Measurement of edge plasma density by energetic beam of Li atoms on the COMPASS tokamak

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Motivation

- Scientific program of COMPASS tokamak is focused to H-mode physics.
- Measuremet of plasma parameters in pedestal region.
- The aim of lithium beam is to realize fast measurement of plasma density in pedestal region.
- The diagnostics is developed in cooperation with Hungarian Association Euratom - HAS.

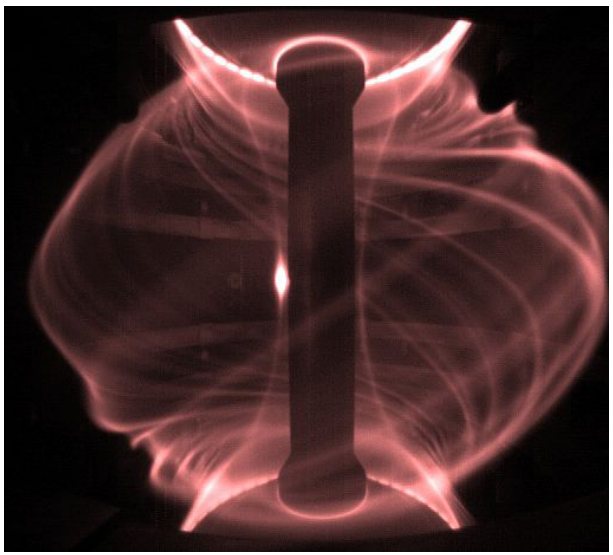

Figure: Edge localised mode - ELM

Lithium beam

Generally

- Device for BES (Beam Emission Spectroscopy) and ABP (Atomic Beam Probe).
- Low power (100 W) - measurement of edge plasma parameters.

Characteristics of BES

- Active spectroscopic method.
- Quasi-2D measurement of electron density fluctuation and radial profile of density.
- Spatial and time resolution.
- H_α spectral line close to observed 2s-2p transition spectral line in Li atom.

Beam parameters

Properties

- Acceleration of charge particles, neutralization, injection to tokamak vessel.
- Beam deflection ± 5 cm, frequence <400 kHz.
- Faraday cup used for background radiation measurement.

Parameters

- Current I=5-10mA, Energy of Li atoms E=20-120keV, Beam diameter d=2-3cm

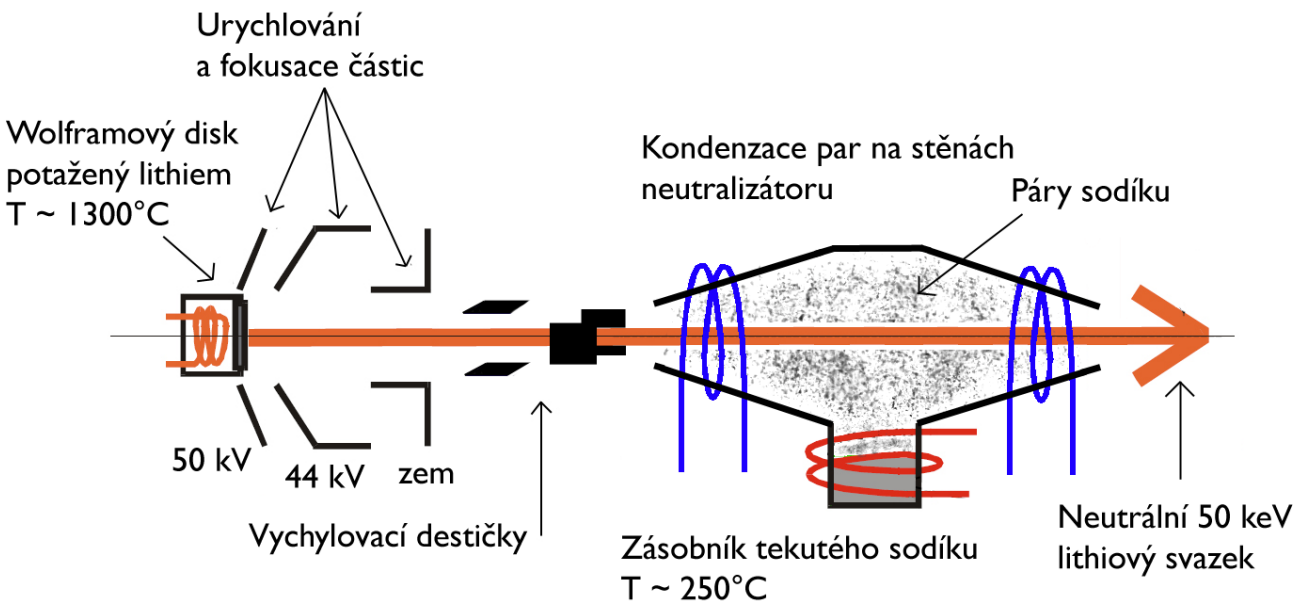

Figure: Schematic drawing of lithium beam device.

