Atomic and nuclear physics

Atomic shell

Electron spin resonance (ESR)

LEYBOLD Physics Leaflets

P6.2.6.3

Resonance absorption of a passive RF oscillator circuit

Objects of the experiments

- Measuring the voltage U_1 at the coil of the RF oscillator circuit as a function of the frequency with inductive coupling to a passive oscillator circuit.
- Measuring the voltage U_2 at the coil of the passive oscillator circuit as a function of the frequency.

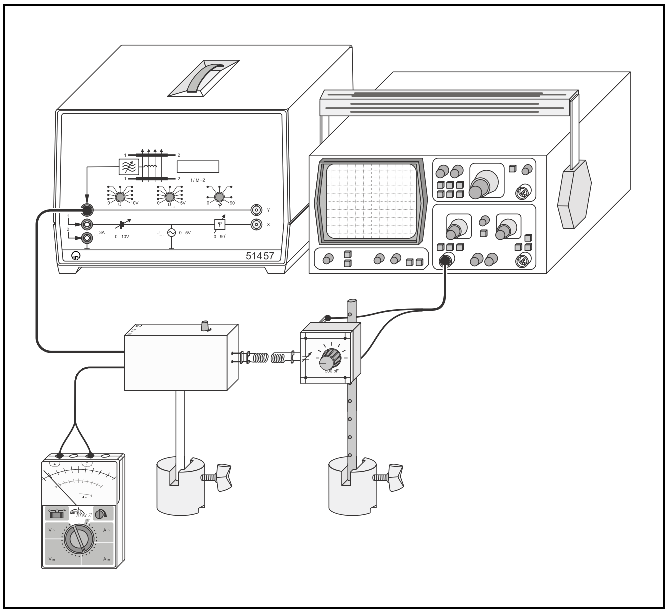

Fig. 1 Experimental setup with the ESR basic unit and inductive coupling of a passive oscillator circuit.

Principles

In the experiment P6.2.6.2, electron spin resonance is detected on the DPPH sample. The sample is placed in an RF coil which is part of a high-duty oscillator circuit. The oscillator circuit is excited at frequencies between 15 and 130 MHz by an RF oscillator with adjustable frequency. If the electron spin resonance condition is fulfilled at a frequency ν_0, the DPPH sample absorbs energy and the oscillator circuit is loaded. As a result, the AC resistance of the oscillator circuit changes and the voltage at the coil decreases.

In this experiment, the load of the active oscillator circuit is demonstrated by means of a passive oscillator circuit whose coil is placed coaxially opposite the empty RF coil. The resonance frequency

$$\nu_0 = \frac{1}{2\pi \cdot \sqrt{L_2 C_2}} \qquad \text{(I)}$$

of the passive oscillator circuit can be varied by varying its capacitance C_2.

If the active oscillator circuit is excited with the resonance frequency ν_0, it is damped and the voltage U_1 at the RF coil decreases. The rectified voltage U_1 is determined by measuring the current I_1 through a sensing resistor R_1 = 56 kΩ:

$$U_1 = 56\ \text{k}\Omega \cdot I_1 \quad \text{(II)}$$

Apparatus

1 ESR basic unit		514 55
1 ESR control unit		514 57
1 two-channel oscilloscope 303		575 211
1 amperemeter, DC, $I \leq 1$ mA	e.g.	531 100
1 screened cable BNC/4 mm		575 24
1 set of 6 two-way plug adapters		501 644
1 insulated stand rod, 25 cm		590 13
2 saddle base		300 11

Setup

The experimental setup is illustrated in Fig. 1.

- Connect the ESR basic unit to the ESR control unit via a 6-pole cable, and set the maximum sensitivity at the rotary potentiometer.
- Insert the plug-in coil 30–75 MHz and connect the amperemeter to output I via an adapter cable (measuring range 100 A).
- Place the coil of the passive oscillator circuit coaxially opposite the plug-in coil and connect it to channel I of the two-channel oscilloscope via the screened cable BNC/4.

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Carrying out the experiment

- Set the variable capacitor of the passive oscillator circuit to scale mark 3/6.
- Set the minimum frequency at the ESR basic unit.
- Measure the frequency ν at the control unit, the voltage U_2 of the “passive” coil at the oscilloscope and the voltage $U_1 = 56\ \text{k}\Omega \cdot I_1$ of the RF coil, and take the measured values down.
- Increase the frequency step by step and repeat the measurement.
- Record other series of measurements with the variable capacitor set to scale marks 2/ 6 and 1/6.
- Remove the passive oscillator circuit, and record another series of measurements.

