FOM-Institute for Plasma Physics Rijnhuizen
Association Euratom-FOM, Trilateral Euregio Cluster

Preparations for ECRH feedback control of tearing modes on TEXTOR

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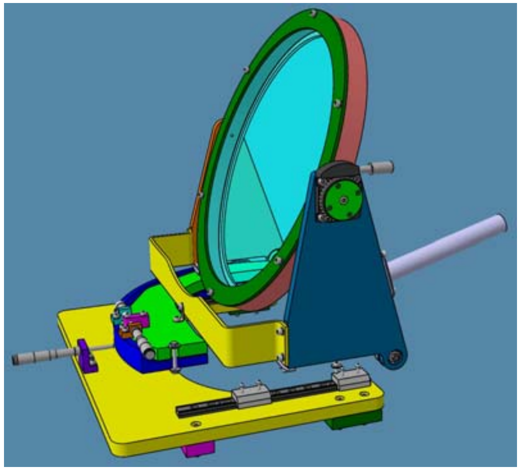
18 – 20 November 2007

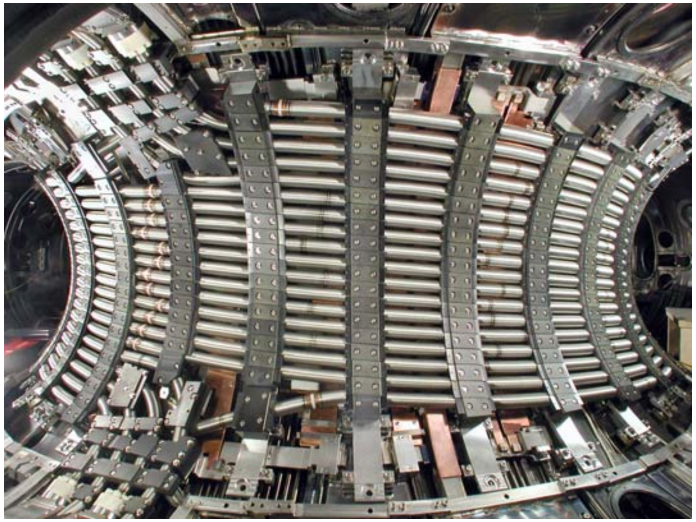
Outline

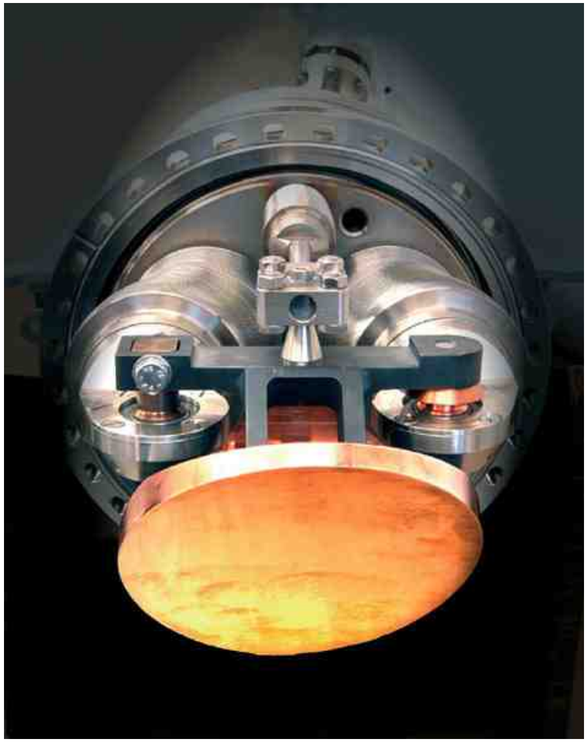
- Motivation and goals
  - ECRH/ECCD control of tearing modes and sawteeth
  - Why feedback control of MHD Instabilities?
- Overall strategy for FB control
  - A control systems approach
  - The principle of same sight line ECE



- The TEXTOR bi-directional ECRH/ECE antenna
  - Design principles and status of implementation
- Implementation on ITER

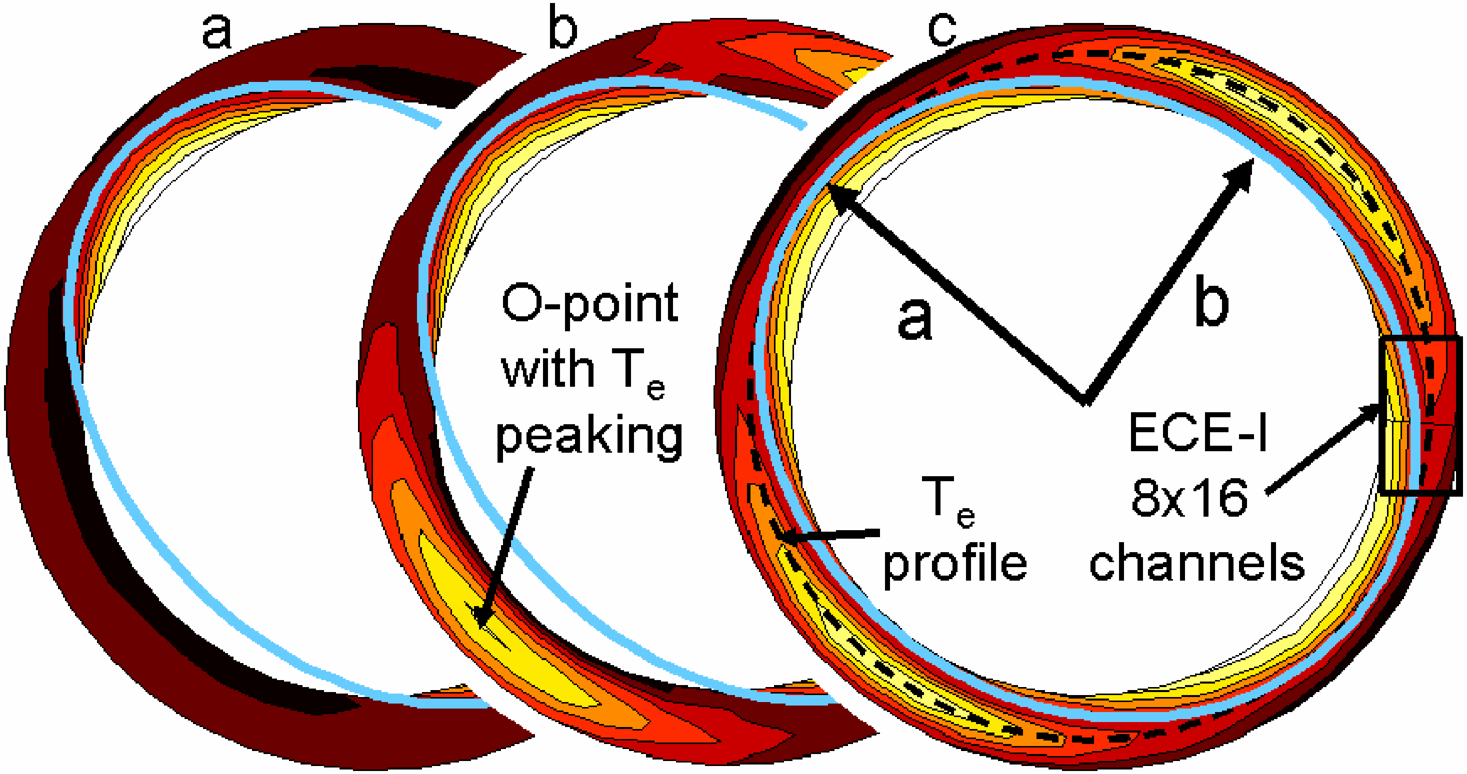
Motivation and Goals





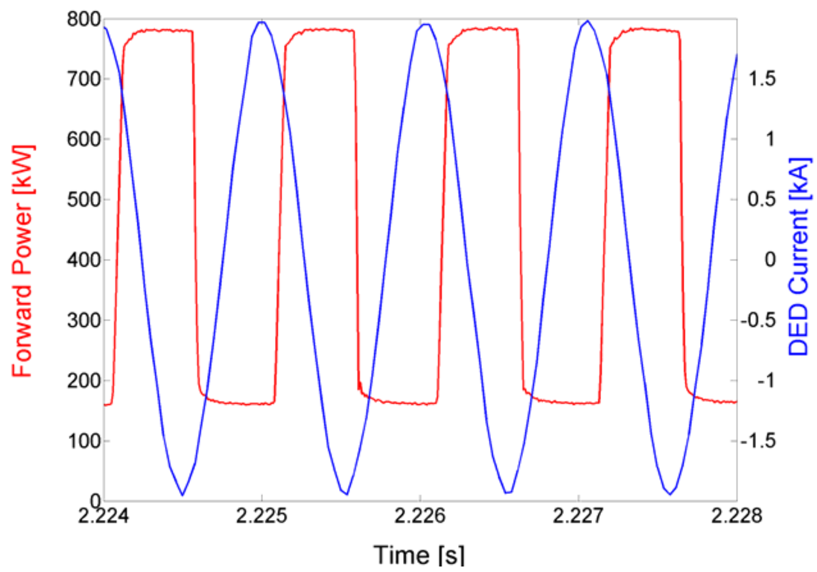
Tearing mode control with ECRH and ECCD

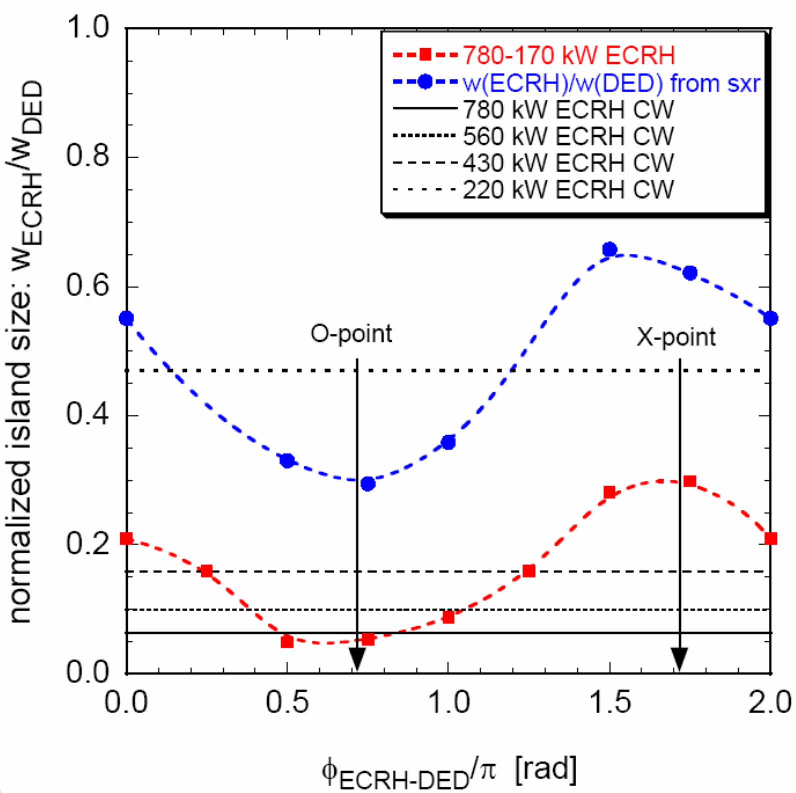
- Stabilization by additional current inside island through heating and / or direct drive
- Requires accurate positioning of EC power
  - – ECE-I observation of effect of island heating



Advantage from ECRH power modulation

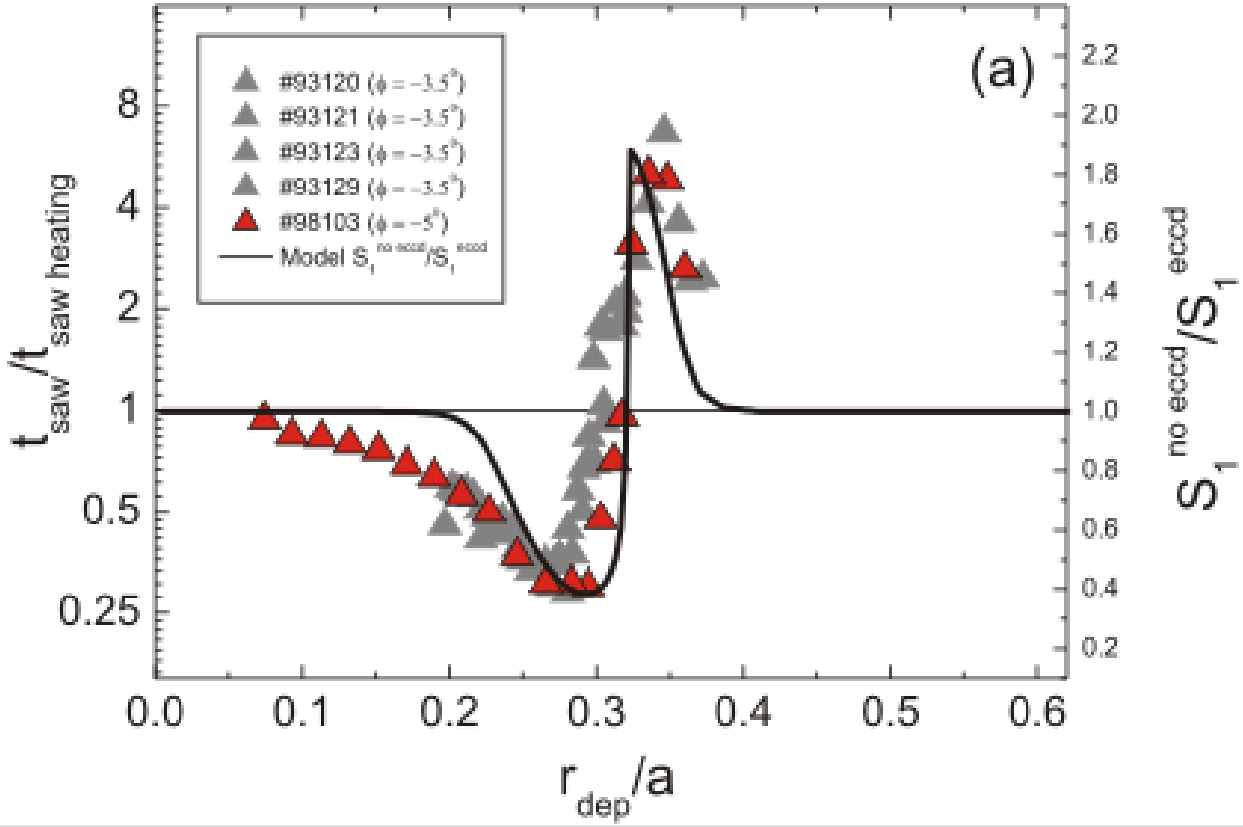
- 2/1 tearing mode created and locked to DED
  - DED frequency 1 kHz
- ECRH power modulation phase locked to DED





