| ESRF | **Experiment title:** High resolution monochromators for Nuclear Resonant Scattering at energies above 30 keV using Bragg backscattering of Synchrotron Radiation | **Experiment number:** MI-710 |
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| **Beamline:** ID18 | **Date of Experiment:** from: 05/05/2004 to: 10/05/2004 | **Date of Report:** August 31, 2004 |
| **Shifts:** 18 | **Local contact(s):** Dr. Ilia Sergueev | *Received at ESRF:* |

**Names and affiliations of applicants** (*indicates experimentalists):

H.-C. Wille*, Yu.V. Shvyd'ko*, E.E. Alp*, O. Leupold*, H.D. Rüter, I. Sergueev*, A. Barla*, A. Chumakov*, R. Rüffer*

## Report:

In this experiment nuclear resonant forward scattering (NFS ) spectroscopy at the 37.13 keV Mössbauer transition of $^{121}$Sb has been performed for the first time. The required high resolution monochromatization was achieved by using a Bragg backscattering monochromator [1,2] consisting of a sapphire ($\alpha$-$Al_2O_3$) crystal located in a temperature controlled prototype liquid $N_2$ flux cryostat with mK stability. Figure 1 shows the energy resolution curve of the used (15 13 14) reflection counting delayed reflected nuclear resonant photons only. By this the backreflection is scanned with the incoming energy bandwidth defined by the sum of the natural linewidths of the $^{121}$Sb nuclear hyperfine transitions ($\Gamma_0 = 10^{-7}$eV). The transition energy was determined to be 37.1297(2) keV at a crystal temperature of 146.54 K using the recently accurately measured values of the sapphire lattice parameters [3].

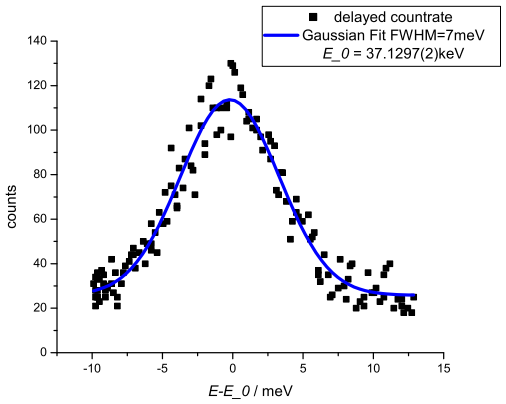


Fig. 1: Energy scan of the (15 13 14) sapphire Bragg backreflection (nuclear resonant quanta).

The shown energy scan was performed by changing the sapphire crystal temperature while the Bragg angle was kept constant at 89.95°. The measured energy width (7 meV) of the reflection is much

bigger than the expected theoretical width of 0.4 meV. This we interpret as a result of imperfections in the sapphire crystal. However, the achieved energy resolution is $\Delta E/E = 2 \cdot 10^{-7}$ and to our knowledge, high resolution monochromatization in the meV regime at energies above 30 keV has not been reported before. NFS spectroscopy was performed on samples of $Sb_2O_3$, USb, DySb of natural abundance in $^{121}$Sb (57.2%) located in a helium closed cycle cryostat. The used detector system has a time resolution of 0.9 ns and consists of twelve Avalanche Photo Diodes in an array arrangement providing high absorption efficiency at 37 keV. Data collection started at $t = 5.8$ ns only which is more than a full lifetime ($\tau = 5.0$ns) of the nuclear level, due to limitations of the timing electronics and an unavoidable detector recovery time in NFS. The countrates were $\leq$ 4Hz. This number strongly depends on the sapphire crystal quality and can be improved by at least one order of magnitude using a crystal of better quality with a reflection bandwidth nearer to the theoretical value. Figure 2 shows the measured time spectra providing access to the hyperfine parameters of the samples. The fits were performed with the program Motif [4].

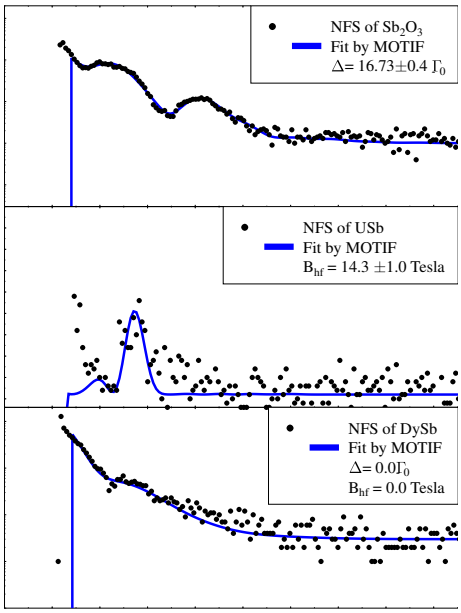


Fig. 2: Nuclear resonant forward scattering time spectra from $Sb_2O_3$, USb, DySb.

$Sb_2O_3$ shows a pure electric quadrupole interaction at 12 K. The determined quadrupole splitting parameter of the ground state $\Delta$ of $(16.73 \pm 0.4)\,\Gamma_0$ is inbetween the reported values of orthorhombic and cubic $Sb_2O_3$ ($17.2\,\Gamma_0$ and $16.0\,\Gamma_0$ respectively) [5]. Unfortunately the mixture ratio of the two phases in the sample is not known. USb shows a transfered magnetic hyperfine field $B_{\rm hf}$ at the Sb site of $(14.3 \pm 1.0)$ Tesla at 65 K (data linearly scaled due to low statistics). In DySb at 16.5 K - a cubic crystal, well above the Neel temperature of 9.5 K - no hyperfine interaction shows up as expected. In conclusion we demonstrated meV resolution mononchromatization of SR at 37.13 keV and performed NFS spectroscopy on $^{121}$Sb for the first time. The results show the applicability of sapphire Bragg backscattering meV-monochromators above 30 keV and open the field of NFS and NIS on $^{121}$Sb with many applications like structural and magnetic phase transitions in Sb and Sb compounds and studies on the magnetic properties of spintronic devices (MnSb).

## References

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