solved 16 Fe/8 Ho coordination shells at 3 Å where the *L/S* ratio for the nearest neighbours is on average close to 1. So magnetic backscattering seems to be unaffected by the angular momentum of the backscattering atom.

Conclusions

It has been demonstrated that dichroic near-edge effects provide a powerful tool for probing the magnetic characteristics of unoccupied density of states and determining, in appropriate cases, local spin and orbital moments separately and with high accuracy. So X-Ray Magnetic Circular Dichroism allows one to study the local magnetic properties of ferro- and ferri-magnetic solids in an element- and symmetry-selective manner.

Moreover, the analysis of dichroic effects beyond the near-edge range (spin-polarized EXAFS) probes magnetic short-range order and the magnetic moments of neighbouring atoms and allows a clear distinction between magnetic and non-magnetic atomic neighbourhoods.

Every spectroscopic or crystallographic technique involving core-level absorption can be extended, in principle, to its magnetic counterpart. Indeed, photons with energies close to an absorption edge are already being applied in magnetic Anomalous Small Angle x-ray Scattering, atomic contrast techniques and x-ray microscopy and microtomography. These innovations are made possible the development of high-brilliance x-ray sources and they demonstrate the growing demand world-wide for circularly polarized x-rays.

Acknowledgments
The authors wish to thank their colleagues, especially H. Ebert, for support and collaboration.

References

[1] G. Schütz *et al.*, *Phys. Rev. Lett.* **58** (1987) 737; G. Schütz, M. Knülle & H. Ebert in *Resonant Anomalous X-Ray Scattering: Theory and Applications*; Eds: G. Materlik, C.J. Sparks & K. Fischer (Elsevier Science, 1994) 535.
[2] C.T. Chen *et al.*, *Phys. Rev. B* **42** (1990) 7262; F. Sette *et al.*, *Proc. 6th Int. Conf. on X-ray Absorption Fine Structure*, Ed: S.S. Hasnain (Ellis Horwood, 1991) 96.
[3] B.T. Thole *et al.*, *Phys. Rev. Lett.* **68** (1992) 1943; P. Carra *et al.*, *Phys. Rev. Lett.* **70** (1993) 694.
[4] G. Schütz, *et al.*, *Phys. Rev. Lett.* **62** (22) (1989) 2620; G. Schütz & D. Ahlers, in *Spin-Orbit Influenced Spectroscopies of Magnetic Solid*; Eds: H. Ebert, G. Schütz, *Lecture Notes in Physics* **466** (Springer, 1996).

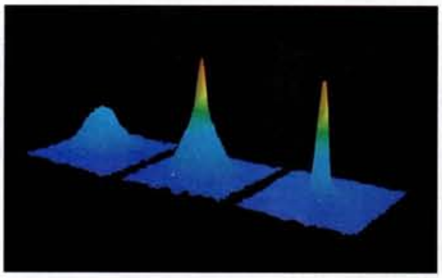
Large Bose Condensate Imaged

The highlight of the *15th General Conference of the EPS Condensed Matter Division: EPS-CMD'96* (Stresa; 22-25 April) was an invited plenary talk by Wolfgang Ketterle from MIT who described major advances in producing and probing a Bose-Einstein condensate (BEC). His group has produced a condensate of 5 million atoms, 10-times greater than the previous record it set last year. Most importantly, the group has been able to directly observe the condensate in the atom trap, and not just the fragments of an exploding condensate as was done previously.

The key development is a novel trap. Like previous devices, trapping uses a strong, inhomogeneous magnetic field but without a zero magnetic field near the centre of the trap, where atoms experiencing this field loose their (spin) orientation and escape. The experiments that achieved BEC last year used a rotating field or optical forces to push the atoms to locations where the magnetic field was non-zero. Such tricks are no longer necessary, because the new trap uses DC magnetic fields which have a minimum value of 1 Gauss and increase in all directions from the centre. The group has also come up with a novel "cloverleaf" winding pattern which gives very good optical access - a crucial requirement because 11 laser beams are needed for cooling and probing the atoms. Trapped atoms suffered very little heating - a condensate could be kept for more than 20 s, and the evaporative cooling was more efficient than before resulting in the large condensate of Na atoms.

With the sizable condensate, the group has tested theoretical predictions, some dating back to the 1940s. Measurements on the condensate agree with theoretical predictions that the fraction of atoms in the condensate should vary with temperature T as $1-(T/T_c)^3$, where T_c is the critical temperature at which the condensate forms. Predictions on the amount of repulsive energy between the Na atoms in the condensate have also been verified. The condensate was pencil-shaped (about 150 μm long and 8 μm wide).

It was also large enough to be directly observed for the first time using laser light scattered onto a sensitive camera. A direct image of an atomic matter wave with a half-wavelength of 150 μm was obtained. A thermal gas with such a long deBroglie wavelength would be at a temperature of 1.5 picokelvin.



A direct image of an expanding Bose-Einstein condensate showing the strong asymmetry in the expansion owing to repulsion between the condensed atoms. A characteristic feature of the trap developed by Ketterle and coworkers at MIT is the extreme aspect ratio of the condensate (150 μm long by 8 μm wide), which can seen in the expansion. The images show that the expanding cloud has both a condensed part and a normal part. The latter expands isotropically like a classical gas whereas the condensate expands into an elliptical shape. The width of the field of view is 6 mm. In the early phase, the cloud appears larger than the true size owing to complete absorption of the laser probe light.

The group has also developed a non-destructive imaging technique. The absorption of near-resonant light and reemission in random directions which was used previously caused the atoms to recoil, since light was absorbed, and the recoil energy heated up the condensate and destroyed it. The new imaging technique employs the dispersion of x-rays: the atoms in the condensate deflect the x-rays at a small angle. The recoil of the atoms is small, and can even be transferred to the magnetic trap through the Mössbauer effect. So the condensate can be imaged without heating to obtain spatially resolved images. Two images of the same condensate have been taken, and multiple images seem possible - a technique that should open the door to studies of the dynamics of a single condensate.

Finally, the group has taken the first step in probing the condensate's optical properties, one of the mysteries of this form of matter. By shinning photons on the condensate with a frequency 1.7 GHz away from the resonance frequency of the condensate it was found that a sodium condensate acts as a lens: indeed, it is transparent but deflects light at a small angle. The angular distribution of the scattered light is anisotropic.

Now that there are several ways to probe condensates one can address specific aspects (*e.g.*, superfluidity; the nature of excited states) of the macroscopic physics of Bose-Einstein condensate "superatoms" consisting of 5 million atoms . Interference effects between two superatoms can perhaps be observed by cutting the condensate into two parts using a laser.