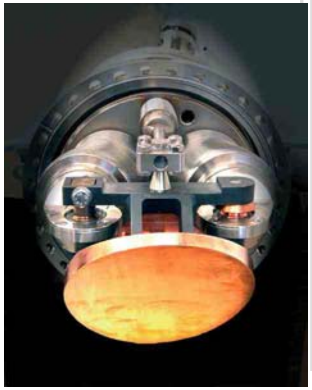
Sawtooth period control by ECCD

- Accurate positioning needed for requested effect
  - Example shows effect of co-ECCD



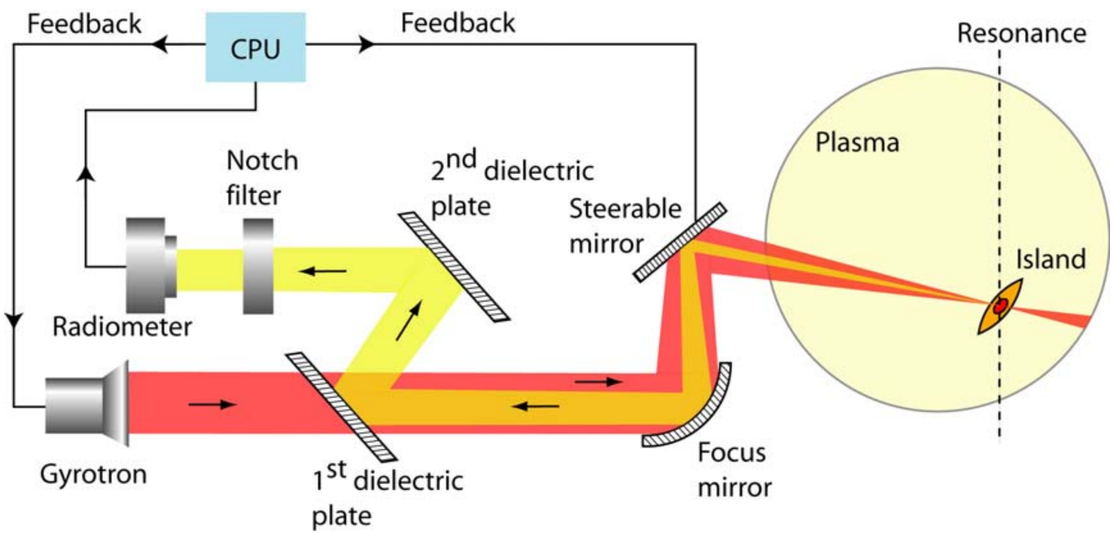
Feedback controlled power deposition

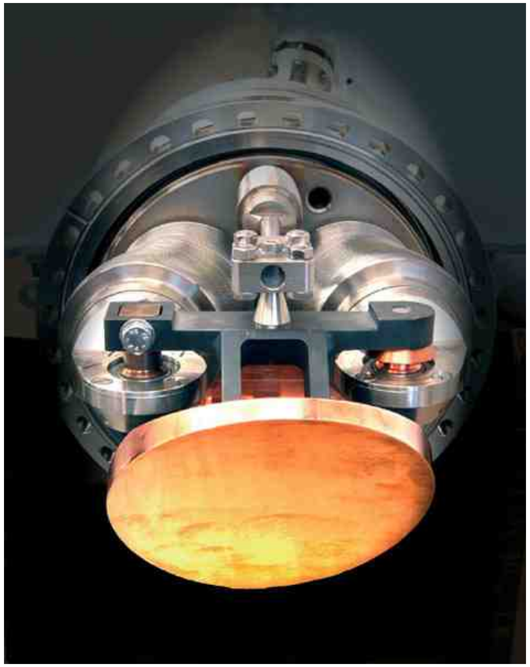
- MHD control requires accurate positioning and timing of ECRH/ECCD for optimum effect
- Problem:
  - Where is the mode resonant surface?
  - What is the phase of the mode
  - What are the plasma profiles?
  - Inaccuracy of measurement + reconstruction!



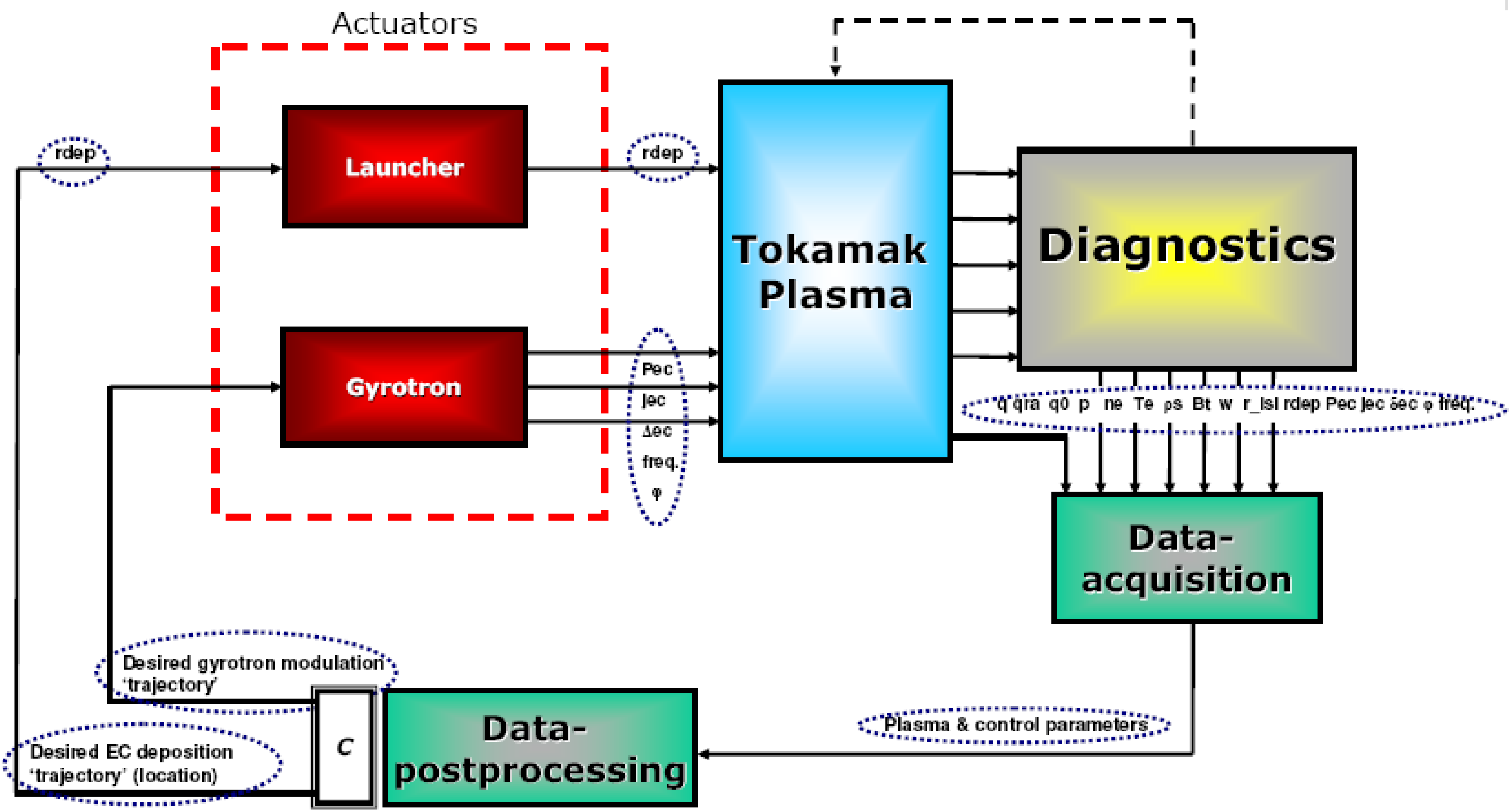
- Solution:
  - Work in EC frequency space
  - Observe ECE along ECRH beam trajectory
  - Island search and EC beam steering in single system

