Local magnetic field and muon site in CeAs *

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We report on zero field and longitudinal field μSR experiments on a CeAs single crystal between 3.3 and 12 K. Below the antiferromagnetic transition at 7.5 K a spontaneously precessing signal with a saturation frequency of ≈ 25 MHz representing the full sample amplitude has been found. From an analysis of the field dependence of the relaxation rate of this signal in ⟨100⟩ and ⟨110⟩ crystal orientation parallel to the muon spin and the applied longitudinal field, a ⟨100⟩ orientation of the local field at the muon site is concluded. This supports an AF-I single-$\vec{k}$ magnetic ordering.

The cerium monopnictides have drawn much attention and inspired a lot of experimental and theoretical work because they show complex magnetic phase diagrams [1] and exhibit unusual transport properties [2]. CeAs orders antiferromagnetically below ca. 7.5 K. From early neutron diffraction experiments an AF-I single-$\vec{k}$ or triple-$\vec{k}$ structure has been concluded [4] while recent high pressure neutron diffraction experiments point to the AF-I single-$\vec{k}$ spin arrangement [5].

Earlier μSR experiments on a polycrystalline sample of CeAs revealed a damping increase below 9 K and the onset of a spontaneous precessing signal fraction below 7.4 K with a low temperature saturation frequency corresponding to a local field of ≈ 0.18 T [6]. Assuming the above mentioned spin structures and the most probable tetrahedrally coordinated muon site which has been successfully used in all other μSR work on cerium and uranium monopnictides [7,8] the occurrence of this precessing signal cannot be understood: dipolar field calculations for this site cancel for the single-$\vec{k}$ and triple-$\vec{k}$ structure and the Fermi contact field will vanish from symmetry considerations also.

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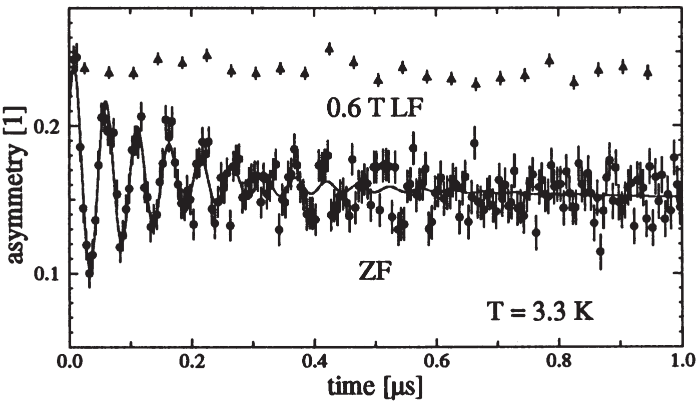

Fig. 1. Typical ZF and 0.6 T LF spectrum of CeAs in ⟨100⟩ orientation.

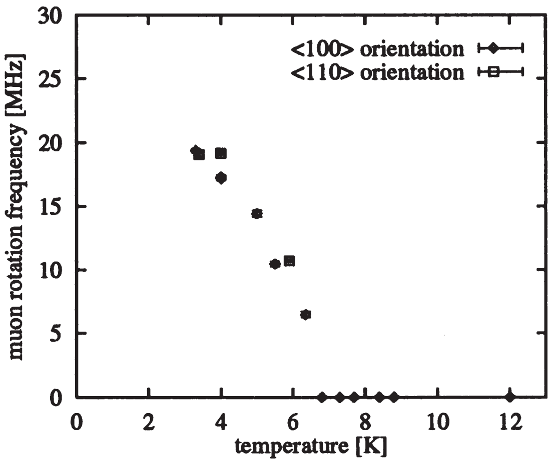

Fig. 2. Temperature dependence of the spontaneous rotation frequency in CeAs.

To clarify this problem we started μSR experiments on a CeAs single crystal with the GPS spectrometer at the PSI muon facility. So far we have carried out zero field (ZF) and longitudinal field (LF) μSR between 3.3 and 12 K to confirm the precession signal.

In the present experiments we found a rotating signal with ≈ 75% of the full sample amplitude in the magnetically ordered state below a transition temperature of 6.8 K. The relaxation rate of this signal is ≈ 8 μs^{-1}. Complete decoupling could be achieved with 0.6 T longitudinal external field (fig. 1).

