

Appendix A

LabVIEW programs

The block diagram of the main Rydberg experiment LabVIEW program is shown in figure A.1.

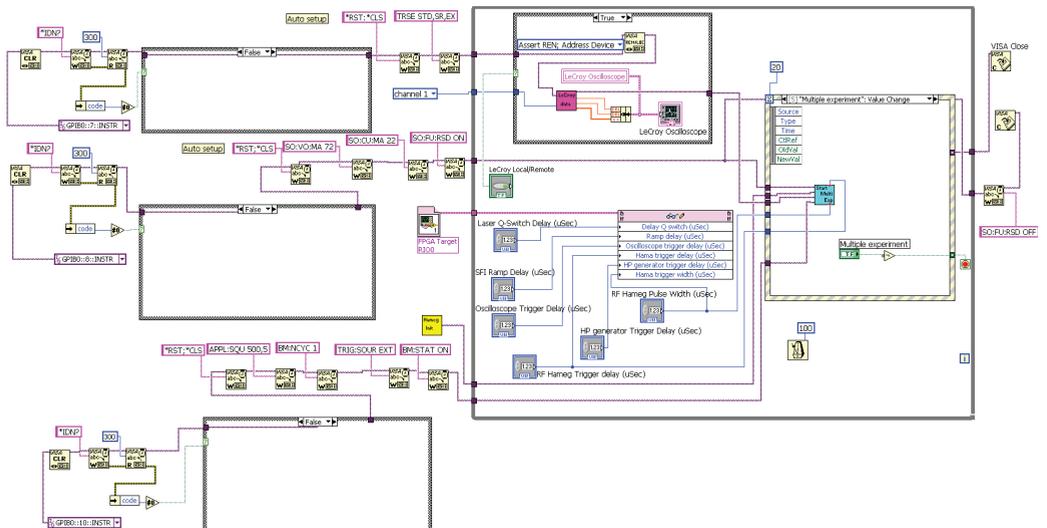


Figure A.1: The block diagram of the main Rydberg experiment LabVIEW program.

In the main Rydberg experiment LabVIEW program, we set the different trigger delay signals:

The Laser Q-Switch Delay, SFI Ramp delay, Oscilloscope Trigger Delay, RF Hameg Trigger Delay, RF Hameg Pulse Width and Hp generator Trigger Delay. The Hameg 8134 wave generator, the HP 33120 wave generator, the LeCroy oscilloscope, and the Delta Elektronika power supply instruments can be remotely controlled using the IEEE488/RS232 interfaces to alter their default experimental instrument setup. By pressing the control buttons "Single" or "Multiple", the software for running a single or multiple Rydberg experiments, respectively, will be initiated. The multiple Rydberg experiment software code is explained in section (4. 4. 2).

The block diagram of the single experiment LabVIEW VI is depicted in figure A.2. The single experiment LabVIEW program allows the user to set the experimental parameters, conduct a single experiment and subsequently store the acquired SFI data (ASCII format data file) to disk. The program also allows for a description of the experiment, which subsequently is merged into the acquired SFI data file. The single Rydberg experiment software code is explained in section (4. 4. 1).

At the end of the single experiment, the user is asked to enter a file name to save the experimental SFI data to disk. The format of the SFI data file (ASCII file) is as shown in figure A.3. The initial part of the SFI data file contains information on the experimental setup, whereas the latter part of the file contains the SFI time series amplitude data output from the LeCroy oscilloscope.

