Laser plasma generation and real-time diagnostics at Wigner Research Center

Miklós Á. Kedves

Department of Plasma Physics
Wigner Research Center for Physics

Contributors:
G.P. Djotyan, B. Ráczkevi, J.S. Bakos, Zs. Sörlei, P.N. Ignácz, J. Szigeti, T. Brigancz, K. Varga-Umbrich, I. Barna, M. Pocsai, A. Czitrovszky, P.Dombi, P. Rácz

Outline

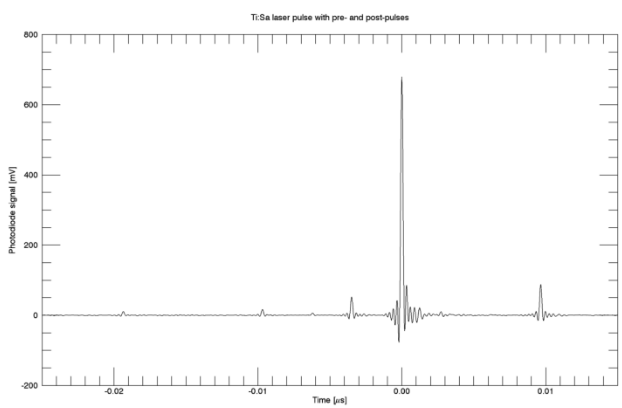
- Introduction
  - Motivation, goals
  - Technique
    - Experimental arrangements
    - Construction of the Rb plasma cell
    - Ti:Sapphire laser
- Measurements
  - Laser ionization of Rb atoms
    - Ion detection
  - Laser plasma generation in Rb vapor
    - The plasma cell
    - Spectroscopic observations
    - Absorption (transmission) measurements with:
      - Fast photodetectors
      - Fast cameras
- Summary and further plans

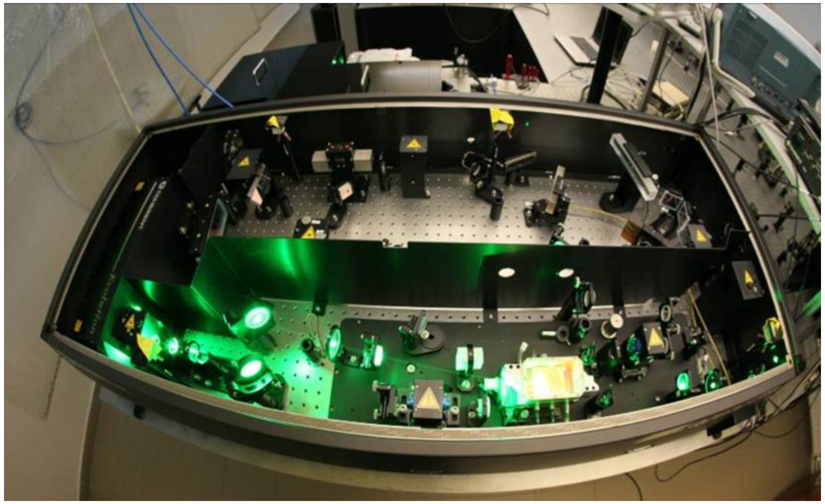
Introduction

- Motivation, goals
  - Develop diagnostic methods for studying the plasma formation process by the fs laser pulse
  - Time-resolved measurements
  - Spatially resolved measurements
  - Investigate the ionization of Rubidium
  - Study the propagation of the laser through the medium
  - Work out methods for decreasing the intensity requirement : pre-excitation, chirped pulses

Introduction

- Ti:Sapphire laser (courtesy of SZFI-group)
  - Home-made oscillator
  - Coherent Legend Elite amplifier
  - Pulse energy 3.5-4 mJ (max)
  - Pulse length: 35-40 fs
  - Repetition rate: 1 kHz
  - Laser pulse shape





  - Courtesy of: A. Czitrovszky,P. Dombi, P. Rácz, I Márton

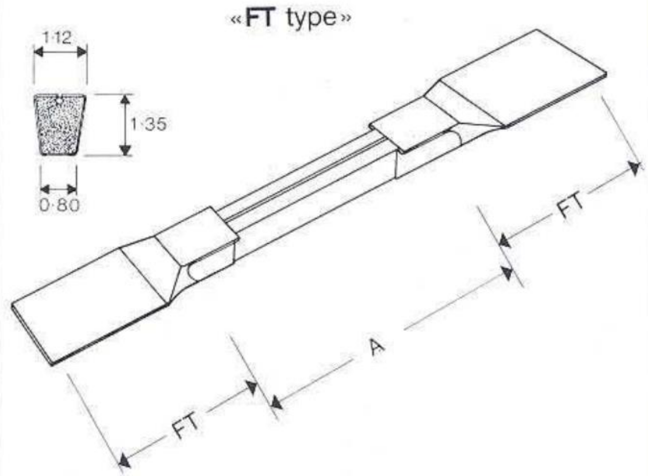
Introduction

- Experimental arrangements
  - Ionization studies
    - Source: Rb-dispenser
    - Detection: ions with MCP
  - Extended Rubidium plasma studies
    - Source: Rb vapor cell
    - Detection: optical
- Construction of the Rb plasma cell
  - Trade-off: spatially resolved observation → sacrificing homogeneity

Measurements

- Laser ionization of Rb atoms
  - Source: Rb-dispenser wire

    Chemical compound of Rb



Specification

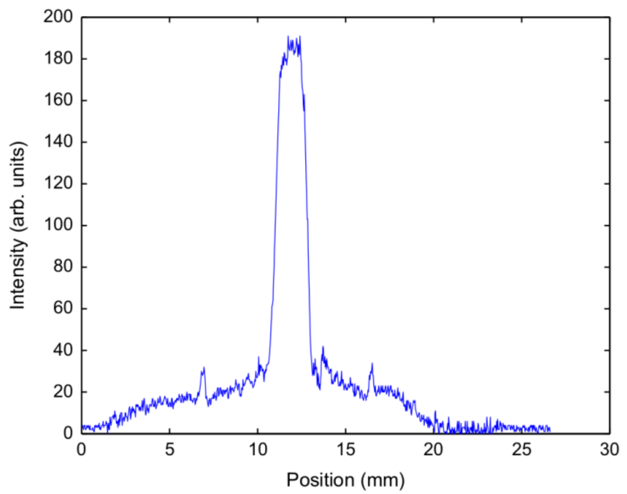
Activation current	4.5-7.5 A
Max degassing temperature	500°C
Standard active lengths	12-17-25-40 mm
Minimum bending radius	40 mm

