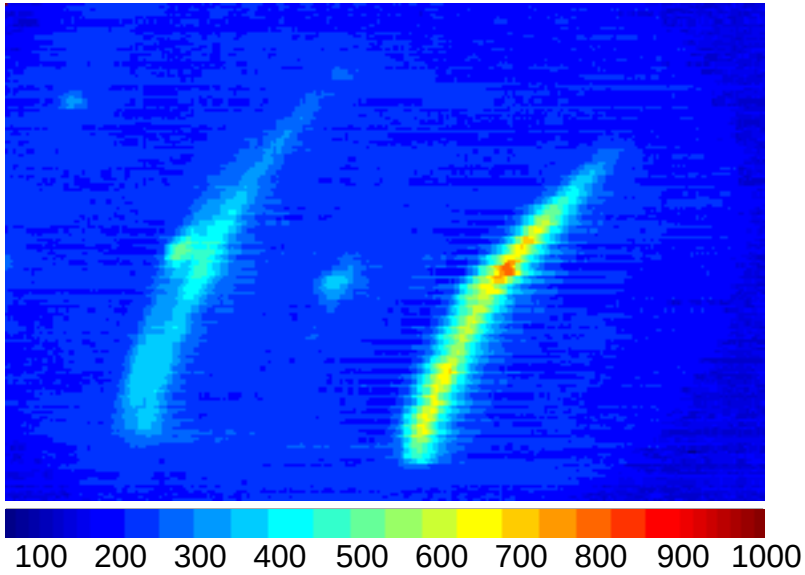
- **Shot 19701: Power ramped above 1 MW with gap > 2.5 cm. Max temp = 420°C.**
- **Shot 19708: Power ramped above 1 MW with gap ~ 1 cm. Max temp = 585°C.**
  - **Plasma loading increases rapidly w/decreasing gap**
  - **Indicates higher density in front of antenna; results in enhanced surface heating**
- **After ~ 5.5s power, gaps, and temperatures are equal**

← Temp decrease follows shortly after plasma loading decrease

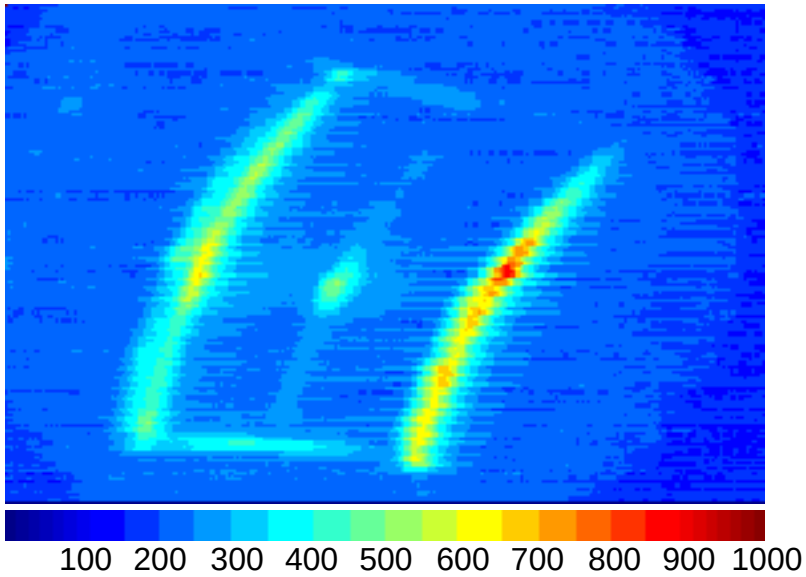
← Bumper temp increase begins in shot #19708

The CEA shield heating exhibits phase dependence, but not strong up/down asymmetry