The frequency of the precessing signal shows a temperature dependence typical for a second order transition with an estimated saturation value of ≈ 25 MHz or 0.18 T local magnetic field strength below 2 K (fig. 2). Taking into account the formation of different magnetic domains the full sample signal corresponds to a site with a well defined static magnetic field at the muon site.

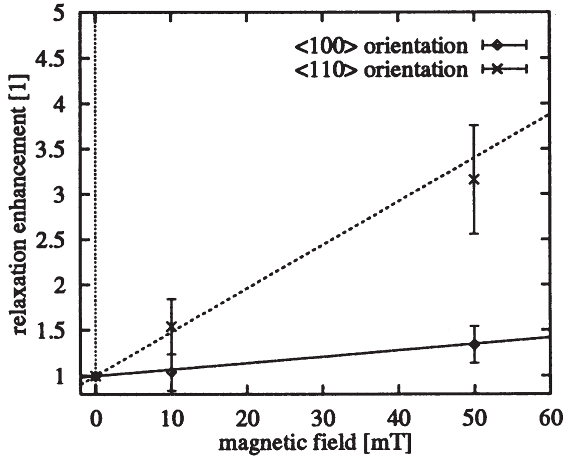

Fig. 3. Scaled field dependence of the LF muon relaxation rate for different crystal orientations. The full and dotted lines are linear fits with slopes of 0.05 μs^{-1}/mT and 0.34 μs^{-1}/mT, respectively.

To determine whether the muon site is of lower than tetragonal symmetry or that the magnetic structure is different from the interpretation of the neutron scattering, we examined the spatial orientation of the static local field seen by the muon probe by applying low longitudinal fields in $\langle 100\rangle$ and $\langle 110\rangle$ crystal orientation parallel to the muon spin and the applied longitudinal field. These experiments were performed at 4 K. Figure 3 shows the obtained change of the muon relaxation rate. The increase of the relaxation rate caused by the longitudinal field is much stronger for the $\langle 110\rangle$ orientation ($\approx$ 0.34 μs^{-1}/mT) than for the $\langle 100\rangle$ orientation ($\approx$ 0.05 μs^{-1}/mT).

For an interpretation of this result we assume the formation of different magnetic domains with equal volume fractions in the crystal. Now we consider a vectorial superposition of the internal and external magnetic fields in the different domains and crystal orientations. For an internal field along $\langle 100\rangle$ directions an external field along $\langle 100\rangle$ should not alter the relaxation rate, since in all relevant domains contributing to the precessing signal (i.e. $\langle 010\rangle$, $\langle 0\bar{1}0\rangle$, $\langle 001\rangle$ and $\langle 00\bar{1}\rangle$) the magnitude of the local field is enhanced by the same amount. In a $\langle 110\rangle$ orientation of the external field (and the initial muon polarization) the local field magnitude for 3 out of 6 domains is enhanced and for the other 3 domains is lowered. This results in a stronger damping of the full signal since the different frequencies are not separated due to the large relaxation rate of the precessing signal already in ZF. If the applied field is small in comparison to the internal field, which is $\approx$ 150 mT at 4 K, the relaxation rate increase is linear with the external field strength and calculated to 1.2 μs^{-1}/mT. Using similar arguments for a $\langle 111\rangle$ orientation of the internal field at the muon site an external field along $\langle 100\rangle$ should result in a two times stronger relaxation enhancement than an external field along $\langle 110\rangle$ with calculated values of 1.0 μs^{-1}/mT and 0.5 μs^{-1}/mT, respectively.

The experimental behaviour follows qualitatively the calculations for a $\langle 100\rangle$ orientation of the magnetic field at the muon site. The observed slope in the $\langle 110\rangle$

orientation is only 1/4 of the calculated value. The reason for this discrepancy is not known. For a final determination similar experiments in $\langle 111\rangle$ crystal orientation are planned.

Recent measurements of the angular dependence of the paramagnetic muon Knight shift [9] reveal a cubic point symmetry of the muon site. Even without an exact knowledge of the muon site in the crystal lattice this information together with the deduced $\langle 100\rangle$ orientation of the local magnetic field in the ordered state proves an AF-I single-$\vec{k}$ magnetic structure.

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