Controlling Beams of Light

Precisely positioning bending magnets keeps electrons on the right path in synchrotron particle accelerator

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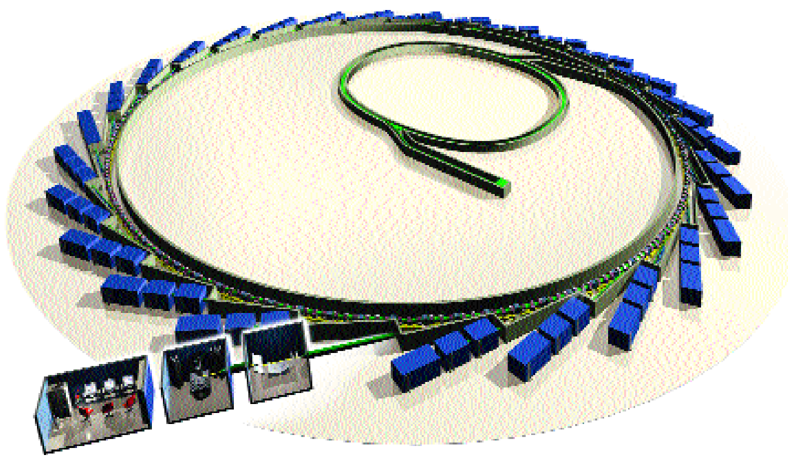


The Diamond synchrotron, as a series of "super microscopes," will ultimately host up to 40 cutting edge research stations.

Building a third-generation synchrotron and "super microscopes" that allow scientists to penetrate deep inside matter and investigate the world at the scale of atoms and molecules has spawned a massive motion control project in the U.K.

Diamond Light Source (www.diamond.ac.uk) is a new scientific facility currently being built in South Oxfordshire that will ultimately house up to 40 cutting-edge research stations. The synchrotron, a circular-shaped machine that uses arrays of magnets called insertion devices, generates bright beams of synchrotron light. Around the machine there are a series of experimental research laboratories called beamlines, where scientists will independently use the light generated by the machine for a wide variety of experiments.

Role of Motion Control

Motion control for a synchrotron, the source of the brightest light available today, is a critical issue because it involves a variety of motor technologies, magnets, and optics directing electrons around a circle a half kilometer in diameter and capturing photons of light as the electrons turn. The process requires precise and repeatable submicron positioning. Because of the distances, fieldbus speed is a crucial factor.

A machine controller and MACRO Ring fieldbus from Delta Tau (www.deltatau.com) has been selected for this project. This solution provides speed, both distributed and centralized control, and a unique interface to the EPICs front end, software environment that scientists use to conduct experiments. This software platform can control a wide variety of devices using a common software interface, including an interface to Delta Tau motion control, which will be used to shape, profile, and trim the beam down to the right type of light for specific experiments.

The increased brightness of this new synchrotron light source will help scientists in such fields as life, physical, and environmental sciences. An example is how the atomic structures of proteins will be determined more quickly, which is crucial for understanding medical conditions such as Alzheimer's disease and cancer, as well as for designing new medicines and treatments.

Shaping the Beamlines

A synchrotron is a particle accelerator that produces very intense and tightly focused light by accelerating electrons close to the speed of light and bending the resulting beam of electrons with magnets. The beam travels in a circular path around a storage ring, essentially a donut-shaped vacuum chamber. As the electrons turn, photons of light are given off. The resulting light—infrared, UV, and x-ray—is directed from the main storage ring through beamlines (pipes) to work areas where scientists run their experiments.

A beamline consists of an array of slits, lenses, and crystals for tuning the beams to various wavelengths and intensities for specific types of scientific techniques. Eight beamlines are currently being integrated and approximately 40 beamlines will be built at Diamond Light, allowing a wide range of experiments.

Diverse Motor Technologies

"The main challenge with the motion control system was the broad spectrum of motor/drive technologies used in the system ranging from simple, non-synchronized stepper control to multiaxis synchronized control using inverse kinematics," says Andy Joslin of Delta Tau, an engineer who has worked extensively on this project.

