

An experimental set-up and measures of relevant «magnetic hygiene» required in the evaluations of small variations of terrestrial magnetic fields in the urbane surroundings are described in the third part. The measures include special unshielded laboratory in a house that has no metal part in construction, suppression of the line pick-ups by gradiometer technique, and building-up the calibration coil system, which provides stable magnetic field in the range 20-100 μT . The noise technique used to specify magnetic resonance (MR) is described.

In the fourth part of the paper, the noise technique has is applied for characterization of a set of coated cells and cells filled with buffer gases. The same part gives results of the investigation of two-laser pumping and estimation of the effect of hyperfine optical depopulation of the working sublevel on the amplitude of the MR. It has been shown, that for properly selected power of optical pumping that does not lead to appreciable broadening of MR the mentioned loss of atoms only slightly decreases signal. Thus, technical problems involved with the incorporation of a second laser in a magnetometer are not justified. We also carried out experiments with optical pumping by linearly polarized light. The whole Zeeman structure of MR has been resolved in terrestrial magnetic field on decreasing laser intensity and the amplitude of RF field. The linear polarization provides the symmetrical shape of the MR line, which can decrease the heading error of magnetometer. A spin generator pumped by linearly polarized laser light has been realized and tested. It produced oscillation at the doubled Larmor frequency but demonstrated smaller signal-to-noise ratio so that circular polarization has been preferred for a model of magnetometer.

The last part describes the developed model of magnetometer. The substitution of the resonant gas-discharge lamp of 3W power consumption by VCSEL laser whose consumption is about 5 mW makes it possible to reject heavy batteries in spite of the addition of GPS/GLONASS receiver and a modern display in the model.

Thus, operating parameters of magnetometer model are improved as compared with those of a prototype magnetometer («ПКМ-1М») while keeping its metrological characteristics.