Experimental setup

- Detection of lithium spectral line 670,8 nm (2s-2p transition).
- Fast (avalanche photodiode, μs) and slow (CCD camera, 10ms) detection.
- ABP for lithium ion detection.

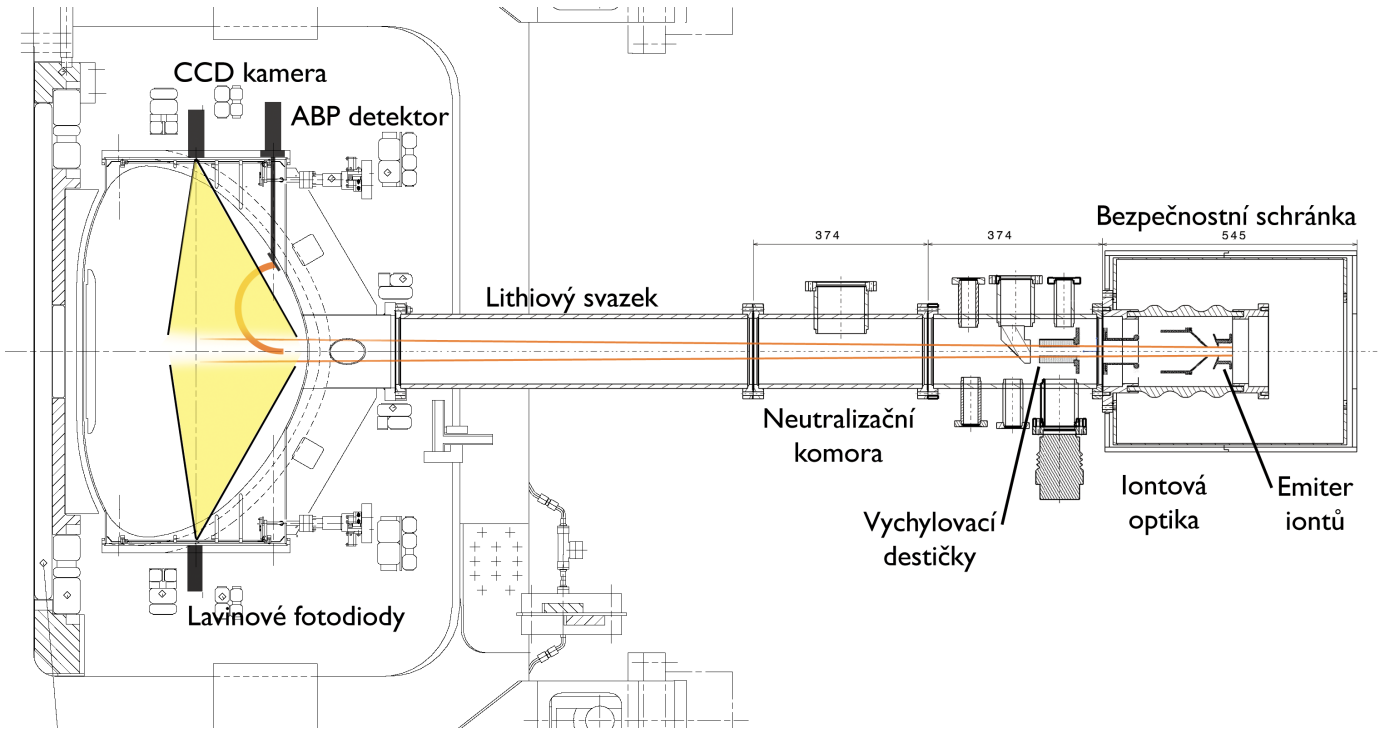

Figure: Experimental setup of lithium beam device and diagnostics device. Poloidal section.

Beam Emission Spectroscopy

Properties

- CCD camera with resolution 640x480 px and sampling frequence 100 Hz.
- Avalanche photodiode (APD) - 22 silicon detectors with efficient surface 25 mm^2 and time resolution a few μs.

