The Diamond Light Source particle accelerator in Oxfordshire © 2013

Brushless DC motors for vacuum conditions.

maxon motor, over several months working alongside Instrument Design Technology (IDT) have customised a small, brushless DC motor enabling it to operate in extreme vacuum conditions of the diamond light source particle accelerator.

The Diamond Light Source particle accelerator has been utilised for projects from examining the results of stress on aircraft wings to analysing the HIV virus, and even studying the content of ancient letters without them being opened. The 45km^2 device accelerates electrons to 3GeV, generating beams of light ten billion times brighter than the sun to study molecular structures. To avoid electrons getting lost in collision with air molecules, the whole process is undertaken in a vacuum; roughly one billion times lower than atmospheric pressure. Building instruments for these conditions requires specialist knowledge.

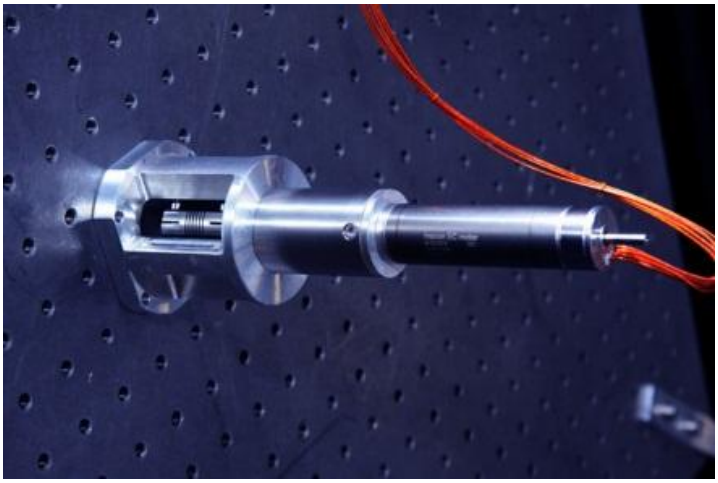
The synchrotron specified that the Double Crystal Monochromator (DCM) for its new X-Ray Spectroscopy beam line should drive the crucial Bragg rotational axis with a DC motor rather than the usual stepper motor. IDT managing director Paul Murray explains: "The goal was to achieve higher rotation speeds, with a lower motor temperature and smoother drivetrain than the stepper motor we had used previously. Stepper motors are inherently noisy, and often sources of vibration. Eliminating this issue would immediately improve results from the DCM - but the new motor would have to work flawlessly in a vacuum of 10-8 Torr." Entrusted to find a solution was Paul Williams, senior engineer at maxon motor. Specialised maxon motor engineers are assigned to work on each stage of a DC motor development project. maxon motor has a rich history of special customisations to high-performance DC motors in critical applications such as space and surgical robotics. "Because the vacuum in the synchrotron must not be compromised, each individual aspect of the motor and its construction had to be analysed for possible outgassing. The challenge for us was effectively to create a brushless motor with virtually no glues or plastics, an incredibly high temperature tolerance, and excellent performance." said Williams.

The standard brushless 22mm heavy duty motor was used as a baseline product from which to base the application specific modifications on. This motor was initially developed around oil and gas applications,

where high pressure, temperature and vibrations were present. However the laser welded construction of the 22mm diameter brushless motor combined with its ability to survive large operating temperature ranges gave the motor a head start towards surviving the rigors of high vacuum applications. Being a brushless DC motor also meant it would be more efficient, quieter and more responsive than a stepper motor.

maxon motor had to account for many different application influences during the customisation of the 22mm brushless DC motor. Temperature management was one of the first factors considered. DC Motors can't dissipate heat via convection when used in vacuum conditions. Thus, it is imperative that the motor can withstand extremes of temperature and still deliver the required performance. Components within the device need to be located appropriately to assist where possible to dissipate heat by conduction. Also assisting in the application was maxon's ability to produce efficient gearboxes in very high ratios. High vacuum levels of up to 99% (7.6mm Mercury) and above draw gas compounds from material such as plastics and glues, compromising performance and contaminating the vacuum. This is known as outgassing.

Every component within the motor was tested, and modified where required. PVC cables were changed for Kapton versions for example. This also emphasises the importance of the 22mm brushless motors all stainless steel construction as opposed to lower grade technologies that utilise plastics and adhesives.
Based on maxon motors experience in aerospace applications, maxon had knowledge of typical bearing lubrication being affected in low pressure environments. Specialised inert lubricants that are highly viscous to restrict outgassing were also specified.
Additionally at the end of the process to any remaining outgassing threat is removed by baking the motors in a vacuum at 120ºC for 24 hours.



Customised 22mm brushless motor installed in the particle accelerator © Diamond Light Source

The DCM fitted with the highly customised brushless DC motors is in service at the synchrotron assisting with vital experiments. Recently a team of scientists used the equipment to analyse dust particles within snowflakes that are over 800,000 years old. This is close to the era of the first hominids. The snow was derived from cores drilled from the Antarctic. As snow falls it encases tiny particles that contain information about the early climatic history of planet earth. X-Ray Absorption Spectroscopy was used by the scientists to study mineral composition and discover its origins, unlocking ancient evidence of changes in global climate patterns over thousands of years.

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Heavy Duty Brushless DC motor © 2013 maxon motor

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