Overall strategy for FB control



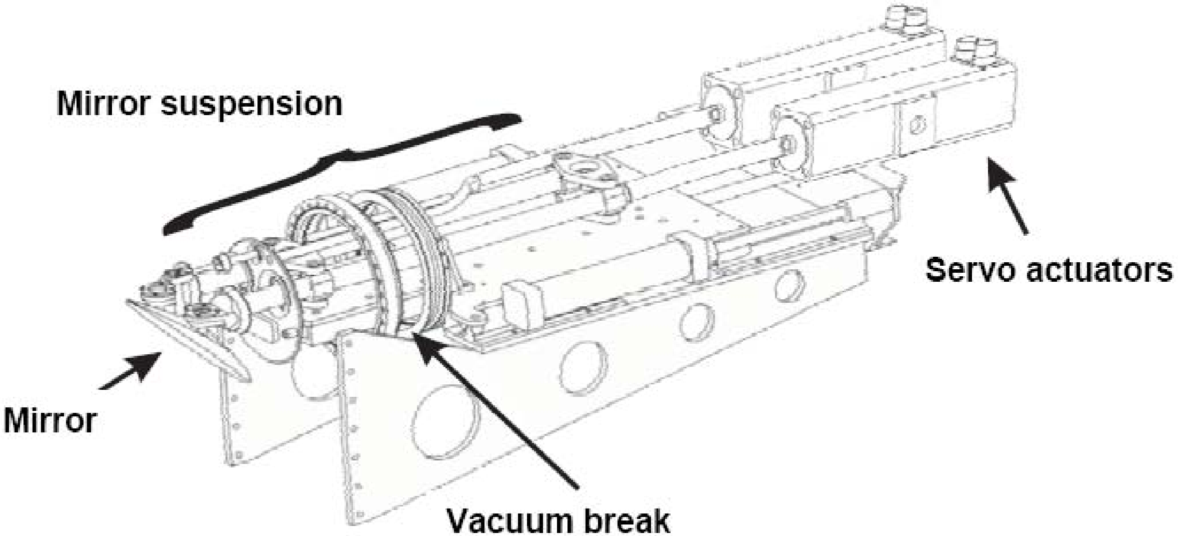


Feedback control loop: to be modeled



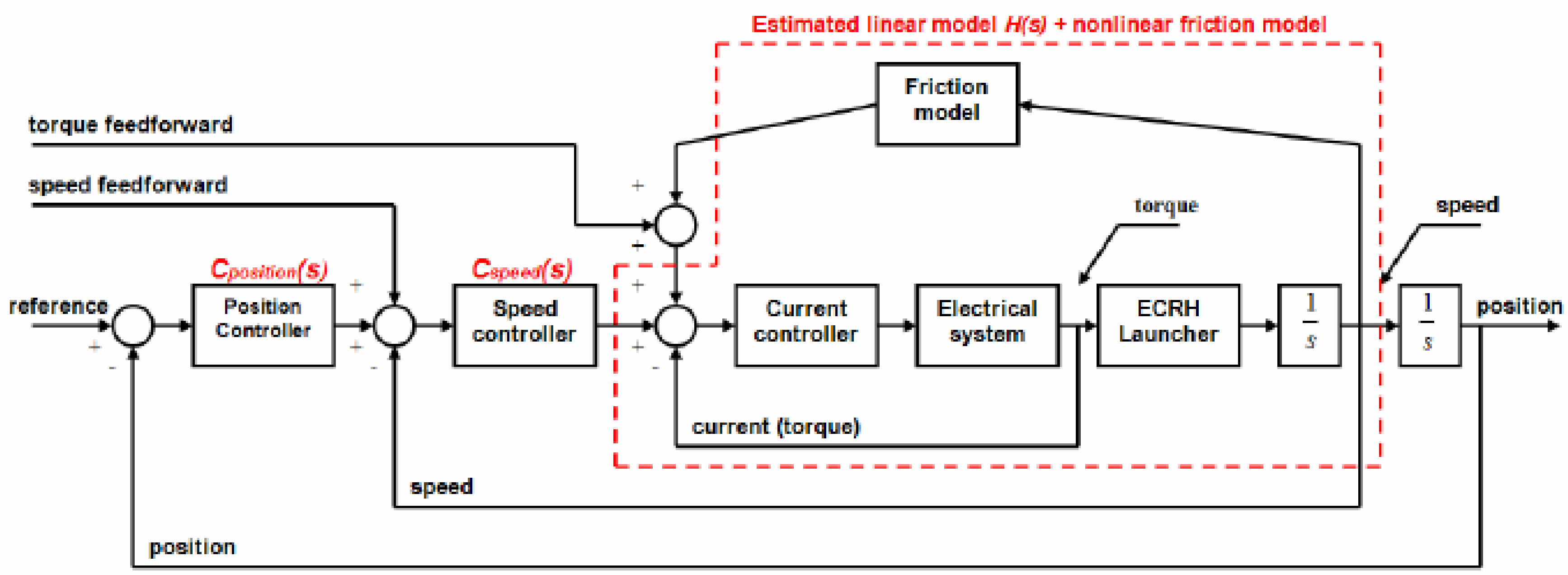
Launcher control

- Launcher design features
  - AC perm. magnet synchronous motor + servo amplifier
  - Actuation in 2 rotational degrees of freedom (DOFs) (range: -30° to 30° poloidal / -45° to 45° toroidal)
- Fast, accurate steering of ECRH launcher requires detailed knowledge of its mechanics
  - 10° in 100 ms, with a position accuracy of 1°



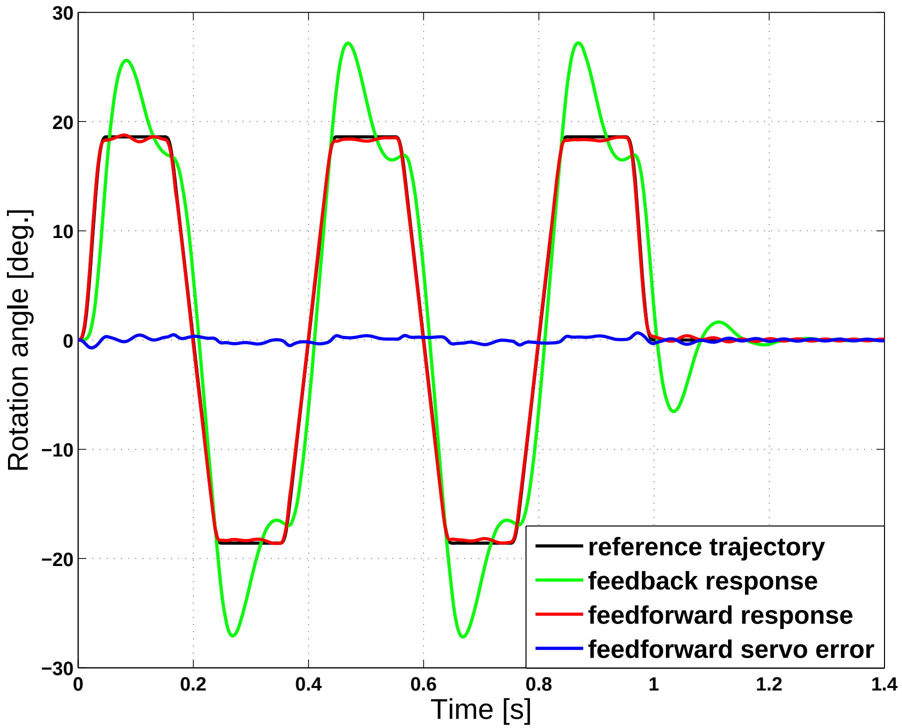
Launcher control

- Mechanics characterized by Frequency Response Function techniques
- Derived linear plant + friction model used in design of advanced launcher feedback controller

