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Kraan, Wicher; Akselrod, LA; Zabenkin, V. N.; Chetverikov, Yu.O.; Grigoriev, SV; Sumbatyan, A.A.

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Finding the empty-beam-calibration for a SESANS setup in a beam line at PIK

W.H. Kraan[1] , *L.A. Akselrod*[2] , *V.N.Zabenkin* [2], *Yu.O. Chetverikov*[2] , *S.V. Grigoriev*[2] *and A.A. Sumbatyan*[2]

[1] *retired from: Delft University of Technology, 2629 JB Delft, The Netherlands*
[2] *Petersburg Nuclear Physics Institute, Gatchina, Leningrad Oblast, 188300, Russia*

SESANS is a neutron Spin-Echo (SE) experiment in devices, effectively operating as regions of length L with magnetic field B, shaped as *parallellograms*.[1] The precession phase "collected" along a trajectory at angle ψ (insert Fig.1) through such a device is

$$\phi \approx \lambda\,(cBL+\Gamma\psi) \qquad \text{Eq.(1)}$$

($c=4\pi\mu_n m_n/h^2= 4.632\ 10^{14}\ T^{-1}m^{-2}$; μ_n , m_n , h = *neutron mass, magn. moment and Planck's constant*). $\lambda\Gamma\psi$ is the angle labeling term, Γ is called "labeling coefficient".

Suppose a neutron is scattered by $\psi_2 - \psi_1 = \theta_S$ in horizontal direction perpendicular to the beam axis. Then, using Eq.(1) we can calculate the *offset* $\phi_1 - \phi_2 = \lambda\Gamma\theta_S$ due to this process. It has wavevector transfer $Q = (4\pi/\lambda)\sin(\theta_S/2) \approx 2\pi\theta_S/\lambda$. If we divide the offset by Q, we get a quantity of dimension length:

$$\delta = \lambda\Gamma\theta_S/Q = \Gamma\lambda^2/2\pi, \qquad \text{Eq.(2)}$$

called "spin-echo length". δ depends on the setup parameters θ_0, L, B and on λ.

The **aim of this report** is to find the **coefficient** Γ and the **empty beam polarisation P_0** for a setup, with each SE-arm made up of 2 *adiabatic/RF/gradient flippers* in special DC magnets existing at PNPI. To get $\Gamma\neq0$, their poles are shaped as parallellograms with apex angle $\theta_0=33.5^O$.

We made software to calculate the (DC/RF/gradient)fields experienced through the setup (4 flippers) along trajectories in a *divergent-ribbon-beam*: the beam defined by 2 vertical slits (2cm high) at distance equal to the total length (4.4 m) of the setup.

The section of a trajectory through each flipper is divided in N steps with fields supposed homogeneous. We simulate Larmor precession as the product of 4 progressing products $P^k_{i,j}$ ($i,j=x,y,z$) of rotation matrices (with number of factors increasing from 1...N) operating on the classical "polarisation vector" - in a coordinate system *rotating* around the DC field direction at the frequency ω_{RF} of the RF coils in the flippers (*time dependence of the RF fields "transformed away" by subtracting a homogeneous field* $B^*=\omega_{RF}/\gamma$; $\gamma/2\pi$=29126 kHz/T). As input we take the polarisation vectors (100 010 001) from an ideal "π/2-flipper" in front. The final matrix product are the polarisation components passing through an ideal π/2-flipper behind the setup.

To study SE, we *must* follow the collected precession phase. After each step k we calculate this phase by: $\phi_k = \tan^{-1}(P^k_{y\,x} / P^k_{y\,y})$. The result comes in the interval [-π,π]. If we choose the number N so high that $\phi_k < \pi$ for all k, we can recover the multiples of 2π. Thus, we can find the final precession phase Φ for all trajectories in our beam through the full setup *without sample*, for given λ. It appears that the SE is not sharp – there is a spread in Φ (for example, for λ=3 Å up to 4 rad).

To get the polarisation $\mathbf{P_0}$**,** we must insert a "phasecoil" in the setup, to make offset from SE by adding precession phase Δφ (equal for all trajectories) in SE-arm 2. $\mathbf{P_0}$ is the amplitude of the signal

$$P_{yy} = \langle \cos(\Phi + \Delta\varphi) \rangle_{beam.}$$

We calculated these signals for λ=2...10 Å, varying Δφ in 13 steps from -π to π. Their amplitudes are identical with $\mathbf{P_0}$ (λ). Using Eq.(2) we convert λ to spin-echo length δ. Then we arrive at the **empty-beam-calibration** $\mathbf{P_0}$(δ) of the setup, supposed to be installed in a beam line of PIK. We also find: the signals for *divergent-ribbon-beams* until 2.5 mrad away from the beam axis are practically in-phase.

We conclude: a SESANS setup based on the existing DC magnets will have an acceptable $\mathbf{P_0}$(δ) up to δ=*20* μm, with a beam of divergence (FWHM) up to 5 mrad.

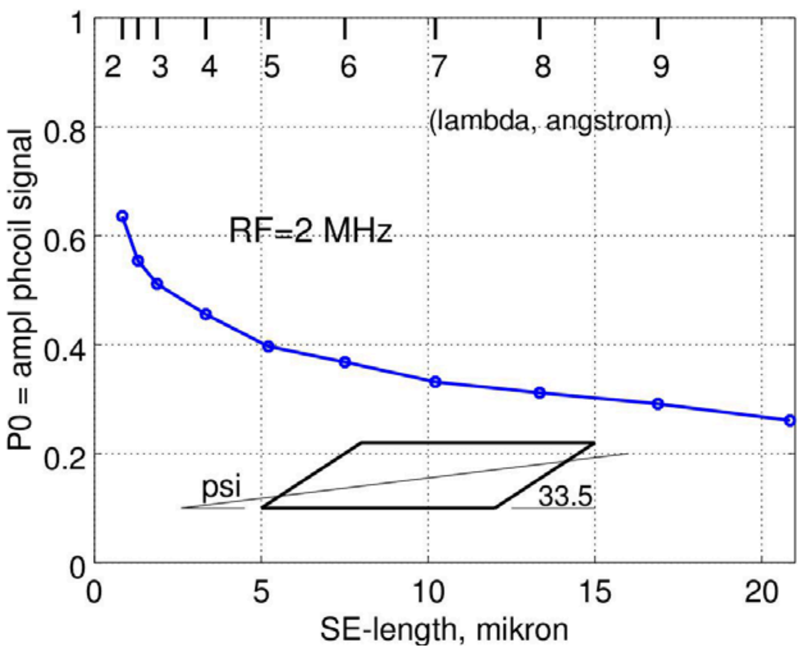

Fig.1: Empty-beam polarisation $\mathbf{P_0}$ *in a SESANS setup based on DC magnets existing at PNPI, with poles shaped as* 33.5^0*-parallellograms, flippers in each SE-arm* 1.4 m *apart.*

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