Plans & Outlook 2021-

Most obvious and immediate:

- Publish PRA paper – revisions needed, referees not malicious, but did not understand some points well, need to clarify
- Evaluate data of April data taking run
- Do matching calculations with improved model – requires some time though
- Do Rb ionization measurements (at Wigner, without propagation)

Plans & Outlook 2021-

Longer term:

Propagation:

- Study multifilamentation
- Improved output diagnostics – gated spectrometer, FROG
- Compressor offset, chirped pulse
- Blue laser plasma diagnostics

Prepare for “Life after Josh”:

- Take part in July preparation & data taking? (Help out, get acquainted with replacement, get update on changes)

Longitudinal probing of the plasma densityin laser ionized rubidium vapor by near-resonant absorption

Measurement principle

- Ionizing Ti-Sapphire laser beam propagating longitudinally through the Rb-cell
- Counter-propagating quasi-resonant diode laser beam
- Detection of the transmitted probe laser beam:
  - Versus time: fast photodetector
  - Lateral distribution: gated camera
  - Measurement of the attenuation of the beam intensity:
    - Naive picture: resonant light in vapor – no transmission
vapor fully ionized – full transmission
    - Realistic picture: (full) transmission cannot be expected (at resonance)
detuned frequency and calculation of the ionzation rate is necessary

    Near-resonant frequency where transmission through the vapor is still detectable necessary.

  - Probe laser beam is propagating in (possibly non-homogenous) residual vapor → deflection, focusing/defocusing possible

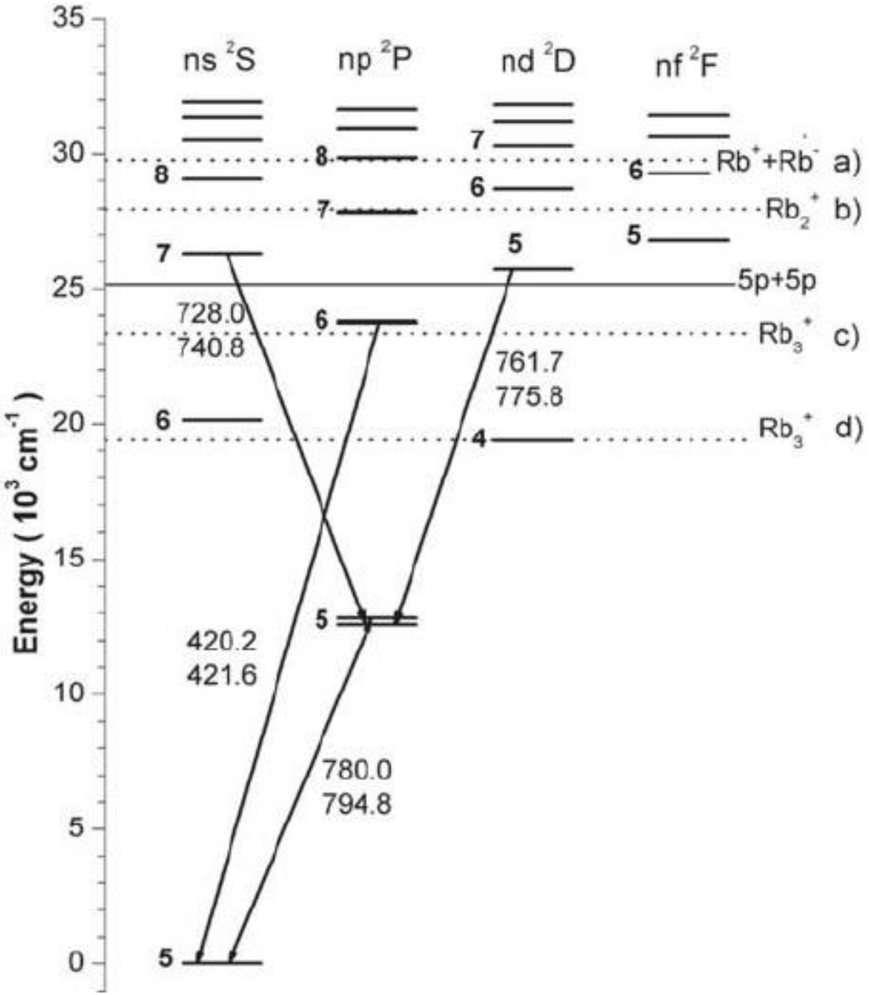
Calculation of the vapor density from the transmitted intensity in the linear absorption regime:

- Lambert-Beer: $I_{transm} = I_0 \cdot e^{-\alpha(\omega,N)\cdot L}$
- $\alpha(\omega, N) \approx \alpha(\omega) \cdot N$
- Ionization rate:

$$\frac{N_{vapor} - N_{plasma}}{N_{vapor} - N_{residual}} = \frac{\ln(I_{plasma}/I_{vapor})}{\ln(I_{residual}/I_{vapor})} = 1 - \frac{N_{plasma}}{N_{vapor}}$$

