EPR su kriogeniniais stiprintuvais nepriklausančiais nuo bandinio temperatūros

EPR with cryogenic amplifiers independent of sample temperature

Vidmantas Kalendra[1], Justinas Turčak[1], Jūras Banys[1], John J.L. Morton[2,3] and Mantas Šimėnas[1]
[1]Faculty of Physics, Vilnius University, Sauletekio 3, LT-10257 Vilnius, Lithuania
[2]London Centre for Nanotechnology, University College London, London WC1H 0AH, UK
[3]Dept. of Electronic & Electrical Engineering, University College London, London WC1E 7JE, UK
vidmantas.kalendra@ff.vu.lt

Cryogenically cooled Nuclear magnetic resonance (NMR) cryoprobes containing cryogenic preamplifiers are frequently used to significantly enhance NMR sensitivity. In these probeheads, the thermal noise is substantially reduced by simultaneous cooling of the NMR coils and low noise preamplifier, independently of the sample temperature. Despite several studies reporting promising Electron paramagnetic resonance (EPR) sensitivity improvements, signal preamplification with cryogenic microwave amplifiers has not yet been widely adopted in the EPR community mainly due to poor compatibility with commercial spectrometers, typical samples and high power pulsed EPR experiments.

Recently, we designed and tested an X-band EPR cryoprobe, which meets these criteria, by placing a cryogenic low noise amplifier (LNA) close to the sample on a commercially available EPR probehead [1]. To protect the LNA from high power microwave pulses employed in pulsed EPR, we incorporated a protection circuit consisting of a limiter and a fast microwave switch. The microwaves were guided to and from the resonator using a directional coupler, which also acted as partial suppressor of the input thermal noise at the expense of the excitation power. The probehead provided a significant voltage signal-to-noise ratio (SNR) improvement close to 10× below 10 K (100× reduction in the measurement time) already rendering some EPR experiments feasible that would otherwise have been impossible in a reasonable amount of time.

Here, we take further inspiration from the NMR cryoprobe and consider a more general approach, where the cryogenic LNA and its protection circuit is kept at a different temperature to that of the sample (for example, using a separate cryostat). This method has a number of potential advantages over our previous demonstration [1], the most significant being that the sensitivity gain is practically independent of the sample temperature. In addition, integrating an LNA together with its protection circuit in a limited space close to the resonator can pose practical challenges in typical cryostats, especially for ENDOR and Q-band probeheads. Using a separate cryostat outside the magnetic field applied to the sample also enables the use of microwave components such as ferrite circulators, which bring potential gains in sensitivity [1].

We use the effective noise temperature formalism to discuss the feasibility of such a cryoprobe setup, which is then realised experimentally. The constructed cryoprobe (Fig. 1) is fully compatible with the commercial and homebuilt EPR spectrometers and, in addition to ordinary pulsed EPR probeheads, it can be easily used with high-Q CW, ENDOR and Q-band resonators. Our new setup shows about 4× voltage SNR improvements at X-band, while for measurements at Q-band, the enhancement is slightly above 2× with prospects for further improvement. In both cases, the obtained sensitivity gain is practically independent of the sample temperature.

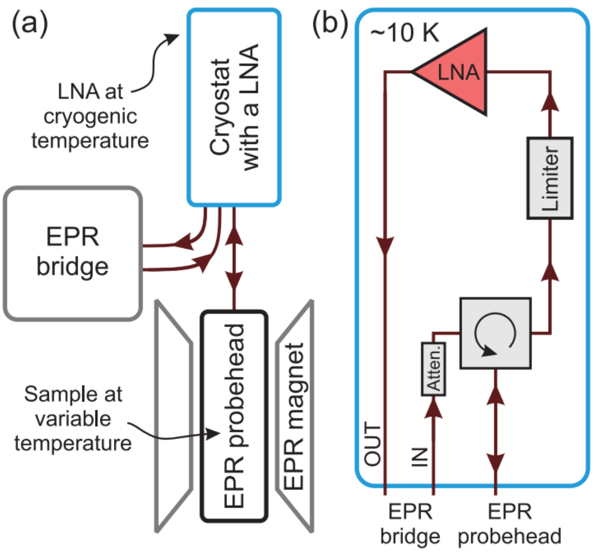

Fig. 1. (a) Block diagram of our cryoprobe EPR setup with an externally cooled cryogenic LNA. (b) Schematic of the microwave circuit within the external cryostat, which is connected to the microwave bridge and EPR probehead.

Keywords: EPR, Cryoprobe, LNA, Sensitivity, SNR

Literatūra

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