References

- Alexandrov E.B., Bonch-Bruевич V.A. Optically pumped atomic magnetometers after three decades // *Optical Engineering*. 1992. V. 31(4). P. 711-717.
- Budker V. and Romalis M. Optical magnetometry // *Nature Physics*. 2007. V. 3(4). P. 227-234.
- Aleksandrov E.B. Progress v kvantovoy magnitometrii diya geomagnitny'x issledovanij // *Uspexi fizicheskix nauk*. 2010. T. 180(5). S. 509-519.
- Pomeranczev N.M., Ry'zhkov V.M., Skrocziy G.V. Fizicheskie osnovy' kvantovoy magnitometrii. M.: Nauka. 1972.
- Budker D., Jackson Kimball D.F. (Eds.). *Optical Magnetometry*. Cambridge: Cambridge University Press. 2013.
- Savukov I., Seltzer S.J. Spin-exchange-relaxation-free (SERF) magnetometers. P. 85-103 v [5].
- Jackson Kimball D.F., Pustelny S., Yashchuk V.V., Budker D. Optical magnetometry with modulated light. P. 104-124 v [5].
- Jackson Kimball D.F., Lamoreaux S.K., Chupp T.E. Tests of fundamental physics with optical magnetometers // P. 339-368 v [5].
- Bokeriya O.L., Kisliczina O.N., Temirbulatova A.Sh. Vozmozhnosti magnito'lektrokardiografii v diagnostike ishemichejskoj bolezni serdca i narushenij ritma // *Analy'aritmologii*. 2009. № 2. S. 45-63.
- Wyllie R., Kauer M., Wakai R.T., Walker T.G. Optical magnetometer array for fetal magnetocardiography // *Opt. Letters*. 2012. V. 37(12). P. 2247-2249.
- Tkach R.W., Chraplyvy A.R. Regimes of Feedback Effects in 1.5- μm Distributed Feedback Laser // *Journal of Lightwave Technology*. V. 4(11). P. 1655-1661.
- Kargapol'czev S.V., Velichanskij V.L., Vasil'ev V.V., Kobayakova M.Sh., A.V. Morozuyk A.V., Shiryayeva N.V., Konyaev V.P. Nizkoporogovij diodny' lazer s korotkim rezonatorom diya miniatyurny'x atomny'x chasov // *Kvantovaya e'lektronika*. T. 39(6). S. 487-493.
- Michalzik R. VCSEL Fundamentals / VCSELs. Fundamentals, Technology and Applications of Vertical-Cavity Surface-Emitting Lasers / Michalzik R. (Ed.). Springer Series in Optical Sciences. 2013. V. 166.
- Bison G., Wynands R., Weis A. A laser-pumped magnetometer for themapping of human cardiomagnetic fields // *Appl. Phys. B*. 2003. V. 76(3). P. 325-328.
- Aleksandrov E.B., Balabas M.B., Vershovskij A.K., Ivanov A.E., Jakobson N.N., Velichanskij V.L., Senkov N.V. Lazernaya nakachka v sxeme Mx-magnitometra // *Opticheskaya spektroskopiya*. 1995. T. 78. S. 325-332.
- Vassiliev V.V., Zibrov S.A., Velichansky V.L. Compact extended-cavity diode laser for atomic spectroscopy and metrology // *Review of Scientific Instruments*. 2006. V. 77(1). P. 013102-013102-4.
- Baxert X.-Ju., Bogatov A.P., Gurov Ju.V., Eliseev P.G., Oxotnikov O.G., Pak G.T., Raxval'skij M.P., Xajretidinov K.A. Radiochastotny'e spektry' bienij mod i pul'saczii intensivnosti inzhekcionnogo lazera s vneshnim dispersionny'm rezonatorom // *Kvantovaya e'lektronika*. 1981 T. 8(9). S. 1957-1961.
- Vershovskij A.K. Novy'e kvantovy'e radioopticheskie sistemy' i metody' izmereniya slabyx magnitny'x polej: Dis. ... d-ra fiz.-mat. nauk. SPb. 2007.
- McGregor D.D. High-sensitivity helium resonance magnetometers // *Rev. Sci. Instrum.* V. 58(6). P. 1067-1076.
- Slocum R.E., McGregor D.D., Brown A.W. Helium magnetometers. P. 190-204 v [5].
- Alexandrov E.B., Vershovskij A.K. Mx and Mz magnetometers. P. 60-84, v [5]
- Dehmelt H.G. Modulation of a light beam by precessing absorbing atoms // *Phys. Rev.* 1957. V. 105. P. 1924-1925.
- Budker D., Kimball D., De Mill' D. Atomnaya fizika: osvoenie cherez zadachi. M: Fizmatlit. 2009.
- Groeger S., Pzalgalev A.S., Weis A. Comparison of discharge lamp and laser pumped cesium magnetometers // *Appl. Phys. B*. 2005. V. 80(6). P. 645-654.
- Balabas M.V., Pzalgalev A.S., Vershovskii A.K., Yakobson N.N. Double-resonance atomic magnetometers: from gas discharge to laser pumping // *Laser Physics*. 1996. V.6(2). P. 244-251.
- Slocum R.E., Scheerer L.D., Tin P., Marquedant R. Nd: LNA laser optical pumping of He-4 - Application to space magnetometers // *Journal of Applied Physics*. 1988. V. 64(12). P. 6615-6617.
- Steck D.A. Cesium D Line Data. Version 2.1.4 [E'lektronny'j resurs]: Oregon Center for Optics and Department of Physics, University of Oregon. 2010. URL: <http://steck.us/alkalidata/cesiumnumbers.pdf> (dataobrashheniya: 01.11.2013)
- Corwin K.L., Lu Z.-T., Hand C.F., Epstein R.J., Wieman C.E. Frequency-stabilized diode laser with the zeeman shift in an atomic vapor // *Optical Society of America*. 1998. V. 37(15). P. 3295-3298.
- Yabuzaki T., Ogawa T. Spectral Profile of rf Modulated Light Beam in Optical Pumping Experiment with Cesium Vapor // Skaliński T. (ed.). *Optical Pumping and Atomic Line Shape: Proceedings of the International Conference OPaLS, Warszawa, 25-28 June 1968 / Warszawa: WydawnictwoNaukowe PWN*. 1969.
- Di Domenico G., Bison G., Groeger S., Knowles P., Pzalgalev A. S., Rebetez M., Saudan H., Weis A. Experimental study of laser detected magnetic resonance based on atomic alignment // *Phys. Rev. A*. 2006. V. 74(6). P. 063415-063415-8.
- Weis A., Bison G., Pzalgalev A.S. Theory of double resonance magnetometers based on atomic alignment // *Phys. Rev. A*. 2006. V. 74(3). P. 033401-033401-8.