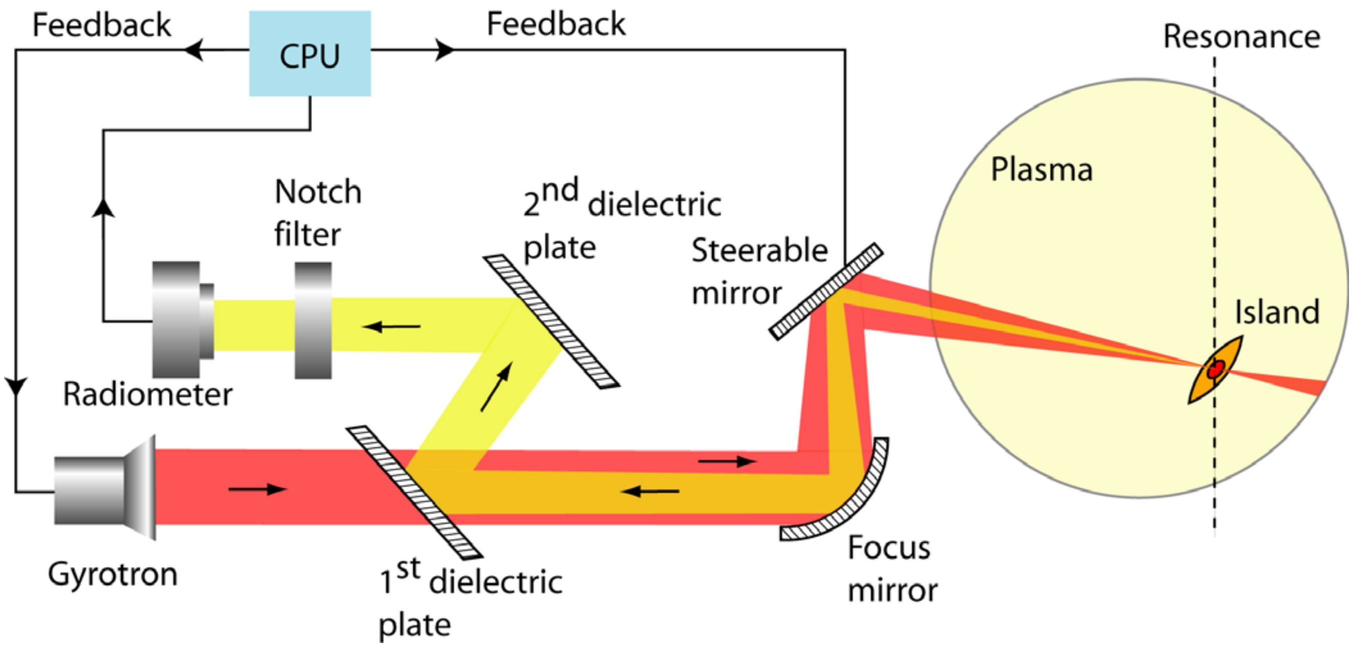


Modeled controller response

- Speed of response: ~ 25° rotation in 100 [ms] ☺
- Max. positioning error: 0.4° ☺

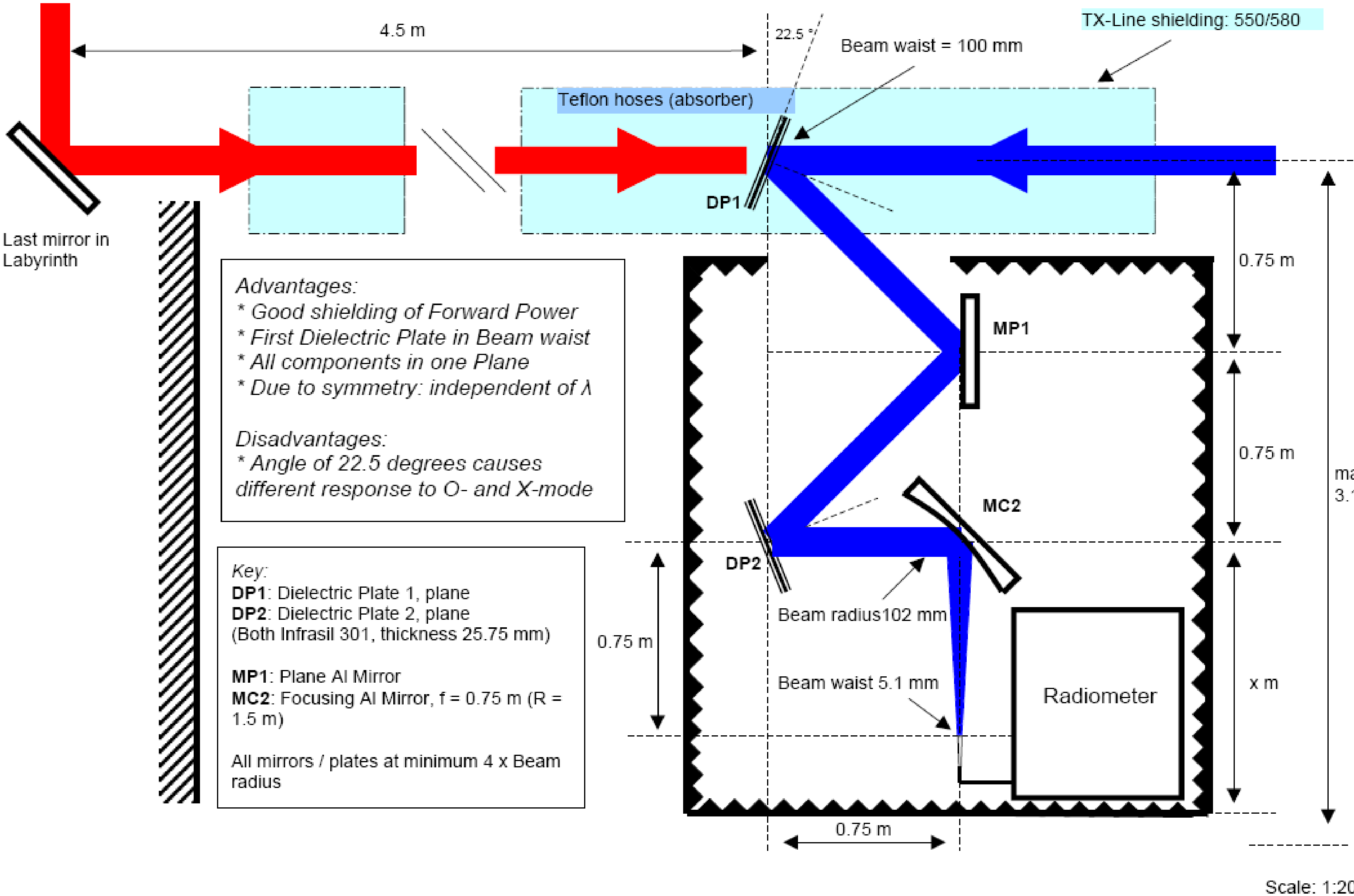


Bi-directional ECRH/ECE antenna for control



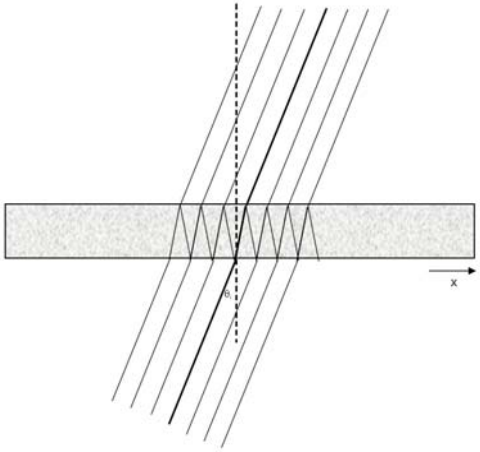
- The principle: ECE is coming from the **exact** position where the ECRH is deposited
  - Combines the island search and ECRH beam steering in a single system and step

