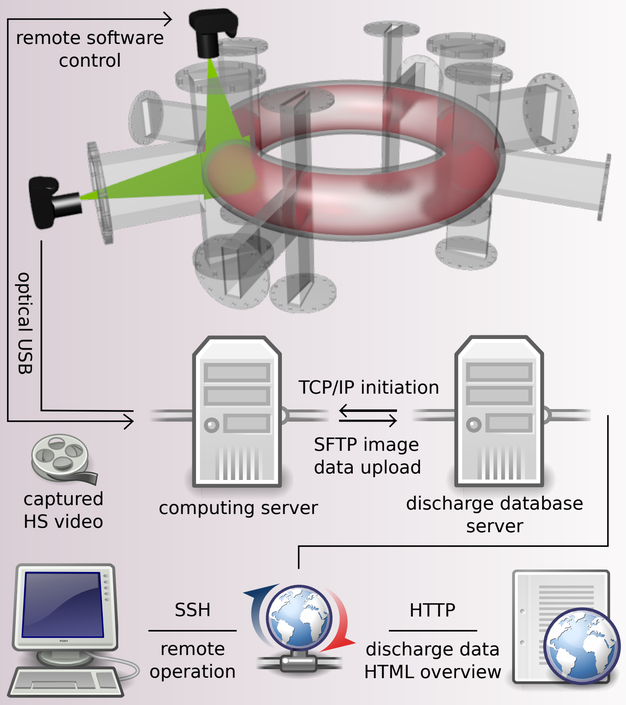
Low Cost Alternative of High Speed Visible Light Camera for Tokamak Experiments

T. Odstrčil[1], M. Odstrčil[1,2], O. Grover[1], V. Svoboda[1], I. Ďuran[1,2],J. Mlynář[1,2]
[1]Czech Technical University, FNSPE, Prague, CZ-115 19, Czech Republic
[2]Institute of Plasma Physics AS CR, CZ-182 21 Prague, Czech Republic

The GOLEM Tokamak



- Became an educational device for domestic as well as for foreign students via remote participation/handling.
- Operates routinely for nearly two years at a modest range of parameters $B_t < 0.5\,\mathrm{T}$, $I_p < 4\,\mathrm{kA}$, pulse length $< 15\,\mathrm{ms}$ with a limited set of diagnostics.
- Wide range of tasks with varying levels of complexity covering tokamak physics, technology and operation can be studied by the future fusion specialists.

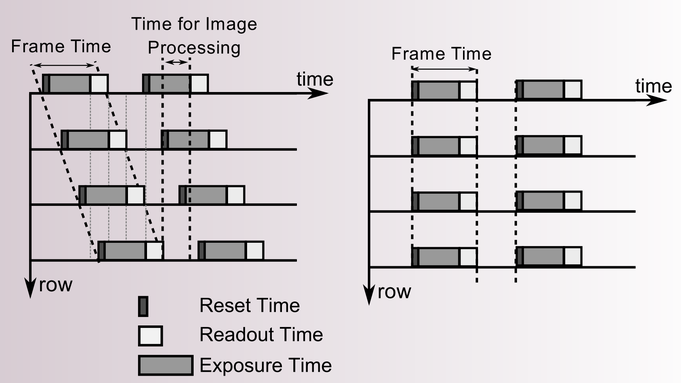
Casio EX-F1 high speed camera

Casio EX-F1 is a commercially available camera with high speed imaging capabilities.

Basic parameters:

- Price under 1000 USD
- 1/1.8 CMOS chip with 6 Mpix resolution
- frame-rate up to 1200 fps with resolution 336×96 pixels
- exposure time from 25 μs
- f-number 2.7
- RGB 8-bit output
- Dynamics range 300 (ISO 800)

Rolling shutter effect: 336×1 at 40 000 fps



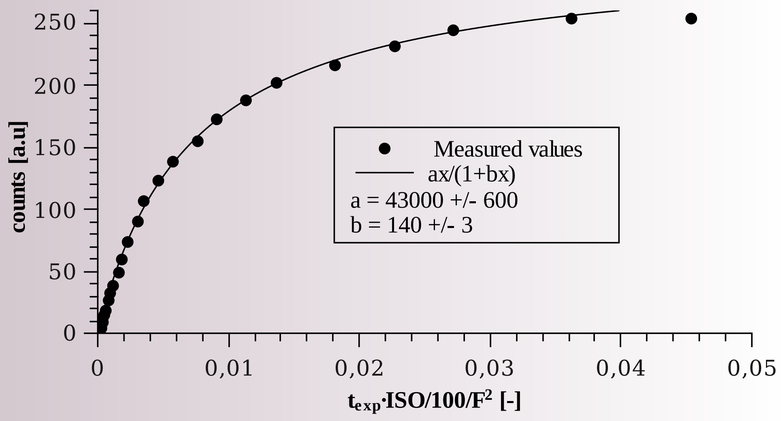
A simplified example of the image readout timing in the rolling shutter mode in the case of the CMOS chip (left) and the CCD chip (right). Each box corresponds to processing time for one row.

Casio EX-F1 – Details

Nonlinearity correction

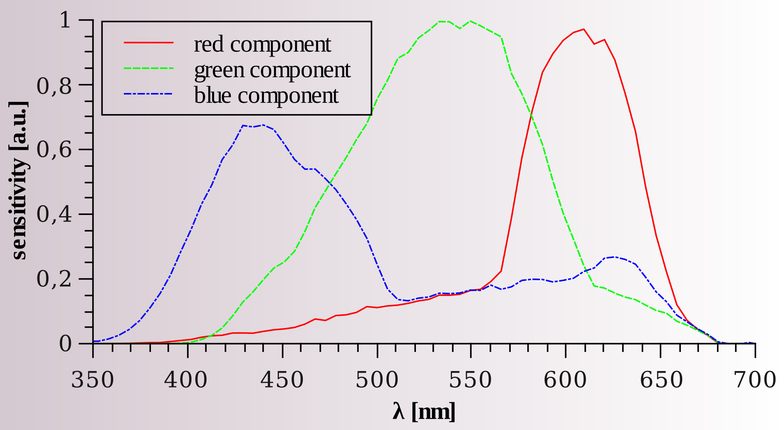
$y = x/(bx + a)$

$a = 43000 \pm 600$, $b = 140 \pm 3$



Nonlinear response function allows to extend the dynamic range

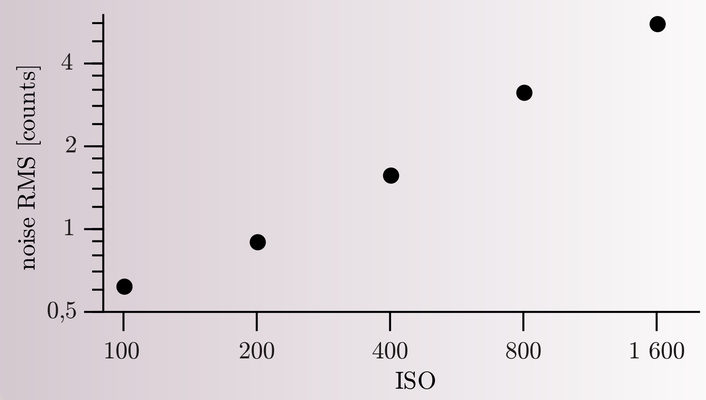
Spectral response



Spectral sensitivity of the camera CMOS sensor with firmware adjustments

Detector noise

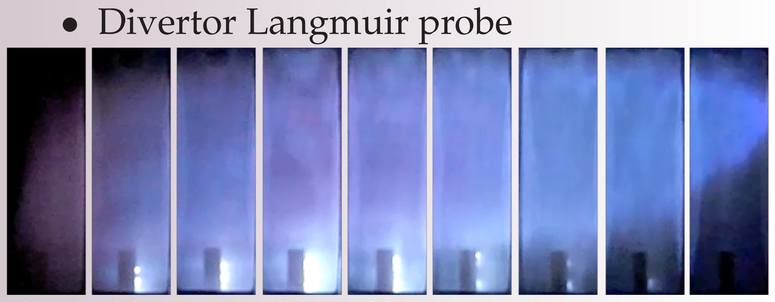
For a high speed application with short exposure time light intensity is critical. Signal intensity can be improved using a preamplifier up to 16×.