SAES

Alkali metal		Content (mg)			Start of evaporation (Amp)*		
		A= 12 mm	A= 17 mm	A= 25 mm	Average	Standard Deviation	
Caesium	Cs	5.2	7.3	10.8	4.7	0.2	Standard Production
Potassium	K	2.9	4.1	6.0	5.3	0.2	
Sodium	Na	1.7	2.4	3.5	6.0	0.2	
Rubidium	Rb	4.5	6.4	9.4	5.3	0.2	Only on Request
Lithium	Li	0.8	1.1	1.7	7.3	0.2	

Measurements

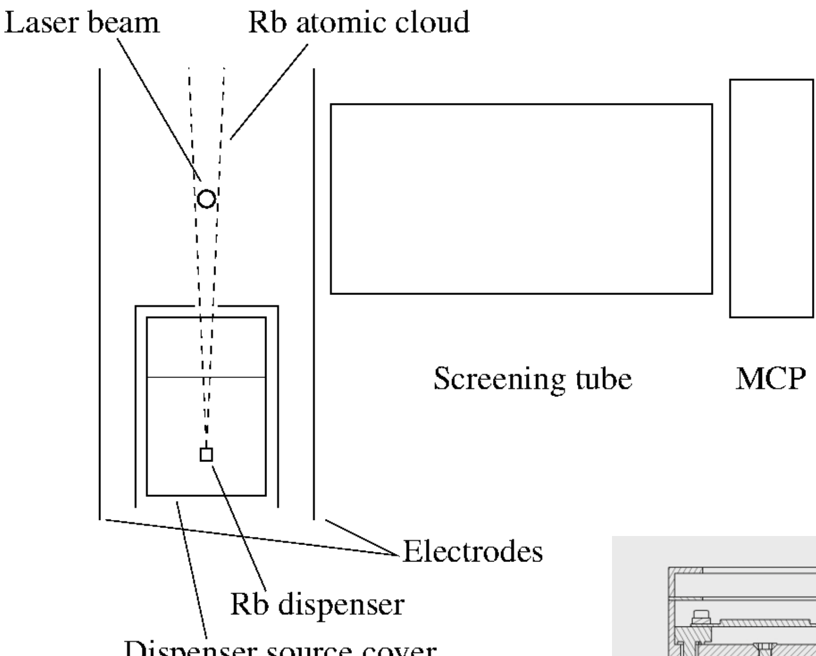
- Laser ionization of Rb atoms
  - Source: Rb-dispenser wire
    - Advantages:
      - Easy to use
      - Clean (apparently)
      - May be intense enough (emission of about 10^{18} atoms/min/cm)
    - Disadvantages:
      - Emission has a spatial distribution
      - Homogeneity???
    - Emission characteristics:
      - Measured by fluorescence
      - Transverse width about 1.8 mm



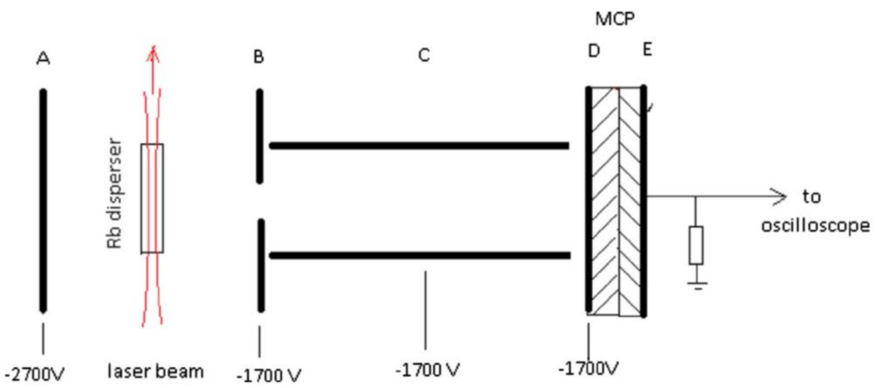
Measurements

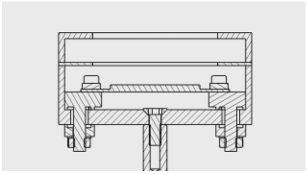
- Laser ionization of Rb atoms
  - Experimental setup

