ESRF	**Experiment title:** Dispersion and precipitation in a Ge-based magnetic semiconductor	**Experiment number**: HE-2378
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Report:

The HE-2378 proposal aims at the investigation of bonding states and the local environment of the magnetic elements in Ge based magnetic semiconductors. Among these, GeMn receives considerable interest in the magnetic semiconductor community both because of high ferromagnetic transition temperatures [1,2] and because of the prediction of the role of Mn as a source of polarised holes in the Ge host matrix [3].

Samples investigated during the experiment were fabricated at the Walter Schottky Institut, Garching, via molecular beam epitaxy. In the fabrication process very low substrate temperatures down to 60°C were used in order to allow and control the dispersion of several percent of Mn into the Ge diamond lattice. Additionally, samples where produced under fabrication conditions favourable for the formation of intermetallic Mn_5Ge_3 precipitates in order to oppose dispersed Mn to precipitation of Mn_5Ge_3 nanocrystals. Refs. 4 and 5 summarise the fabrication details and give a comprehensive picture of the structural and magnetic properties of the precipitate free GeMn alloys as well as of Mn_5Ge_3 nanomagnets embedded in a Ge matrix. He-2378 was planned to improve this picture by measuring the element specific polarisation of Ge and Mn atoms, thus probing the chemical environment of dispersed Mn atoms and gaining further insights beyond the limitations of SQUID magnetometry and TEM microscopy.

Experimental details

All XMCD measurements were performed in the 7T cryostat at the ID12 beamline. Measurements were taken at 10 and 100 K with samples cooled down in an external magnetic field of 7T. XANES measurements were taken in a separate UHV detector array at room temperature without external magnetic field

Results

In order to investigate the influence of the different forms of Mn incorporation into the Ge matrix on the absorption spectrum, we investigated a series of samples containing only dispersed Mn as well as samples with Mn_5Ge_3 precipitates and samples containing a mixture of dispersed Mn and Mn_5Ge_3 precipitates. Typical post-edge normalised XANES spectra depicted in the Fig. 1 clearly show different, distinct XANES curve shapes that can be attributed to the presence or absence of precipitates. A simulation of the XANES spectra to get further insight into the structural environment of the Mn atoms has not been performed yet since this is hampered by the strong structural inhomogeneity of the samples investigated [4].

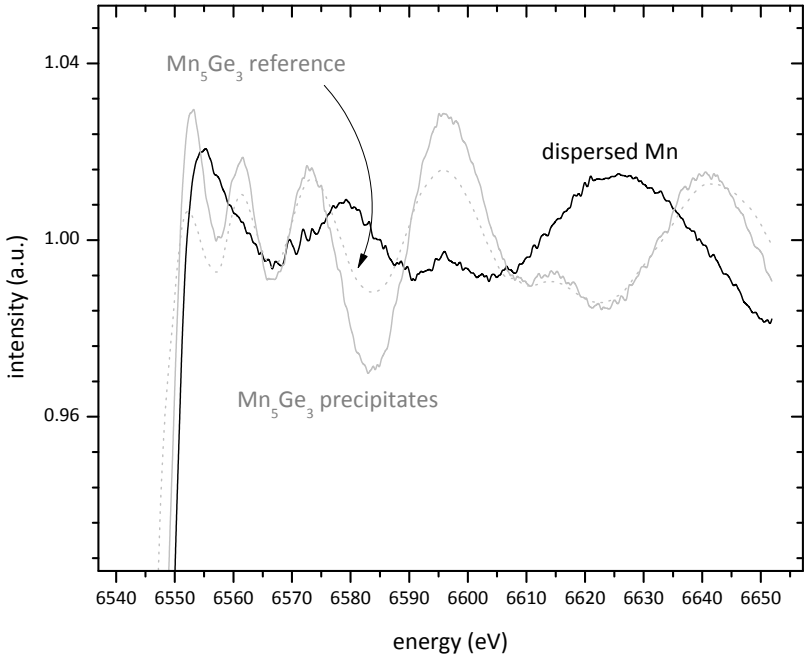

Figure 1: XANES spectra of GeMn with and without Mn_5Ge_3 precipitates

In contrast to the expectations and first test measurements performed by F. Wilhelm before the start of HE-2378 reliable XMCD spectra of GeMn alloys without Mn_5Ge_3 precipitates turned out to be impossible to record. This was mainly due to a superposition of the recorded signal with high index diffraction peaks of the Ge substrate close to the Mn edge. These peaks were very sensitive to the incidence angle of the synchrotron photons, so that even after carefully tilting the sample away from the peak, small instabilities of the synchrotron beam position on the sample during the scans caused a reappearance of the background signal. To raise the magnitude of the expected XMCD signal above the background level different external fields, temperatures and scan procedures were tested, each of which, however, did not result in an improved signal to noise ratio for reliable XMCD data. Unfortunately, there was no time during the experiment to switch to a different setup with a flipper magnet that would better account for the beamline instabilities. It was therefore not possible to separate the possibly weak signal of the dispersed Mn from the Ge background signal.

References:

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[2] C. Zeng *et al.*, Phys. Rev. Lett. **100,** 066101 (2008)
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[5] S. Ahlers *et al.*, Phys. Rev. B **74**, 214411 (2006)