Towards magnetoencephalography based on ultra-sensitive laser pumped non-zero field magnetic sensor

A.E.Ossadtchi[1], N.K.Kulachenkov[2], D.S.Chuchelov[3], S.P.Dmitriev[4], A.S.Pazgalev[4], M.V.Petrenko[4], A.K.Vershovskii[4]
[1]National Research University “Higher School of Economics”, Moscow, Russia
[2]State Research Center of the Russian Federation – Concern CSRI Electropribor, JSR, St. Petersburg, Russia
[3]P.N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia
[4]Ioffe Institute, St. Petersburg, Russia
ossadtchi@gmail.com, vershovski@gmail.com

***Abstract*—The principal possibility of creating optically pumped compact magnetic sensor for MEG operating in a wide magnetic field range is experimentally proved.**

***Keywords*—magnetoencephalography; magnetic resonance; optical magnetometers; laser pumping; laser detection.**

I. INTRODUCTION

Magnetoencephalography (MEG) is a functional brain imaging modality allowing to resolve neuronal events on the sub-centimeter spatial and millisecond temporal scales. This is achieved by the use of SQUID sensors arranged into a multi-channel probe to sense fT scale fields. These systems are expensive, not mobile, have fixed probe shape (Dewar vessel), and are prone to flux trapping.

Optically pumped magnetometers (OPMs) is a viable alternative to SQUIDS. The OPM based MEG systems will allow for the sensors to be placed practically on a scalp which will reduce the distance to the cortex and boost the signal-to-noise ratio of MEG measurements. There are currently several attempts worldwide aimed at building a multichannel OPM-based MEG system using the spin exchange relaxation free (SERF) mode-based OPMs [1]. However, the extremely high sensitivity (≤ 10 fT/Hz$^{-½}$) of SERFs is accompanied by a low (~5 nT) dynamic range which requires ultra-high external magnetic field uniformity.

II. NON-ZERO FIELD SENSOR FOR MEG

The use of semiconductor lasers is a way to create an OPM sensor for MEG operating in a wide magnetic field range based on the effect of spin-exchange relaxation rate decrease at high laser pumping intensities [2,3]. Here we have exploited this effect in a two-beam M_X OPM scheme [4], which yields the following advantages: the speed unattainable in M_Z scheme; non-sensitivity to the laser and environment low-frequency noise due to the OPM frequency transfer up to hundreds of kHz; non-sensitivity to the laser power noise brought about by the balanced signal detection.

III. RESULTS

We have estimated the ultimate sensitivity of our scheme by measuring signal-to-noise-to-resonance width ratio [4]; the result is shown in Fig.1. In fact, for the first time we have demonstrated the possibility of achieving in a compact (0.5 cm^3 cell) non-zero-field OPM the sensitivity typical for the SERF mode. Our next task is a direct demonstration of sensitivity in the MEG context.

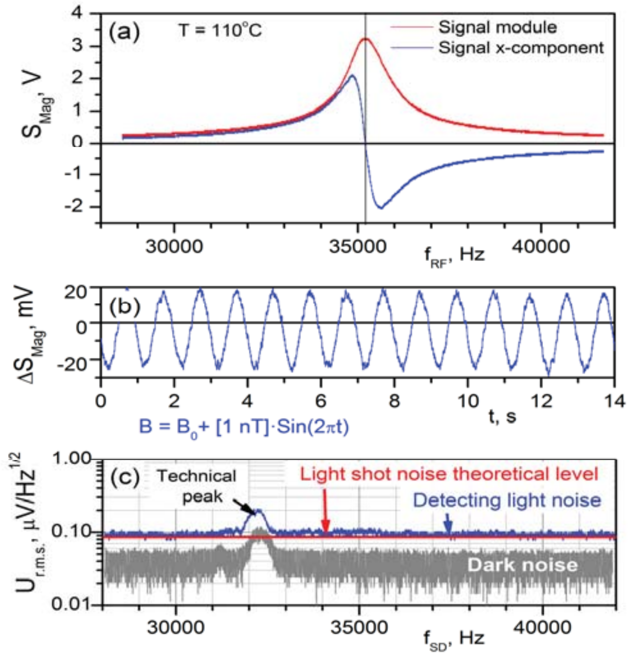

Fig. 1. (a) – The line of Cs magnetic resonance (MR). (b) – Response of MR to 1 nT magnetic field modulation; the noise corresponds to the real magnetic field fluctuations in the field stabilizer. (c) – Detecting light noise r.m.s. level as compared to the theoretical quantum shot noise limit.

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