Wave Heating & Current Drive: Experimental Results

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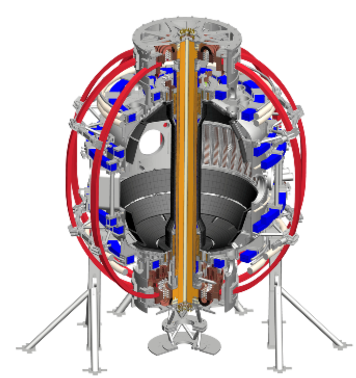
Results Review 2016
September 21, 2016



Overview

- HHFW system recommissioning
- HHFW-related studies during run:
  - Scoping study to couple HHFW during start-up
  - Outer gap response to step-changes in heating
- Synthetic Aperture Microwave Imaging (SAMI) preliminary measurements of magnetic pitch
- HHFW SOL loss analysis
  - RF rectification in the (NSTX) divertor
  - Annulus resonances in cylindrical plasmas and potential application to tokamaks

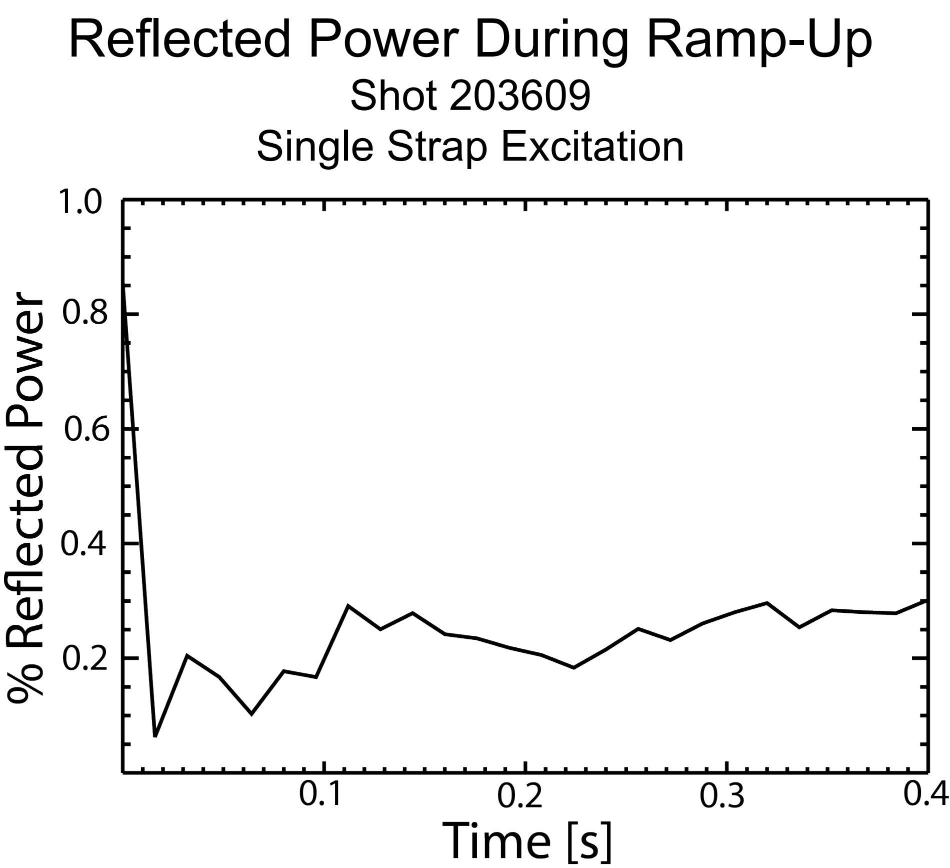
HHFW Recommissioning: system readied for plasma conditioning

- System upgraded following breaker failure
  - Lengthy repair/rebuild/replacement process to the crowbar circuit, breakers, and relays
    - Both in the HHFW systems and in the AC power yard.
  - The modified system is improved and more resilient.

- Vacuum conditioning prepared system for 1-2 MW operation into plasma
  - High-voltage breakdown is limiting factor in coupling RF power
  - All six sources were conditioned to at least 19 kV and for a duration of at least 100 ms.