The block diagram of the multiple experiment LabVIEW VI is presented in figure A.4. The multiple experiment LabVIEW program allows for the experimental parameters to be entered via a MS Excel file using ActiveX software interface programming, i.e. each row in the MS Excel file will contain the experimental parameters for a single Rydberg experiment. When running the multiple experiment LabVIEW program, the user has the option of either to enter the experimental data into an MS Excel file via LabVIEW, or alternatively to enter the experimental data into an MS Excel file independent of LabVIEW. The MS Excel file must have the format shown in figure A.5

	A	B	C	D	E	F	G
1	Amplitude [mV]	Frequency [Hz]	Electrical current [A]	HP Amplitude[V]	HP offset[V]		
2	800,00	18000000	5,05	1,11	0		
3	800,00	18200000	5,05	1,11	0		
4	800,00	18400000	5,05	1,11	0		
5	800,00	18600000	5,05	1,11	0		
6	800,00	18800000	5,05	1,11	0		
7	800,00	19000000	5,05	1,11	0		
8	800,00	19200000	5,05	1,11	0		
9	800,00	19400000	5,05	1,11	0		
10	800,00	19600000	5,05	1,11	0		
11	800,00	19800000	5,05	1,11	0		
12	800,00	20000000	5,05	1,11	0		
13	800,00	20200000	5,05	1,11	0		
14	800,00	20400000	5,05	1,11	0		
15	800,00	20600000	5,05	1,11	0		
16	800,00	20800000	5,05	1,11	0		
17	800,00	21000000	5,05	1,11	0		
18	800,00	21200000	5,05	1,11	0		
19	800,00	21400000	5,05	1,11	0		
20	800,00	21600000	5,05	1,11	0		
21	800,00	21800000	5,05	1,11	0		
22	800,00	22000000	5,05	1,11	0		
23	800,00	22200000	5,05	1,11	0		
24	800,00	22400000	5,05	1,11	0		
25	800,00	22600000	5,05	1,11	0		

Figure A.5: Format of the MS Excel input file used in the multiple experiment LabVIEW program.

