DIAMOND LIGHT SOURCE VACUUM SYSTEMS COMMISSIONING STATUS

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ABSTRACT

Commissioning of the ultra-high vacuum systems for the 3 GeV Diamond Light Source is in progress. All the machine vacuum systems are installed, under vacuum and performing well. The vacuum control system and machine protection systems are also operational. The measured static pressure in the storage ring is 5 x 10^{-10} mbar. Pressure rises up to the 10^{-8} mbar region have been observed during initial beam tests at 700 MeV 2 mA. The effective initial photon stimulated desorption (PSD) yield is estimated to be of order 10^{-3} molecules per incident photon which is in agreement with expectations.

DIAMOND VACUUM SYSTEMS OVERVIEW

Diamond Light Source is a new synchrotron light source currently being commissioned in Oxfordshire in the UK.

The main vacuum systems are a 561.6 m circumference 3 GeV electron storage ring and a 158.4 m circumference booster ring which cycles between 0.1 and 3 GeV. There is also a 100 Mev Linac and two beam transfer lines. 7 experimental beamlines and their associated insertion devices and front ends are currently being installed.

The storage ring has 24 cells with 24 identical achromat (arc) sections each 17.35 m long and 24 straight sections: 18 x 5.3 m long and 6 x 8.3 m long. 21 of the straights are dedicated ultimately for insertion devices but are fitted with simple "make-up" vessels for initial commissioning. Water-cooled copper "beamport absorbers" are fitted to the 48 beam extraction ports where no front end is fitted.

The storage ring target operating pressure is 10^{-9} mbar with 300 mA of stored beam after 100 A.h of beam conditioning. The operating pressure is critical both for the lifetime of the stored beam and to control the Gas Bremsstrahlung radiation. The booster ring target pressure is 10^{-8} mbar.

In-situ bakeout is limited to the storage ring straights and front ends; the storage ring arcs are not bakeable *in situ*.

VACUUM VESSELS

The main construction material for the vacuum vessels is 316LN austenitic stainless steel, chosen for its cost-effectiveness, low magnetic permeability and high mechanical strength. Joining techniques used include TIG welding, e-beam welding, explosion bonding and vacuum brazing. The most complex vessel is the dipole and crotch vessel assembly pictured in Fig. 1.

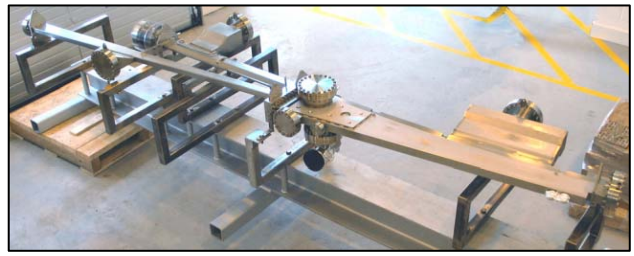

Figure 1: Dipole and crotch vessel assembly 3.8 m long. The two vessel sections are joined with a rectangular CF type flange.

All vacuum vessels were subject to stringent factory acceptance tests including vacuum bakeout to 250°C followed by helium leak test, specific outgassing rate measurement and residual gas analysis.

Storage ring photon absorbers are manufactured from OFHC copper. A combination of discrete and distributed absorbers is used. Discrete crotch and finger absorbers are fitted to the dipole and crotch vessels. A number of discrete cooled tapers are used to shadow uncooled surfaces. Distributed absorbers are incorporated into the dipole and crotch vessels and the quadrupole vacuum vessels. The stresses and temperature distribution in the absorbers were modelled using Finite Element Analysis.

In order to reduce the RF impedance of the storage ring stored beam channel, all the CF flange joints have been modified with the addition of a spigot to reduce the gap between flanges to between 0.1 and 0.2 mm. All pumping and gauging ports are fitted with grilles. RF shielded gate valves and bellows are used throughout and all changes in cross section have been tapered with a maximum 1:10 slope.

VACUUM EQUIPMENT

The machine is pumped by 718 commercially-available discrete noble diode ion pumps. Noble diode pumps were chosen for their high pumping speed and high capacity for pumping argon without instability. The total nominal applied ion pumping speed in the storage ring is 117,000 l/s and in the booster ring is 8,000 l/s.

Titanium sublimation pumps provide additional pumping speed at the storage ring crotch absorbers where high gas loads are expected. NEG cartridge pumps are also fitted to the storage ring in areas where additional pumping is needed but where space is limited.

Pressure from atmosphere to below 10^{-10} mbar is monitored by 374 pairs of inverted magnetron gauges

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(IMGs) and Pirani gauges. A small field emitter has been incorporated into each IMG to improve striking at low pressures. Vacuum quality is monitored by 154 residual gas analysers (RGAs).

To reduce radiation damage to electronics and cables and for ease of access during operations, most of the vacuum equipment control units are located in separate control and instrumentation areas outside the storage ring tunnel.

A total of 140 all-metal gate valves (57 of which are RF shielded) are used to isolate vacuum sections for maintenance and for vacuum protection. These valves are linked into the machine protection system and close automically in the event of a vacuum incident. The storage ring can be isolated into 48 vacuum sections in this way. Fast closing valves (10 ms closing time) in the front ends and booster-to-storage-ring transfer line provide additional storage ring vacuum protection.

Rough pumping is carried out by mobile pumping carts. Mobile pumping carts are used rather than fixed pumping stations as they offer greater flexibility to apply additional pumping speed where needed locally and they can also be removed during operations to prevent radiation damage. The pumping carts can be remotely monitored and controlled over the site Ethernet network.

VACUUM CONTROLS

Total pressure and status information is read back from gauge controllers, ion pump controllers and valve controllers into the Diamond EPICS control system. The pressures are archived for later analysis and are also displayed in real time on the EPICS graphical user interface (GUI) screens.

RGA partial pressure data is recorded using the RGA manufacturer's software running on Windows based local computer systems. The RGA data is incorporated in the overall EPICS displays and archiving.

Control and monitoring of vacuum equipment, vacuum data archiving and control screens are operational in all machine areas. Refinements and debugging are in progress. One area which is still being commissioned is the RGA network with over 50% of the RGAs currently commissioned for remote operation.

Commissioning of the vacuum hardwired and programmable logic controller (PLC) based machine vacuum protection system is complete.

STORAGE RING VACUUM PROCESSING AND INSTALLATION

The storage ring vacuum assembly and installation process is shown schematically in Fig. 2.

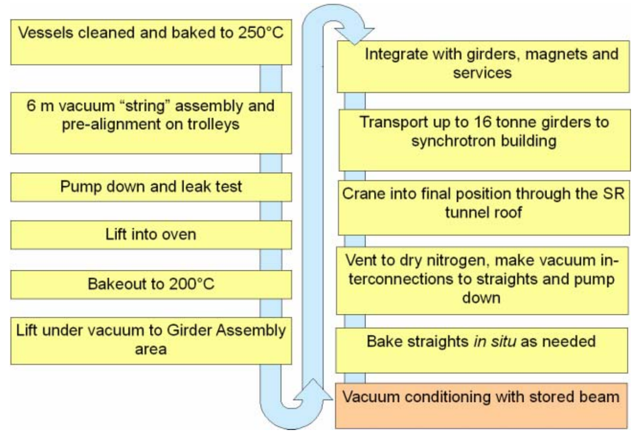

Figure 2: Flow chart of storage ring vacuum assembly, processing and installation sequence.

All the storage ring vacuum vessels and major components were supplied clean, pre-baked and under vacuum from the suppliers.

As the storage ring arcs are not bakeable *in situ*, the "strings" of vacuum vessels were assembled and pre-baked to 200 °C in 72 sections, each typically 6 m long, in a separate assembly building. After bakeout and vacuum tests these were incorporated with the magnets on to support girders and transported, still under vacuum (typically 1 - 2 x 10^{-10} mbar), to the storage ring tunnel.

Once in the storage ring tunnel, the vacuum vessel assemblies were vented to high purity dry nitrogen and the vacuum interconnections were made inside laminar flow tents using only clean, pre-baked components. The vacuum sections were then pumped down again and regained the 10^{-10} mbar pressure range after several days pumping. Back flushing with clean dry nitrogen and re-pumping several times was found to reduce the time to regain ultra-high vacuum conditions.

Following installation of the arcs, the 24 straight sections were installed and connected up to the arcs. 3 of the 8.3 m straights (RF straight, diagnostics straight and injection straight) have special components installed. Of these 3 only the diagnostics straight was baked out *in situ*.

The remaining 21 straights are fitted with so-called "insertion device make-up straights" for initial storage ring commissioning. It was not found necessary to bake these out *in situ* as these had previously been baked out at the supplier's premises and delivered under vacuum.

STORAGE RING VACUUM PERFORMANCE

When reviewing the vacuum performance of the storage ring it is important to distinguish the static performance (with no stored beam) from the dynamic performance (with stored beam). The dynamic pressure is higher than the static pressure due to the effects of photon stimulated desorption (PSD).

Information on the dynamic behaviour is limited so far as the storage ring has only been operated at 700 MeV and up to 2 mA for a total *current x time* of less than 0.01 A.h. The design operating conditions are 3 GeV and 300 mA (and later possibly up to 500 mA).

