Experimental Report

Proposal: **3-15-68** **Council:** 10/2011

Title: High-precision determination of Si-neutron coherent scattering length

This proposal is continuation of: 3-15-61

Researh Area: Physics

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Samples: silicon / Si

Instrument	Req. Days	All. Days	From	To
S18	25	25	21/05/2013	13/06/2013

Abstract:

We propose to continue our last experimental run (3-15-61), to interferometrically determine neutron coherent scattering length b_c for silicon to within a few parts per million, using a dual non-dispersive sample.
During our 3-15-61 experimental run, we lost one week due to a vacuum pump inadvertently placed on the rooftop of the S18 cabin by the ILL operational staff. The pump could not be shifted during the reactor cycle. We could hence only try to isolate its vibrations from the cabin. The observed phases therefore fluctuated wildly. We could nevertheless select a few of the several hundred recorded interferograms and determine silicon b_c to within 30 parts per million.
If in our next run, all sources of vibration and thermal variations are scrupulously kept away from S18, we can achieve the proposed ppm precision.

We carried out an interferometric experiment at S18 beam port to determine the neutron coherent scattering length b_C for silicon to high precision [1-2, 4] using a dual non-dispersive sample. A dual sample of thickness D and atomic number density N inserted in both gaps of one beam of the interferometer (IFM) with its surfaces aligned parallel to the IFM Bragg planes (Fig.1) yields an exactly non-dispersive phase given by

$$\Phi = 4\pi D\left(\sqrt{\frac{1}{4d^2} - \frac{Nb_c - N_a b_a}{\pi}} - \frac{1}{2d}\right),$$

where d denotes the IFM Bragg planar spacing and quantities N_a, b_a and n_a stand for atomic number density, coherent scattering length and refractive index respectively of air.

