Adiabatic High-Frequency Transitions for the Munich ABS ◊

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A polarized atomic beam of hydrogen with an electron spin polarization close to 100 % is created by the sextupole magnets in the Munich Atomic Beam source (ABS) [1,2]. Adiabatic radio-frequency transitions [3] are able to transfer the electron spin polarization to the nucleus by the selective interchange of an occupied magnetic hyperfine substate into an unoccupied one. Efficiencies of almost 100 % are feasible using a combination of 3 magnetic fields: a homogeneous static magnetic field, a static magnetic field with a gradient along the beam direction and a rf-magnetic field [3].
Tab. 1 gives a survey of the rf-transitions for the Munich ABS. The transitions for protons have been built and tested and will be discribed in the following. The static magnetic fields are realized for all transitions as a C-magnet with gradient coils.

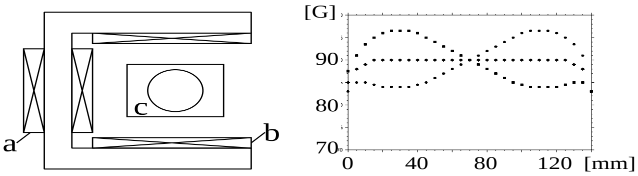

Fig. 1: Schematic of the magnets for the static fields:
The left side shows a cross sectional view of the C-magnet (a) with the gradient-coils (b). The housing with the rf-field-generator is indicated by (c). The view is along the beam axis.
The right side shows a measurement of the static fields along the beam axis. The homogeneous field was adjusted to 90 Gauss, the gradient field to 2 Gauss/cm with positive and negative slope. The active length of the rf-field-generators is about 5 cm.

For the creation of the rf-field we distinguish between two types of generators: for the lower frequencies (ΔF=0) we use coils of a resonant oscillating circuit and for the higher frequencies (ΔF=1) cavities. The impedance of the respective oscillating circuit is adapted to 50 Ω by directly coupling of the rf-power to the 50 Ω point of the coil or rod. A capacitor in parallel to the coil is adjusted to the resonance frequency of the circuit. The principle is demonstrated in the middle and right part of fig. 2. Ref. [4] gives a detailed description. For 6 and 12 MHz, only one rf-tansition is used alternately. The adaption with two variable capacitors allows in both cases for proper matching of impedance (left part of fig. 2).

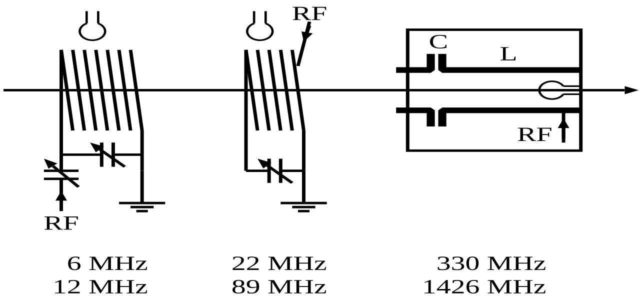

Fig. 2: Schematic of the rf-field generators: Coils of seven windings and five windings are used for the lower frequencies (6 to 89 MHz), cavities are used for 330 and 1426 MHz. The capacitors of the cavities are variable. The rods in the cavities correspond to the coil of the conventional circuits. All transitions are controlled and stabilized by the induced voltage in small pick-up loops.

All transitions for protons were tested in the ABS. They were installed after the first two magnets of the sextupole-system. In the ideal case, the intensity of the atomic beam decreases by a factor of two when the transition is switched on, as the newly populated state gets fully deflected by sextupole magnets 3 and 4. All transitions showed a decrease in beam-intensity by a factor of 1.85±0.05. The deviation from the ideal factor of 2 is explained in the detailed analysis in ref. [4] by taking into account the exact transmissions for all substates through the sextupole magnetic system of the ABS. Efficiencies of 100 $\pm^{0}_{5}$ % were found for all tested transitions. It is pleasant that the necessary rf-power for saturation of the rf-transition is well below 1 Watt. As a consequence, no instabilities due to heat-up have been observed during typical running-times of 1 to 3 hours. Tests over longer time scales will follow.

References

[1] R. Hertenberger et al., Rev.Sci.Instrum. **67 (2)** (1996)
[2] K. El Abiary, diploma thesis, LMU München, 1996
[3] A. Abragam, J. Winter, Phys.Rev.Lett. **1** (1958) 347
[4] S. Trieb, Zulassungsarbeit, LMU München, 1996

	Transition	Frequency [MHz]	B_{stat} [Gauss]	Selection rule	Orientation	Type	Gradient [G/cm]
Protons	$1 \to 3$	12	8	$\Delta F = 0, m_F \leftrightarrow -m_F$	$\perp$	coil	2
	$2 \to 3$	89	60	$\Delta F = 0, \Delta m_F = 1$	$\perp$	coil	2
	$2 \to 4$	1426	44	$\Delta F = 1, \Delta m_F = 0$	$\Vert$	cavity	2
Deuterium	$1 \to 4, 2 \to 3$	6	6	$\Delta F = 0, m_F \leftrightarrow -m_F$	$\perp$	coil	2
	$1 \to 4, 3 \to 4$	22	24	$\Delta F = 0, \Delta m_F = 1$	$\perp$	coil	-2,+2
	$2 \to 6$	330	12	$\Delta F = 1, \Delta m_F = 0$	$\Vert$	cavity	2
	$3 \to 5$	330	90	$\Delta F = 1, \Delta m_F = 0$	$\Vert$	cavity	2

Table 1: Scheme of the adiabatic rf-transitions for the Munich ABS. All transitions for protons have been tested successfully [4]. The 89 MHz transition is a test case for the HERMES polarimeter, it will be not used in the Munich ABS. The 330 MHz rf-transition for deuterium is built, but not yet tested. The selection rule $\Delta m_F=0$ requires parallelity between rf- and static magnetic fields, $\Delta m_F \neq 0$ requires the fields to be perpendicular.

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