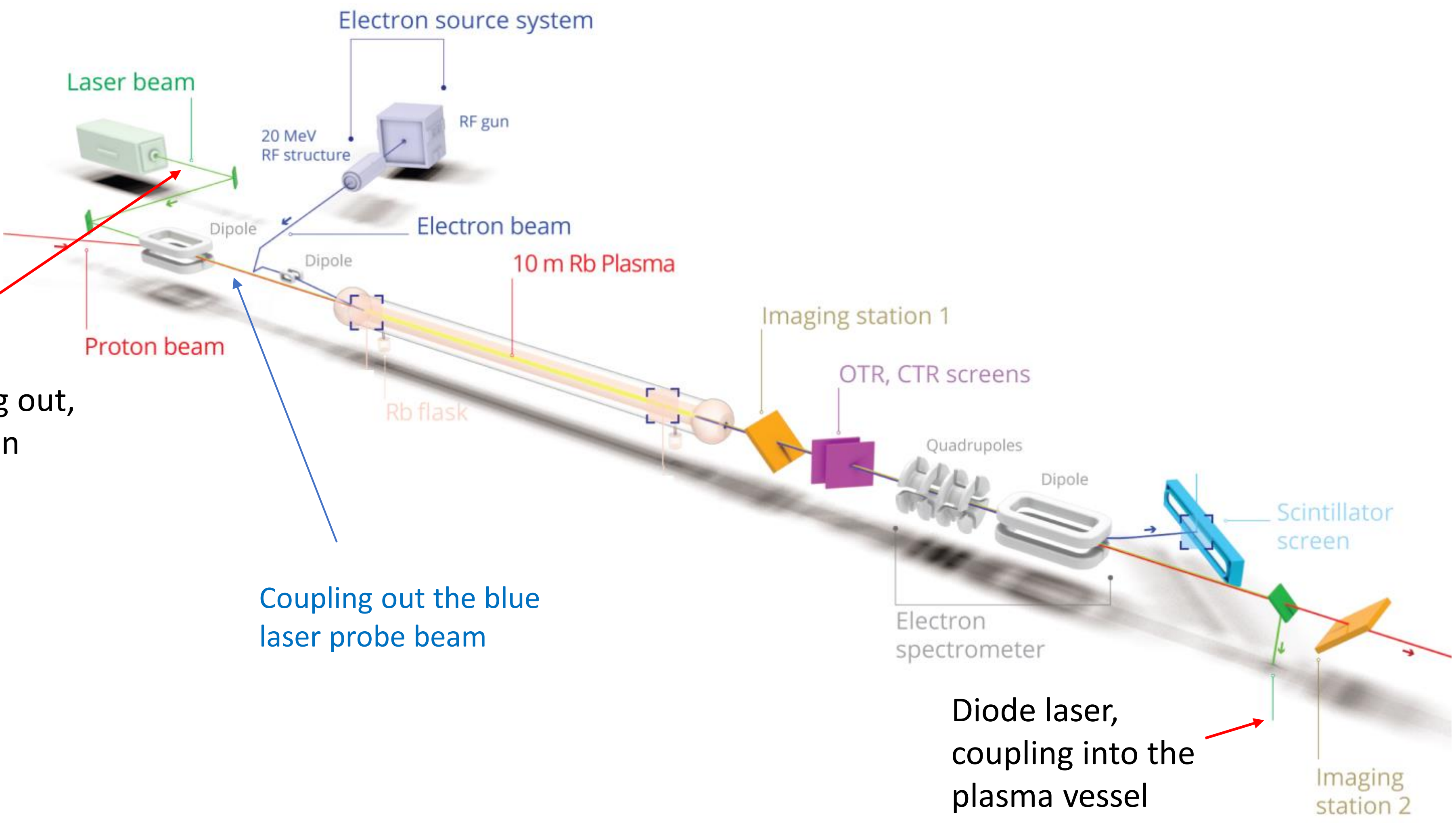
where $N_{vapor}, N_{plasma}, N_{residual}$ are the (ground state) atomic densities in the different media.

Energy level diagram of the Rb atom



Rb2 diffuse band emission excited by diode lasers
T. Bana, D. Aumiler, R. Beuc, and G. Pichler
Eur. Phys. J. D 30, 57–64 (2004)