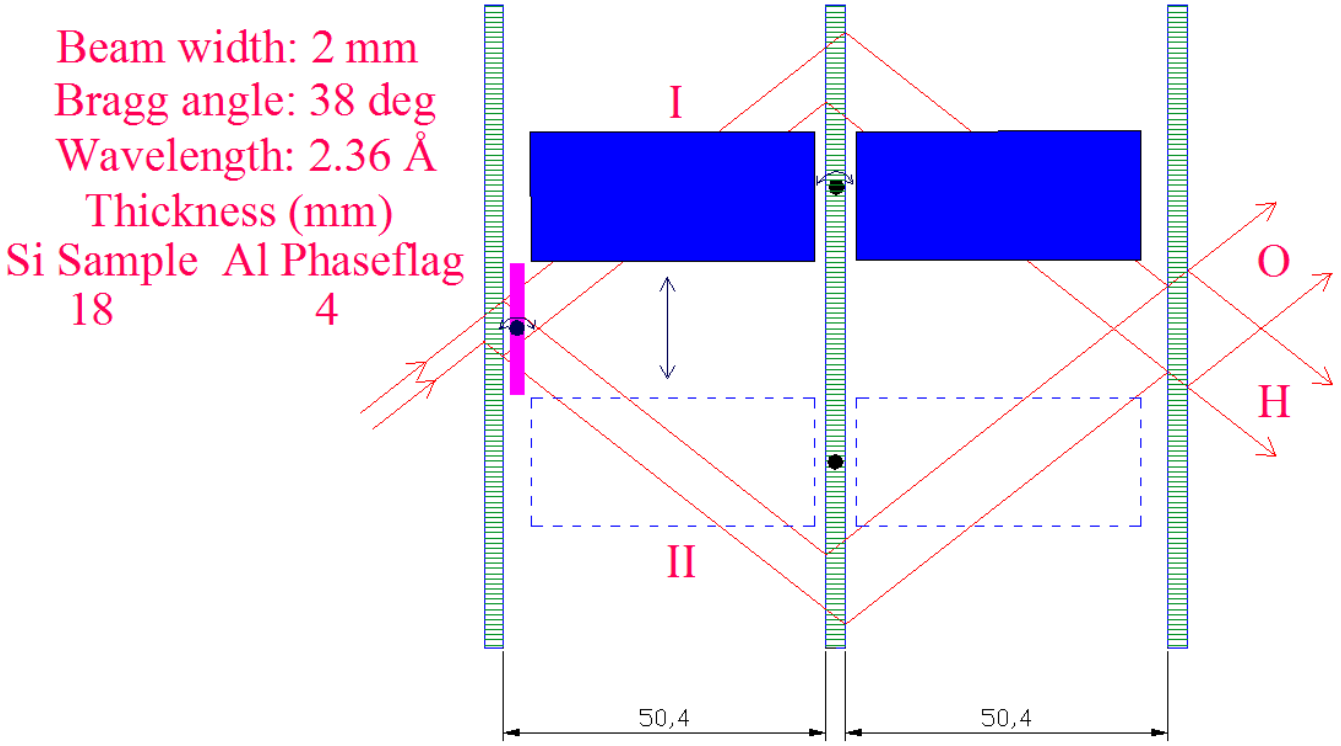

Fig.1 High precision b_C determination (schematic) employing a thick dual nondispersive sample in a large symmetric LLL interferometer.

In the experimental run, we used a symmetric 220 LLL interferometer, with 50.4 mm gaps between successive blades, operating with 2.36 Å neutrons at a Bragg angle of 37.9283° which allowed a 17.995 mm thick dual non-dispersive silicon sample (Fig.1). The dual Si sample was fabricated at BARC in Mumbai by making high precision cuts on a Si single crystal ingot using diamond cutting tools. The sample was then chemo-mechanically polished to high precision to attain parallel surfaces with a thickness of

17.995 ± 0.00025 mm. A mylar foil was wrapped around the cylindrical enclosure housing the IFM setup to minimise air currents and temperature variations. The O+H intensity was recorded as a function of the sample location in the IFM and the sample positions for paths I and II were set at the centres of the intensity plateaus obtained for the respective paths. The phases extracted from interferograms acquired at several rotations ε and tilts γ of the sample in path I and II were fitted to parabolic curves to arrive at the sample orientation (ε_0, γ_0) where the sample surfaces were parallel to the Bragg planes of the IFM.

