Characterisation of the Coupled Dark State Magnetometer Prototype

M. Ellmeier[1], R. Lammegger[1], A. Pollinger[2], W. Magnes[2] and L. Windholz[1]

[1] *Institute of Experimental Physics, Graz University of Technology, Petersgasse 16, 8010 Graz, Austria*

[2] *Space research institute, Austrian Academy of Sciences, Schmiedlstraße 6, 8042 Graz, Austria*

e-mail: michaela.ellmeier@tugraz.at

The Coupled Dark State Magnetometer (CDSM) is a new type of an optically pumped magnetometer [1], which measures the scalar value of the magnetic field. Its functional principle is based on the quantum mechanical interference effect called Coherent Population Trapping (CPT) effect. The formation of the CPT effect causes a trapping of the atomic level population into so called dark states resulting into a sharp dip in the absorption profile. In contrast to Doppler broadened spectral lines (in our case about 500 MHz), the dark state resonance line widths are in the order of about 30 Hz under optimized experimental conditions (Rubidium cell with 30 mbar Neon buffer gas pressure) and are thus perfectly suited for precision measurements.

In our setup the CPT effect is established within the hyperfine structure (hfs) of the ^{87}Rb D_1 line via a circularly polarized, polychromatic laser field consisting of frequency components 3.4 GHz apart from each other. Experimentally these discrete frequency components are created by modulation of a vertical cavity surface emitting laser (VCSEL) diode and using both first order sidebands lying 2x3.4 = 6.8 GHz apart from each other. By applying this modulation technique the hyperfine ground state level splitting frequency can be bridged over and a coherent coupling of the hfs levels is established causing the CPT effect.

In the presence of external magnetic fields the degeneracy of the hyperfine structure energy levels is lifted and the levels are split according to the Zeeman effect. As a consequence, six magnetic field dependent resonances arise forming a CPT resonance spectrum, which components lying symmetrically around the hyperfine ground state transition frequency ($5^2S_{1/2}$ F = 1 $m_F = 0 \rightarrow 5^2S_{1/2}$ F' = 2 $m_F' = 0$). These resonances are again pair wise coupled to three CDSM resonances using a second modulation, with frequencies typically in the range of 300 Hz to 1 MHz, exactly matching the Zeeman components of the CPT resonance spectrum. The magnitude of the magnetic field is determined by measuring the CDSM resonance frequency by means of phase sensitive detection techniques and applying the Breit-Rabi formula. The benefit of this approach is a significant reduction of the unwanted (buffer gas induced) temperature shift of the dark resonance frequency and thus a more precise measurement of the magnetic field.

We present an ongoing development of a compact prototype for the measurement of the scalar value of the magnetic field designed for an application on a spacecraft. The advantages of this instrument are a simple sensor design and its high dynamic range (from weak magnetic fields in the lower nT-range up to fields in the mT-range like the earth's magnetic field). The accuracy of 0.2 nT will be demonstrated and results of the recent reached performance (noise levels, accuracy, etc.) will be presented.

References:

[1] R. Lammegger, Patent No. WO/2008/151344 (2008)