A series of electric motors, mostly stepping motors, and some ac, dc brush, and piezo motors (for fine adjustments), receive motion commands generated by the controls capable of managing the mixed motor technologies, providing submicron position control of angles and displacement. Each type of beamline has varying motion requirements: a typical beamline will have 60 axes of motion, while one will have up to 150 axes.

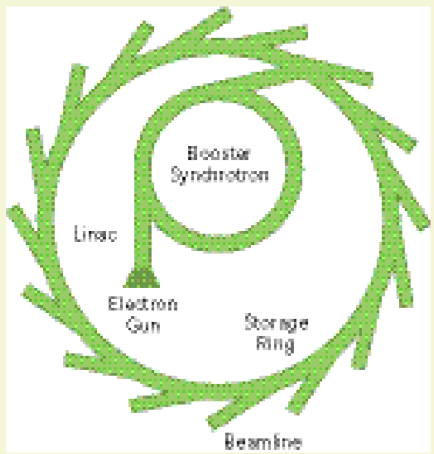
Many of the axes are controlled discretely, but multiple axis interpolation is required for workholding and manipulation of specimens. These tools include "Stewart Platforms" (hexapod positioning stages with six-axis motion control) based on inverse kinematics (non-Cartesian) calculations. Delta Tau's Turbo PMAC motion controller allows the use of user-written kinematics routines that are customizable for such unique mechanisms and can automatically execute routines in real time, which allows all subsequent programming to be written in terms of the tool-tip position, usually in Cartesian coordinates.

The first beamline equipment is being supplied by Oxford Danfysik. The system architecture includes a central PMAC2-VME 32-axis controller networked via the MACRO fieldbus to a Universal Motion and Automation Controller to provide distributed motion control.

The UMAC system provides a capability to access a wide variety of motion control boards, I/O boards, and communication interfaces (USB, Ethernet, etc.). Interfaces are also available for a variety of feedback sensors or to implement communications with host computers or external devices, and are flexible enough to accommodate the requirements within each of the beamlines.

In the Diamond Light synchrotron application—where tight coordination between axes is required—this motion control approach provides required synchronization mechanisms to insure precise coordination. Whenever the motion of multiple axes is simultaneous, whether or not tightly coordinated, the potential exists for many problems. For example, when an axis faults out, the UMAC controllers can control these problems because they receive information in time to prevent damage to the mechanism.

To get the hardware benefits of a distributed system while maintaining the software benefits and performance of a centralized system, the MACRO Ring utilizes distributed interface electronics with centralized control software. Most of the calculations are computed on a single processor for quick, deterministic, and easy-to-code interactions. The central processor executes such high frequency, hard real-time tasks as cyclical tasks that require a high bandwidth and deterministic communications link.



Diamond is a third-generation 3 Giga electron volt synchrotron light source. It will use arrays of magnets called insertion devices to generate extremely intense, narrow beams of electromagnetic light for scientific experiments.

The motion controls and mechanical assemblies were integrated by the McLennan Servo Supplies of Surrey, UK. The systems make use of microstepping motors that were tuned for maximum accuracy prior to installation in the beamlines. Vic Sawyer of McLennan says, "It was important to investigate all the variables in the system, such as resonance, mechanical stiffness, and so forth, as well as to prove the system overall before fitting."

An example is the manipulation of a double crystal monochromic system. For this specific requirement, the motion controller creates a "virtual axis," enabling the two crystals to position in relation to each other. Positioning is such that a straight beam is maintained even when the first crystal is positioned to deflect the beam, such as when monochromatically filtering white light by Bragg diffraction for inspection tasks. The motion controller recognizes the virtual axis as theoretical and is able to compute the real-life motion required for each axis of the crystals.

Enormity of Project

The Diamond synchrotron is the largest UK-funded scientific facility to be built in over 30 years. Just the first eight beamlines alone incorporate more than 500 axes of motion control.