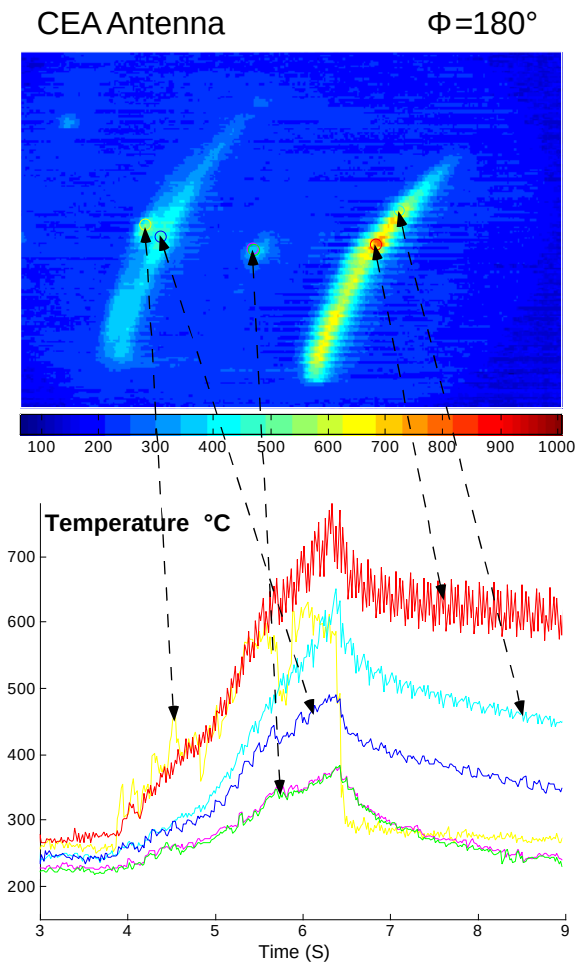
$\varphi = +\pi$

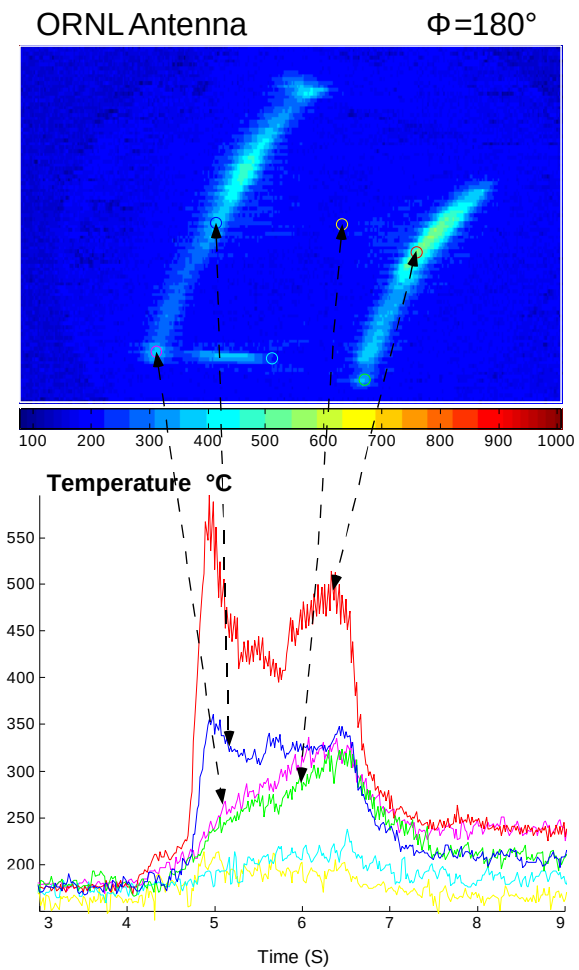


$\varphi = \pi/2$



The time to reach thermal equilibrium is different for the two shields



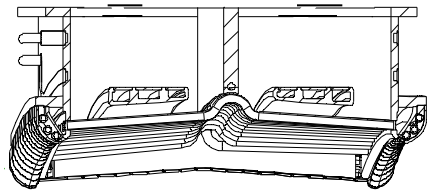


Discussion

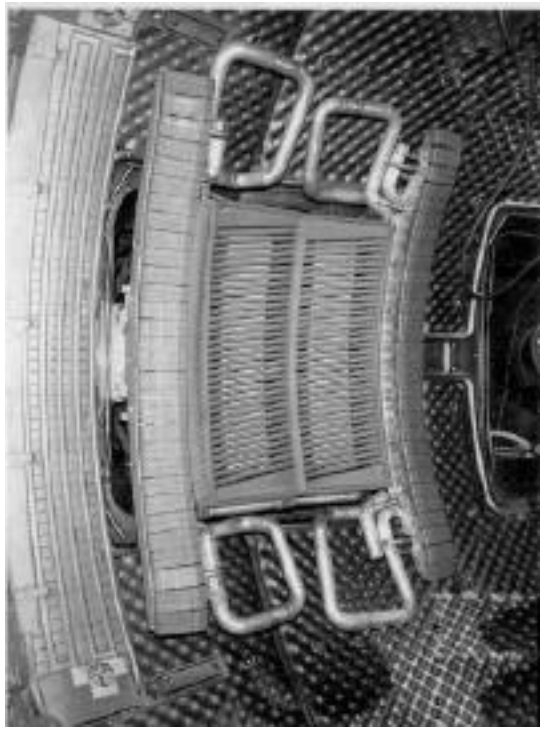
- Rectification of box currents can explain concentration of heating at top and bottom of bumpers, but not differences between ORNL and CEA antenna behavior
- RF inductive fields can explain some of this difference, assuming the protruding septum on the CEA antenna reduces neighboring surface potentials