Side view



Top view





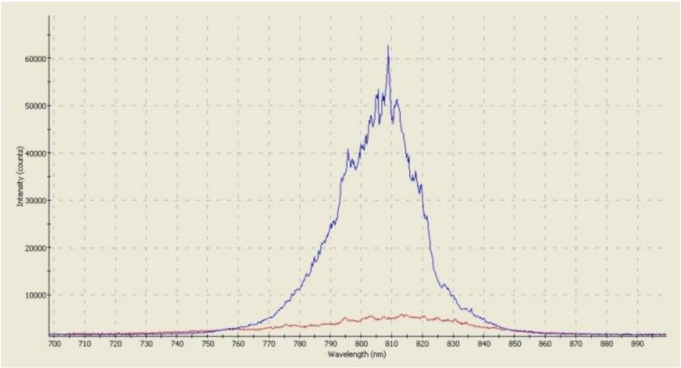
Dispenser box

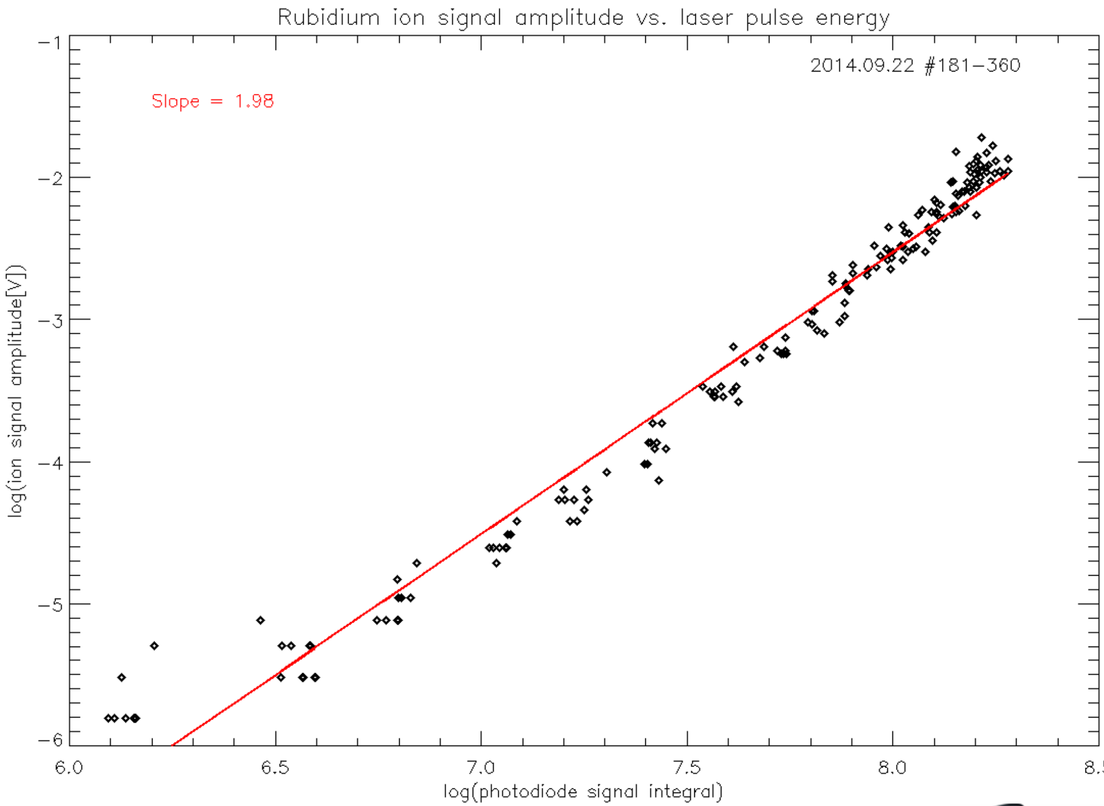
Measurements

- Laser ionization of Rb atoms
  - Results: ionization dependence on laser intensity

Slope: ~ 2

Resonant excited level, laser spectrum overlaps With the D-lines of RB





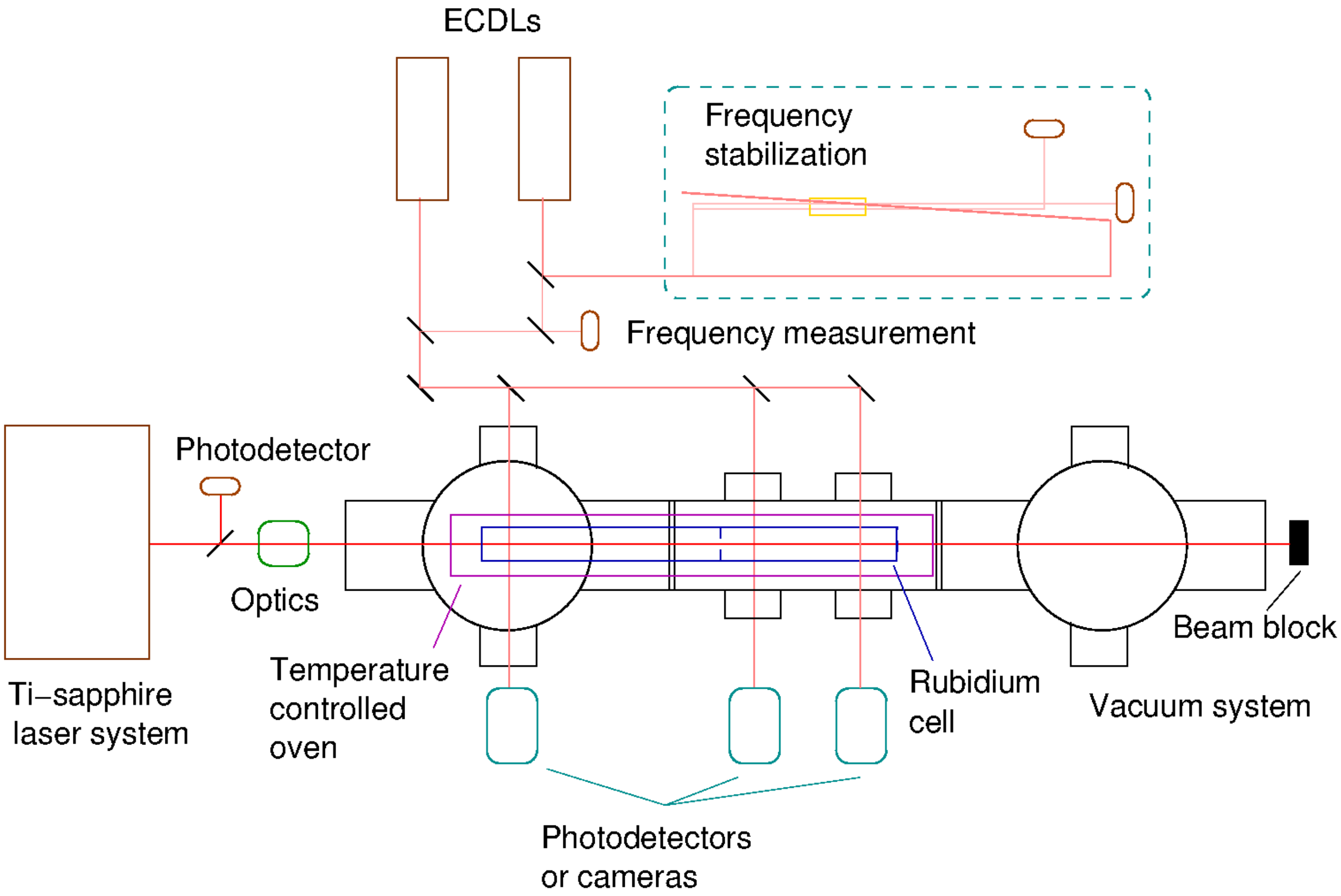
Maximum laser intensity: 10^{11} W/cm^2

Measurements

- Laser plasma generation in Rb vapor
  - Experimental setup
    - Source: Rb vapor cell
      - Quartz or glass tube of 25 mm outer diameter
      - Length 25 and 75 cm
      - Temperature controlled oven
    - Longitudinal ionizing beam (Ti:Sapphire laser)
    - Observation in the transverse direction through windows at several longitudinal locations
    - Absorption (transmission) measurements with ECDLs (Toptica DL100, New Focus Velocity TLB-6721)
    - Optical measurements using fast photodetectors, photodetector array (APDCAM), image intensified CCD camera, fast spectrometer