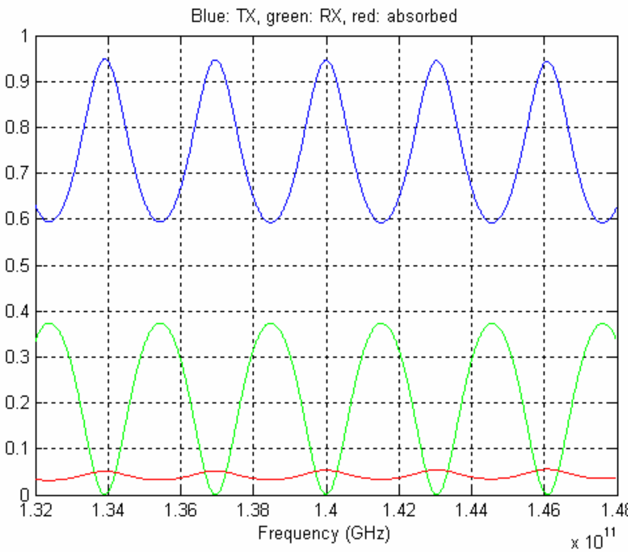
TEXTOR bi-directional ECRH/ECE antenna



Challenge and solutions

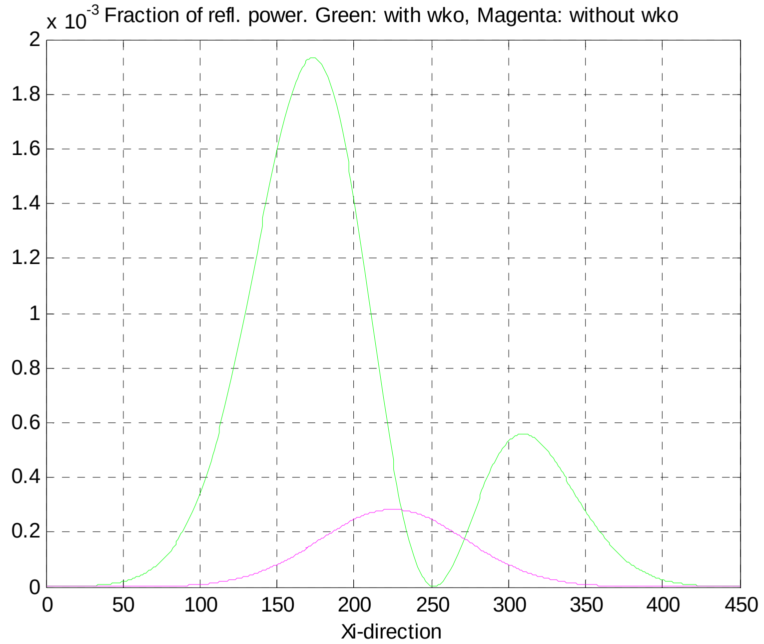
- Measure ~8 nW per channel of ECE power in environment with 1 MW gyrotron power
- Frequency selective element: dielectric plate
  - Principle:
    coherent addition of multiple reflections from interfaces
  - Dual purpose: ECE selection / gyrotron suppression
  - Further gyrotron suppression by notch filter

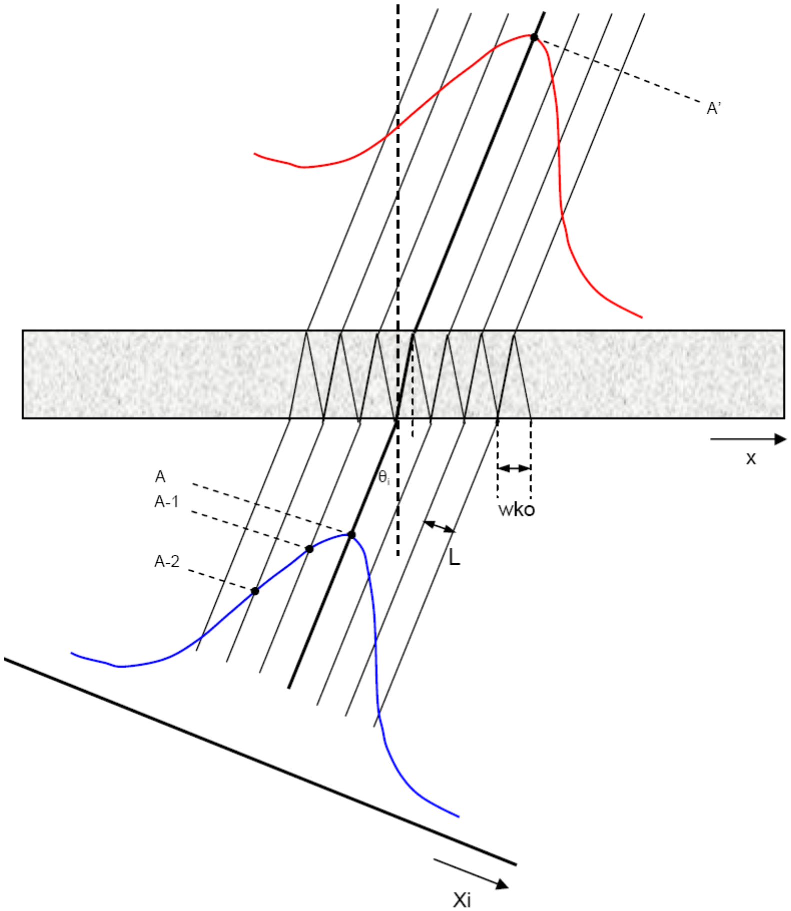




Performance prediction

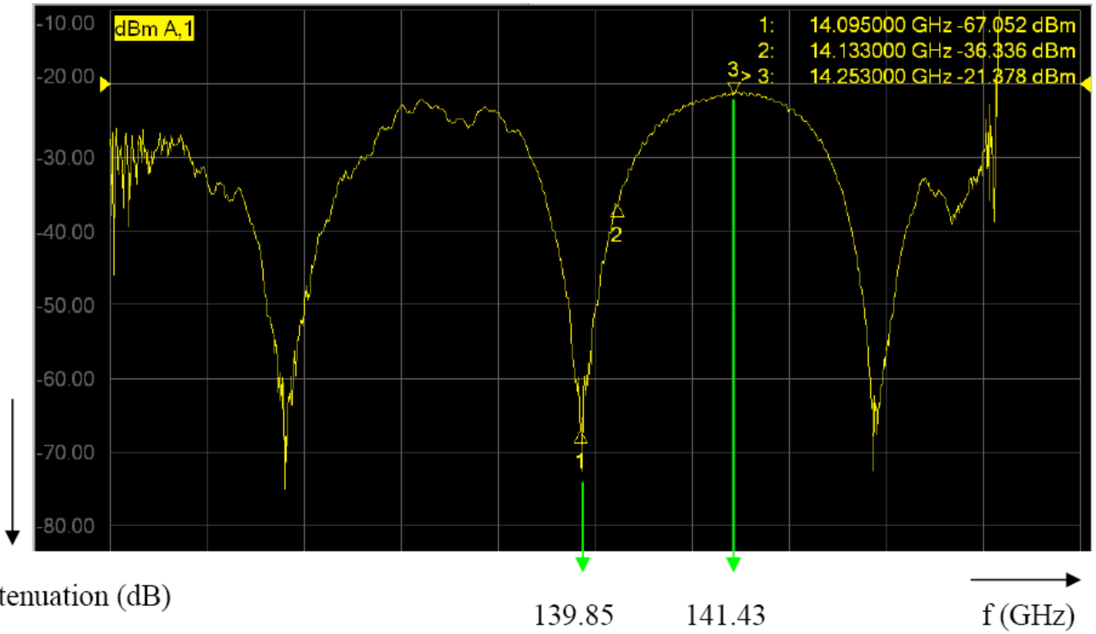
- Finite beam width: walk-off
  - Reflection in resonance up from -35 dB to -27 dB
  - Transmission unaffected





