Characterisation of the Coupled Dark State Magnetometer in the Earth's Field

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The innovative principle for measuring the magnetic field strength was discovered in 2008 and is currently under development for future space missions. At the Conrad Observatory, important instrument parameters such as long-term accuracy and the sensor heading characteristic could be investigated.

The Coupled Dark State Magnetometer (CDSM) is an instrument which measures the magnitude of the surrounding magnetic field by an artificially generated light field which interacts with rubidium atoms.
The magnetic field measurement is based on the Zeeman effect which is the splitting of a spectral line into several components in the presence of a quasi-static magnetic field. Additionally, a quantum interference effect called Coherent Population Trapping (CPT) enables a more precise measurement of the magnetic field magnitude. Systematic errors which usually degrade the accuracy of single CPT magnetometers are cancelled or at least minimized by the use of several CPT resonances in parallel. Thus far CPT is the only known effect used in optical magnetometry which inherently enables omni-directional measurements. This leads to a moderately complex, all-optical sensor design without double cell units, excitation coils or electro-mechanical parts (see Figure 1).

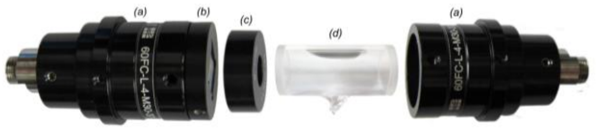

Figure 1: The CDSM sensor consists of two fibre couplers (a), a polariser (b), a quarter-wave plate (c) and a rubidium-filled glass cell (d).

The measurement principle was discovered in 2008 and since then the instrument is developed by the two involved institutes for future space missions. The first demonstration in space will take place aboard the China Seismo-Electromagnetism Satellite (CSES) mission. The flight model will be launched into a low Earth orbit in August 2017.
In 2014 and 2015, the CDSM team compared the performance of several CDSM models with the observatory reference in the geomagnetic tunnel of the Conrad Observatory. Important parameters such as long-term accuracy and the sensor heading characteristic could be investigated. Figure 2 shows measurement data of the Earth's magnetic field strength detected by the CDSM (blue) and a reference instrument based on the Overhauser effect (red). One can clearly see the diurnal periodicity with high magnetic activity during the last day.
To better understand the influence of the sensor orientation in relation to the pointing of the magnetic field vector, the CDSM team developed a rotation device which enables an omni-directional and repeatable orientation of the sensor's optical axis with respect to the Earth's field vector (see Figure 3).

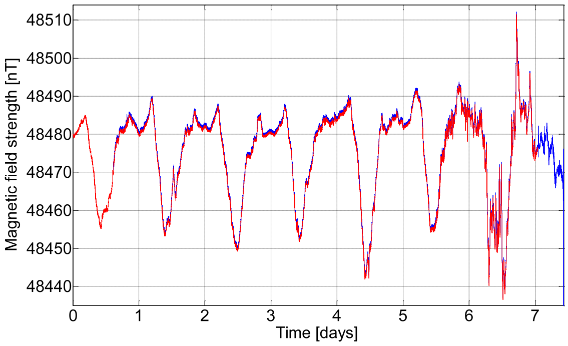

Figure 2: Earth's magnetic field strength measured with the CDSM (blue) and an Overhauser reference magnetometer (red).

Figure 3: The CDSM sensor unit is mounted on the rotation device on a pillar of the Conrad Observatory. Measurements are compared to an Overhauser reference magnetometer on another pillar.

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