ESRF	**Experiment title:** Study of the U-As/Co multilayers by XMCD at the U M-edges	**Experiment number:** HE226
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Report:

Some years ago a group at IBM Yorktown Heights manufactured a series of multilayer films of Co and U-As layers with in mind that polarisation could be induced in the U through exchange coupling to the Co layers [1,2]. The aim of the IBM effort was to discover if they could make a room temperature ferromagnet with a large magneto-optical Kerr effect (MOKE) by using uranium.

We have three of these multilayers with the formula $Co(200\,Å)[U\text{-}As(t\ A)/Co(20\,Å)]_n$ with [U]/[As] $\simeq 1.5$ and $t = 40$ A, $n = 20$; $t = 60$ Å, n = 15; $t = 80$ A, $n = 12$; total uranium thicknesses ~ 500 Å. The magneto-optical experiments at IBM [2] claimed that there was a moment on the uranium site at low temperature and even at room temperature in these multilayers. In view of the large magneto-optical Kerr effect known to exist for uranium compounds [3], this is an important finding, and could conceivably lead to some specialised device applications. The main problem is to distinguish the U moment from the Co moment which is considerably larger. This is possible with the X-ray magnetic circular dichroism (XMCD) method.

We performed XMCD measurements with the IBM multilayer $Co(200\,Å)[U\text{-}As(80\,Å)/Co(20\,Å)]_{12}$ (the polar Kerr rotation is maximum for this multilayer). We used a magnetic field of 4 T (polar Kerr effect measurements were done with 3 T) applied perpendicular to the multilayer plane. We did measurements at 35 K and 288 K for the M_{IV} and the Mv edges of uranium. The signal was detected in fluorescence mode.

In Fig. 1, we present the fluorescence spectra and the dichroism signal for the two temperatures at the M_{IV} uranium edge. We observe a dichroic signal for both temperatures. Due to the small thickness of the sample, the fluorescence-yield signal is directly proportional to the absorption coefficient [4]. A dichroic signal is also observed at the Mv edge for both temperatures. Nevertheless, the statistic is not sufficient to be confident about the shape of the signal. Note that the machine was operating in 16 bunch mode during our experiment.

Since the intensity of the dichroism at the Mv edge is about an order of magnitude less than at the M_{IV} edge, we can apply the sum rules to our data with reasonable confidence. This will result in slightly increased error bars.

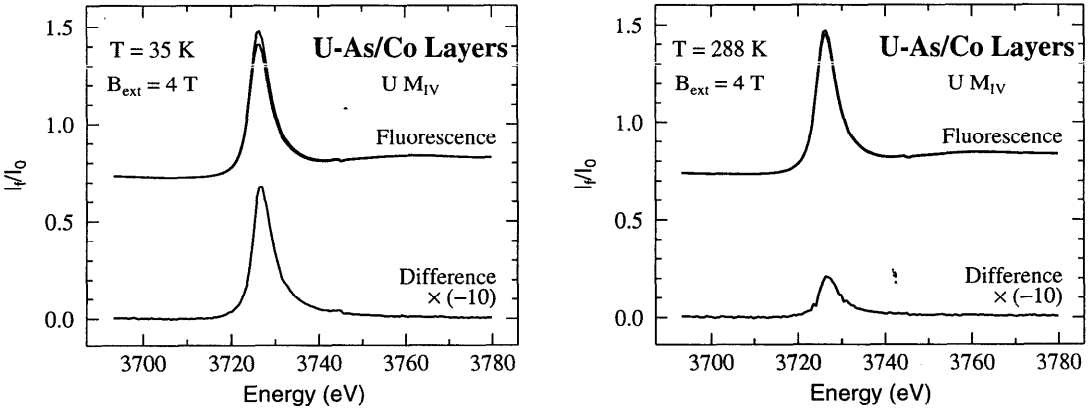
We can, first, consider the case of a pure U^{3+} ionic state in intermediate coupling, valid for 5f electrons. The first sum rule gives $\langle L_Z \rangle \simeq$ -0.49 (4) at 35 K. From this value, we obtain a uranium orbital magnetic moment, μ_L, of 0.49 (4) μ_B. For the second sum rule, we need the magnetic dipolar operator, $\langle T_Z \rangle$; a theoretical calculation gives $\langle T_Z \rangle / \langle S_Z \rangle$ = 0.62 [5]. Then, we deduce $\langle S_Z \rangle \simeq$ 0.11 (1) and a spin moment, μ_S, of -0.22 (2) μ_B, antiparallel to the orbital moment.The total uranium moment, μ, is 0.27 (6) μ_B , parallel to the applied field, and we have $-\mu_L/\mu_S \simeq$ 2.23 (40) (the value expected for a pure U^{3+} ionic state is 2.60 [5]).

Now if we consider a pure U^{4+} ionic state, the first sum rules gives $\langle L_Z \rangle \simeq$ -0.54 (4). We have $\langle T_Z \rangle / \langle S_Z \rangle$ = 1.16 [5], then, with the second sum rule, (Sz) $\simeq$ 0.08 (2). Finally, μ_L = 0.54 (4) μ_B, μ_S = -0.16 (2) μ_B and, therefore, μ = 0.38 (6) μ_B. We are not far away from the expected value of the magnetisation of amorphous U_{61}-As_{39} that is 0.5 μ_B/U [6]. Moreover we have $-\mu_L/\mu_S \simeq$ 3.37 (70) while the theoretical ratio is 3.36 [5].

But, due to our big error bars, we are not able to say if we have a pure U^{3+} or U^{4+} ionic state.

From the ratio of the dichroic signal at the M_{IV} edge at 35 K and 288 K, we deduce an estimate for the U moment at 288 K $\mu \lesssim 0.1\ \mu_B$.

This report shows that it is possible to see a dichroic signal, even at 288 K at the uranium M edges on U based multilayers.



Figures 1 : Fluorescence spectra and dichroic asymmetry spectrum AI (AI = ***I+ − I-)*** measured at ***the*** M_{IV} edge ***of*** uranium ***in*** a U-As/Co multilayer for two temperatures. The intensity of the field was 4 T and ***the*** temperature 35 K (left hand ***side)*** and 288 K (right hand ***side).*** The index + (-) specifies that ***the field is*** parallel (antiparallel) to ***the X-ray*** helicity. ***The*** data have been corrected for the ***energy*** dependence of the circular polarization rate of the monochromatic x-ray beam.

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