A diode laser optically pumped potassium vapour magnetometer

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Geophysical investigation, both in regional scale in order to model crustal composition, and in local scale, like the prospection in archeological sites, needs of magnetometer instruments with high sensitivity and accuracy.

Optically pumped magnetometer is the current choice when the highest sensitivity is needed. Optical pumping by circular polarized resonance radiation allows the detection of the Zeeman resonance frequency of the hyperfine structure in alkali ground state atoms, giving the scalar value of the local magnetic field. Commercial instruments make use of Cesium atom, and of a radiofrequency resonance lamp as pumping source. The use of Potassium, in particular the isotope 41, can however be advantageous. It has a nuclear spin of 3/2 (in spite of 7/2), a value of gyromagnetic ratio two times larger (7 Hz/nT) and a very small hyperfine structure (242 MHz). This means a smaller number of Zeeman transitions, that are more easily resolved: at the typical geomagnetic field of 50000 nT, Cs presents 14 transitions at about 6 Hz of distance one from the other, while Potassium 41 presents only 6 transitions separated by about 960 Hz. The choice of Cesium was dictated by the difficulty of realizing reliable K lamps.

We present here the experimental work performed in order to build an optically pumped potassium magnetometer, where the pumping source is a diode laser emitting at 770 nm, corresponding to the D1 line of the potassium spectrum. In this way the output radiation can be focused in an optical fiber, allowing the physical separation between the electronic apparatus, radiation source included, and the probe. The atomic sample is optically pumped in the direction of the static magnetic field (z-direction) and an rf radiation, produced by a VCO (Voltage Controlled Oscillator) and frequency modulated at a low frequency, is applied through a couple of coils. A phase-sensitive amplifier detects the corresponding modulation in the transmission signal, observed by a Si-photodiode. A resonance dispersion-like signal is obtained, used to lock the VCO to the resonance peak. The line-width observed in a magnetically quiet environment is about 40 Hz, with a signal to noise ratio, measured in a bandwidth of 1 Hz, better than 103, resulting in an evaluated instrument sensitivity of a few pT/Hz1/2. The instrument has been placed in a quiet location, and a magnetogram has been recorded and compared with a commercial magnetometer. The results will be presented.