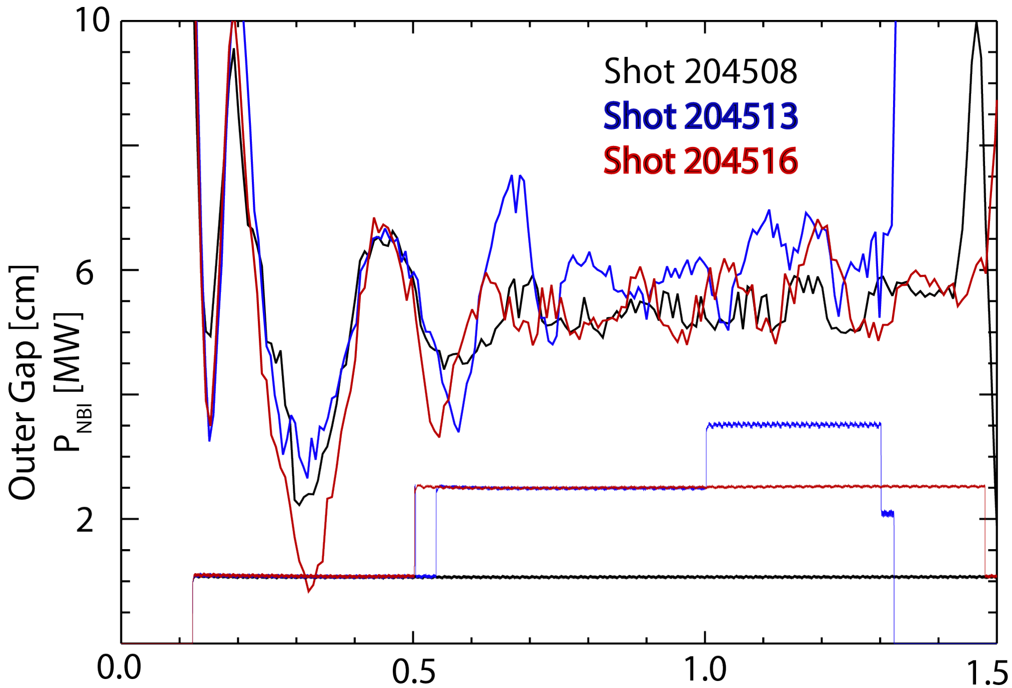
Initiated study of HHFW coupling during start-up

- Coupling HHFW during start-up is highly desirable for solenoid-free operation
  - … but is difficult because changing plasma can detune RF match
- Idea: apply low-power signal to antenna for non-perturbative measurements of loading resistance
  - Sample a large number of discharge scenarios
- Ideally: determine an intermediate match with acceptable power reflection throughout ramp-up



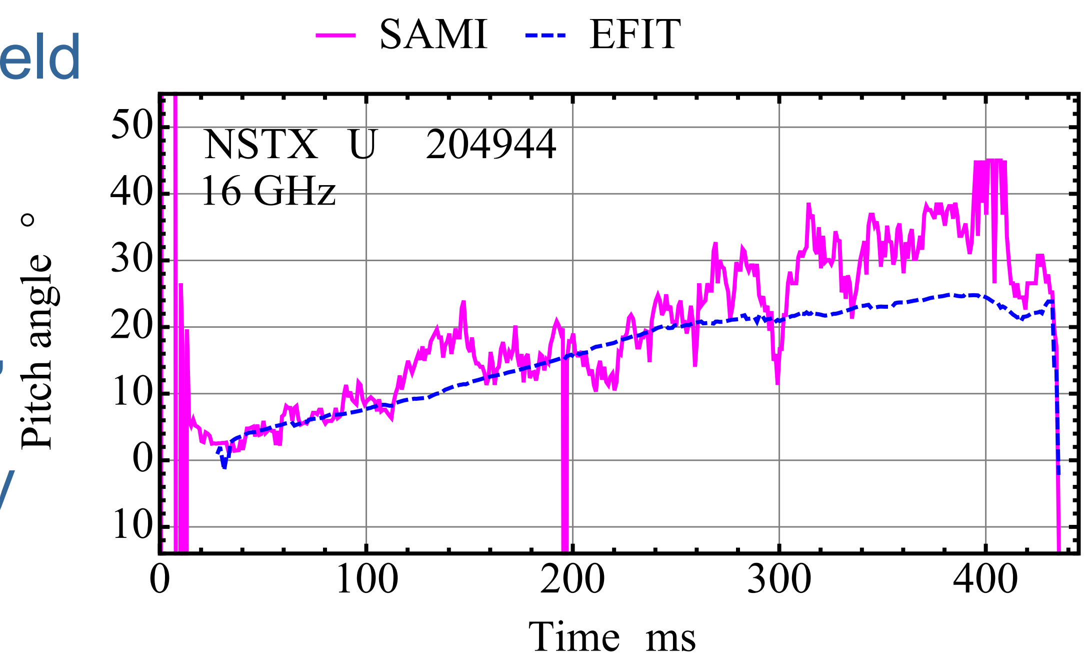
Studying outer gap response to step-changes in plasma heating

- HHFW coupling is sensitive to outer gap size
  - A change in outer gap could trigger an antenna arc
- Idea: study gap response to NBI as a surrogate to HHFW
- Large excursions in outer gap are observed in conjunction with step-changes in NBI