  - Requires invoking convective cells or wave coupling phenomena as modeled by RANT to explain up down asymmetry
- More data needed to assess effect of plasma shape/position

Future work

ORNL antenna



CEA Antenna with new poloidal limiters



•Tiles attached to CuCrZr substrate through gradient bonding process

- ORNL antenna will be modified for compatibility with new poloidal limiters and operated in 2002
- Will compare hot spot formation on two antennas, now with identical limiters, hot spot formation with old and new limiters

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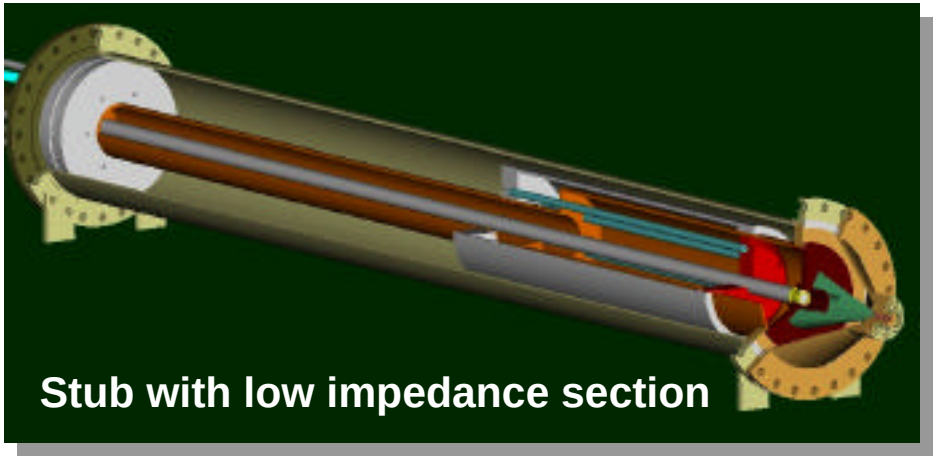
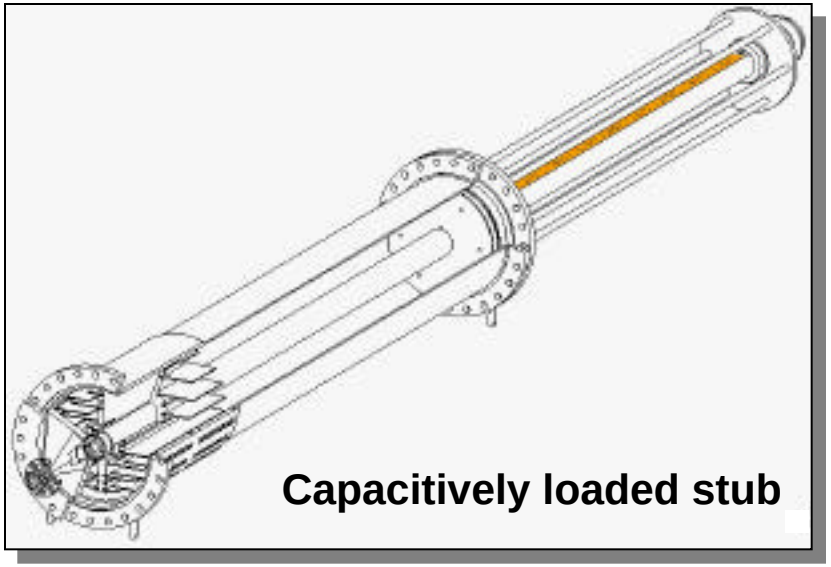
ornl

