TOKAMAK GOLEM FOR FUSION EDUCATION - CHAPTER 6

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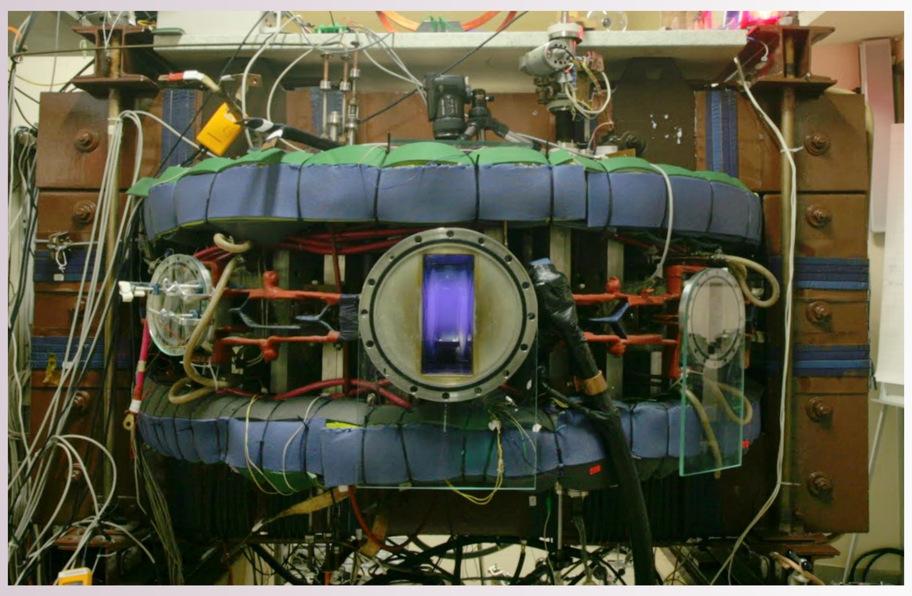
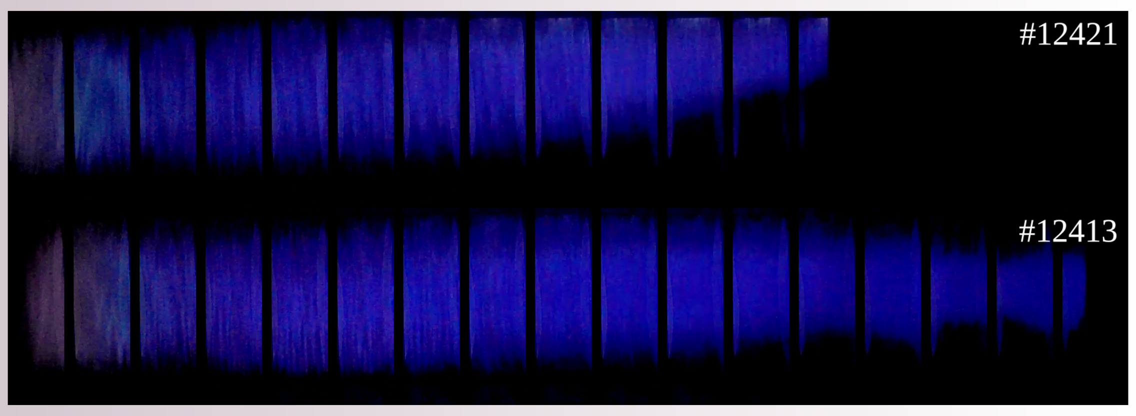
The GOLEM Tokamak



- Parameters: $B_t < 0.5$ T, $I_p < 8$ kA, pulse length < 15 ms
- An educational device for domestic as well as for foreign students via remote participation/handling
- Subject of several Bachelor's degree projects and Master's degree theses each year.
- At present used in an experimental laboratory course in the basic physics curriculum. Students become familiar with probe measurements, data analysis and basic tokamak diagnostics.

Position control

- Plasma position estimated from Mirnov coils signals using either a Grad-Shafranov model or a straight conductor approximation
- The actuators are controlled by a combination of a nonlinear P controller with predefined waveforms (can be configured from the virtual control room)
- The effects on plasma evolution have been verified



A comparison of the plasma evolution without position control (top) and with the closed loop control (bottom); Images from the radial fast camera

References

[1] J. Kocman, Řízení polohy plazmatického prstence na tokamaku Golem, Master Thesis, FNSPE CTU (2015)

[2] L Matena, Microwave interferometry on the GOLEM tokamak, Master Thesis, FNSPE CTU (2015)

[3] O Ficker, Generation, losses and detection of runaway electrons in tokamaks, Master Thesis, FNSPE CTU (2015)