In all locations the residual gas spectrum is characteristic of a clean ultra-high vacuum system. The main component is H_2, with some CO and CO_2. As expected, the relative partial pressure of H_2O is higher in the less-well-baked regions.

The measured average static (no stored beam) pressure in the whole storage ring is 5 x 10^{-10} mbar. This is derived from an unweighted mean of all the IMG pressure gauge readings along the storage ring stored electron beam path.

During initial beam operations at 700 MeV and 2 mA of current, a correlation between pressure and current was observed. Local pressure rises typically into the low 10^{-8} mbar range were observed near the beamport absorbers (which are not in the stored electron beam path) and into the low 10^{-9} mbar range in the dipole vessels (see Fig. 3).

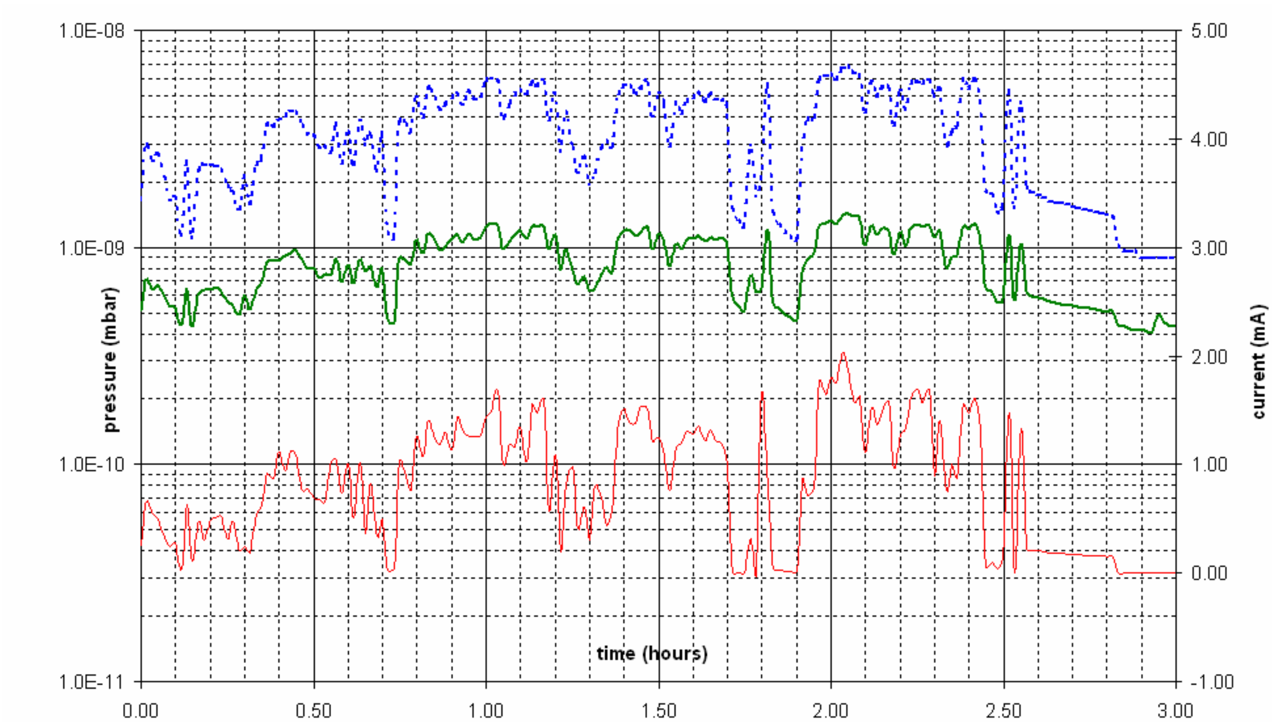

Figure 3: Correlation between dynamic pressure rise and beam current in a typical storage ring cell as a function of time during initial beam studies at 700 MeV and up to 2 mA. Beam current (light continuous line), Stored beam channel (heavy continuous line), Beamport absorbers (heavy broken line).

Until a stable, well-characterised electron beam orbit has been established it is difficult to relate this with confidence directly to the PSD yield from the vacuum vessel walls. However, comparison of the preliminary measured dynamic pressure behaviour averaged around the storage ring with vacuum model simulations indicate the effective PSD yield is of the order of 10^{-3} molecules per incident photon. This is within the range of initial PSD yield values which have been reported elsewhere for copper surfaces with various pre-treatments [1 - 4].

A period of beam conditioning will be needed to reduce the PSD yield to the value of around 10^{-6} molecules per incident photon which will be needed to achieve an average operating pressure of 10^{-9} mbar with 300 mA of stored beam at 3 GeV. It is expected that 100 A.h at 3 GeV will be sufficient to achieve this target performance. Further data collection and analysis will be carried out as beam commissioning progresses.

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