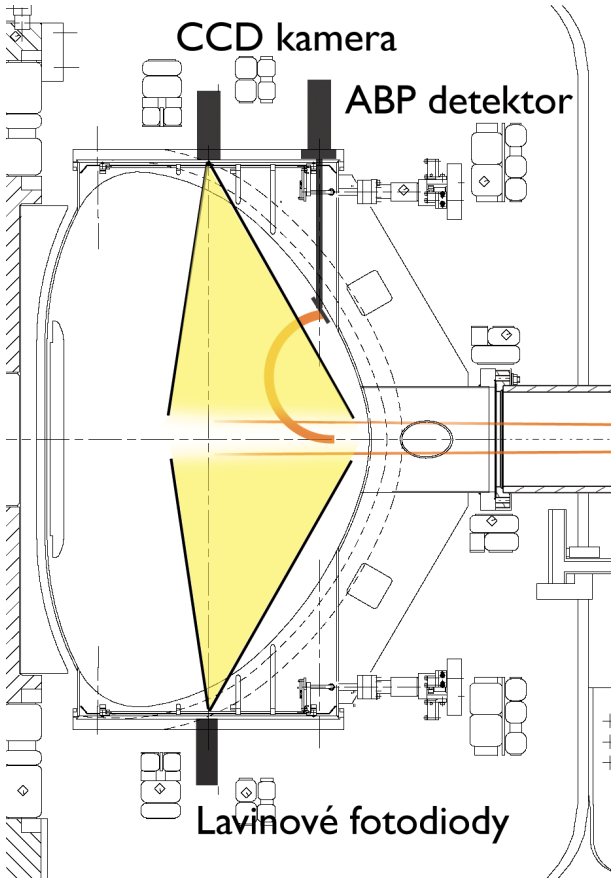

Figure: Diagnostics setup. Poloidal cut.

