Application of optical atomic magnetometry for exotic incarnation of nuclear magnetic resonance

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Nuclear magnetic resonance (NMR) is a powerful technique, enabling spectroscopic measurements of molecules, providing information about their chemical structure, strength and orientation of chemical bonds, hybridization, etc., but also noninvasive imaging, which is routinely used in medical diagnostics. Typically, NMR measurements are performed using an extremely strong magnetic field, which, at the same time, is the largest disadvantage of the technique, which limits its application to nonmagnetic objects and makes NMR spectrometers/scanners bulky, heavy, and expensive devices.

While NMR measurements at much weaker fields seem like an interesting alternative to a conventional NMR, a number of important problems need to be addressed in order to perform such measurements. One of them is detection of spin dynamics at a magnetic field orders of magnitude smaller than in conventional NMR, which generated low-frequency oscillating magnetic signals (<1 MHz). Under such conditions, a traditional, inductive detection suffers from a dramatic deterioration of sensitivity and needs to be replace by a different type of sensor. **Optical atomic magnetometers** (OAMs) are one of the best choices for the purpose.

During the talk, some basics of application of OAMs for NMR at **zero- and ultra-low magnetic fields** (ZULFs) will be presented [1]. We will show, how operation under such conditions changes dynamics of nuclear systems and what new information can be extracted from such measurements. Specific example of application of OAMs for ZULF NMR will be discussed and future directions in the field will be highlighted.

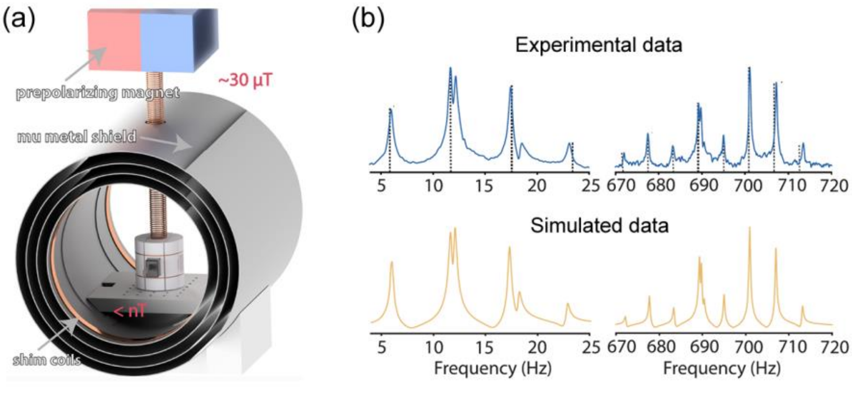

Fig 1.(a) Schematic of experimental setup for ZULF NMR detection [2] and (b) experimental (top) and simulated (bottom) ZULF NMR data of representative molecule (dimethyl phosphite) [3].

[1] M. C. D. Tayler, T. Theis, T. F. Sjolander, J. W. Blanchard, S. Pustelny, A. Pines, and D. Budker, Rev. Sci. Instrum. **88**, 091101 (2017).

[2] P. Put, S. Pustelny, D. Budker, E. Druga, T. F. Sjolander, A. Pines, and D. A. Barskiy, Anal. Chem. **93**, 3226-3232 (2021).

[3] S. Alcicek, P. Put, V. Kontul, and S. Pustelny, Phys. Chem. Lett. **12**, 787-792 (2021).