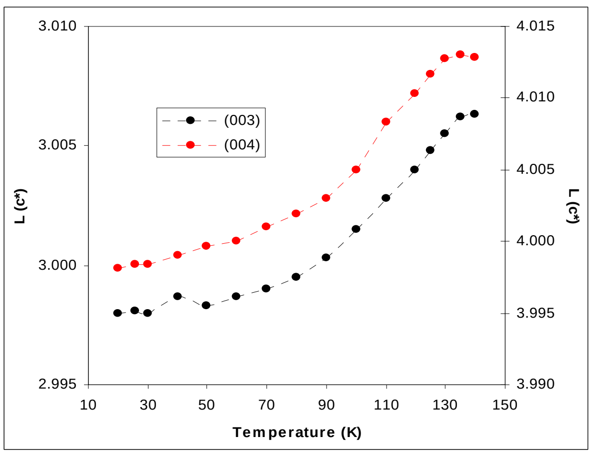
<u>Experiment number 28-01-757</u>

During in-house time, the spitting of the d-band was observed in holmium [1]. We extended the study to all the other heavy rare-earths (Gd, Tb, Dy, Er and Tm) at the L3 edge [2] and we saw the same d-band split which is characterized by a double peak in both the FM and AFM data. Both peaks are of dipole origin unlike what was published before [4]. The results have been subsequently submitted to Nature [5]. Having established the split dipole resonances across the heavy RE, we decided to accurately quantify the quadrupole (E_2) resonances. We started the study with holmium in the AFM phase looking at the (00 $l \pm \tau$) satellites with l =2,4 and 6 at the Ho L_3 edge scattering from horizontally and then vertically [6]. Graphite (006) was used to analyse the polarization. The data is being fitted with a program written by Alessandro Mirone which is based on [7]. This program was firstly written assuming that Ho is a centro-symmetric system. The author decided to extend his theory to a non-centrosymmetric case which later revealed that the (00*l*) reflections with *l*=1,3, 5 etc… are allowed reflections and that (00 $l \pm \tau$) satellites should also exist. These ″new″ satellite reflections are expected to have a six fold azymuthal dependence and only exist in the s-p and p-s channels. Before continuing our study of the angular dependence of E_2 with the other heavy rare-earths, we decided to first search for the presence of the (003) and its satellites in order to confirm the legitimacy of the theory. In the mean time, with this concept the analysis of our previous Ho data is almost finished. A paper will shortly be submitted to PRL and a draft is available on request.

The experiment was carried out at the Ho L_3 edge in the vertically scattering geometry. The (00*l*) direction was in the scattering plane whereas the (*h*00) direction was pointed along the incident beam. At room temperature, we found a (003) peak in both $\sigma\rightarrow\sigma$ and $\sigma\rightarrow\pi$ rocking the Graphite (006) analyzer crystal. This peak was considerably weaker than the (004) charge peaks as it was measured with no attenuation. The intensity of the (003) in the $\sigma\rightarrow\pi$ channel was found six time larger than in the $\sigma\rightarrow\sigma$.
The sample was realigned at 40K. We then performed an energy scan for each azymuthal angle by steps of 5º. They are also expected to have a six fold azymuthal dependence. Holmium has always been treated as a centro-symmetric system for which the (00L) reflections with L odd being forbidden.

This part of the experiment was started at 40K where the (003) peak was found in both $\sigma\rightarrow\sigma$ and $\sigma\rightarrow\pi$ channels but three orders of magnitude weaker than the (004). The intensity in $\sigma\rightarrow\pi$ channel was found twice as large as in $\sigma\rightarrow\sigma$. The FWHM of both the (003) and (004) were comparable. The presence of any satellite peak was also verify. The intensity was so weak that only a peak in $\sigma\rightarrow\pi$ was observed (4 counts in 1 second with a background of 0.3 counts per second). It was therefore decided to continue the measurements with no analyser crystal. We also discovered that the (003) possessed two satellite peaks ($\pm\tau_n$) but two orders of magnitude less intense than the (004) magnetic satellites. A study of the (003) peak (Figure 1) and its satellites ($\pm\tau_n$) (Figure 2) as a function of temperature was consequently performed in order to definitely rule out the possibility of dealing with multiple reflections. The exact position of each reflection was determined performing individual Lscans for each temperature. The temperature dependence of the average τ and τ_n (Figure 2) reveals that the (003) satellite peaks have the same vector as the magnetic vector, τ and follow the same trend. The trend is also in agreement with published data [8]. Note that the (003$\pm\tau_n$) peaks were only measured up to 110K above which the intensity became too weak. The trend in Figure 1 is explained by the fact that the Lscans were performed without realigning each Bragg reflection, and what is observed corresponds in fact to the decrease of the c-axis lattice constant in warming as in reference [8].