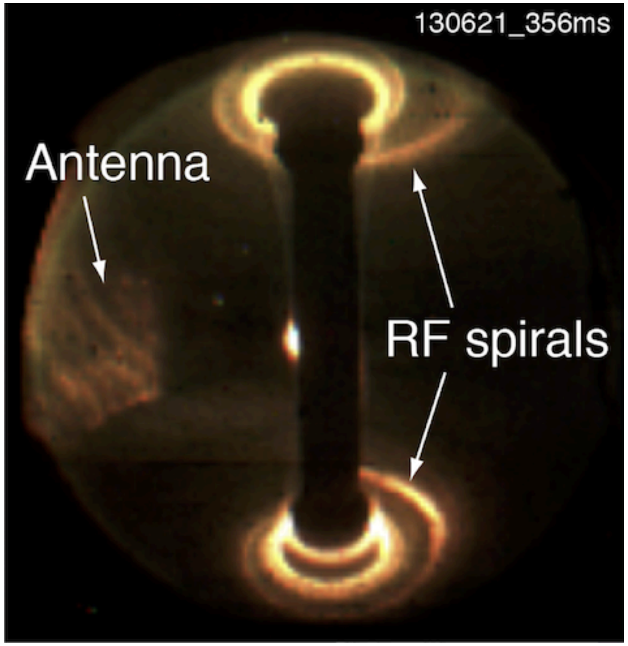
First SAMI diagnostic measurements of field pitch near edge of NSTX-U

- Preliminary SAMI diagnostic measurements, using Doppler back scattering of probing beam show good agreement with EFIT just inside LCFS
  - SAMI measures larger field pitch than EFIT outside LCFS
  - Without a larger dataset, not possible to say whether this discrepancy is a physics result related to moving inside LCFS



Analysis performed during FY16 in support of HHFW operation

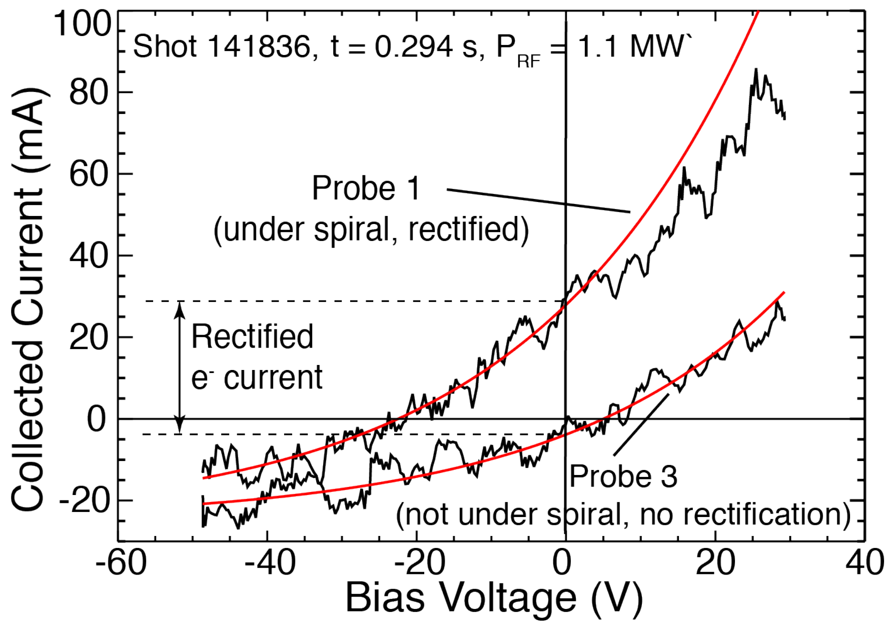
- The next two topics are dedicated to minimizing SOL losses of HHFW power
  - SOL losses produce spirals on upper and lower divertors
  - Losses are a serious operational issue preventing efficient HHFW heating



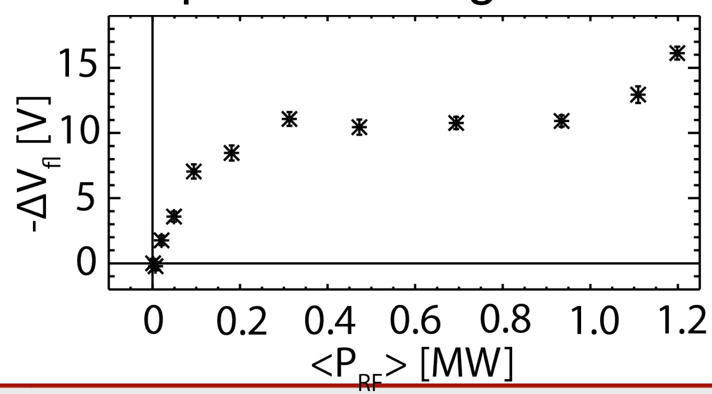
RF rectification is believed to convert HHFW power into heat flux under spiral

- NSTX divertor presents an *unconventional regime* for RF sheaths
  - Rectified currents are observed
    - Such currents are often assumed to be neutralized by rise in plasma potential
  - Heat flux scaling with V_{RF} is **greater** with rectified currents than otherwise predicted
  - Change in floating potential (related to rectified current) captured as function of applied HHFW power

Divertor Langmuir Probe during HHFW



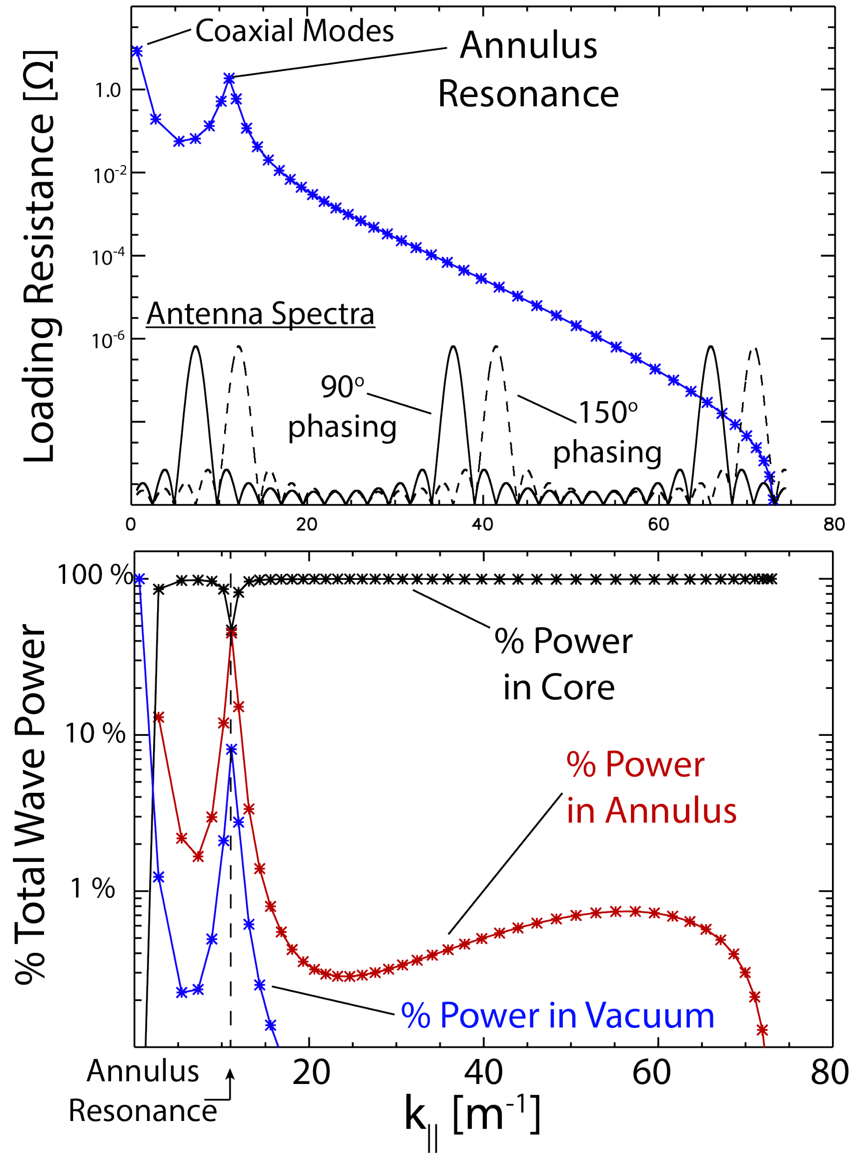
Probe Response During HHFW Ramp



J. C. Hosea, 41st EPS Conference (2014) P5.049
R. J. Perkins, Phys. Plasmas 22, 042506 (2015)
R. J. Perkins, submitted to *Journal of Nuclear Materials and Energy*

“Annulus resonant” modes in cylindrical cold plasmas offer insight into NSTX SOL losses

- HHFW amplitude in SOL suspected to be large when righthand cutoff layer is close to the antenna
- Cylindrical cold plasma model developed to test fundamental physics of enhanced RF field amplitude in edge
- New mode, “annulus resonance,” offers insight into losses
  - Modes appear when ½ radial wavelength fits outside core region
  - Such modes have anomalously high loading resistance
  - About 50% of wave power is conducted in the relatively small edge region



R. J. Perkins, *Phys. Plasmas* **23**, 070702 (2016)