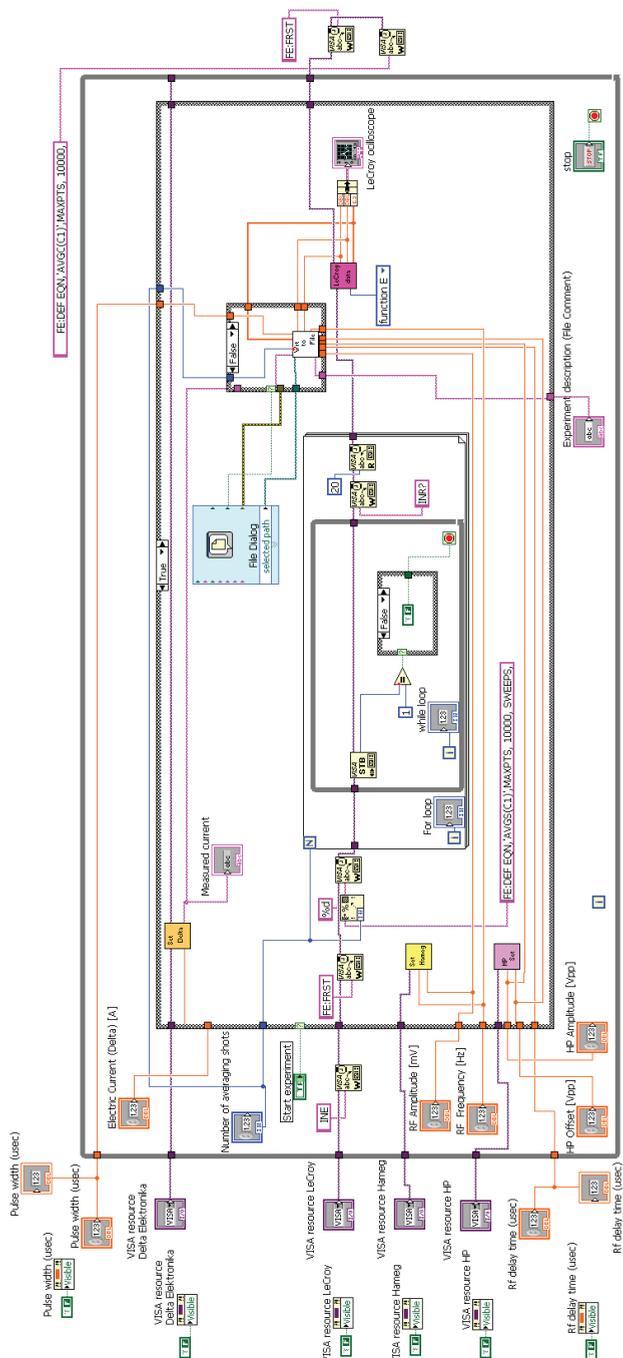


Figure A.2: The block diagram of the single experiment LabVIEW program

```

r1sfi17.dat - Notepad
File Edit Format View Help
Date: 23.03.2011
Time: 11:28:55
Amplitude [mV]: 650.00
Frequency [Hz]: 32000000
Electrical current (input value) [A]: 5.97
HP amplitude [V]: 0.21
HP offset [V]: 0.00

Number of shots:100
RF delay time [usec]: 20.00
RF pulse width [usec]: 5.00
T0 [s]: 4.999950E-4
deltaT [s]:1.000000E-8
Comment:

-0.000047
-0.000036
-0.000022
-0.000030
-0.000043
-0.000020
-0.000023
-0.000031
-0.000034
-0.000040
-0.000041
-0.000038
-0.000043
-0.000047
-0.000038
-0.000026
    
```

Figure A.3: Format of experimental SFI data file output from the single experiment LabVIEW program shown from top: Date, Time, Amplitude and frequency of harmonic pulse, current in coils for B-field, HP-amplitude and offset, number of laser shots, delay and width of harmonic pulse, SFI-ramp delay, time step of SFI spectrum and a comment entered by the user.

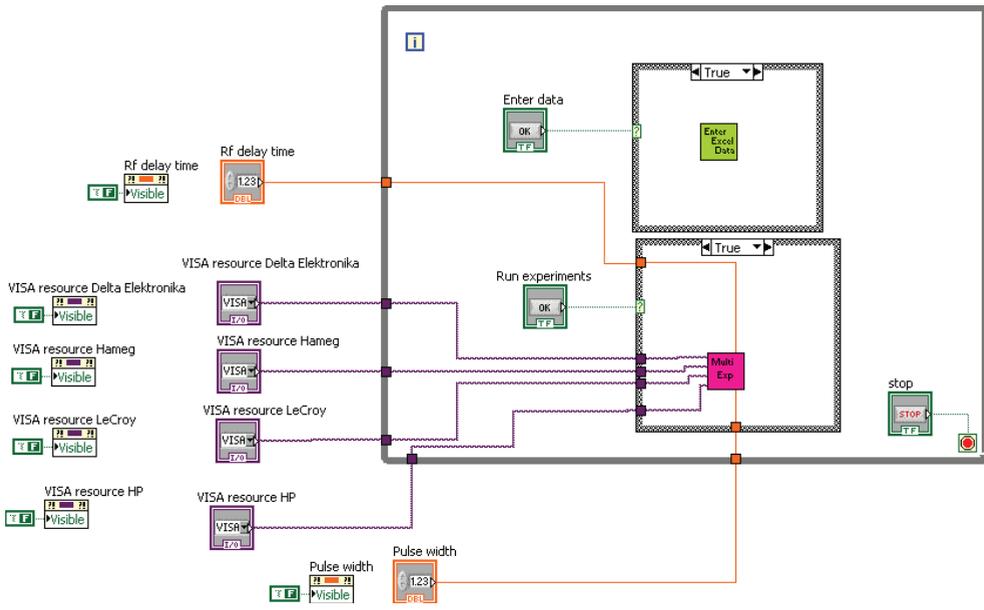


Figure A.4: Block diagram of multiple experiment LabVIEW program.

Appendix B

Vacuum controller

In our vacuum system we have two sets of rotary and turbomolecular pumps which are electrically interconnected through the front panel of the vacuum controller. To start the turbomolecular pump TMU 261 located in the upper chamber, one needs to start rotary pump first by pressing the push button labelled chamber pump on the left side of the front panel of the Vacuum controller shown in figure B.1. Turbomolecular pump (TURBOVAC 50) [40] is used to create the vacuum in the lower chamber located under the oven assembly. It is controlled by the TURBOTRONIK NT 10 [39] solid state frequency converter fitted in the lower panel of the right of the vacuum controller (see figure B.1).



