NSLS-II BOOSTER VACUUM SYSTEM

V.A. Kiselev, V.V. Anashin, S.M. Gurov, A.M. Semenov*, Budker Institute of Nuclear Physics SB RAS, Novosibirsk, Russia
A.A. Krasnov, Budker Institute of Nuclear Physics SB RAS, Novosibirsk, Russia and Novosibirsk State University, Novosibirsk, Russia

Abstract

NSLS-II - one of the latest third-generation SR sources - is currently under commissioning at the Brookhaven National Laboratory. In order to improve the operation efficiency in a continuous mode with maximum brightness, the injectors of these SR sources are operated continuously at the energy of up to the energy of the main ring (linac or synchrotron booster) [1]. The full injection energy allows adding electrons to the travelling electrons in a storage ring rather than to regulate a magnet system. This operating mode is often named "Top-Up". NSLS-II consists of a linear accelerator with the electron energy of up to 200 MeV, a synchrotron booster with the energy of 3 GeV, and a main storage ring. The status and review of the NSLS-II Booster vacuum system are presented in this paper.

INTRODUCTION

Since 1992, the first specialized storage rings (3rd generation SR sources) with a large number of straight sections of a sufficient length for installation of undulators (or wigglers) and more perfect systems of the storage ring parameter stabilization have been built.

In the first specialized SR sources, electrons were injected into the storage ring at a low energy, then the energy was increased, stabilized, and experiments were carried out. The beam current decreased with time, SR intensity dropped. The cycle with energy decrease, electron storage and energy increase was repeated in 1-2 hours. This was the mode of NSLS-I operation. NSLS-I booster was designed for acceleration of electrons from the energy of 120 MeV up to 700 MeV, the energy of storage rings was 800 MeV (vacuum ultra-violet spectrum) and 2.8 GeV (hard X-rays).

For today, mostly 3rd-generation SR sources are in operation and under construction in the world. One of latest sources scheduled for starting-up in 2015 is NSLS-II (Brookhaven National Laboratory, USA). Main parameters of the NSLS-II Synchrotron are presented in [1].

VACUUM SYSTEM DESCRIPTION

The perimeter of the booster vacuum chamber is 158.4 meters. 8 all-metal electropneumatical gate valves (actuation time ~ 2-3 sec) are installed in the ring for isolation of certain sections of the booster vacuum chamber. The booster consists of 4 arc sections (about 31 m each) and 4 straight sections (8 m each). All vacuum chambers are made of 316 L stainless steel, with Conflat flanges. The vacuum chamber aperture in arc sections is an ellipse of 41x24 mm (molecular conductivity of the chamber is about 3.2 l·m/sec); and the aperture of the majority of the chambers in straight sections is an ellipse of 62x22 mm (molecular conductivity of the chamber is about 4 l·m/sec). After manufacturing all vacuum chambers were exposed to special chemical treatment to reduce the outgassing rate [2].

For smoothness of the vacuum chamber and reduction of electron beam losses, special transitions from elliptical cross-section (24x41 mm) to circular cross-section (46 mm diameter) were produced, places for pumping were made from a one-piece tube with cut-out slots for pumping, besides, some bellows in straight sections were supplied with RF contacts having the shape of the vacuum chamber.

Residual gas pressure after accumulation of current integral of an order of 1 A·h should be not worse than 1E-7 Torr. Vacuum is provided with Gamma Vacuum ion-pumps (71 pieces) with pumping speed of 45 l/sec, placed at an average distance of 2.3 meters from each other. Two inverted-magnetron cold cathode gauges are installed in each section for vacuum measurements, and convection-enhanced Pirani gauges (MKS) are planned for forevacuum measurements. Detection of residual gas spectrum and of micro-leaks is carried out by means of MKS mass-spectrometers. Fig.1 shows the arrangement of the main components of the booster vacuum system.

RESULTS OF THE WORK PERFORMED

A rather strong synchrotron radiation results in an additional radiation-induced desorption of the residual gas molecules from the vacuum chamber walls and can cause a significant mechanical stress in vacuum chamber due to a non-uniform heating.

Despite a pulse operation mode of the booster (SR intensity duty ratio is 1/7 at a 2Hz repetition frequency), gas desorption under the influence of photons on vacuum chamber walls will exceed thermal desorption.

A relatively low SR power (maximum power is 44 W/m in BD bending magnets) does not require any special radiation absorbers. However, such radiation can cause mechanical stresses in vacuum chamber.

---

*A.M.Semenov@inp.nsk.su

As it was found, synchrotron radiation power density on the vacuum chamber wall is about 44 W/m, this results in a non-uniform heating of the chamber in places of SR direct effect by 60 degrees Celsius (calculated Δ□ = 62 ° C).

