Zeeman-effect

The Zeeman-effect contains all effects that can be observed related to spectral lines whose emitters are exposed to a magnetic field. It is differentiated between the "normal" and the "anomalous" Zeeman-effect. The normal Zeeman-effect emerges at pure orbital angular momentum L (S=0), every state splits into 2L+1 equidistant levels. At the anomalous Zeeman-effect the spin- and the orbit-momentum couple to the total momentum J=L+S (S ≠ 0) causing a splitting into 2J+1 levels.
At strong external magnetic fields the Paschen-Back effect occurs whereby the L-S-coupling becomes negligible compared to the energy of the single magnetic moments in the field.
In the experiment the shift from 3^3D to 2^3P (λ = 587.6 nm) in Helium in a variable magnetic field is analyzed.

I. Required knowledge

Multiplet systems, nomenclature of terms (Lit. 1, 2, 3)
Zeeman effect (normal and anomalous) and Paschen-Back effect (Lit. 1, 2, 3)
Selection rules and polarization (Lit. 1, 2, 3)
Energy level schemes for the visible He-spectrum (Lit. 1)
Arrangement of the Fabry-Perot spectrometer (dispersion range, resolving power, interference order, finesse) (Lit. 4)
Digital camera (CMOS and CCD array, creation of colors) (Lit. 5, 6)

II. Literature

1. H. Haken, H.C. Wolf: Atomic and Quantum Physics, Springer-Verlag 1987
2. W. Demtröder: Atoms, molecules and photons, Springer 2006
3. R. Eisberg R. Resnick: Quantum physics of atoms, molecules, solids, nuclei and particles, 1985
4. W. Demtröder: Laser spectroscopy, Springer 2003
5. http://micro.magnet.fsu.edu/primer/digitalimaging/concepts/ccdanatomy.html
6. http://www.microscopyu.com/articles/digitalimaging/ccdintro.html

III. Experimental task

The splitting of a spectral line of Helium (3^3D-2^3P, λ = 587.6 nm) in a magnetic field is investigated at different field strengths with the help of a Fabry-Perot interferometer. The ring-shaped interference pattern is recorded by a digital camera.

1. Calibrate the magnetic field with the Hall probe (remanence of the magnet?).
2. Adjust the optical assembly of the transversal observation so that you can see a sharp, high-contrast and good illuminated ring system.
3. Vary the exposure time, shutter and ISO-Values for optimal results.
4. Take images of the ring system at different magnetic field strength (increment 50 mA – 100 mA, up to 1.0 T).
5. Adjust the optical assembly of the longitudinal observation so that you can see sharp, high-contrast and good illuminated sections of the ring system.
6. Take images by rotating the polarizer (increment 5°).

IV. Experimental analysis

Transversal observation:

Plot the squared of the ring diameters against the magnetic field B.
Determine Bohr's magneton μ_B under the assumption, that Paschen-Back effect prevails.

Longitudinal observation:

Create a Video-clip from the images and explain what can be seen.

V. Necessary data

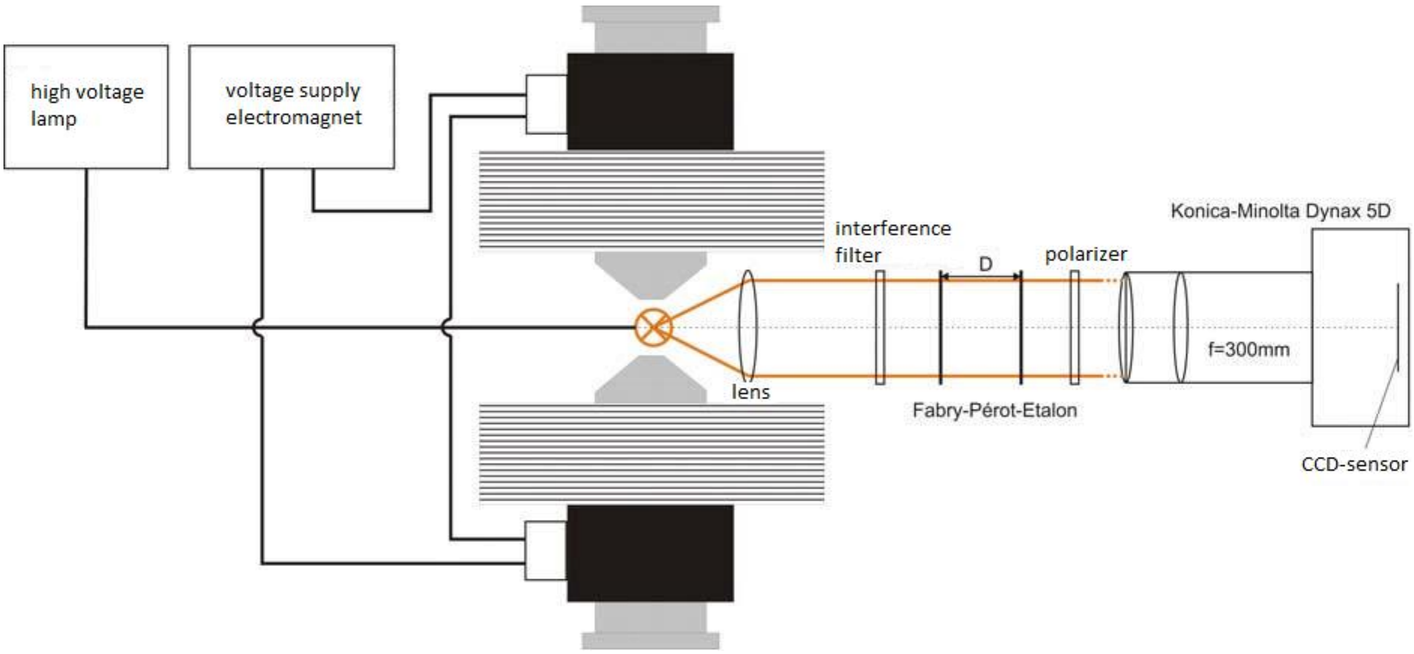
Wavelength:	λ = 587.6 nm
Etalon distance:	d = 9.462 mm
Interference filter:	λ = 589 nm, HW = 23 nm
Pixel dimensions:	7.81 µm × 7.81 µm

VI. Attention

1. **Caution:** High voltage up to 4.9 kV (4.0 mA) at the lamp! Do not change the adjustment of the power supply and do not touch the set-up while the lamp is switched on.
2. **Caution:** The current for the magnet coils has to be lower than 1.0 A for permanent use, 2.0 A for short times.
3. Do not turn bolts and nuts at the Fabry-Perot-Etalon!
   The polarization of the turnable polarizer is **not** indicated by the mark on the mounting but by the red line near the screws (important for the optimal adjustment).

VII. Experimental set-up:

Transversal:



Longitudinal: