Scope of Supply
Ampegon system engineers provided design services, factory testing, installation on site, integration in existing DLS system as well as commissioning of three high-frequency amplifier systems (300 kW/500 MHz) each including:

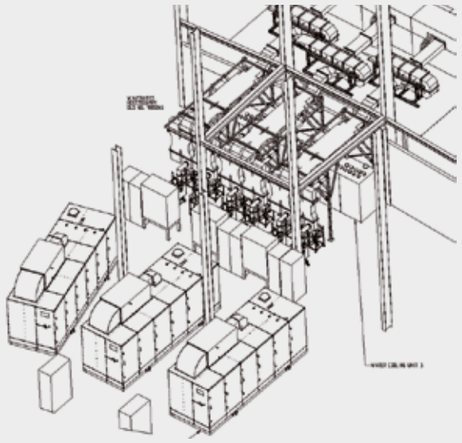
- 4 IOTs (TH793)
- Waveguide combiner
- Circulator
- Waveguide load
- All power supplies (HVPS)
- Local water distribution
- EPICS based control system

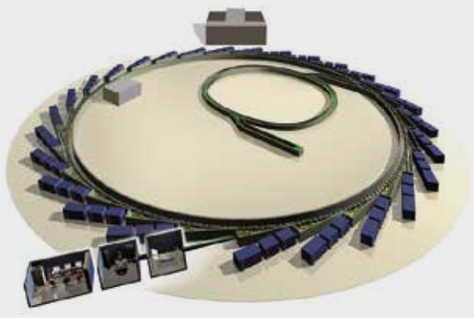
The waveguide combiner system was produced and tuned in the Ampegon factory in Southwick, MA, US and then shipped to the Ampegon factory in Turgi, Switzerland, where all of the high-power testing was completed. Ampegon delivered all systems in 2004 and the project was completed in 2008.

System Layout
The DLS building is a steel construction with a ceiling supported by vertical columns. Thus, the positioning of the system in the building was an important element during the design phase. The waveguide run has to pass above a corridor to the labyrinth and then inside the tunnel. The building and all of the machines were modeled by DLS using the ProEngineer 3D CAD software package. Ampegon uses the same software for the mechanical design, allowing easy integration of the RF system into the overall building computer model.

Key Benefits

- Ampegon designs and delivers RF amplifier systems and voltage regulated DC power supplies for largescale research projects based on particle acceleration
- DLS is the first synchrotron worldwide to be fed with inductive output tubes (IOT)
- Ampegon offered a complete system approach
- RF amplifier systems manufactured by Ampegon were ideally suited due to their high flexibility, reliability, accuracy, efficiency, and long lifetime
- The project is an important milestone in Ampegon's engagement in light source projects, combining for the first time HVPS systems with IOT technology
- The building and machines were modeled by DLS using the ProEngineer 3D CAD software package. Ampegon uses the same software for the mechanical design, of its RF transmission systems
- The HVPS are based on the PSM modulator technology, originally developed by Ampegon for use with its high-power broadcasting transmitters





3D Model of the synchrotron machine (image courtesy of DLS).

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Diamond Light Source

Case Study

Diamond Light Source

Deep within the Diamond Light Source project, Ampegon RF amplifiers are the power source for advanced scientific research

Ampegon designs and delivers RF amplifier systems and voltage regulated DC power supplies (HVPS) from Ampegon for large-scale research projects based on particle acceleration. One of the most interesting and challenging applications is that of light source facilities.

These make use of exceptionally intense, tightly focused beams of X-rays, ultraviolet radiation, as well as infrared. The light from these beams can penetrate deep inside matter, allowing scientists to investigate the world around us at the scale of atoms and molecules. Among a wide range of valuable applications, synchrotrons have been highly beneficial in the effort to develop anti-flu and other important medical vaccines.

This exceptional light is produced using high-energy accelerators, where electrons are energized and increased to almost the speed of light. In electromagnetic cavities, the electrons are energized by special RF amplifiers manufactured by Ampegon, which are ideally suited for such applications due to their high flexibility, reliability, accuracy, efficiency, and long lifetime.

Diamond Light Source (DLS) is the UK's national synchrotron facility and the first 3rd generation light source in the country. In 2003, DLS hired Ampegon to design and supply a series of RF amplifier systems including high-voltage power supply systems (HVPS) from Ampegon. DLS became fully operational (on schedule) in January 2007. The massive construction project – with a 45,000 square meter floor – required over two million man-hours (or 1,100 «man-years») from the construction team and over 2,100 tons of steel.