Figure B.1: Picture for the front view of the Vacuum controller

This turbomolecular pump is operated by the the front panel of the frequency converter, while the supporting rotary pump is controlled by the front panel of the Vacuum controller. Before we start the turbomolecular pump it is necessary to have a pressure $\leq 2.8 \cdot 10^{-3}$ mb from the rotary pump. To obtain the required pressure one needs to start the rotary pump first. To start the rotary pump one can press a small push button labelled (Oven pump) located on the right side of the front panel of the

Vacuum controller. When the pirani gauge measures a pressure $\leq 2.8 \cdot 10^{-3}$ mb which is read out on the front panel of total pressure controller TPG 300 (located on the lower panel on the left side of the Vacuum controller) the turbomolecular pump put *ON* by pressing start button on the TURBOTRONIK NT 10. Successful start up of the pump is indicated by the green light labelled normal on the front panel of TURBOTRONIK NT 10 can be seen in figure [B.1](#).

Appendix C

Hartree atomic units

In this thesis we use a system of atomic units, usually referred to as Hartree's atomic unit system. This is based on the four basic quantities i.e, the elementary charge (e), the electronic mass (m_e), angular momentum (\hbar) and electrostatic constant ($4\pi\epsilon_0$) which are listed in the upper part of the Table C.1. The quantities measured in SI unit system are presented in column on the right. Other units given in the lower part can be obtained by combining these four basic quantities [63]. One can alternately define the atomic

Table C.1: Shows fundamental and derived quantities in the atomic unit system.

Quantity	Unit	Physical significance	Value in SI-units
Charge	e	Absolute value of electron charge	$1.602\ 18 \times 10^{-19}$ C
Mass	m_e	Electron mass	$9.109\ 38 \times 10^{-31}$ kg
Angular momentum	$\hbar = h/2\pi$	Planck's constant divided by 2π	$1.054\ 57 \times 10^{-34}$ Js
Electrostatic constant	$4\pi\epsilon_0$	4π times the permittivity of free space	$1.112\ 65 \times 10^{-10}$ Fm ⁻¹
Length	$a_0 = 4\pi\epsilon_0\hbar^2/m_e e^2$	Bohr radius of atomic hydrogen	$5.291\ 77 \times 10^{-11}$ m
Energy	$E_h = \hbar^2/m_e a_0^2$	Twice the binding energy of atomic hydrogen	$4.359\ 75 \times 10^{-18}$ J
Time	$\tau_0 = \hbar/E_h$	Time required for electron in first Bohr orbit to travel one Bohr radius	$2.418\ 88 \times 10^{-17}$ s
Velocity	$v_0 = a_0/\tau_0 = 1/\alpha c$	Magnitude of electron velocity in first Bohr orbit	$2.187\ 69 \times 10^6$ ms ⁻¹
Angular frequency	$\omega_0 = \frac{v_0}{a_0}$	Angular frequency of electron in first Bohr orbit	$6.579\ 69 \times 10^{15}$ s ⁻¹
Electric field strength	$F_0 = \frac{e}{(4\pi\epsilon_0)a_0^2}$	Strength of the Coulomb field experienced by an electron in the first Bohr orbit of atomic hydrogen	$5.142\ 21 \times 10^{11}$ Vm ⁻¹

units by setting the measures of mass, length and time as units, i.e ($m_e = a_0 = \tau_0 = 1$). This arrangement will produce the other quantities in Table C.1 except e and $4\pi\epsilon_0$. However, these two quantities together have the value, $\frac{e^2}{4\pi\epsilon_0} = 1$. Letting α denote the fine structure constant, the velocity of light has the value $\alpha^{-1} = 137.03599$ in atomic units (a.u). In atomic physics we often use another unit to measure an electron volts, and $1\text{eV} = 1.60218 \times 10^{-19}$ J. The Hartree energy in eV is thus $E_h = 27.21138$ eV.