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ESRF	**Experiment title: X-ray Resonant Scattering Study of the Antiferroquadrupolar order in $TmGa_3$**	**Experiment number**: 28-01-116
Beamline: XMaS	**Date of experiment**: from: 19/9/01 to: 25/9/01	**Date of report**: 8/4/03
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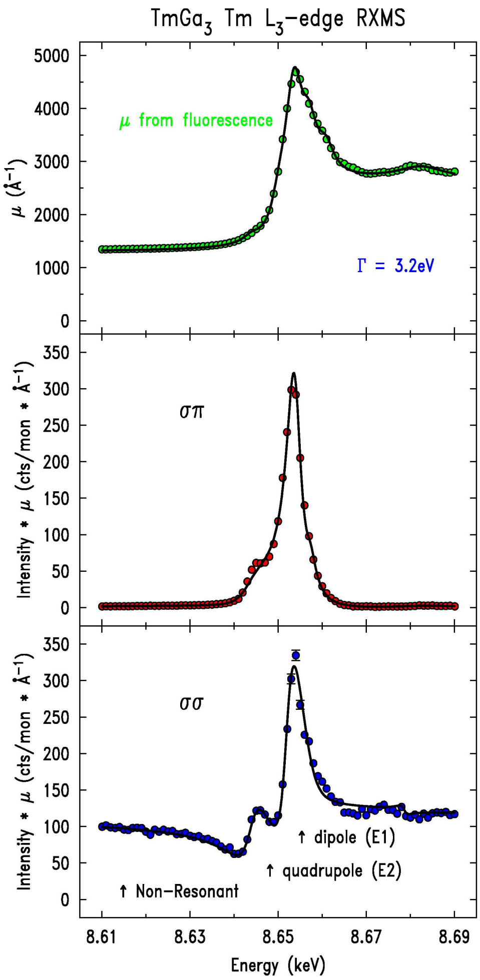
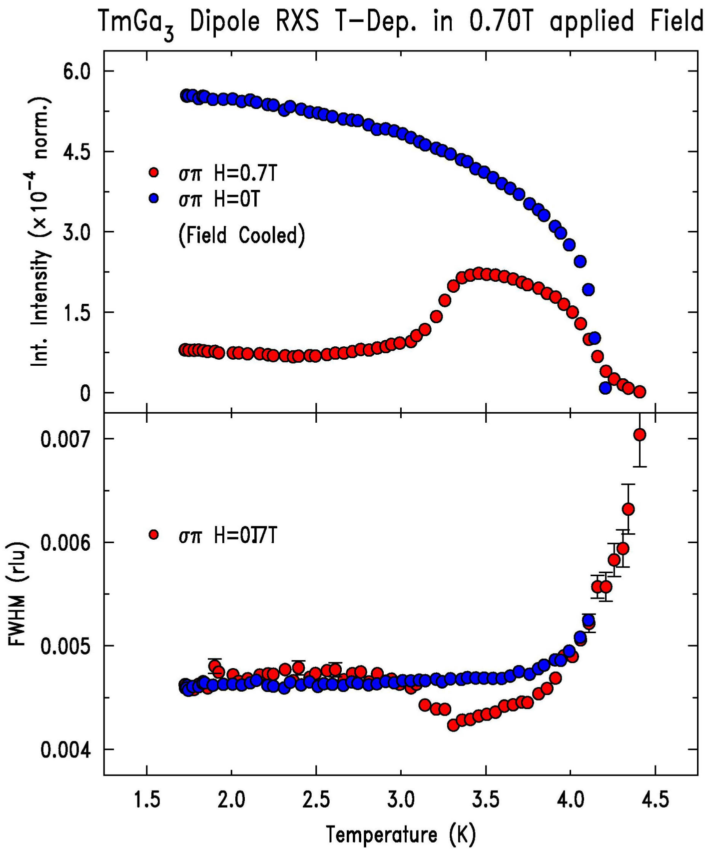
Report:

The aim of this experiment was to investigate the antiferromagnetic (AFM) and antiferroquadrupolar (AFQ) order in $TmGa_3$, using resonant x-ray scattering (RXS) also in applied magnetic field. We wished to study the interplay of these orderings in an applid magnetic field, which is know to have a dramatic effect on the transition temperatures [1]. Neutron diffraction studies [2] have determined that $TmGa_3$ is antiferromagnetic below T_N = 4.26K with magnetic propagation vector (0 ½ ½). However, neutrons do not directly couple to quadrupolar interactions so that the AFQ order parameter was unknown, but specific heat measurements [3] have identified the AFQ phase transition to be T_Q= 4.29K.

The integrated intensities of the (0 ½ 1½) peaks, in the vicinity of the Tm L_3 edge, are shown in **figure 1;** the middle panel are the $\sigma\pi$ and bottom panel the $\sigma\sigma$ scattered polarisations. The top panel shows the absorption coefficients from the fluorescence that was used to correct the data for absorption. RXS is observed in the dipole threshold for the $\sigma\sigma$ intensities, shown in figure 1 (bottom panel). This $\sigma\sigma$ scattering cannot arise from the magnetism since dipole resonant x-ray magnetic scattering is forbidden for this polarisation. This scattering arises from the antiferroquadrupolar ordering in $TmGa_3$, indicating that the AFQ ordering wave-vector is the same as the AFM, - superimposed at q=(0 ½ ½). The figure demonstrated that the AFQ and AFM scattering can be easily separated using polarisation analysis. The temperature dependence of the (0 ½ 1½) reflection for the $\sigma\pi$ scattered polarisation, is shown in **figure 2** for in applied field of 0 (blue circles) and 0.7 (red circles) Tesla. The data were taken at

incident x-ray energy corresponding to dipole transitions. We find a dramatic interference





effect for the data taken at 0.7T upon cooling at around 3.3K. The widths of the peaks also change as shown in the bottom pannel on figure 2. The interference effects probably arises from an interference effect between rank 2 (probing AFQ) and rank 1 (probing AFM) tensors. At temperatures, the σπ scattering arises from AFQ order while at low temperatures the scattering arises from AFM order. The data indicate that the field phase diagram of AFM and AFQ ordering in $TmGa_3$ can be easily followed using resonant x-ray scattering. We have also data taken in fields of 0.5 and 1.0 Tesla which are not shown in figure 2.

Figure 1 (left). Top panel: absorption coefficients from fluorescence. Middle panel: The (0 ½ 1 ½) σπ intensities in the vicinity of the Tm L_3 edge. Bottom panel: The σσ intensities of the (0 ½ 1½) reflection.

Figure 2 (right). The temperature dependence of the (0 ½ 1½) σπ taken in 0 and 0.7 Tesla applied fields. (top panel) and the widths of the scattering (bottom panel) with the incident x-ray energy at the dipole threshold.