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* In Kazan University the Electron Paramagnetic Resonance (EPR) was discovered by Zavoisky E.K. in 1944.

Application of Overhauser DNP and K optics INTERMAGNET quantum magnetometers to fundamental physics and cosmology

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This article provides suggestions and ideas on the use of magnetic observatories to observe the stability of the gyromagnetic ratio of the proton and the electron in order to detect the effects of new fundamental physics and cosmology. The idea consist in long continuous recording of the signals Overhauser and optical pumping K magnetometers. Such systems can be highly effective network for forecasting earthquakes due to highest long term sensitivity.

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1. Introduction

The recent LIGO project successful proof of the basic statements of Einstein theory on existence of the gravitational waves [1] was a major motive of this proposal. Similar to magnetic field that appears to be a consequence of the electrical field relativistic transformation under condition of speed of light invariance, experimental proof of the gravitational waves leads to a conclusion of existence of the quasi-magnetic gravitational field initiated by accelerated motion of masses [2]. The extremely high cost of the developed network of the LIGO laser detectors naturally leads to increased attention to alternatives methods for gravitational waves detection based on high precision nuclear magnetometers and theoretically predicted spin-gravitational effects. High precision atomic magnetometers can be used for other fundamental research including spin-gravity coupling, tests of Lorentz and CPT violations, detection of dark matter and dark energy [3-5].

2. Method of measurement based on comagnetometers

For resolve above mentioned problems in [3] is discussed a use of so-called comagnetometers made of two scalar magnetometers, for example, built on a pair of nuclear magnetometers, or nuclear (proton) and electron K optical quantum magnetometers. The fig. 1 and text with the permission of the authors the design of co- magnetometer shows.

The best known application of such devices is high precision gyroscope sensors based on the observation that the proton precession frequency changes due to sensor rotation [6]. There is already the similar network GNOME [7]. In fact, these systems are based on the observation of the stability of the word gyroscopic constants and their mutual change when viewed as part of multi-sensor remote networks over long distances.

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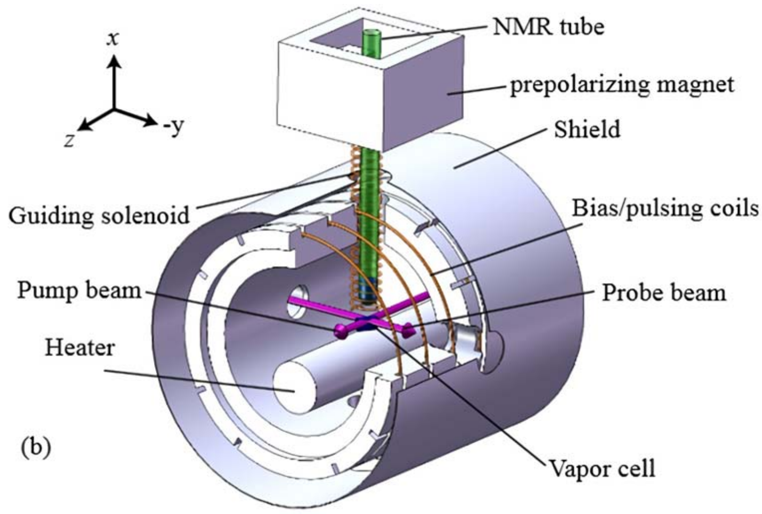

Figure 1. Experimental setup for the pentane nuclear-spin co-magnetometer. A sample of pentane is polarized in 2 T magnet an moved into a low-field detection region. After the guiding field is removed, the spins precession in a Z directed magnetic field about of 1 mG (100 nT). This precession is monitored by an alkali vapor (K) magnetometers operating in the continues regime.

A short incomplete list of the requirements to such systems is presented below:

- Minimal possible level of industrial magnetic interferences.
- Maximal homogeneity and stability of a weak magnetic field in which the nuclear and electron precession is measured.
- Network of spin-gravitational sensors placed at maximal large distances with data transmission to a single data center.
- High precision measurement synchronization (for example, using the GPS).
- Long term (multiyear) data accumulation in a single (or cloud) data center with public access for independent processing.
- Highly qualified research and management personnel servicing spin-gravitational sensors and data processing of high precision multi-parameter measurements.

3. Proposals for INTERMAGNET observatories

It is easy to see that these requirements are completely satisfied by the existing network of magnetic observatories INTERMAGNET (including some magnetometer sensor types as a proton precession and K optic quantum magnetometers).

The developers of magnetometer spin-gravitational sensors are working on resolving difficult scientific and technical problems from industrial interference magnetic shielding to sensor deployment in space. Various sensors are under development, including those analogous to optical potassium (K) or cesium magnetometers, and NMR magnetometers with nuclear magnetization amplification based on hyperpolarization (including Overhauser nuclear dynamical polarization). The above considerations lead to a proposal of development of a network for cosmological spin-gravity effects detection based on existing network of magnetic observatories. The development cost of such network (with insignificant hard- and software tuning and access to the original measurements database for data analysis using specialized soft) as it shown on the fig. 2.