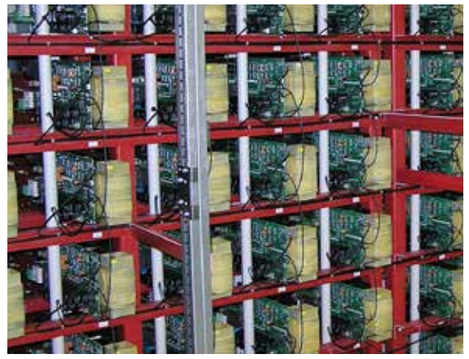
Located in South Oxfordshire, DLS's storage ring (the main part of the accelerator) is 561 meters (more than a third of a mile) in circumference. The facility represents the largest UK scientific investment in 40 years and can ultimately host up to 40 beamlines. With the investment, DLS has ensured that researchers have access to cutting-edge analytical techniques and services for at least the next 30 years.

Ampegon High Voltage Power Supply Systems
All four IOTs of one amplifier are fed from a single high voltage power supply. This power supply, which is based on Ampegon pulse step modulator (PSM) technology, is already in use for klystron amplifiers at various synchrotron light sources with flexible voltage and power ratings. As a fully solid state switched mode power supply without the need for a crowbar, it has proven to be very reliable. Consisting of a series connected switched mode power supplies with IGBT transistors, PSM systems incorporate the most advanced pulse step modulator technology and are renown for superior quality, high overall efficiency, sophisticated remote control facilities, and rugged day-to-day reliability.

The IOT tubes are connected to the HVPS via solenoid actuated high voltage isolators, enabling the operation of any combination of IOT tubes. All currents and voltages are measured individually for all tubes, achieving a high degree of protection. An automatic wire test assembly makes it possible to remotely test fast 'switching off' from the control system.

Ampegon systems during installation at DLS.

The IOT filament, grid, and ion pump is supplied from power supplies placed on the cathode level. The power supplies are controlled and monitored from the control computer by serial fiber optic links. This allows the remote adjustment of the tube parameters from the control system.



HVPS cabinet with PSM modules.

Ampegon's EPICS Control System
The control system is based on the EPICS control system. The input/output controller (IOC) runs on any VME-Bus system with a Power-PC CPU. This system provides the control and acquisition functionality and the interface to the DLS control system. The interlocking functionality is covered by the interlock control system (ICS), specialized hardware developed by Ampegon. A modular system in a 19-inch chassis, it can be equipped with interface boards for digital input and output signals. The ICS provides a high degree of flexibility and the capability for fast interlocking, based on a state-machine with up to nine sequential states. The interlocking logic is programmed as a static logic into programmable logic devices (PLD). Completely different sets of interlocking logic devices are possible for different operation modes. Different modes, such as operation on dummy load, can have different interlocking functionality. The interlocking function is defined for each signal separately in a spreadsheet table. The database for the EPICS-IOC and the ICS is generated automatically with a visual basic script, and the ICS software can be downloaded from any Windows PC with an adapter cable. Therefore logic signal changes can be accomplished easily onsite, without special software. Analog inputs are processed on analog interface boards, providing galvanic insulation and adjustable thresholds for interlocking. Each channel is equipped with a debug connector for easy system debugging.

Advantages of IOT Tubes
The Ampegon 300 kW RF amplifier system for DLS works with a Thales TH792 IOT tube. Advantages of the IOT include high efficiency and easy handling. The IOT is a separate device, thus there is no need to exchange cavity and magnets for replacement. TH792 has a CW output power of approximately 80 kW and an efficiency of 67 %.

From Design to Turnkey Installation
DLS is the first synchrotron world-wide to use inductive output tubes (IOT) as opposed to klystrons. The decision to use IOT's as opposed to klystrons was made because DLS engineers wanted to improve system efficiency and guarantee longer availability of spares and service. However the use of IOT's was also a big challenge, because the system configuration required the ability to reach the highest output power to date with IOT technology. At the time, Ampegon partnered with Thales components and subsystems (the tube suppliers) for a turnkey system delivery with a superior technical solution based on broadcasting expertise, the Ampegon team won this prestigious contract against tough national and international competition. DLS also mentioned that a key deciding factor was the excellent experience it had with Ampegon HVPS systems, in operation at the CLRC Daresbury Laboratory in Cheshire, UK. Benefiting from its unique wide range of in-house technologies, Ampegon provided a complete system approach. This project represented an important milestone in Ampegon's involvement in light source projects, combining for the first time Ampegon HVPS systems with IOT technology. In addition, the systems are an environmentally friendly solution due to their high efficiency.

System Overview
To achieve 300 kW output power, a combination of the output of four tubes is required. To minimize losses inside the combiner, Ampegon selected a waveguide combiner system similar to that used for very high power TV transmitters. The first combination step is performed with classical 3 dB hybrid combiners. The second step is made with a switchless magic-T combiner. This combiner type has built-in two phase shifters, allowing it to compensate unequal power on both input ports. The phase shifters are implemented with movable Teflon blocks inside the waveguides. The switchless combiner provides 100 % of the input power to the output port with two IOTs (as long as these two IOTs are on the same input combiner). In the event of a tube failure, the system can remain operational at reduced power levels without all tubes functioning. With a single tube fault, a total output power of 187.5 kW is still achievable. The combiner also allows single tube operation for testing.