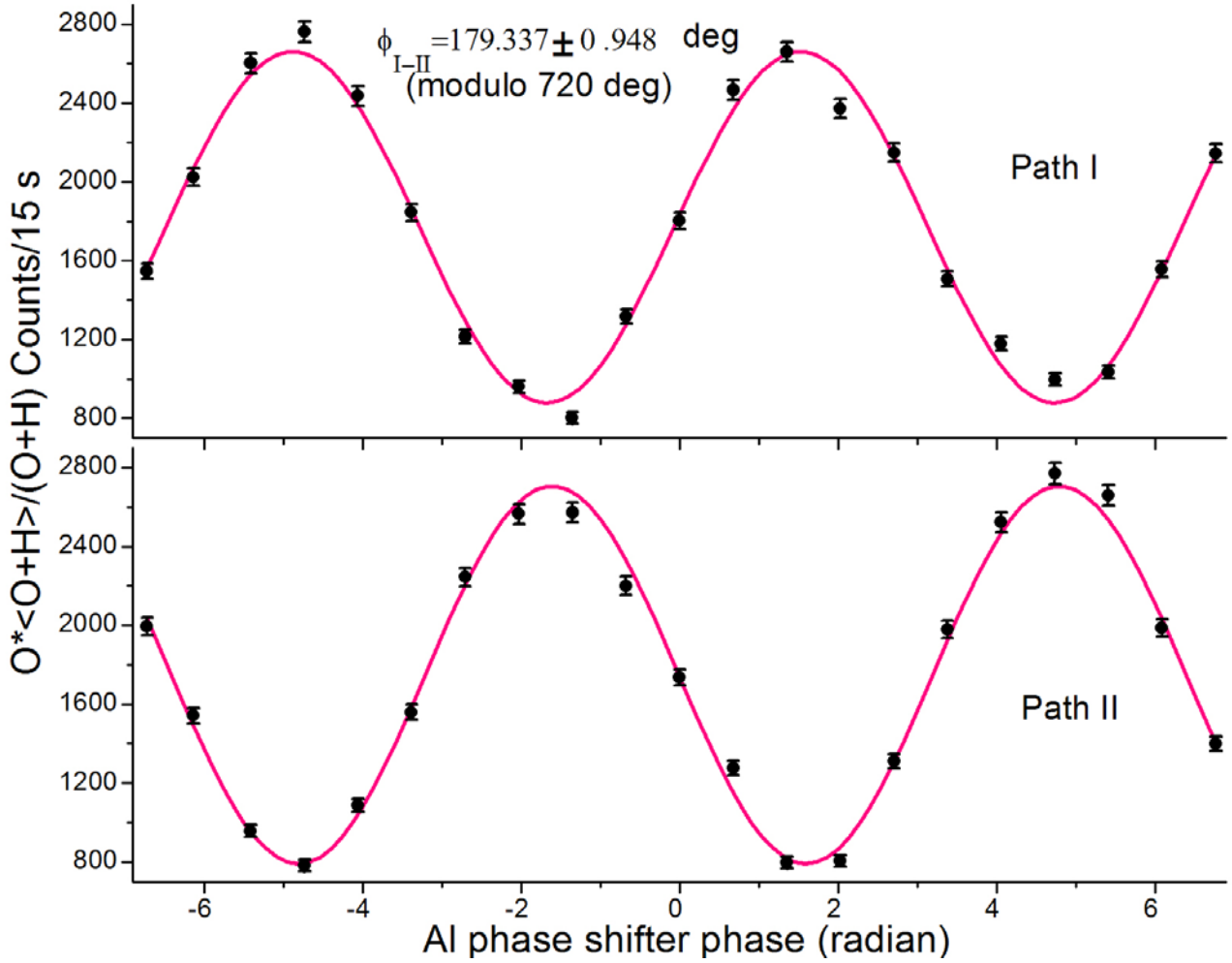

Fig.2 Typical interferograms with the sample placed in path I and path II.

We then recorded sample-IN and -OUT interferograms alternately for paths I and II with ~ 60% contrast. The observed sample-IN and -OUT interferograms had equal oscillation frequencies for path I as well as path II. The observed IN-OUT phases remained equal and opposite for paths I and II. Their variation over the experimental duration is displayed in Fig. 3. From 224 and 220 best and stable interferograms for paths I and II respectively and using the previous measurements of b_c for Si, we deduced IN-OUT

phases of – 455 X 360 + 89.62157 ± 0.046654 deg and + 455 X 360 – 89.71547 ± 0. 045523 deg for paths I and II respectively so that Φ_{I-II} = - 455 X 720 + 179.33704 ± 0.06525 deg. Applying corrections of 0.009137 fm for ambient air and of -1.01x10^{-5} fm due to refraction at air-sample interfaces to b_C and accounting for the thermal expansion of silicon at 26.2°C and for the 0.5 μm uncertainty in the sample thickness of 35.99 mm, a Si b_C value of 4.151197 ± 0.000057659 fm was arrived at.

This b_C determination is a factor of ~ 4 more precise than in the earlier measurement [3].