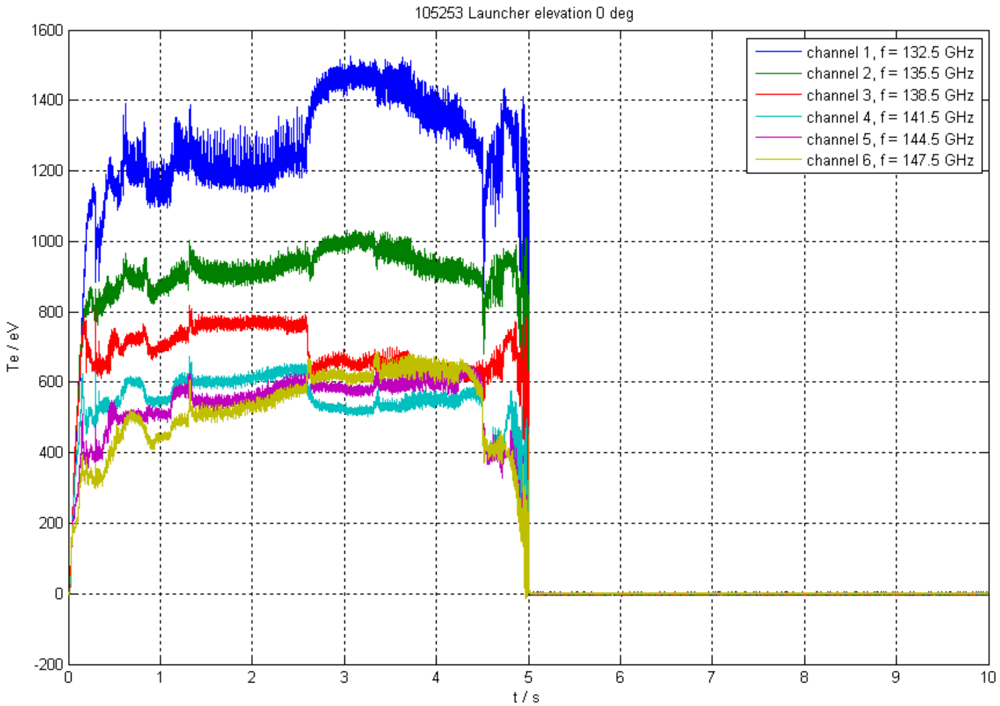
Low power performance test

- Whole system test, two plates: reflection in resonance reduced by -50 dB ☺



First ECE measurements ☺

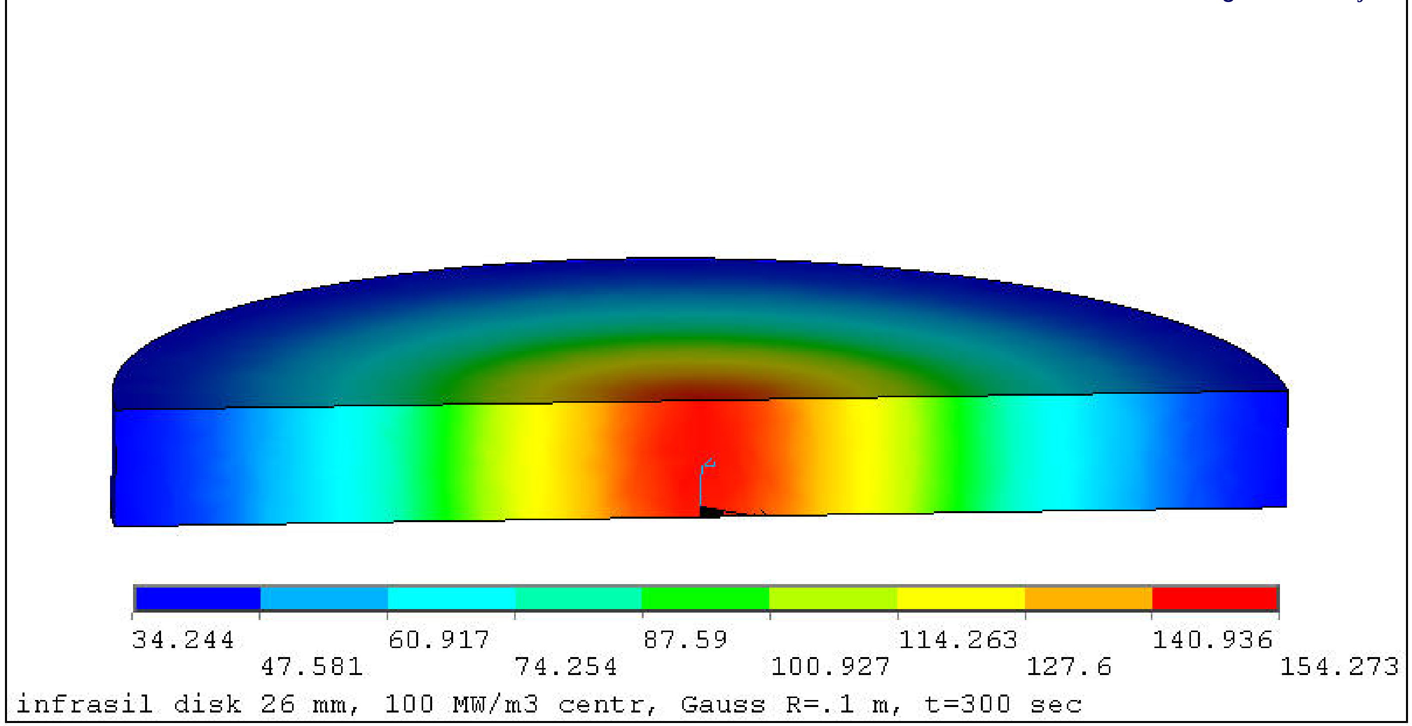
- Good signal to noise: clear detection of islands
- Still without gyrotron power



High power, long pulse aspects

- Finite power absorption in plate: ~5%
- Temperature rise during ECRH ~50 K / s

Ackn. M.A. van den Berg, O.G. Kruijt

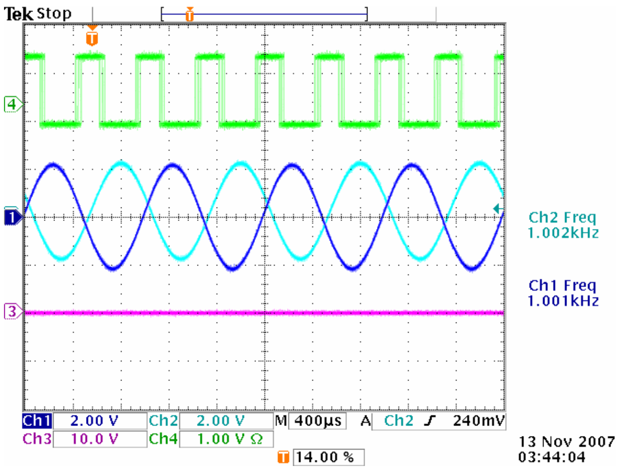


Handling reflected power

- Provisional dump for reflected gyrotron power
  - Active cooling: calorimetry foreseen

