Approaching Free-Electron – Bound-Electron Resonant Intesractions with a Modulated Electron Beam

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Quantum optics with free-electrons is a promising field emerging based on the technology of electron microscopy [1]. One part of the framework of free-electron quantum optics is the resonant and coherent interaction of free-electrons with bound-electron systems [2]. Experimental access to this interaction is particularly challenging, since the bound-electron state has to couple directly to the near-field of the free electrons. With our experimental setup we are aiming to show this interaction for the first time [3]. In this proof of principle experiment (see Fig. 1), we utilize a modulated free-space electron beam in a customized scanning electron microscope, to coherently drive electron spins. The near-field of this spatially modulated beam excites Zeeman levels in a α,γ-Bisdiphenylen-β-phenylally (BDPA) sample placed in a magnetic field. These quantum transitions couple inductively to a micro-coil. The signal in the micro-coil is measured with a lock-in amplifier, sensitive down to the thermal noise floor. A successful implementation of the proposed experiment will lay the foundation for coherently coupling modulated electron beams to bound-electron transitions. Realizing it in a electron microscope, allows to exploit the nano-scopic spatial resolution of electron microscopy. Apart from new spectroscopic methods utilizing the modulated near-field of an electron beam, higher order transitions may also be excited.

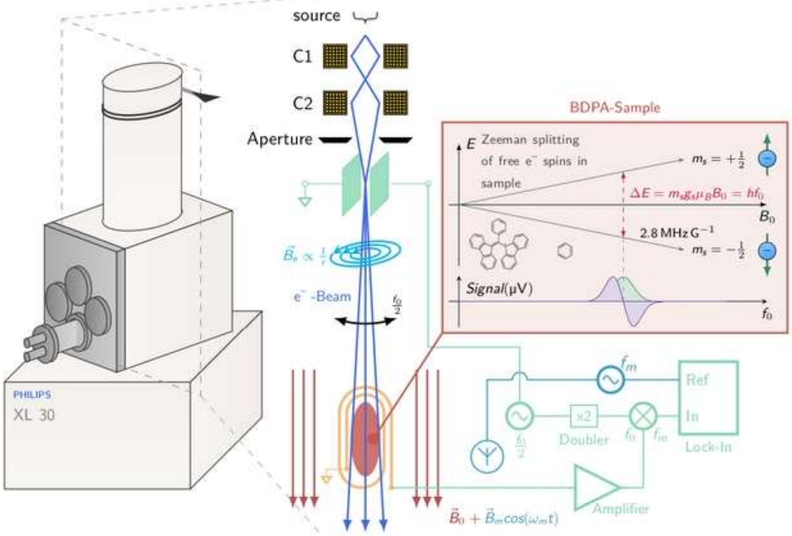

Figure 1. The electron beam in the center (dark blue) of a customized scanning electron microscope (on the left) near field of the beam B_e, couples to the Zeeman levels of the spins in the BDPA sample placed in a bias magnetic field B_0 (red). Sweeping the frequency f_0 and modulating the bias field B_0 at a frequency f_m, enables measuring the spins coupling inductively to a micro-coil (orange), wrapped around the sample, with a homodyne lock-in detection setup.

References

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