Measuring example

In tables 1–4 the measured values are compiled for different settings of the variable capacitor in the passive oscillator circuit.

Table 1: The voltages U_1 and U_2 at scale mark 3/6

$\frac{\nu}{\text{MHz}}$	$\frac{U_2}{\text{V}}$	$\frac{U_1}{\text{V}}$	$\frac{\nu}{\text{MHz}}$	$\frac{U_2}{\text{V}}$	$\frac{U_1}{\text{V}}$
22.1	1.17	2.48	24.5	0.32	3.25
22.3	1.25	2.31	25.0	0.25	3.34
22.5	1.30	1.90	25.5	0.19	3.37
22.7	1.29	1.75	26.0	0.15	3.43
22.9	1.25	1.93	27.0	0.09	3.54
23.1	1.11	2.34	28.0	0.07	3.67
23.3	0.93	2.67	29.0	0.05	3.75
23.5	0.76	2.86	30.0	0.03	3.83
24.0	0.48	3.10			

Table 2: The voltages U_1 and U_2 at scale mark 2/6

$\frac{\nu}{\text{MHz}}$	$\frac{U_2}{\text{V}}$	$\frac{U_1}{\text{V}}$	$\frac{\nu}{\text{MHz}}$	$\frac{U_2}{\text{V}}$	$\frac{U_1}{\text{V}}$
22.5	0.49	2.97	26.1	0.88	2.72
23.0	0.55	3.01	26.3	0.76	2.93
23.5	0.64	3.04	26.5	0.64	3.08
24.0	0.79	3.02	27.0	0.45	3.33
24.2	0.87	2.97	27.5	0.34	3.43
24.4	0.96	2.84	28.0	0.27	3.54
24.6	1.08	2.72	29.0	0.17	3.67
24.8	1.15	2.36	30.0	0.12	3.72
25.0	1.20	1.89	31.0	0.09	3.82
25.2	1.19	1.49	32.0	0.06	3.91
25.5	1.15	1.53	33.0	0.05	3.96
25.7	1.10	2.01	34.0	0.04	4.04
25.9	1.02	2.37	35.0	0.04	4.05

Table 3: The voltages U_1 and U_2 at scale mark 1/6

$\frac{\nu}{\text{MHz}}$	$\frac{U_2}{\text{V}}$	$\frac{U_1}{\text{V}}$	$\frac{\nu}{\text{MHz}}$	$\frac{U_2}{\text{V}}$	$\frac{U_1}{\text{V}}$
23.0	0.28	3.10	33.3	0.91	1.79
24.0	0.28	3.23	33.5	0.89	1.44
25.0	0.28	3.32	34.0	0.86	1.47
26.0	0.28	3.42	34.2	0.85	2.04
27.0	0.29	3.52	34.4	0.80	2.59
28.0	0.31	3.60	34.6	0.76	2.82
29.0	0.34	3.68	34.8	0.67	3.14
30.0	0.39	3.71	35.0	0.60	3.36
31.0	0.48	3.70	35.5	0.46	3.70
31.5	0.54	3.70	36.0	0.36	3.86
32.0	0.64	3.60	36.5	0.30	3.99
32.5	0.77	3.32	37.5	0.22	4.14
32.7	0.83	3.10	38.5	0.15	4.26
32.9	0.88	2.79	39.5	0.12	4.30
33.1	0.91	2.36			

Table 4: The voltage U_1 without resonance absorption

$\frac{\nu}{\text{MHz}}$	$\frac{U_1}{\text{V}}$	$\frac{\nu}{\text{MHz}}$	$\frac{U_1}{\text{V}}$	$\frac{\nu}{\text{MHz}}$	$\frac{U_1}{\text{V}}$
22.2	3.14	30.0	3.92	40.0	4.48
25.0	3.47	35.0	4.26		

Evaluation and results

The RF oscillator is damped by the passive oscillator circuit. In the case of a resonance, the voltage decreases significantly.

Fig. 2 The voltage U_1 of the PF coil (upper curves) and U_2 of the “passive” coil (lower curves) for three capacitances (○ : scale mark 1/6 , □ : scale mark 2/6 , ◇ : scale mark 3/6 , ● : without passive oscillator circuit) as functions of the oscillator frequency ν.