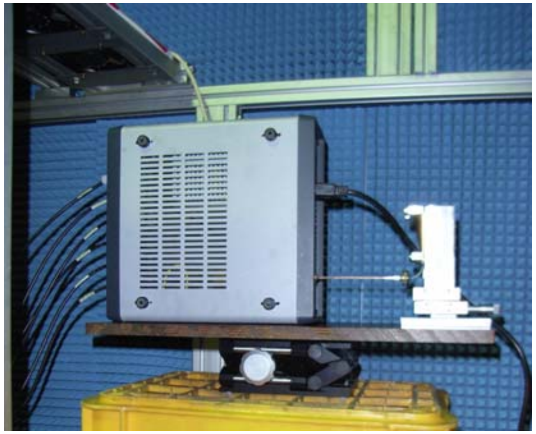
DAQ / Signal processing / Control

- Island recognition:
  search for 180º phase jump across ECE channels
- FPGA based hardware
- Status:
  - hardware available
  - software under development



Simulation of power modulation control

Next steps

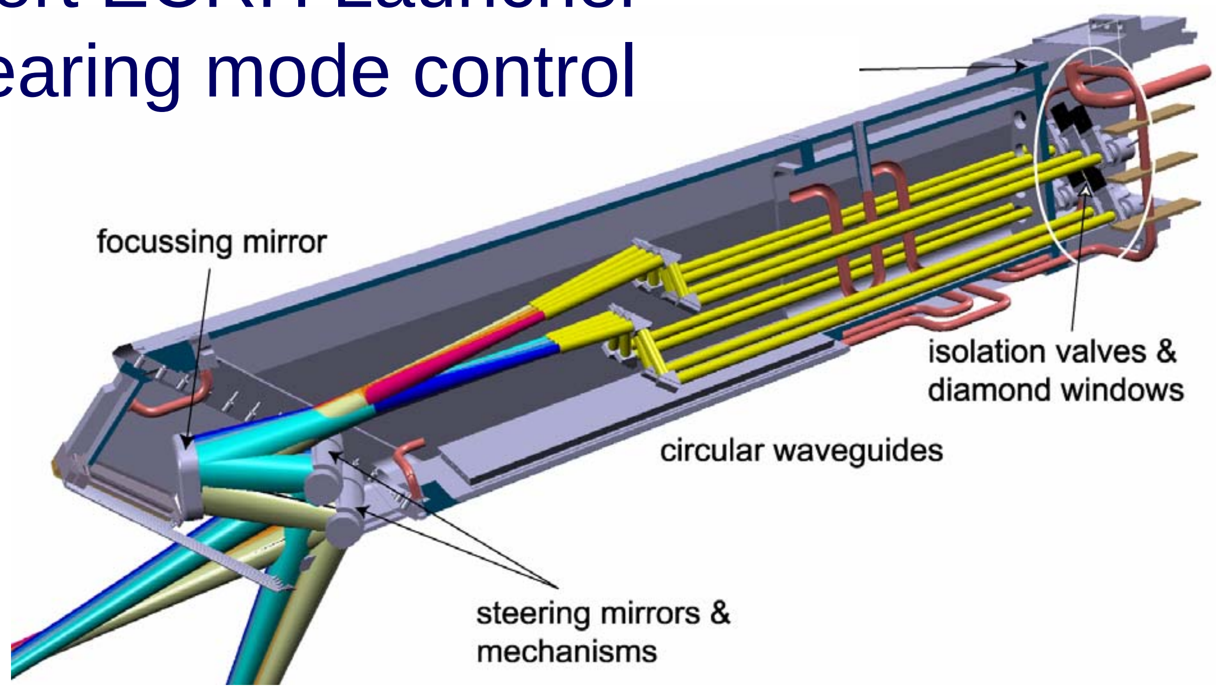


High power performance test

1. Gyrotron power transmission
   - Check minimum in reflected power
   - Proof handling of reflected power
   - Control heating of the dielectric plate
2. ECE measurement during ECRH
   - Check residual level of gyrotron power at horn
   - Proof measurement capability during ECRH
3. Implement full feedback control scheme
   - (after) TEXTOR shutdown March – August 2008

Implementation on ITER

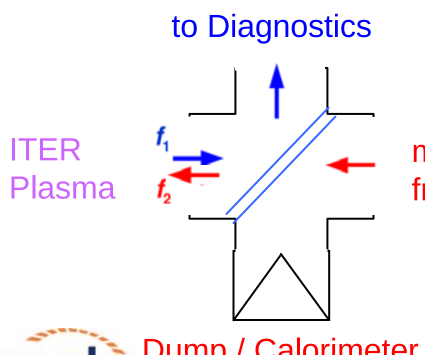
- ITER Upper Port ECRH Launcher neoclassical tearing mode control

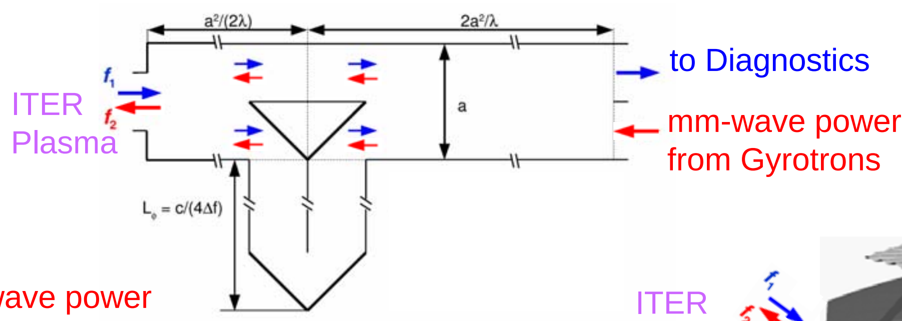


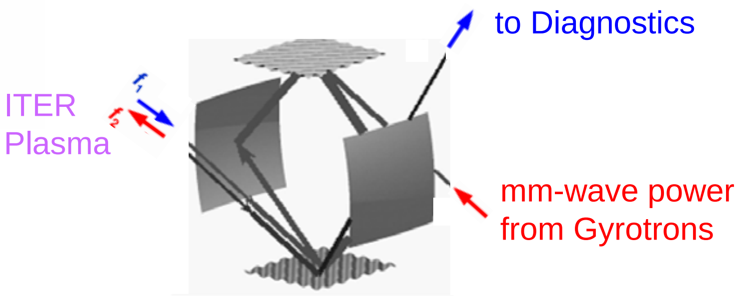
- Requires
  - CW capability
  - Compatibility with ITER wave guide transmission
- TEXTOR system neither CW capable nor consistent with waveguide transmission ☹

Development program for waveguide coupler

- Design study of possible waveguide couplers
  - edge cooled diamond disk Fabry-Perrot
  - Waveguide interferometer using Talbot effect
  - Quasi-optical inserts with gratings
- Prototyping selected solution
  - High power performance tests on prototype







Summary and Conclusions

- TEXTOR feedback control system for tearing modes on basis of bi-directional ECRH antenna
  - System passed low power tests
  - First ECE measurements
  - High power test to follow shortly
  - Feedback control experiments 2nd half 2008
- ITER compatible system under development
  - Selection of waveguide coupler design ongoing
  - Manufacture and high power performance tests under planning