ESRF	**Experiment title: High resolution x-ray diffraction investigation of the interaction between the vortex and crystal lattices in $ReNi_2B_2C$**	**Experiment number:** HS-552
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Report:

In this report, we present the first x-ray investigation of the interaction between the vortex and crystal lattices in a superconductor. The measurements were done on superconducting rare-earth borocarbides, $ReNi_2B_2C$ (Re = rare-earth). The interest in these compounds has been triggered by the discovery by small angle neutron scattering on $ErNi_2B_2C$ of a square vortex lattice when a large magnetic field is applied along the c axis [l]. Subsequently, a crossover to a conventional hexagonal vortex lattice at low field has been observed [2]. This crossover has also been observed for $LuNi_2B_2C$ and YNi_2B_2C [3,4]. The high field square vortex lattice is now believed to be stabilized by nonlocal corrections to the London model [5].

The measurements were done at the triple crystal diffractometer of the high energy beamline (ID15A). The non-dispersive mode was used and the x-ray beam energy was $\sim$ 200 keV. With this experimental set-up it has been shown that the lattice parameters of URu_2Si_2 can be determined with a relative precision of $\sim 3 \times 10^{-6}$ [6].

Note that the reported measurements are the first diffraction measurements done with a cryomagnet at ID15A. We used a cryomagnet which belongs to the ESRF Mössbauer group. The temperature was fixed to 4.2 K and we were authorized to apply a field up to 3 T. A strong constraint for the possible measurements was that the sample could not be heated. In addition, it was not possible to tilt the cryostat.

For our first attempt to study the flux line lattice (FLL) by x-ray, we have simply followed the position of charge Bragg peaks as a function of the field intensity for $LuNi_2B_2C$ and $ErNi_2B_2C$. The measurements were performed with the field applied along the (001) and (110) directions, respectively. We used a zero-field cooling procedure, increasing the field at 4.2 K up to either 1.5 T or 3 T and then decreasing it down to 0 T.

As an example of our results we present in Fig. 1 the relative change of the interplanar spacing ***d*** measured as a function of the time elapsed since the beginning of the field cycle. The measurements were done on $LuNi_2B_2C$ at the [220] Bragg peak. Although there is a drift of the Bragg peak position due to an instability in the diffractometer of unknown origin ($\delta d/d$ increases as a function of the time without changing the experimental conditions), the reported data indicate that the crystal lattice responds to modifications in the FLL: at a characteristic field, B^*, the slope of $\delta d/d$ versus the time changes. It is remarkable that B* has approximately the same value when determined from data taken when increasing or decreasing the field. We have $B^* = 0.3$ T - 0.4 T. If we suppose that the drift of the Bragg peak position is linear in time (see Fig. l), we determine that $\delta d/d \sim -3 \times 10^{-5}$ for B_{ext} = 1.5 T compared to $B_{ext} \lesssim B^*$.

In order to link the strong response of the crystal lattice for B_{ext} larger than B^* to the properties of the FLL, we consider the small angle neutron scattering results reported for the same compound at Ref. [4]. In Fig. 2 we display the field dependence of the width of the rocking curve as a function of the field intensity. This width is inversely proportionnal to the longitudinal (parallel to B_{ext}) FLL correlation length. We note that it decreases up to $\sim B^*$, presents a broad minimum near 1 T, and then gradually increases. These neutron data can be understood in terms of the pinning force F_p in hard superconductors, which is a strongly decreasing function of the field: $F_P \propto 1/B$. Below B^*, this force disorders the FLL. Above B^* it is greatly reduced. The x-ray data indicate that the effect of the coupling of the FLL to the crystal lattice is strong when the FLL is well ordered, i.e., above B^*.

While the preliminary data shown here can also be obtained from dilatometric measurements [7], several new venues are opened up through the use of x-rays. First, the magnetostriction can be measured as a function of position on the sample, eliminating effects [8] due to sample shape. Second, the modulation of the Bragg reflection due to the FLL periodicity may yet be revealed.

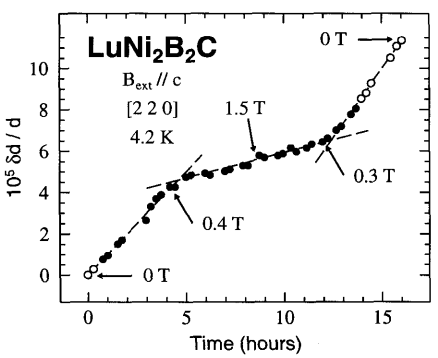

Figure 1: the relative inter planar spacing versus the elapsed time measured for $LuNi_2B_2C$. The full and empty circles indicate the measurements recorded in applied and zero magnetic field, respectively.

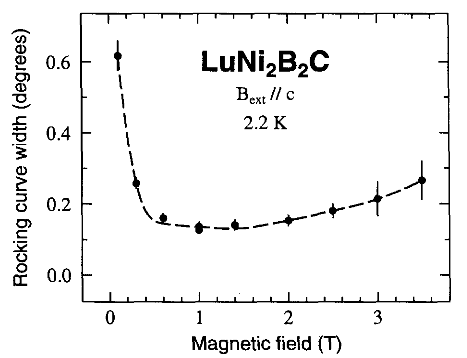

Figure 2: the rocking curve width as a function of the field intensity for the same compound as determined by small angle neutron scattering (from Ref. [4]).

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