New magnetometric methods using "classical" quantum optical sensors

AntonVershovskii[1]

[1] *Ioffe Phys.-Tech. Institute of RAS, Polytechnisheskaya 26, St.-Petersburg, 194021 Russia*
E-mail: antver@mail.ioffe.ru

Application of lasers to the tasks of magnetic resonance optical pumping and detection has resulted in the development of various magnetometric systems using substantially new principles. In comparison to these systems, magnetometric sensors that use "classical" optically detected magnetic resonance (with or without laser pumping) may be somewhat controversially characterized as “Classical Quantum” Optically Pumped Magnetometers (CQOPM).

The present report is devoted to various modifications of CQOPMs, developed by Prof. E.Alexandrov and colleagues (Ioffe Phys.-Tech. Institute of RAS, Vavilov State Optical Institute), and demonstrating a set of absolutely new features, or new combinations of features.

The main, and most relevant, task that can be solved using CQOPM is a measurement of the scalar value of the magnetic field (usually the Earth’s field, and its natural and artificial variations). For a long time the Potassium Optically Pumped M_X Magnetometer (M_X-POPM, also developed by Prof. Alexandrov and his group) demonstrated the most impressive combination of time response, short-term resolution and stability among all the devices suitable for measuring geomagnetic field [1]. However, even though the M_X-POPM accuracy exceeds the accuracy of a Cs magnetometer by two orders of magnitude, it is still two orders of magnitude lower compared to the potential accuracy of Potassium M_Z Magnetometer (M_Z-POPM); the main reason for this is the M_X signal phase determination error. Recently we have developed a prototype of a magnetometer that combines the advantages of these M_X and M_Z devices, built on a single sensor and using the classical M_X pumping scheme [2]. A slow modulation was introduced into M_X-POPM scheme, allowing us to pick out from the ordinary M_X signal a relatively slow M_R signal proportional to the amplitude of the transverse component of the rotating magnetic moment. This M_R signal has all the advantages of the M_Z signal, including the line stability and symmetry, and independence from the detection phase; but unlike the M_Z signal, it can be observed on Larmor frequency together with the M_X signal in a transverse registration scheme.

Various methods of measuring components of the magnetic field with scalar sensors placed in an auxiliary field system are widely known. We have also developed two devices using this principle – K and Cs vector variometers [3]. While all the existing devices used fast switching of the auxiliary field direction, we applied rotating auxiliary fields, which allowed us to retain the total field module, and therefore to obtain much faster time response.

The idea of an absolute three-component magnetometer was suggested as an extension of these projects. In this scheme the total magnetic field vector in the sensor rotates, retaining its length, around the initial field direction. In each rotation cycle it passes through the three positions such that in each position, two components of the measured magnetic field are compensated with high accuracy, while the third one is fully uncompensated and amenable to measurement [4].

We have also suggested a concept of the M_X device that is able to measure the field scalar value with the accuracy and resolution achievable in M_X-POPM, and simultaneously indicate the direction of the magnetic field with the same laser beam that is used for optical pumping. The angular accuracy of such a laser compass is extremely high – when converted to the intensity of transverse field components, it is no more than one or two orders of magnitude lower than the resolution of M_X-POPM. This scheme has been modeled numerically [5], but at this time it has yet to be implemented experimentally. This scheme does not require recalculation of its readings from the local coordinate system to the world coordinate system, and its accuracy does not depend on the precision of its positioning in space. Its additional advantage is the absence of generated magnetic fields, which enables its use in magnetometric observatories jointly with other devices.

Thus, new methods using CQOPMs allow us to solve various classes of magnetometric tasks, including the simultaneous measurement of the magnetic field modulus and components, and the optical indication of the direction of the magnetic field.

References

1. E.B. Alexandrov, M.V. Balabas, A.S. Pazgalev, A.K. Vershovskii, N.N.Yakobson, *Laser Physics*, **6**, 2, 244-251 (1996).
2. A.K. Vershovskii, A.S. Pazgalev, *Tech. Phys. Lett*., .**37**, 1, 23-26 (2011).
3. A.K. Vershovskii, M.V. Balabas, A.E. Ivanov, V.N. Kulyasov, A.S. Pazgalev, and E.B. Aleksandrov, *Tech. Phys*., **51**, 1, 112-117 (2006).
4. A.K. Vershovskii, *Opt. Spectr.,* **101**, 2, 309-316 (2006)
5. A.K. Vershovskii, *Tech. Phys. Lett*., **37**, 2, 140-143 (2011).