commissioned at the Hamburg DESY Laboratory.

Zeus' iron magnet yoke and the superconducting solenoid and compensator have been in place for some time and successfully tested. Uranium-scintillator calorimeter elements began to go in last November, initially for the forward (proton direction) and rear modules, and installation of the central barrel is now underway. All proportional-tube chambers for the backing calorimeter in the iron yoke are in place.

The toroids of the forward muon detector have been mounted and operated. All drift chamber planes have been installed as well as two of the four limited-streamer tube planes for the trigger. The inner chambers of the muon barrel are in place and mounting of the outer layer has begun.

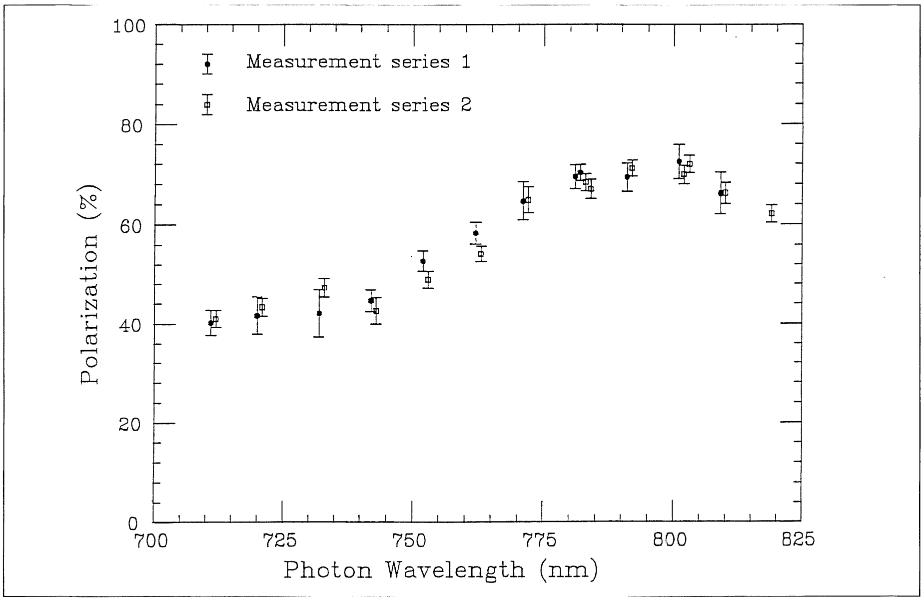
The inner tracking system – vertex detector, central drift chamber and planar drift chambers alternating with transition radiation elements in the forward direction, together with its special section of beam pipe – is taking shape.

After initial installation to ensure its compatibility with HERA machine components, the luminosity monitor has been removed awaiting the availability of well-controlled beams.

KEK
Producing highly polarized electrons (1)

With the Japan Linear Collider (JLC) electron-positron project having highest priority in Japanese high energy physics planning, many associated research and development tasks are underway at the Japanese KEK Laboratory. Despite a relatively recent appearance on the scene, work on a polarized (spin oriented) electron source has nevertheless made significant progress.

Work at the Japanese KEK Laboratory has shown how to obtain highly polarized electron beams from a laser-irradiated treated semiconductor photocathode. Shown here is the variation in polarization with laser wavelength.



After a brief but intensive spell of work to find the optimal superlattice photocathode structure, an impressive polarization level, 71 per cent, has been achieved for a solid-state photocathode at room temperature by a team of researchers from KEK, Nagoya and NEC Corp (see also page 6).

This should go on to pay dividends in a future research programme. In the electroweak picture of electromagnetism and the weak nuclear force, 'handedness' plays a vital role. Particularly when the weak force is in action, Nature cares about the direction in which things happen, and a reaction open to left-handed electrons can be totally blocked for their right-handed counterparts.

With particles spinning in their direction of motion (clockwise) being right-handed, and those spinning against the direction of motion being left-handed, polarized particles provide a powerful probe of these effects.

Thus polarized beams are a major goal in electron-positron colliders. In conventional storage rings, orbiting particles become transversely polarized due to radiation emission – for example, polarizations of about 40 per cent were observed at 29 GeV at KEK's TRISTAN ring (December 1990, page 11) and 10 per cent at 50 GeV at CERN's LEP (November 1990, page 3). But this effect depends strongly on machine parameters and is difficult to control.

In contrast, in a linear collider such as JLC, once polarized electrons are injected, the spin could be maintained through to an interaction point, provided depolarizing effects are avoided. Thus a key requirement is a highly polarized electron source.