Voltage handling capabilities of internal structures of advanced compact stub designs will be tested in the ORNL vacuum RF breakdown test line

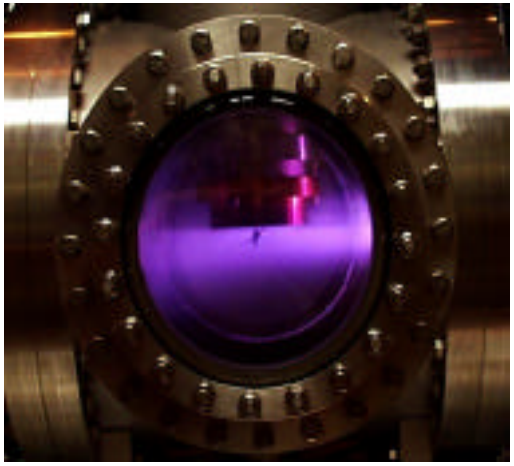


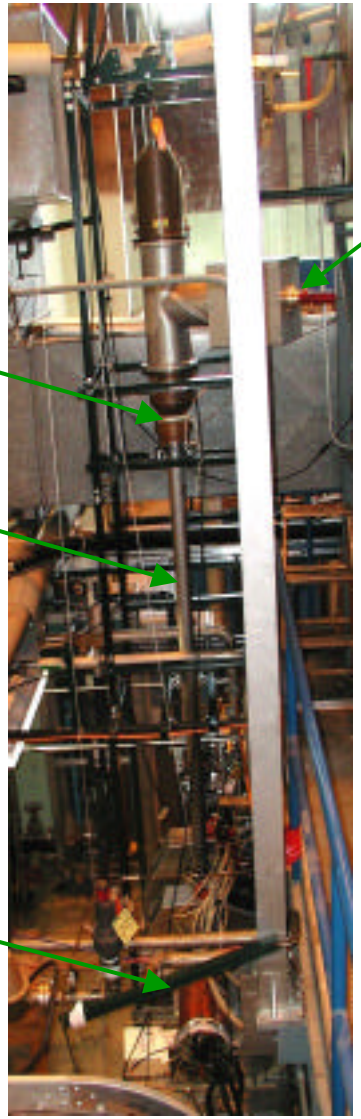


The ORNL high voltage RF breakdown tester

- **Can perform vacuum tests of high voltage structures, with capability to add gas, magnetic field, UV light, and plasma**

High voltage end with plasma





Summary

- Tore Supra data together with modeling effort best chance to identify and characterize surface heating mechanism - important clues already obtained
- ORNL will work with CEA to develop new internal matching components through voltage standoff tests of component structures