Beam Emission Spectroscopy

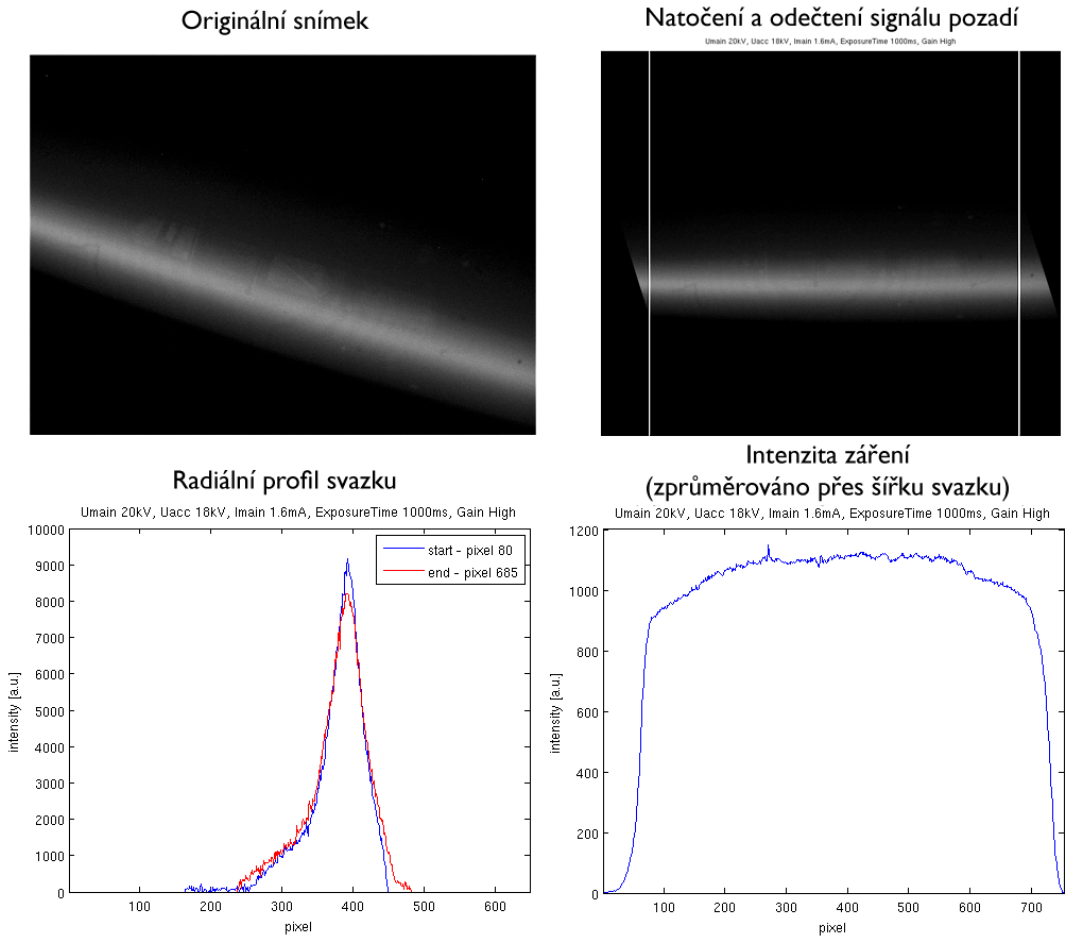

Figure: Picture from CCD: injection of Li ion beam into hydrogen gas. Accelerating voltage 18 kV, emitor current 1,6 mA, expozition 1000 ms.

Collisional-radiative model

The general equation which describes a population of state i is:

$$\frac{\partial}{\partial t} n_i = \sum_{j,j\neq i} \langle \sigma_{e,ji} v \rangle n_e n_j - \sum_{j,j\neq i} \langle \sigma_{e,ij} v \rangle n_e n_i + \sum_{j,j\neq i} \langle \sigma_{p,j\neq i} v \rangle n_{ion} n_j - \sum_{j,j\neq i} \langle \sigma_{p,ij} v \rangle n_{ion} n_i \quad (1)$$
$$+ \sum_{j,j>i} A_{ji} n_j - \sum_{j,j<i} A_{ij} n_i - \langle \sigma_{e\rightarrow ion,i} v \rangle n_e n_i - \langle \sigma_{p\rightarrow ion,i} v \rangle n_{ion} n_i - \langle \sigma_{cx,i} v \rangle n_{ion} n_i$$

The equation was simplified for the numerical calculation.

$$\frac{\partial}{\partial t} n_i = \sum_{j,j<i} \langle \sigma_{e,ji} v \rangle n_e n_j - \sum_{j,j>i} \langle \sigma_{e,ij} v \rangle n_e n_i + \sum_{j,j<i} \langle \sigma_{p,ij} v \rangle n_{ion} n_j - \sum_{j,j>i} \langle \sigma_{p,ij} v \rangle n_{ion} n_i \quad (2)$$
$$+ \sum_{j,j>i} A_{ji} n_j - \langle \sigma_{e\rightarrow ion,i} v \rangle n_e n_i - \langle \sigma_{p-eloss,i} v \rangle n_{ion} n_i$$

The equation 2 describes spatial evolution of population of state i. It is necessary to watch more than just 2s and 2p levels population because higher energetic levels have also influence to the lower energetic state. The system of the five ordinary differential equation is used for numerical calculations.

Program

The whole program consist of a few subprograms.

- RCEEtable.m and RCEItable.m - rate coefficients calculation
- isi.m - main code
- BESphoto.m - light profile from the CCD camera photo
- Last program uses genetic algorith to find correct input plasma density for program isi.m

Parameters		Euler method		RK4 method	
Number of points	Step size [cm]	Time [s]	Rel. error [%]	Time [s]	Rel. error [%]
400	0.055	0.072	1.2	0.0164	0.0928
800	0.0275	0.0149	0.6	0.0309	0.0252
1600	0.0137	0.0290	0.3	0.0616	0.0082
3200	0.0068	0.0572	0.15	0.1224	0.0018
6400	0.0034	0.1159	0.07	0.2471	0.0005

Table: Dependence of evaluation time and relative error on step size for Euler and RK4 method.

Genetic algorithm

- Forward run of a code is supplemented with GA.
- Serves for optimalization of finding correct input parameters (density profile).
- Uses principles of evolution biology - crossing, mutation.