Without going into details underline that comagnetometer Overhauser channel should have a continuous signal similar to optical magnetometer. It can be provided by Overhauser DNP sensors, for example, using the Salvi-Glenat method or maser scheme. The maser one is based on continuous generation of proton precession signal in high-Q resonant coil with maintenance of nonequilibrium

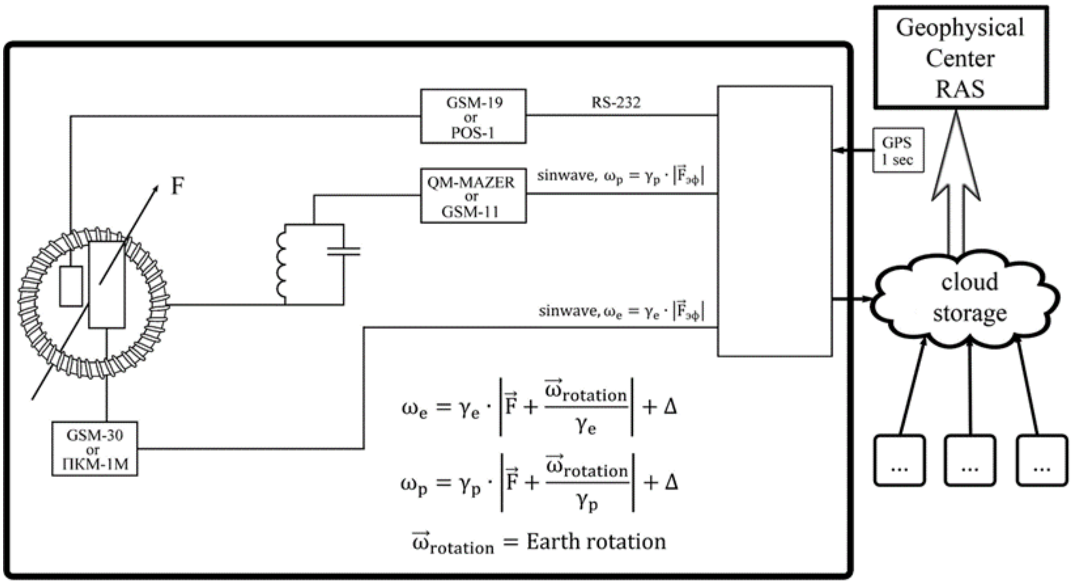

Figure 2. Simultaneous measurement circuit of the proton and K optic continuous magnetometers.

negative spin temperature of proton subsystem. The negative temperature is due to inverse proton level population with excitation of specific transitions in electron subsystem of nitroxyl radical solutions.

An existence of the IAGA developed network of seismic observation bases supports the proposed network of spin-gravitational sensors which in its turn might appear a powerful tool for global seismic prognosis as ground-based spin-gravitational sensor measurements are significantly dependent on geolocation and Earth rotation parameters.

It is assumed that the spin-gravitational effect signal would of the order of magnitude of few fT with the registration time of 100 s and over. Such a signal can be easily detected by K optical magnetometer and potentially by the Overhauser magnetometer with large volume sensors and special algorithms for the signal accumulation. It requires synchronous operation of multiple pairs of magnetometers to eliminate gyroscopic and seismic effects and mutual verification.

The report shows that the magnetometer equipment GEM employed in INTERMAGNET network might satisfy the required parameters after some tuning aimed to direct output of the original electron and proton precession signals to the specialized registration device resolution. It will allow significant increase of magnetic field measurements. A multiyear signal accumulation will make possible to reach the precision level of a few fT in measurement of gradient between Overhauser and potassium magnetometers.

We discuss development of the Overhauser POS magnetometer with GPS synchronization of the proton precession signal. The signal processing algorithm also includes a possibility of real time output time series of the zero crossing for data accumulation and significant increase measurement sensitivity and bit depth. We also describe a regime of precession wide-band registration [8] of several nuclei simultaneously. Simultaneous Overhauser polarization of these nuclei is also possible with the coefficients of an order of (gyromagnetic electron ratio/gyromagnetic nucleus ratio). This option can be useful for development and design of new types of gyroscope and spin-gravitational sensors.

In other words, the rotating Earth is just a float bobbing in a gravitational wave and the INTERMAGNET network can serve as a fishing net for the gravitational waves.

4. Conclusion

We hope that the proposals for the aggregation of the optical and Overhauser magnetometers will be interesting to study the mutual stability of world constants. At least, such research can improve the data of magnetic observatories and earthquakes forecasting systems.

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