Langmuir probes observation

This camera is a universal tool for observing interaction between plasma and probe diagnostics

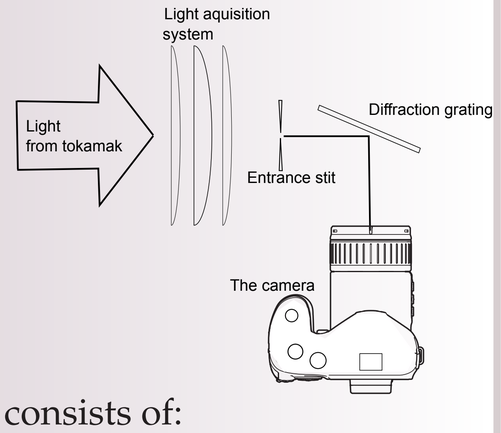
- Rake probe (multiple Langmuir probes)
- Ring of Langmuir probes
- Reciprocal probe
- Divertor Langmuir probe



An example of time evolution of the arc discharge between the rake probe and the tokamak chamber in shot #7509.

Low-cost fast spectrometer

Simplified scheme of the spectrometer

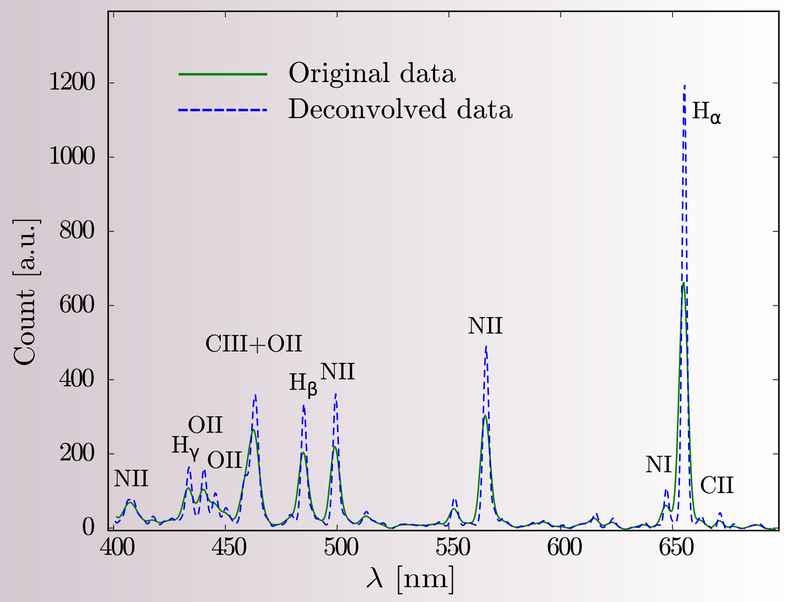


The spectrometer consists of:

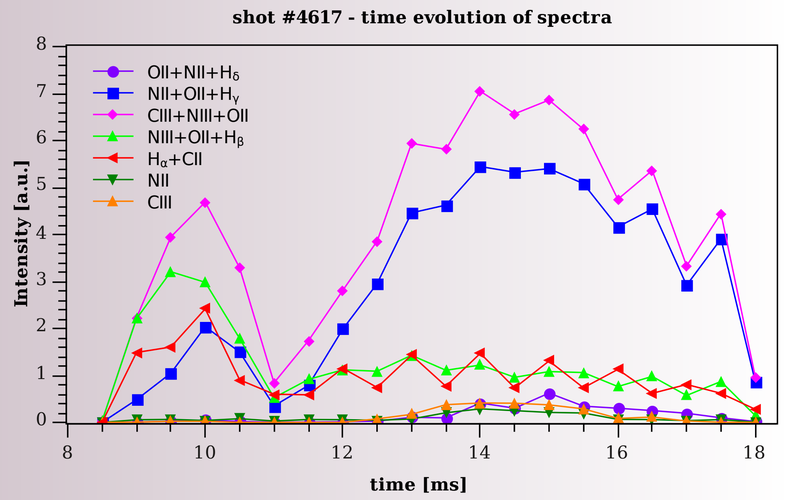
- light collecting lens
  - diameter 15 cm
  - output focal length: 10 cm
- aluminum coated ruled grating
  - 1200 grooves/mm
  - size: 7×6 cm.

Basic spectrometer parameters:

- Resolution power: $\lambda/\mathrm{d}\lambda \approx 200$
- Dynamic range: 3000
- Time resolution $\leq 5\,\mathrm{kHz}$
- Range: visible light spectrum



Resulting spectrum from discharge #4615. Distortion of the image was caused by a curved projection of the slit onto the detector and was corrected using 2D deconvolution based on the Tikhonov regularization.



Time evolution of spectrum from discharge #4617.

Contact us

Tokamak GOLEM
Brehova 7, Prague
Czech Republic
golem.fjfi.cvut.cz
svoboda@fjfi.cvut.cz