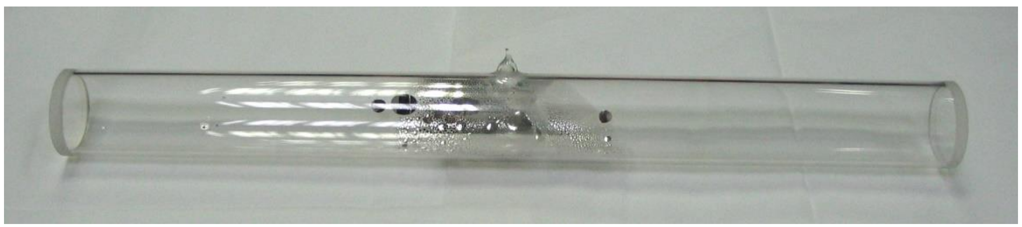
Measurements

– Experimental setup



Measurements

– The plasma cell
  - Quartz: 25 cm long, (company-filled), AR-coated
  - Glass: 75 cm long (home-filled)



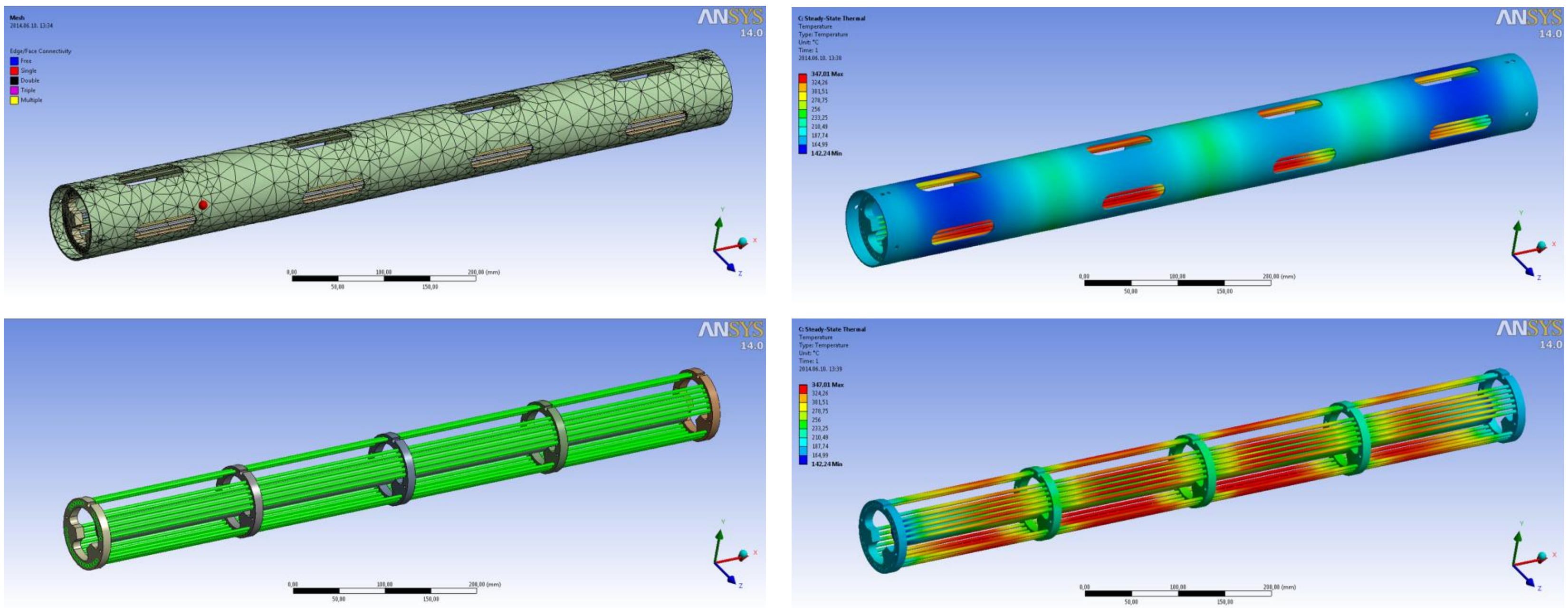
– Oven
  - Longitudinal heating wires
  - Heat reflector steel tube
  - Temperature measurement using PT100 resistance thermometers
  - Observation windows

Courtesy A. Bendefy (BME)

Measurements

– Oven temperature distribution
  - Calculated by finite element method

Courtesy A. Bendefy (BME)

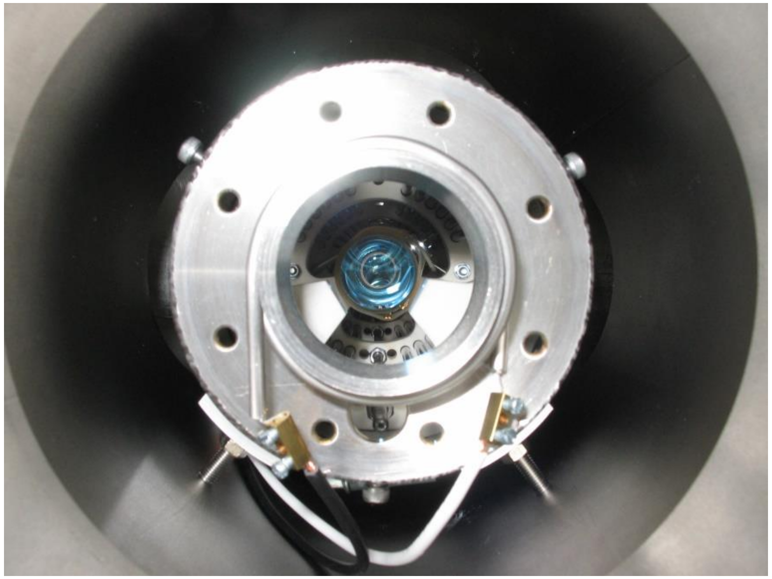


Temperature inhomogeneity: original design: several 10 degrees
Improved construction with extra end heatings: few degrees (max 5-10)