The conventional source is bulk gallium arsenide with a negative electron affinity surface, illuminated by circularly polarized monochromatic photons from a laser. But the polarization obtainable this way

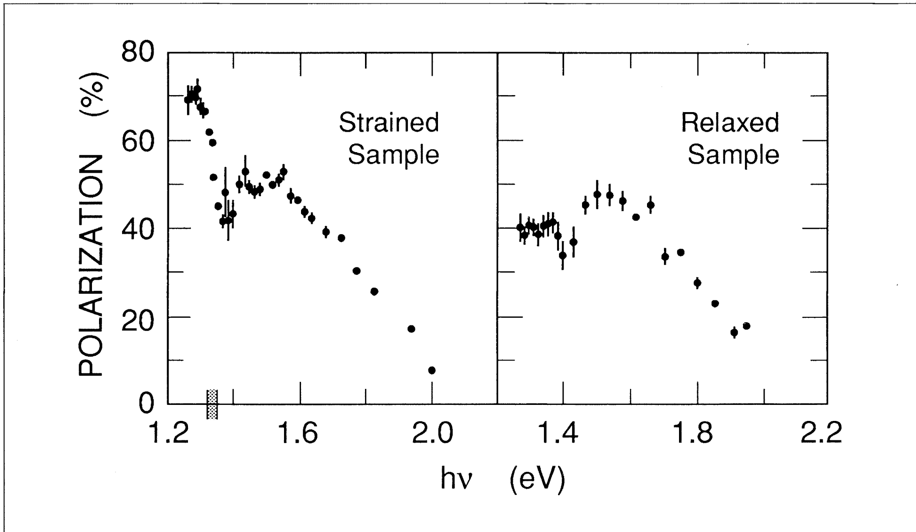
never exceeds 50 per cent because of spin degeneracy. One way to eliminate this intrinsic limit is to remove the degeneracy by a suitably arranged periodic potential in a superlattice structure. If the level splitting is made larger than the thermal noise level, selective pumping from a single state will be possible. Subsequently the pumped electrons need to be efficiently transported from superlayer to superlayer, with minimal depolarization in transit.

The important first step was an optimization study of GaAs-AlGaAs superlattice parameters such as layer thicknesses and Al content. The first photocathode resulting from this study was tested last year with a titanium/sapphire tunable laser, and 53 per cent polarization was quickly seen.

Careful examination of this result led to a second sample with thinner superlattice layers. First measurements gave 71 per cent polarization at a wavelength of 802nm. Greatly encouraged by this achievement, the collaboration is aiming for even better production polarized electron sources for JLC.

Polarized electron sources

These two articles, from the Stanford Linear Accelerator Center (SLAC) in California, and from the Japanese KEK Laboratory, highlight the world-wide effort underway to develop new techniques for the next generation of electron-positron linear accelerators.



Highly polarized electron sources at Stanford. Left, a thin (0.1 micron) indium gallium arsenide layer on a gallium arsenide substrate, when irradiated, shows increasing electron polarization, eventually attaining 71 per cent. At about 1.34 eV, the spectrum shows the onset of the selective pumping of electrons from a higher energy valence band to the conduction band (see text). Right, a 'thick' 1.14 micron layer with no crystal strain shows no similar effects.

STANFORD Producing highly polarized electrons (2)

Electron spin polarization above 70 per cent by photoemission from a specially prepared semiconductor has been achieved by T. Maruyama and E. Garwin of the Stanford Linear Accelerator Center (SLAC), R. Prepost and G. Zapalac of Wisconsin, and J. Walker and S. Smith of Berkeley.

Since the first use of a gallium arsenide photocathode at SLAC for the historic 1978 experiment which saw left-right asymmetry in electron scattering, semiconductor photoemitters have become standard for linear accelerators. These sources give high peak currents and short pulses, for example satisfying the 16 ampere/2.5 nanosecond pulse requirement for Stanford's SLC linear collider.

The conventional cathode material, gallium arsenide, has a theoretical maximum polarization of 50 per cent due to its crystal structure. In practice, polarization levels of about 40 per cent are achieved with bulk gallium arsenide, while thin epitaxial layers can approach the theoretical 50 per cent limit.

For over a decade much effort has gone into investigating other semiconductors to avoid this inherent limit due to valence band degeneracy. This degeneracy can be broken by deforming the crystal structure or by engineering suitable quantum wells or superlattice structures, opening up the possibility of 100 per cent polarizations by selective pumping of the higher energy valence band.

The SLAC/Wisconsin/Berkeley group has looked at indium gallium arsenide layers grown epitaxially on a gallium arsenide substrate, with the indium giving about a one per cent lattice mismatch. If this top layer is thin enough, the resulting crystal has a compression strain that splits the valence band degeneracy by some 50 meV.

Two samples were studied – an 0.1 micron indium gallium arsenide layer thin enough to give a high quality strained structure, while a 'thick' 1.14 micron layer without strain provided a control.

The thin strained sample showed a dramatic increase in el-