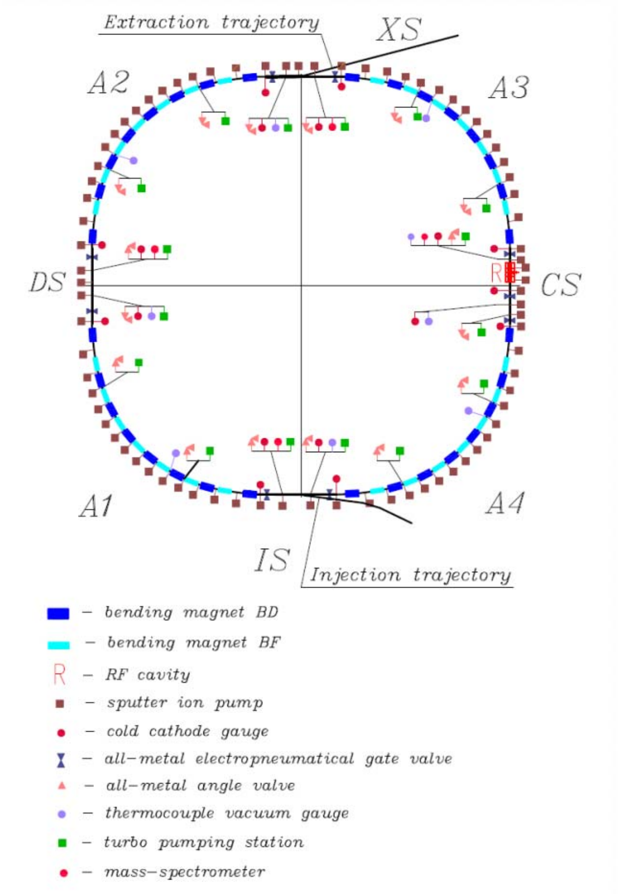

Figure 1: Layout of the NSLS-II booster vacuum system.

Heating of a narrow strip of the chamber (≈ 1 mm) causes mechanical stress of the chamber of about 114.5 MPa at permissible value of no more than 150 MPa that is a reliable safety factor.

BOOSTER COMMISSIONING

To the commissioning of the booster the whole vacuum system was assembled, leak-checked and was under vacuum. A residual gas pressure level in each section before commissioning of the booster is represented in Fig.2. In December, 2013 commissioning of the booster was started and, two days after, the first electron beams were obtained. The maximum electron energy (3 GeV) was successfully achieved in a month after start of the commissioning. The SR-induced dynamic pressure after the beginning of operation with electrons at a 3GeV energy is shown in Fig. 3.

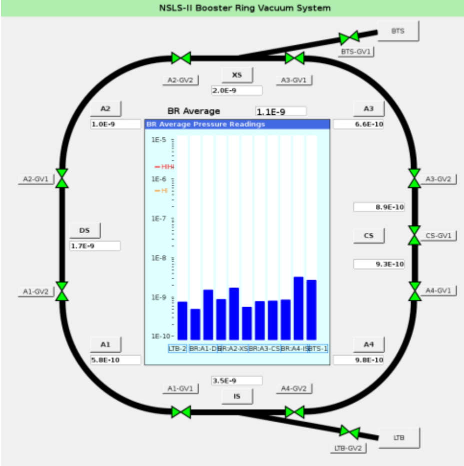

Figure 2: Residual gas pressure level in each section without a beam.

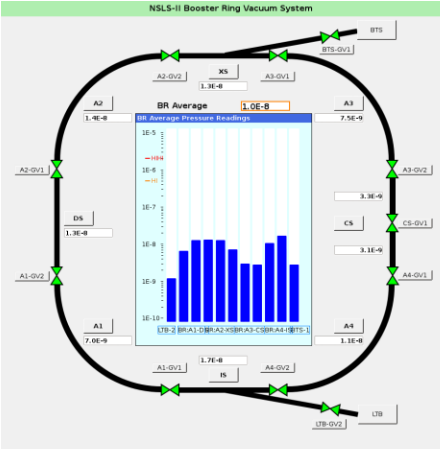

Figure 3: Residual gas pressure level in each section with a beam.

Table 1 gives a comparative analysis between the calculation and the experimental data. Some discrepancies in the experimental data and calculations are caused by the fact that, at calculations, the average vacuum in the whole section is considered, while the experimental data can be obtained only with indications of the pressure gauges placed at the points of connection of ion pumps.

Theoretical forecasting of the vacuum level for arc sections at the locations of pumping ports agrees with the data obtained at the accelerator, but for the straight sections this statement strongly depends on location of the pressure gauge as, with distance from the radiation source, the quantity of the photons causing additional outgassing reduces linearly.

Table 1. Comparative analysis between the calculation and the experimental data. Pressure (Torr)

		Arc section	Diagnostics	Extraction	Injection
Calculation (average)	Without beam	2.5E-8	3.7E-8	2.8E-8	3.8E-8
	With beam	4E-8 at 1.4 Ah	5.6E-8 at 1.4 Ah	5.8E-8 at 1.4 Ah	4.9E-8 at 1.4 Ah
Experiment	Without beam	9E-10	1.7E-9 Torr	2E-9 Torr	3.5E-9 Torr
	With beam	1E-8	1.3E-8	1.3E-8	1.7E-8

REFERENCES

[1] F. Willeke. Status of NSLS-II, Proceedings PAC'11, New York, NY, USA, 2011.

[2] LHC-BINP-LC-PR-001.