We also tried to measure the azymuthal dependence of the (003+τ) reflection at 30K. To do so, we first performed an Lscan to locate the peak (Figure 3 left & right) for each azymuth and then we rocked the analyzer crystal (Figure 3 left). Despite the very low count rate, one can observe a trend every 30º but not every 60º.



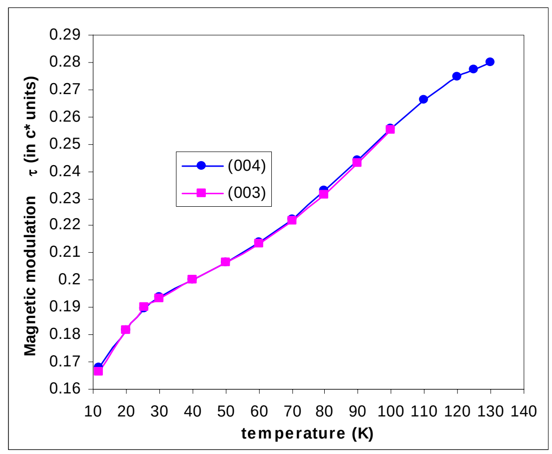


Figure 1: Temperature dependence of both the (003) (black dots) and (004) (red dots) Bragg peaks. The dotted lines are only guides to the eye.

Figure 2: Magnetic modulation vector τ vs temperature (blue for 004 and pink for the 003). The dotted lines are only guides to the eye.

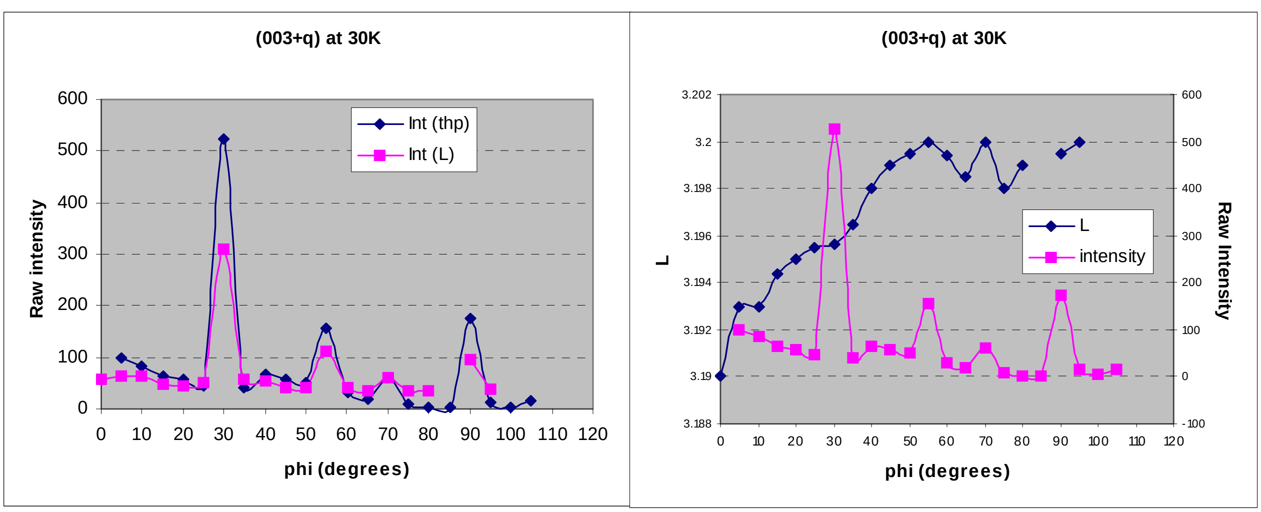


Figure 3: Phi dependence of the (003+q) satellite looking at the Lscans (right and left) and at the analyzer scan (left)

References:

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