Measurements

– Oven
  - Cell with heating wires

Cell inside the heat reflector tube, placed into the vacuum system



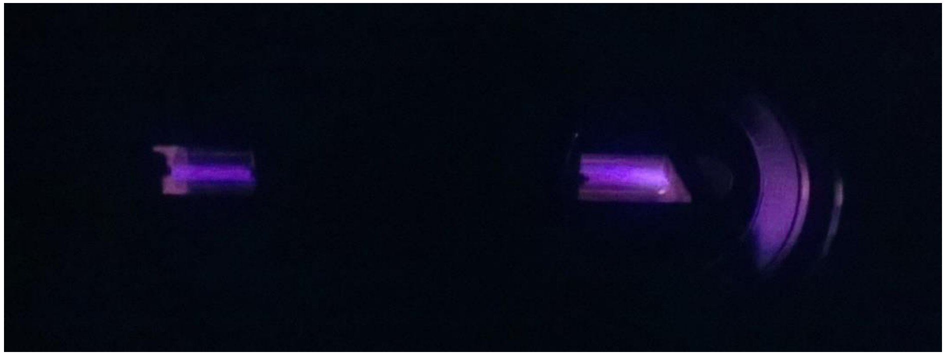
Measurements

– Spectroscopic observations

- Detection of the radiation of the plasma by a fast spectrograph (Andor Mechelle 5000)
- High spectral resolution (0.05 nm accuracy)
- High temporal resolution with intensified camera (~ ns)

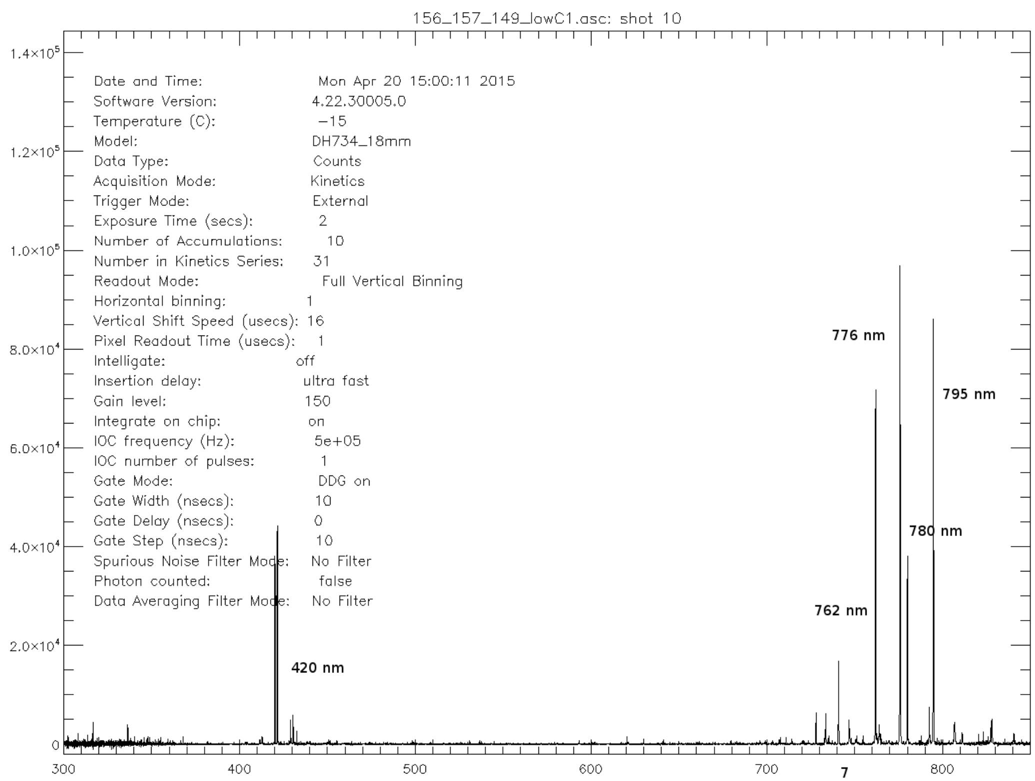
(Spectrograph courtesy of L. Kocsányi (BME), and help with the measurements R. Bolla (WRCP))