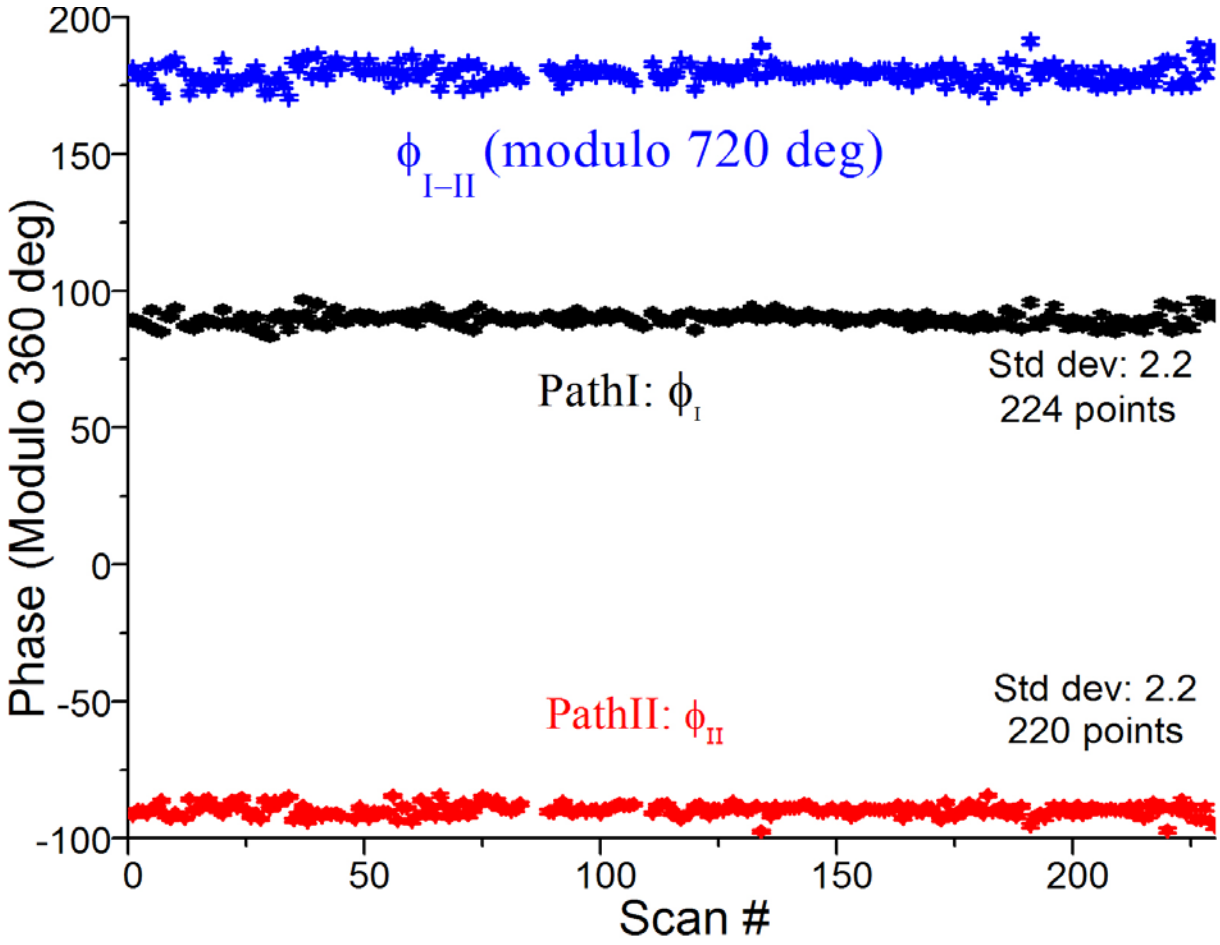

Fig.3 Observed IN-OUT phases with the nondispersive dual sample placed in path I and path II.

1. A. G. Wagh and S. Abbas, *J. Res. Natl. Inst. Stand. Technol.* **110** (2005) 237.
2. H. Lemmel and A. G. Wagh, *Phys. Rev. A,* **82** (2010) 033626.
3. A. Ioffe et al. *Phys. Rev. A* **58** (1998) 1475.
4. S. Abbas, A. G. Wagh, R. Loidl, H. Lemmel and H. Rauch, *AIP Conf. Proc.*, **1447** (2012) 479; A. G. Wagh, S. Abbas, Thomas Potocar, H. Lemmel and H. Rauch, ILL Experimental Report (2012).