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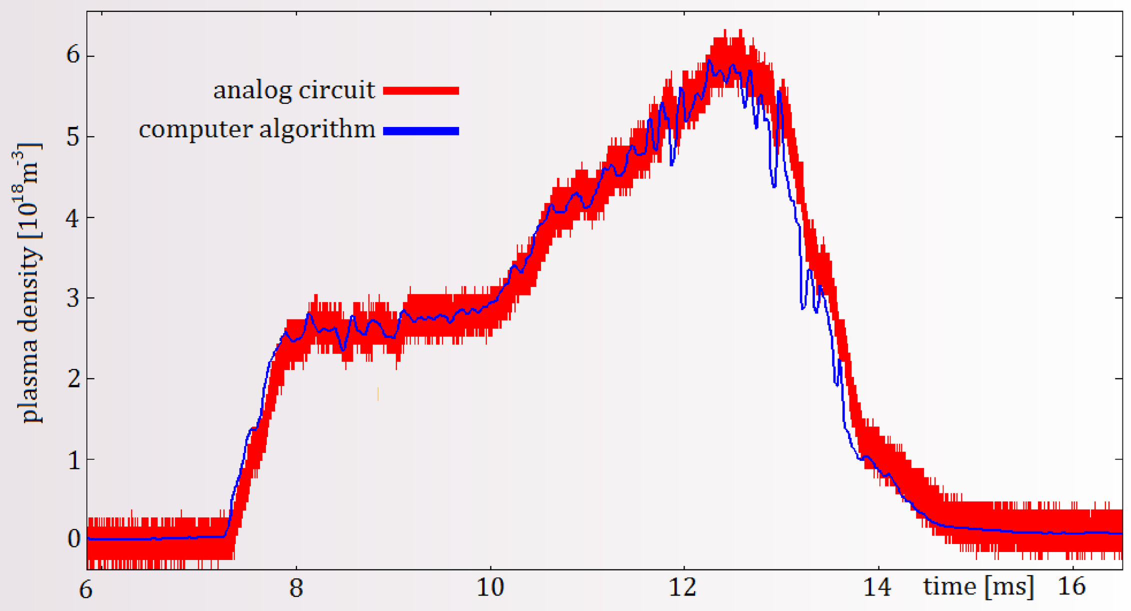
Microwave interferometry

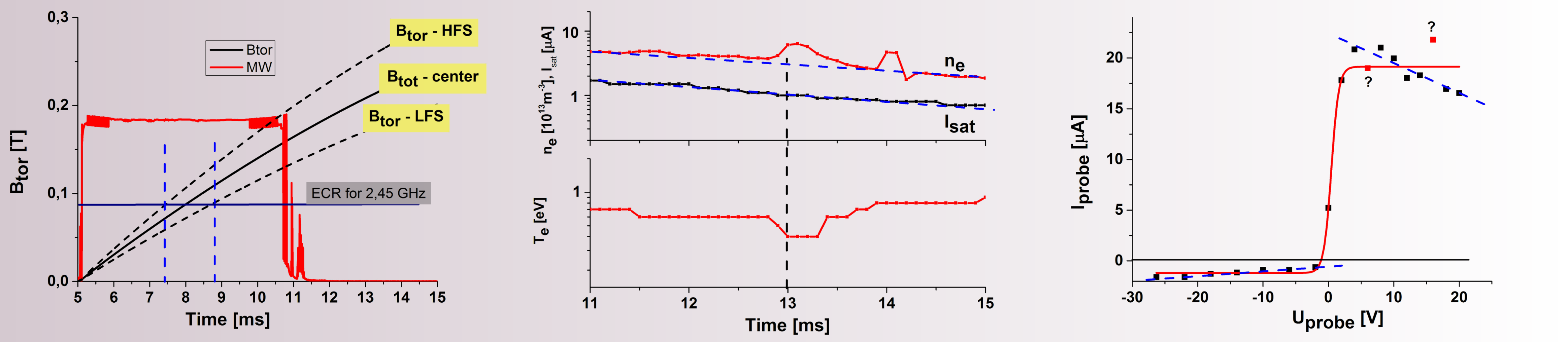
- An interferometer from the CASTOR tokamak made operational
- Wharton interferometer: The MW frequency is modulated, the plasma density is derived from the phase shift evolution
- An analog circuit has been developed to process the signal and derive the density (immediate output, but noisy and delayed by low-pass filtering)
- Average density calculated (from the assumption of the plasma diameter corresponding to the limiter)



The analog circuit output compared to the traditional computer algorithm (#19513)