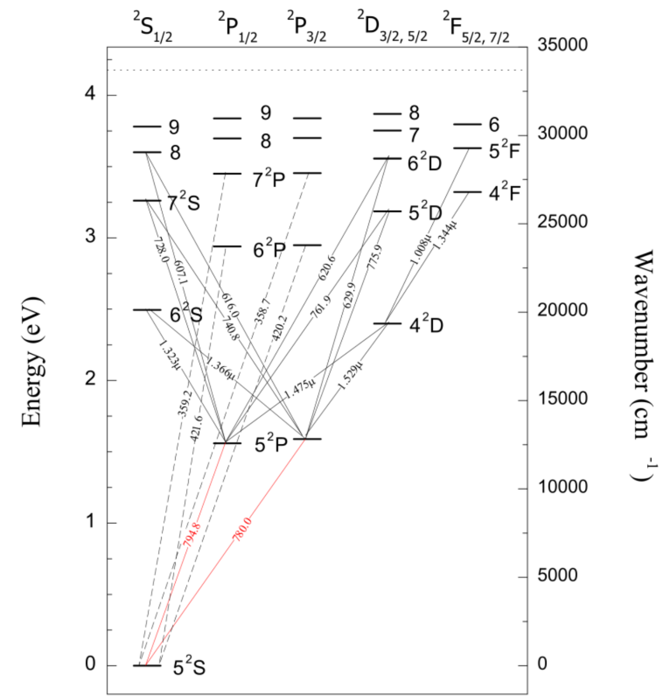
– Picture of the plasma



Measurements

– Spectroscopic observations





Rubidium

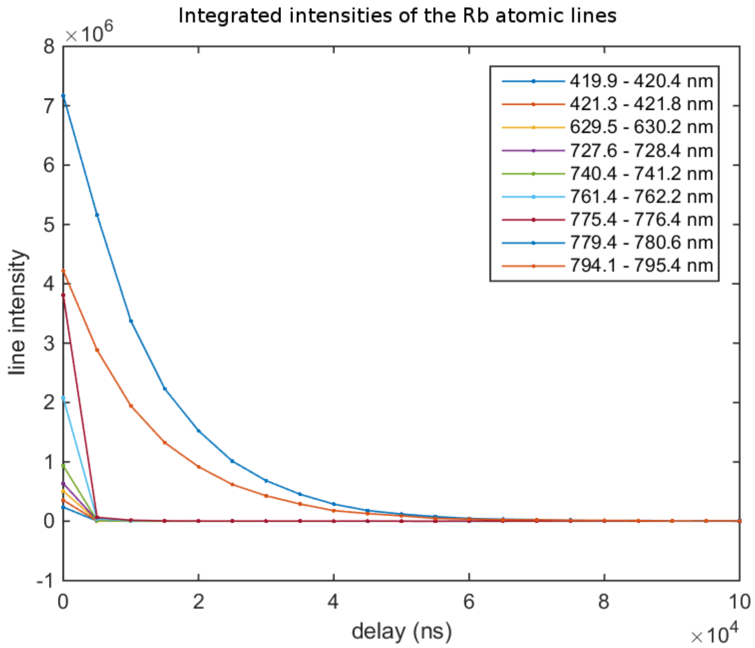
Z : 37 Ioniz. Pot. : 4.176 eV

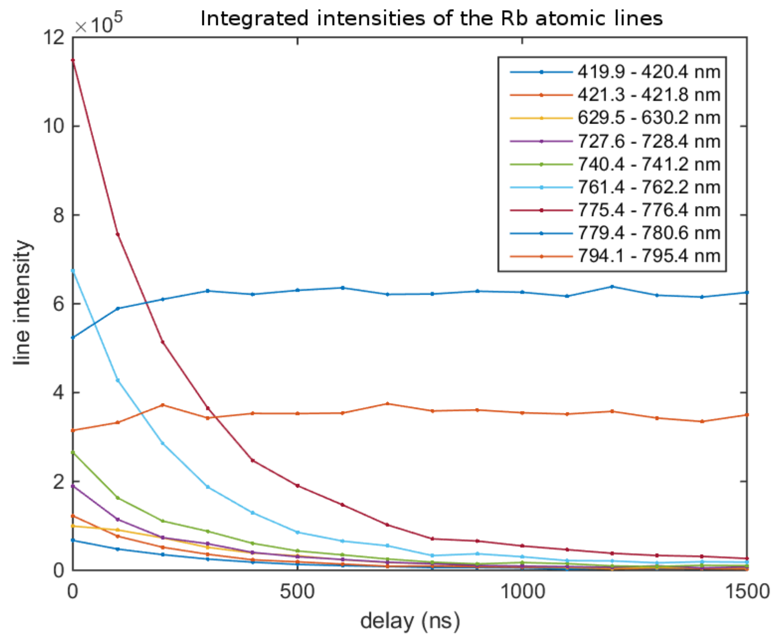
ground state : 1 $s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 5s$

Measurements

– Spectroscopic observations

  • Time dependence of the spectral emissions

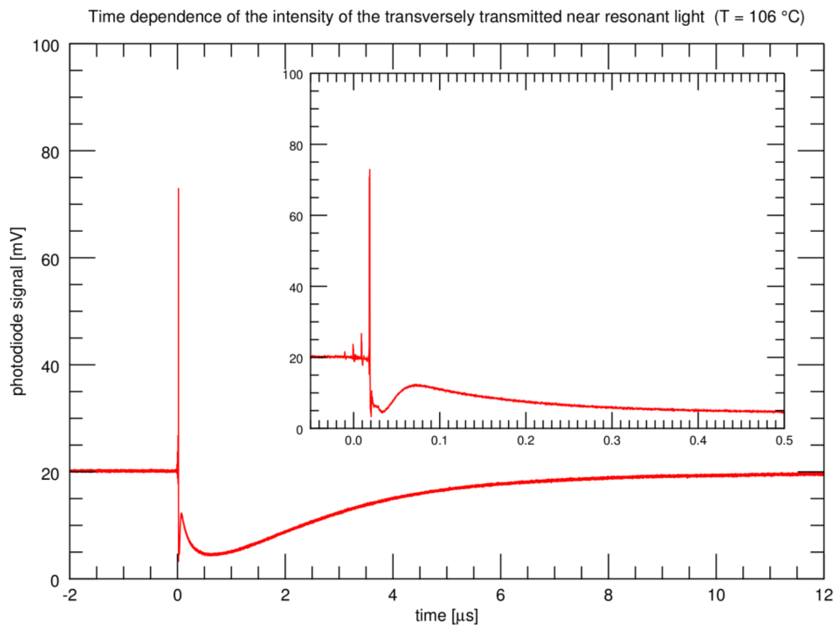




Measurements

– Absorption (transmission) measurements

- Time resolved transmission signal detected with fast photodetectors (New Focus 1591NF): 4.5 GHz
- Typical transmission signal:



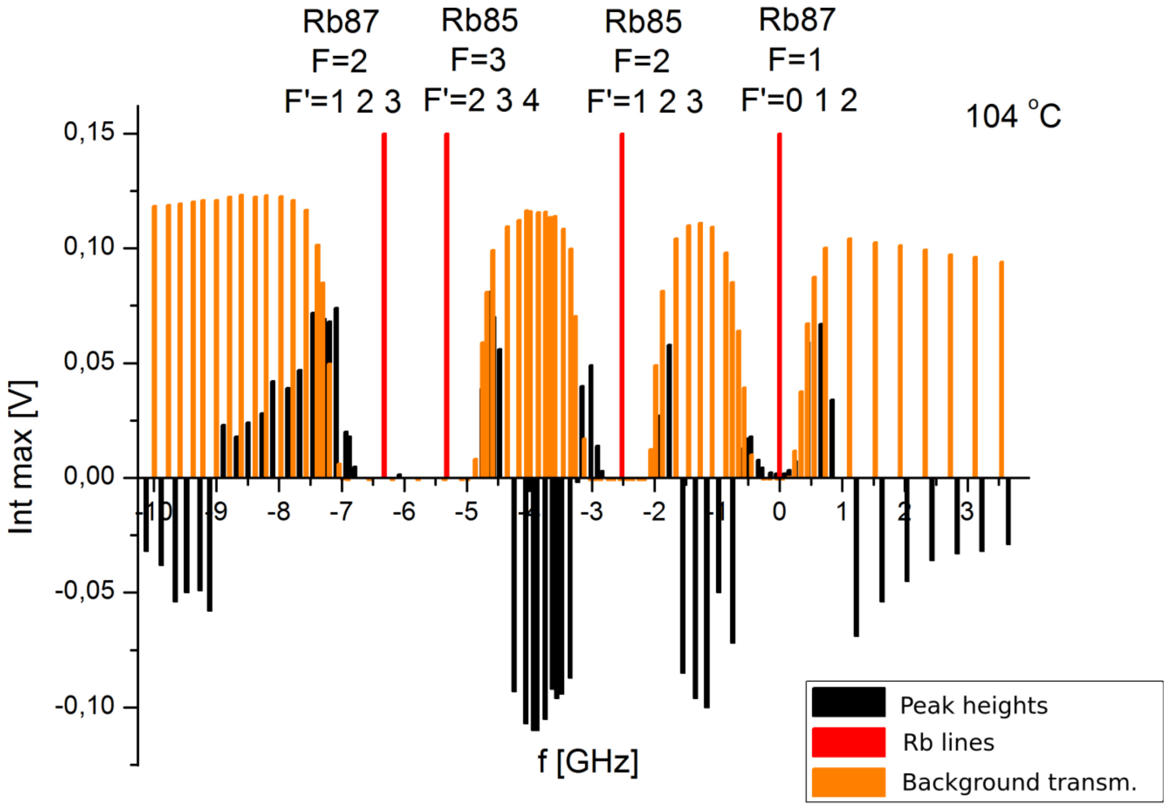
Interpretation of the components of the signal:

- Very fast peak: AC Stark shift
- 10 ns decay: atomic relaxation
- Slow (1-10 microsec) decay: plasma relaxation

Decrease of transmission is attributed to reflection on the boundaries of the plasma channel.

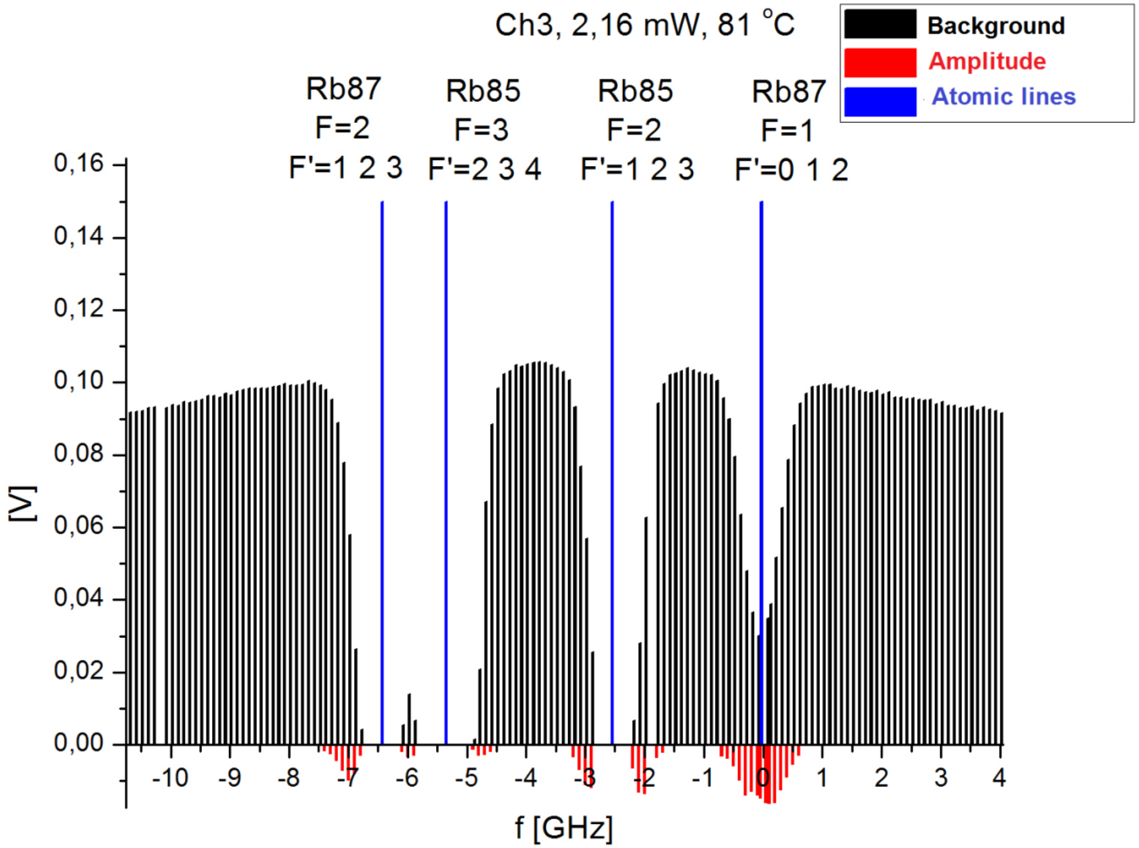
Measurements

– Dependence of the fast peak maxima on the laser frequency



Measurements

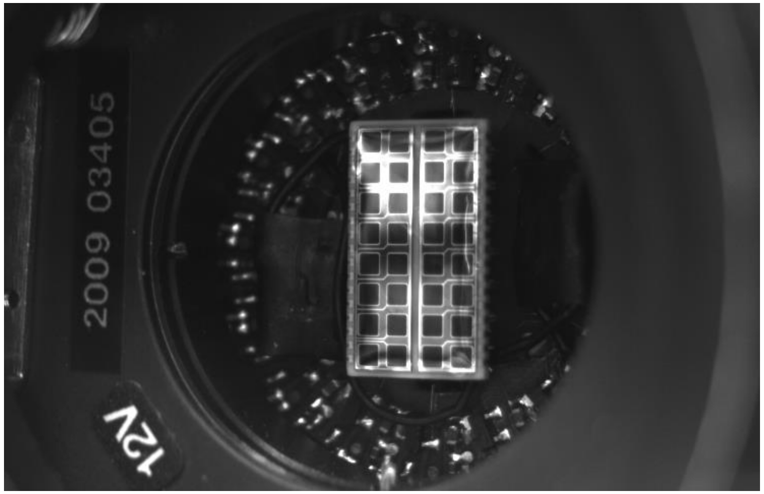
– Dependence of slow relaxation component on the laser frequency