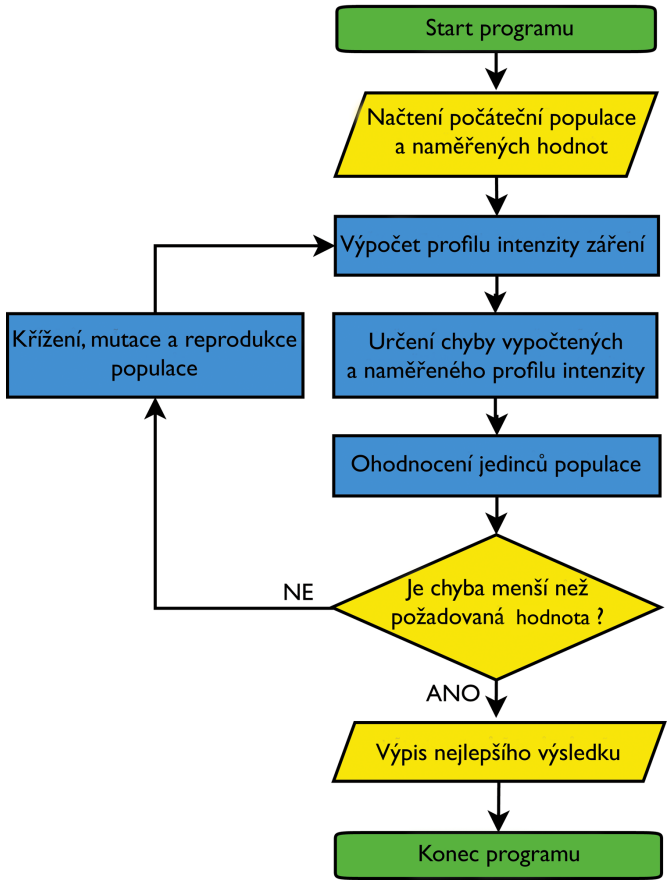

Figure: Flowchart of the program.

Results

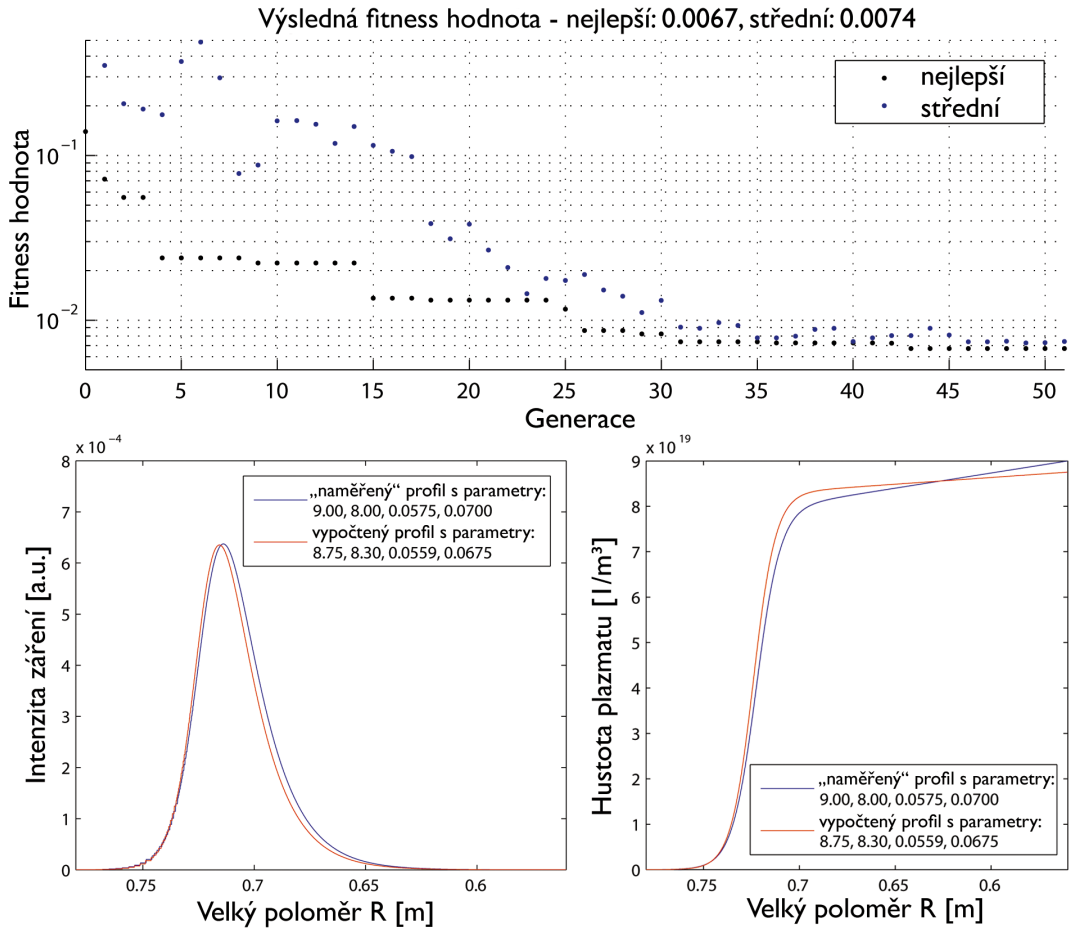

Figure: Evolution of fitness value and results of plasma density and light intensity. Population consist of 10 subject.

Thank you for your attention.