Measurement of the noise spectrum using a multiple-pulse sequence
多重パルス印加による雑音スペクトルの測定

A method is proposed for obtaining the spectrum for noise that causes the phase decoherence of a spin (qubit) system directly from experimentally available data. The method is based on a simple relationship between the spectrum and the coherence time of the spin (qubit) in the presence of a pulse sequence. Here, we assume a simple sequence of equidistant pulses such as an APCP (shown in Fig. 1) or CPMG sequence. In the long time limit (large pulse number limit) keeping the interpulse time (2τ) fixed, we find that the coherence exhibits an exponential decay. This time dependence enables us to define uniquely the coherence time T_2^L for a multiple-pulse sequence. We call the obtained T_2^L as "generalized" coherence time, because this T_2^L indicates T_2 time for a certain frequency in contrast to the Hahn echo T_2 reflecting a static T_2 time.

More interestingly, this generalized T_2^L has a simple relation with a noise spectrum $S(\omega)$ as

$$\frac{1}{T_2^L} = \frac{4}{\pi^2}\sum_{l=0}^{\infty}\frac{1}{(2l+1)^2}S(\omega_{2l+1}).$$

Since the factor $1/(2l+1)^2$ is smaller for larger l, we can approximate the above equation into

$$\frac{1}{T_2^L} \simeq \frac{4}{\pi^2}S(\pi/2\tau),$$

if $S(\omega)$ rapidly decreases as ω increases. These relationships are qualitatively explained as follows. In many systems, coherence time is dominated by the lowest-frequency component of the noise spectrum (fluctuation-dissipation relation). The pulse sequence with time interval $\sim\tau$ cancels out the noise at frequencies lower than $\sim 1/\tau$ (dynamical decoupling). Therefore, the noise spectrum around the frequency $\sim 1/\tau$ dominantly contributes to the coherence time in the presence of the pulse sequence. The relationship is found to hold for every system of a spin (qubit) interacting with the classical-noise, bosonic, and spin baths.

The proposed noise spectrum measurement provides us very useful method to evaluate the noise spectrum of spin, nuclear spin, and many types of qubits.

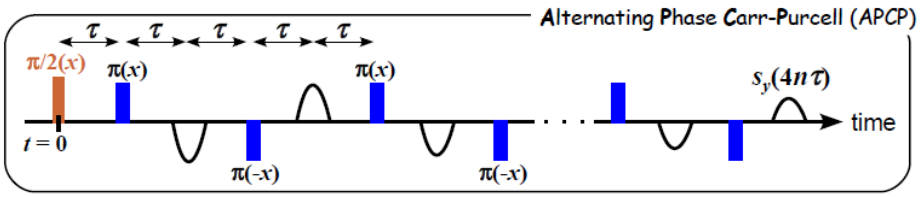

Fig. 1 Example of the pulse sequence

Representative ubication:
Tatsuro Yuge, Susumu Sasaki, and Yoshiro Hirayama, Phys. Rev. Lett. 107, 170504 (2011).