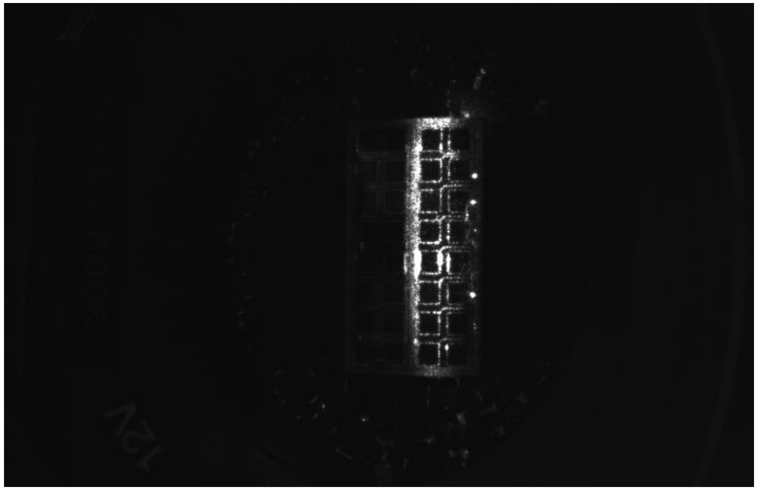
- Amplitude of the slow relaxation component follows the spectral lines of the atom: refractive index is dependent on the frequency

Measurements

- Measurements with an APD camera (Avalanche Photodiode Array) (Courtesy of S. Zoletnik, WRCP)



- 4x8 array of avalanche photodiodes (Hamamatsu S8550)
- Very high sensitivity
- Sampling rate 1 Msamples/sec at each channel

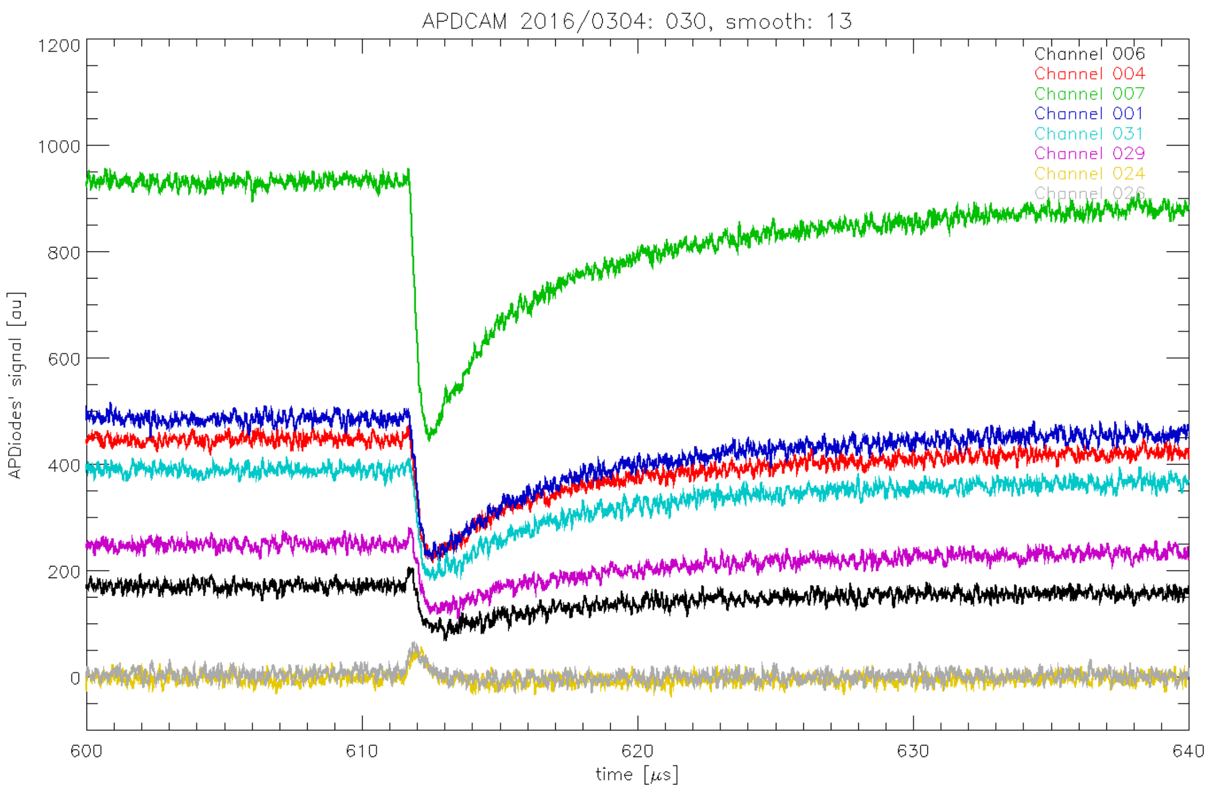


Distribution of the laser transmitted beam on the detector array

Measurements

- Measurements with an APD camera

  Result: time-, and spatially dependent transmission signals



- Transmission dependence on the vertical position in the beam
- May indicate the refraction of the beam, correcponding to refractive index changes

Summary

- Optical diagnostic tools have been used for detecting the formation of the laser plasma
- Indirect indications of the plasma channel have been observed
- Dependence of the observed features on the temperature, density, laser intensity are under study

Further plans

- Installation of new Rb cells equipped with electrodes for measuring the changed particles directly

- Comparison of the optical observations with the detection of the plasma electrons
- Improve the temperature homogeneity with efficient additional heating the cell ends, and installing heat-reflective windows at the side openings of the reflector tube
- New Ti:Sapphire laser with 25 mJ of pulse energy at 10 Hz

Thank you very much for your attention!