Probe measurements in MW plasma

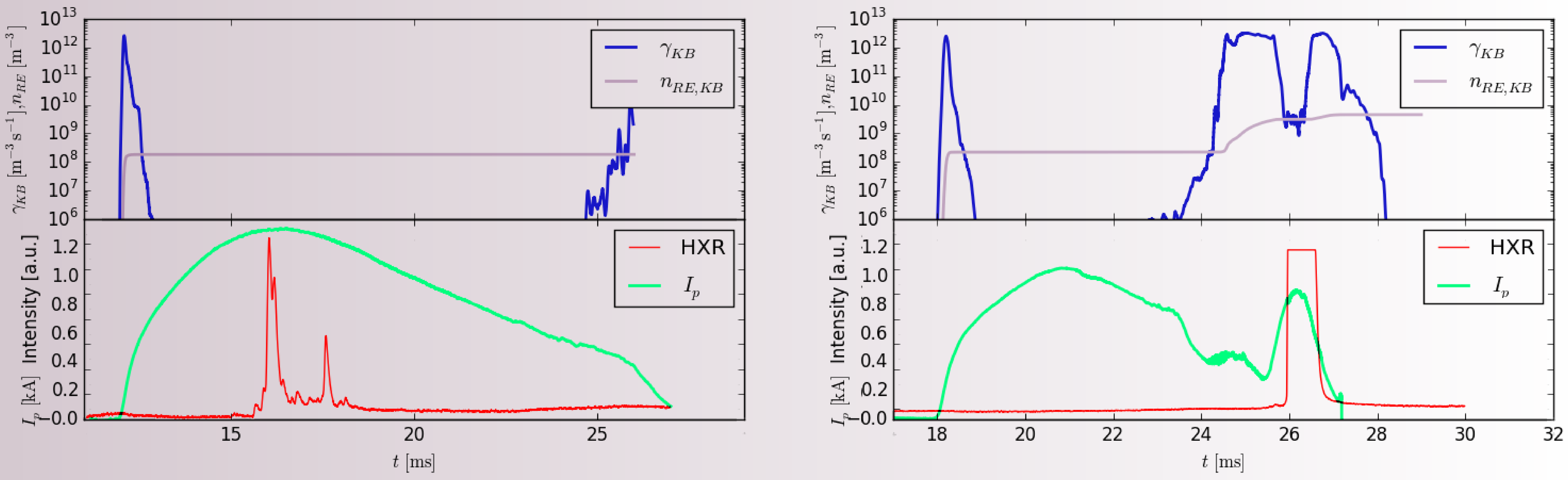
- Microwave plasma generated by the preionization has been examined after MW switch-off
- Relatively long confinement of plasma measured, probably due to the low electron temperature



Left: *Temporal evolution of the toroidal magnetic field and the microwave power. The ECR resonance occurs inside the vessel in the time interval t = 7.4 - 8.8 ms.* Center: *Temporal evolution of selected plasma parameters in the time interval, when MW power is already switched off.* Right: *IV characteristics constructed at t = 12 ms; Measured on a shot-to shot basis with the probe voltage changing between shots*

Runaway electrons

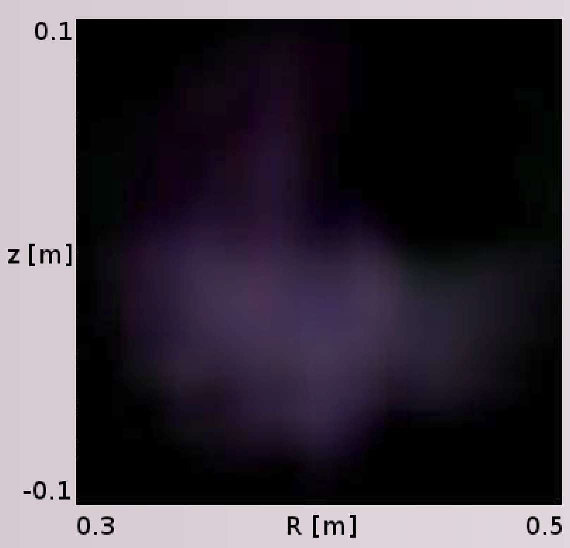
- A new NaI(Tl) scintillation detector with a photomultiplier tube was installed
- Kruskal-Bernstein criterion used for estimating the RE generation rate
- RE generation observed during the breakdown phase as well as during position instabilities
- Plasma recreation observed after the loss of RE (probably due to secondary electrons)



Left: *A shot with RE creation during breakdown (#18970).* Right: *A shot with RE occuring during a position instability (#18850); Plasma recreation can be observed.*

Visible light tomography

- Tomography is being calculated from the images captured by two fast cameras
- A new algorithm using the Tikhonov regularization has been developed; No assumption about the magnetic flux surfaces is made
- The reconstructions show a hollow profile during the main phase of the discharge
- The reflections from the walls seem to be the main source of artifacts



Left: *A tomographic reconstruction of the beginning of the shot #18731 (approximately 100 μs after the breakdown; The hollow emissivity profile is not yet formed).* Right: *A later phase of the same discharge.*