First experiments at the AWAKE facility

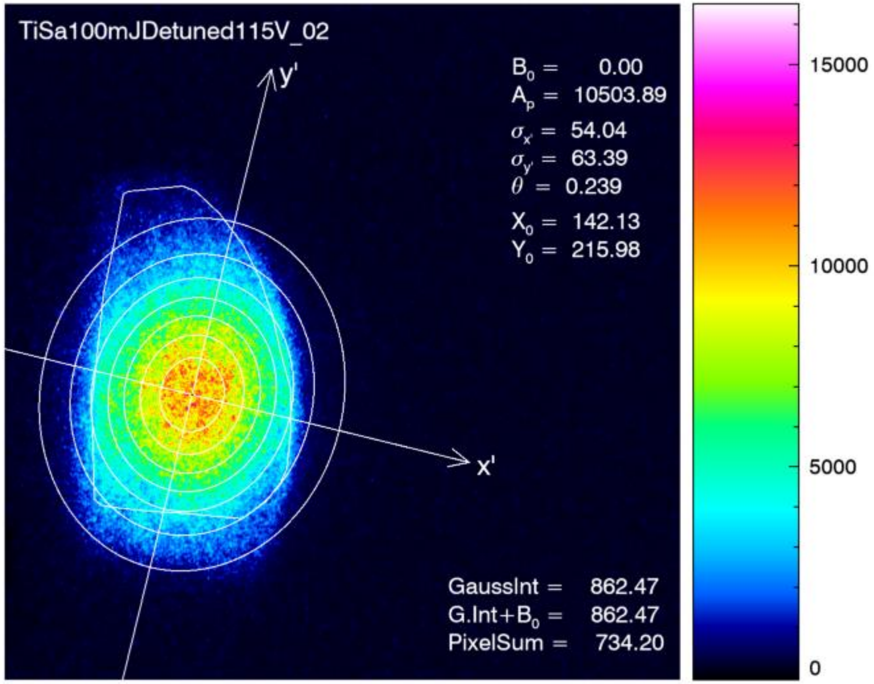


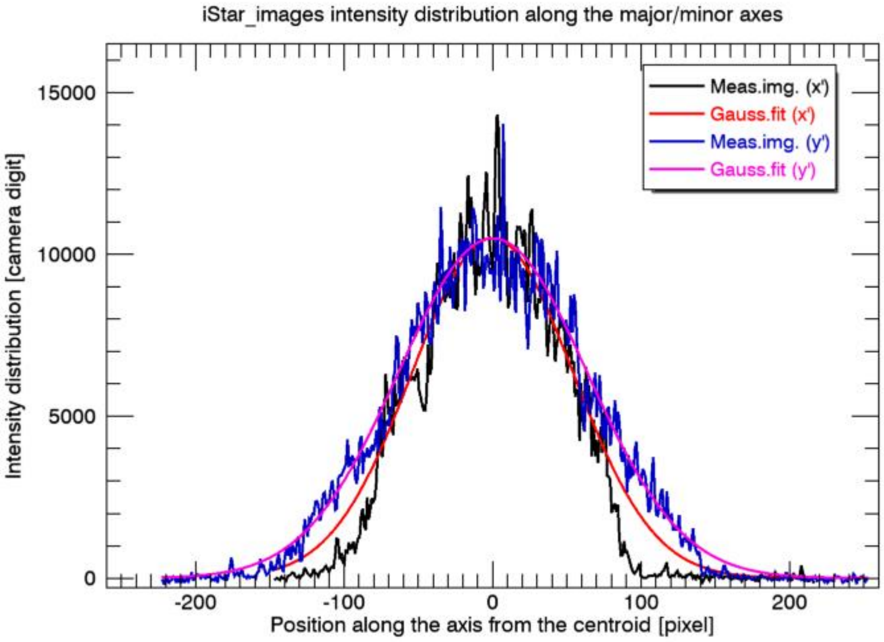
Coupling out, detection

Coupling out the blue laser probe beam

Diode laser, coupling into the plasma vessel

Transmitted probe laser beam signal





Conclusions

- Advantages:
  - Feasibility of the method could be demostrated
  - Detection of the disappearance of the (ground state) atoms and calculation of the ionization rate is possible
  - Relatively simple to implement

- Difficulties:
  - Overlap of the ionizing and probe beams is critical, jitter of the pointing is problematic
  - Isolation of the high intensity pulse from the diode laser and the detector (because of equal wavelength) is difficult
  - Monitoring of the probe laser parameters (diode laser frequency and power) is important
  - Measurement of „real vacuum” reference transmission

Proposal for improving the technique

Use of the 5S -> 6P transition at 420 nm wavelength for probing the plasma

Advantages:

- Shorter wavelength -> smaller beam diameter -> easier and more robust to fit inside the plasma channel, less sensitive to spatial jitter
- Spectral filtering is possible both at the detector and at the diode laser
- Outcoupling from the vacuum is possible much closer to the vapor pipe -> easier to implement, and smaller spotsize on camera/detector, less sensitive to clipping
- Due to the more efficient filtering from the 780 ionizing light, simultaneous measurement during (partly before/after) the ionizing pulse is possible ->
- Time resolved measurement during the propagation of the ionizing pulse is possible -> spatial resolution of the ionization
- Maybe even the detection of the future density step is possible ?
- Easier to upgrade to interferometric detection (if necessary)